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PAPERS PRESENTED AT MEETINGS

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MEETING #	DATE	PLACE	ABSTRACT DEADLINE	ABSTRACT ISSUE
1140	June 11–14, 2018	Shanghai, Peoples Rep of China	May 10	NONE
1141	September 29–30, 2018	Newark, DE	July 31	Vol 39, No. 3
1142	November 3–4, 2018	Fayetteville, AR	September 4	Vol 39, No. 3
1143	October 20–21, 2018	Ann Arbor, MI	August 21	Vol 39, No. 4
1144	October 27–28, 2018	San Francisco, CA	August 28	Vol 39, No. 4
1145	January 16–19, 2019	Baltimore, MD	September 25	Vol 40, No. 1
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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	TBA
1150	September 14–15, 2019	Madison, WI	July 16	Vol 40, No. 3
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1153	November 9–10, 2019	Riverside, CA	September 3	Vol 40, No. 4
1154	January 15–18, 2020	Denver, CO	TBA	TBA

COLUMBUS, OH, March 16–18, 2018

Abstracts of the 1136th Meeting.

00 ► General

1136-00-51 **sinem odabasi*** (sinem.odabasi@uach.cl), , Chile. *on equivalence of subcategories of complexes.*

The notion of adjoint functors is a weaker version of equivalence functors. So when one has an adjoint functor based on an object, it is natural to come up with the question of determining objects in such a way that its associated adjoint functor turns out to be an equivalence of categories just like it happens in the so-called Morita equivalence. Having this phenomenon, an (right) R-module P is said to be $*$-module if the representable functor $\mathrm{Hom}_R(P, -)$ induces a *maximal equivalence* between Mod-R and Mod-A, where $A := \mathrm{End}_R(P)$, that is, an equivalence between the subcategory gen(P) of P-generated R-modules and the subcategory cogen(P^*) of $P^* := \mathrm{Hom}_R(P, E)$-cogenerated A-modules, where E is a cogenerator for Mod-R. Inspired from this, we introduce two notions of chain complexes, called $*$-*complex* and *modified* $*$-*complex* each of which leads to a *maximal equivalence* between categories of chain complexes through the total hom complex and modified hom-complex, respectively. In this talk, we will discuss their characterizations and their relations with (pre)silting complexes. This is a work in progress. (Received December 15, 2017)

1136-00-210 **Asiyeh Rafieipour*** (ar996517@ohio.edu), 24 1/2B S SHAFER ST, ATHENS, OH 45701, and **Majid Mazrooei**. *New construction of linear codes including a wide family of MDS codes.* Preliminary report.

Let Z_p be the finite field of integers modulo p, where $p > 3$ is a prime. This paper presents a new construction of linear codes over Z_p. Based on our construction, linear codes of length $p - 1$, include a wide family of MDS codes. We shall discuss the parameters of the codes defined while describing a generator matrix for the family. (Received January 15, 2018)

1136-00-307 **James P. Solazzo*** (jsolazzo@coastal.edu), Coastal Carolina University, P.O. Box 261954, Conway, SC 29528, and **Thomas R. Hoffman**. *Complex Two-Graphs.*

In 'A survey of two-graphs' , J.J. Seidel lays out the connections between simple graphs, two-graphs, equiangular lines in $\mathbb{R}^k$ and strongly regular graphs. It is well known that there is a one-to-one correspondence between two-graphs and sets of equiangular lines in $\mathbb{R}^k$. In this talk we will present a generalization of two-graphs by allowing the entries of the Seidel matrix to be roots of unity beyond ± 1. Many of the results regarding *real* two-graphs have a natural generalization in the complex setting including equiangular lines in $\mathbb{C}^k$. (Received January 19, 2018)

03 ► Mathematical logic and foundations

1136-03-604 **Paige North*** (north.138@osu.edu). *Type theory and concurrency.* Preliminary report.

In this talk, we will describe extensions of Martin-Löf type theory to directed type theory. The aim of this project is to produce an internal language of directed topology with applications in the analysis of concurrency in computer programs. (Received January 22, 2018)

05 ► Combinatorics

1136-05-16 **M M Jaradat*** (mmjst4@qu.edu.qa), Department of Mathematics, Statistics and Phy, Doha, 2713, Qatar. *Extremal number of theta graphs of order* 7.

For a set of graphs $\mathcal{F}$, let $H(n;\mathcal{F})$ denote the class of non-bipartite Hamiltonian graphs on n vertices that does not contain any graph of $\mathcal{F}$ as a subgraph and $h(n;\mathcal{F}) = \max\{\mathcal{E}(G) : G \in \mathcal{H}(n;\mathcal{F})\}$ where $\mathcal{E}(G)$ is the number of edges in G. In this paper we determine $h(n;\{\theta_4,\theta_5,\theta_7\})$ and $h(n;\theta_7)$ for sufficiently odd large n. Our result confirms the conjecture made by Bataineh for $k = 3$. (Received October 22, 2017)

1136-05-24 **Martin Rolek** and **Zi-Xia Song*** (zixia.song@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Coloring Graphs with Forbidden Minors.*

Hadwiger's conjecture from 1943 states that for every integer $t \geq 1$, every graph either can be t-colored or has a subgraph that can be contracted to the complete graph on $t+1$ vertices. Hadwiger's conjecture is true for $t \leq 6$ and remains open for $t \geq 7$. It is not even known yet whether graphs with no K_7 minor are 7-colorable. In this talk, we present our recent results on Hadwiger's conjecture. We prove that every graph with no K_t minor is $(2t-6)$-colorable, where $t \in \{7,8,9\}$. We further prove that if Mader's bound for the extremal function for K_t minors is true, then every graph with no K_t minor is $(2t-6)$-colorable for all $t \geq 6$. We believe that the Kempe-chain method we have developed in proving these results is of independent interest.

This is joint work with Martin Rolek. (Received November 20, 2017)

1136-05-47 **Asaf Ferber***, Building 2 (Math department), 1182 Memorial Drive, Cambridge, MA 02139, and **Kyle Luh**. *On 1-factorizations of graphs.*

A 1-factorization of a graph G is an edge-partitioning into perfect matchings. Clearly, if a graph G admits a 1-factorization then it must be regular, and the converse is easily verified to be false.

It is an easy exercise to show that every d-regular bipartite graph has a 1-factorization, and in the special case where G is the complete bipartite graph $K_{n,n}$, a 1-factorization of G corresponds to a Latin Square.

In this talk we survey known results/conjectures regarding the existence and the number of 1-factorizations in graphs and the related problem about the existence of a proper edge coloring of a graph with exactly $\Delta(G)$ colors. Moreover, we present few new results in this area that settle some classical problems about the existence and the number of 1-factorizations in general graphs and random graphs.

This is based on joint works with Kyle Luh and with Vishesh Jain. (Received December 14, 2017)

1136-05-48 **Catherine H. Yan*** (cyan@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843. *Interpolation Polynomials, Operator Methods, and Theory of Enumeration.* Preliminary report.

Goncarov Polynomials are the basis of solutions of the classical Goncarov Interpolation Problem, which have been studied extensively by analysts due to their significance in the interpolation theory of smooth and analytic functions. These Polynomials also play an important role in combinatorics due to their close relations to parking functions. This is not just a coincidence. In this talk we will present the interpolation problems with delta-operators, develop the algebraic and analytic theory of delta-Goncarov polynomials, and apply these results to problems in binomial enumeration and order statistics.

This is joint work with Rudolph Lorentz and Salvatore Tringali. (Received December 14, 2017)

1136-05-54 **Robert E.L. Aldred** (raldred@maths.otago.ac.nz), Otago University, Dunedin, New Zealand, **Michael D. Plummer*** (michael.d.plummer@vanderbilt.edu), Nashville, TN 37240, and **Watacharintorn Ruksasakchai** (watcharintorn1@hotmail.com), Nakhon Pathom, 73130, Thailand. *Distance restricted matching extension missing vertices and edges in 5-connected triangulations of the plane.*

In 2011 the first two authors showed that in a 5-connected even planar triangulation G, every matching M of size $|M| < |V(G)|/2$ can be extended to a perfect matching of G, as long as the edges of M lie at distance at least 5 from each other. In 2017, Kawarabayashi, Ozeki and the second author proved the following result: Let G be a 5-connected triangulation of a surface Σ *different from the sphere.* Let $\chi = \chi(\Sigma)$ be the Euler characteristic of Σ. Suppose $V_0 \subset V(G)$ with $|V(G) - V_0|$ even and M and N are two matchings in $G - V_0$ such that $M \cap N = \emptyset$. Finally suppose that the pairwise distance between two elements of $V_0 \cup M \cup N$ is at least 5 and the face-width of the embedding of G in Σ is at least $\max\{20|M| - 8\chi - 23, 6\}$. Then there is a perfect matching M_0 in $G - V_0$ which contains M such that $M_0 \cap N = \emptyset$.

Here we present some results which, in a sense, lie in the gap between the above two theorems, in that they deal with matching extension in a plane triangulation when a set of vertices which lie pairwise at sufficient distance from one another has been deleted. In particular, we prove an exact planar analogue of the second result above. (Received December 16, 2017)

1136-05-59 **Mikhail Muzychuk**, Department of mathematics, Ben-Gurion University, Beer-Sheva, Israel, and **Bangteng Xu*** (bangteng.xu@eku.edu), Department of Mathematics and Statistics, Eastern Kentucky University, Richmond, KY 40475. *Quasi-thin and double quasi-thin table algebras and association schemes.*

A quasi-thin table algebra is a standard table algebra whose basis elements have degrees 1 or 2, and a double quasi-thin table algebra is a commutative quasi-thin table algebra whose standard dual basis elements also have degrees 1 or 2. In this talk we first present conditions under which the basis of a quasi-thin integral table algebra has an old complement. Then we discuss the relations between the thin radical and thin residue of a quasi-thin table algebra, and show that under certain conditions a quasi-thin table algebra is double quasi- thin. Structure constants in a quasi-thin table algebra are also studied, and as an application, we show that the Krein parameters of a commutative double quasi-thin association scheme are rational integers. The classification of commutative double quasi-thin association scheme will also be discussed. (Received December 20, 2017)

1136-05-75 **Jae-Ho Lee*** (jaeho.lee@unf.edu), 1 UNF Drive, Jacksonville, FL 32224, and **Hajime Tanaka**. *Dual polar graphs and non-symmetric dual q-Krawtchouk polynomials.*

The dual polar graphs are a classical family of Q-polynomial distance-regular graphs arising naturally as homogeneous spaces of finite classical groups by maximal parabolic subgroups, and correspond to the dual q-Krawtchouk polynomials. Consider a dual polar graph with diameter D. Using a pair of vertex of this graph and a maximal clique containing it, we construct a 2D-dimensional irreducible module for a nil-DAHA of rank one. From this module, we capture non-symmetric dual q-Krawtchouk polynomials and describe their orthogonality relations. (Received January 22, 2018)

1136-05-98 **Bojan Mohar*** (mohar@sfu.ca), Burnaby, BC , Canada, and **Ross Churchley**. *Totally odd immersions of graphs.*

Graph immersions are a close relative to graph minors. It has been proved rather recently that graphs in which a fixed graph K cannot be immersed are sparse and their rough structure can be described by using small edge-cuts. The corresponding problem of totally odd immersions will be discussed in the talk. (Received January 04, 2018)

1136-05-103 **Jim Geelen*** (jfgeelen@uwaterloo.ca), **Bert Gerards** and **Geoff Whittle**. *Computable bounds for Rota's Conjecture.* Preliminary report.

Earlier we announced a proof of Rota's Conjecture, that the class of matroids represented over any given finite field has only finitely many excluded minors. In this talk we will discuss simplifications to the proof that now give computable bounds on the size of the excluded minors. (Received January 05, 2018)

1136-05-111 **Sung Y Song*** (sysong@iastate.edu), 442 Carver Hall, 411 Morrill Road, Ames, IA 50011-2014. *Character tables of group-case commutative association schemes.*

We give a survey of results concerning calculation of character tables of group-case commutative association schemes. We restrict ourselves to the association schemes coming from linear groups acting on classical geometries. (Received January 06, 2018)

1136-05-112 **Desmond Coles**, **Neelav Dutta**, **Sifan Jiang**, **Ralph Morrison*** (10rem@williams.edu) and **Andrew Scharf**. *Most planar graphs aren't tropical.*

Given a smooth tropical plane curve, we can consider a distinguished metric graph inside of it called its skeleton. In this talk, we consider the question: which combinatorial types of graphs appear as the skeleton of a smooth tropical plane curve? In addition to computational results, we'll present a lower and upper bound for any fixed genus. We use the upper bound to prove the following: in the limit, zero percent of trivalent connected planar graphs appear tropically. (Received January 06, 2018)

1136-05-119 **Jacob D. Baron** and **Jeff Kahn***, Hill Center, Busch Campus, Piscataway, NJ 08854. *On the cycle space of a random graph.*

Write $\mathcal{C}(G)$ for the cycle space of a graph G; $\mathcal{C}_\kappa(G)$ for the subspace of $\mathcal{C}(G)$ spanned by the copies of the κ-cycle C_κ in G; $\mathcal{T}_\kappa$ for the class of graphs satisfying $\mathcal{C}_\kappa(G) = \mathcal{C}(G)$; and $\mathcal{Q}_\kappa$ for the class of graphs each of whose edges lies in a C_κ. We prove that for every odd $\kappa \geq 3$ and $G = G_{n,p}$,

$$\max_p \Pr(G \in \mathcal{Q}_\kappa \setminus \mathcal{T}_\kappa) \to 0;$$

so the C_κ's of a random graph span its cycle space once they cover its edges.
(Received January 07, 2018)

1136-05-130 **Andrzej Dudek*** (andrzej.dudek@wmich.edu), **Patrick Bennett** (patrick.bennett@wmich.edu) and **Bernard Lidicky** (lidicky@iastate.edu). *Minimizing the number of 5-cycles in graphs with given edge-density.*

Motivated by the work of Razborov about the minimal density of triangles in graphs we study the minimal density of cycles C_5. We show that every graph of order n and size $\left(1 - \frac{1}{k}\right)\binom{n}{2}$, where $k \geq 3$ is an integer, contains at least

$$\left(\frac{1}{10} - \frac{1}{2k} + \frac{1}{k^2} - \frac{1}{k^3} + \frac{2}{5k^4}\right) n^5 + o(n^5)$$

copies of C_5. This bound is optimal. The proof is based on the flag algebras framework.

This is a joint work with Patrick Bennett and Bernard Lidický. (Received January 08, 2018)

1136-05-140 **Megumi Harada***, Department of Mathematics and Statistics, 1280 Main Street West, Hamilton, Ontario L8S4K1, Canada, and **Martha Precup**. *The cohomology of abelian Hessenberg varieties and the Stanley-Stembridge conjecture.*

The Stanley-Stembridge conjecture in combinatorics states that the chromatic symmetric function of the incomparability graph of a so-called (3+1)-free poset is e-positive. We will briefly describe this conjecture, and then explain how recent work of Shareshian-Wachs, Brosnan-Chow, among others, makes a surprising connection between this conjecture and the geometry of Hessenberg varieties, together with a certain symmetric-group representation on the cohomology of Hessenberg varieties. In particular, it turns out (a graded version of) the Stanley-Stembridge conjecture would follow if it can be proven that the cohomology of regular semisimple Hessenberg varieties (in Lie type A) are permutation representations of a certain form. I will then describe joint work with Precup which proves this statement for the case of abelian Hessenberg varieties, the definition of which is inspired by the theory of abelian ideals in a Lie algebra, as developed by Kostant and Peterson. Our proof relies on the incomparability graph of a Hessenberg function and previous combinatorial results of Stanley, Gasharov, and Shareshian-Wachs, as well as previous results on the geometry and combinatorics of Hessenberg varieties of Martha Precup. (Received January 09, 2018)

1136-05-141 **Guoli Ding***, Mathematics Department, Louisiana State University, Baton Rouge, LA 70803, and **Emily Marshall**, Computer Science & Mathematics, Arcadia University, Glenside, PA 19038. *Excluding a large Theta graph.*

Let Θ_t denote the graph consisting of three paths of length t that have the same ends and that are otherwise disjoint. We characterize graphs that do not contain a Θ_t-minor for large t. This result implies a well-known theorem of Robertson and Chakravarti on graphs that do not have a bond containing three specified edges.
(Received January 09, 2018)

1136-05-154 **Andrew Woldar***, Dept. of Math and Stats, SAC 380, Villanova, PA 19085, and **Nimrod Kriger**, Arugot, Israel. *Automorphism groups of classical affine association schemes of Latin type.* Preliminary report.

We consider the family of **complete classical affine association schemes** $\mathcal{A}_p$ of order p^2 andrank $p+2$ where p is an odd prime. Each such scheme is known to be amorphic, meaning that every possible merging of its $p+1$ classes results in a fusion scheme. We refer to such fusion schemes as **classical affine schemes**.

Let $\mathcal{M}$ be a classical affine scheme of order p^2. Then the automorphism group $Aut(\mathcal{M})$ contains $Aut(\mathcal{A}_p) \rtimes K$ where K is the stabilizer of $\mathcal{M}$ in $PGL(2,p)$. We are especially interested in the case when $Aut(\mathcal{M}) = Aut(\mathcal{A}_p) \rtimes K$. We call such schemes **standard**.

We make strong use of a bijection between all classical affine schemes $\mathcal{M}$ and all ordered partitions π of the point set of the projective line $\mathrm{PG}(1,p)$. We write $\mathcal{M} = \mathcal{M}(\pi)$.

Special attention is paid to schemes of **Latin type**, i.e., schemes $\mathcal{M}(\pi)$ in which every cell of π has size ≥ 3. Motivated by a question of Christopher French, we make the following supposition based on exhaustive computer data for $p \leq 11$ and partial data for $p = 13$:

Conjecture: *Every scheme of Latin type is standard.* (Received January 10, 2018)

1136-05-158 **Sergei Chmutov***, chmutov@math.ohio-state.edu. *Symmetric chromatic polynomial and the Vassiliev invariants.*

In 1995 R. Stanley introduced the *symmetric chromatic polynomial* as a generalization of the chromatic polynomial of graphs. It is a symmetric polynomial of infinitely many variables. R.Stanley formulated two, still opened, conjectures. One of them claims that the symmetric chromatic polynomial distinguishes tree.

In fact, the expression of the symmetric chromatic polynomial in terms of the symmetric power functions was introduced one year earlier, in 1994, in my joint work with S. Duzhin and S. Lando about Vassiliev knot invariants. The key ingredient there was a Hopf algebra structure on the space spanned by graphs modulo four-term relation. This Hopf algebra is graded, commutative, and cocommutative. Its primitive space is one-dimensional in every grading. According to the Milnor-Moore theorem, it is isomorphic to the algebra of polynomials in countably many variables, one for each basic vector of the primitive space. For a special choice of the basic vectors, this polynomial becomes exactly the expression of the symmetric chromatic polynomial in terms of the symmetric power functions.

I will explain the relation of the symmetric chromatic polynomial with Vassilev invariants and reformulate Stanley's conjecture in terms of Vassiliev knot invariants. (Received January 10, 2018)

1136-05-160 **Jacques Verstraete*** (`jacques@ucsd.edu`), Department of Mathematics, 9500 Gilman Drive, La Jolla, CA 92093-0112, and **Dhruv Mubayi**. *Counting trees in graphs.*

For a tree T and a graph G, let $N_T(G)$ denote the number of isomorphic copies of T in G. If T has k edges and G is a d-regular n-vertex graph, then $N_T(G) \geq nd(d-1)\cdots(d-k+1)$. We ask whether this inequality holds more generally for n-vertex graphs of average degree $d \geq k$, and we prove for such graphs that

$$N_T(G) \geq (1 - O(\tfrac{1}{d^2}))nd(d-1)\cdots(d-k+1)$$

This improves earlier results of Erdős and Simonovits.

Joint work with Dhruv Mubayi (Received January 10, 2018)

1136-05-192 **Xiaofeng Gu***, Department of Mathematics, University of West Georgia, 1601 Maple St, Carrollton, GA 30118. *Sparse subgraph and spanning rigid subgraph decomposition.*

A graph G is sparse if $|E(H)| \leq 2|V(H)| - 3$ for every subgraph H of G with $|V(H)| \geq 2$; If in addition $|E(G)| = 2|V(G)| - 3$, then G is minimally rigid. A graph is rigid if it contains a spanning minimally rigid subgraph. By definition, every rigid graph with at least 3 vertices is 2-connected. To find sufficient conditions for edge-disjoint higher-connected spanning subgraphs is a difficult problem. We survey some sufficient conditions for edge-disjoint spanning rigid subgraphs and spanning trees, and give improved sufficient conditions. As analogues of forest covering problems, sparse subgraph covering problems are also studied. (Received January 15, 2018)

1136-05-193 **Mark Ellingham*** (`mark.ellingham@vanderbilt.edu`) and **Joanna Ellis-Monaghan**. *Graph embeddings and DNA reporter strands.*

In DNA computing, strands of DNA (deoxyribonucleic acid) are allowed to self-assemble into a structure from which the solution to a problem can be derived. In some situations a *reporter strand* of DNA is used to read off the solution. In DNA origami, DNA strands self-assemble into structures of a prescribed shape. A *scaffolding strand* of DNA may be used as a framework for the overall shape. Both reporter strands and scaffolding strands correspond to a *reporter strand walk*, a closed walk in a graph that uses every edge at least once and occurs as a face boundary in some orientable embedding of the graph. Jonoska, Seeman and Wu showed that such a walk always exists. We give a short algorithmic proof of this. We also show that it is NP-complete to determine whether a graph has a reporter strand walk whose length meets a natural polynomial-time-computable lower bound, even for 3-connected 3-regular planar graphs. (Received January 15, 2018)

1136-05-202 **Liaao Li**, **Carsten Thomassen**, **Yezhou Wu** and **Cun-Quan Zhang*** (cqzhang@mail.wvu.edu), Dept. Math, West Virgiia University, Morgantown, WV 26506-6310. *The flow index and strongly connected orientations.*

We prove that, for any natural number p, the flow index $\phi(G) < 2 + \frac{1}{p}$ if and only if G has a strongly connected modulo $(2p+1)$-orientation. For the case $p = 1$ we prove that the flow index of every 8-edge-connected graph is strictly less than 3. (Received January 15, 2018)

1136-05-209 **Wei-Hsuan Yu*** (u690604@gmail.com) and **Alexey Glazyrin**. *New bounds for equiangular lines and spherical two-distance sets.*

The set of points in a metric space is called an s-distance set if pairwise distances between these points admit only s distinct values. Two-distance spherical sets with the set of scalar products $\{\alpha, -\alpha\}$, $\alpha \in [0, 1)$, are called equiangular. The problem of determining the maximal size of s-distance sets in various spaces has a long history in mathematics. We determine a new method of bounding the size of an s-distance set in two-point homogeneous spaces via zonal spherical functions. This method allows us to prove that the maximum size of a spherical two-distance set in $\mathbb{R}^n$ is $\frac{n(n+1)}{2}$ with possible exceptions for some $n = (2k+1)^2 - 3$, $k \in \mathbb{N}$. We also prove the universal upper bound $\sim \frac{2}{3}na^2$ for equiangular sets with $\alpha = \frac{1}{a}$ and, employing this bound, prove a new upper bound on the size of equiangular sets in an arbitrary dimension. Finally, we classify all equiangular sets reaching this new bound. (Received January 15, 2018)

1136-05-217 **Vaidy Sivaraman***, Department of Mathematics, Orlando, FL 32765, and **Maria Chudnovsky**. *Odd holes in bull-free graphs.*

The complexity of testing whether a graph contains an odd hole (induced cycle) of length at least five is currently unknown. We show that this can be done in quintic time if the input graph has no induced subgraph isomorphic to the bull (a triangle with two disjoint pendant edges). This is joint work with Maria Chudnovsky. (Received January 16, 2018)

1136-05-221 **Hong-Jian Lai*** (hjlai@math.wvu.edu), 320 Armstrong Hall, West Virginia University, Morgantown, WV 26506-6310. *The s-hamiltonian problem in line graphs.* Preliminary report.

Thomassen in early 1980 conjectured that every 4-connected line graph is hamiltonian. Kuczel and Xiong (2004) conjectured that every 4-connected line graph is hamiltonian-connected. Both conjectured conditions are possible sufficient conditions but they are not necessary. It is well known that if a graph G is s-hamiltonian (or s-hamiltonian-connected, resp.), then G is $(s+2)$-connected (or $(s+3)$-connected, resp.). Broersma and Veldman in 1987 proposed an open problem of determining the range of integral values s such that within triangular graphs, $L(G)$ is s-hamiltonian if and only $L(G)$ is $(s+2)$-connected. This problem was first settled by Chen et al in [Graphs and Combinatoircs, 23 (2007), 241-248] and extended in [J. Graph Theory, 74 (2013), 344-358]. These motivates the following conjectures:
(i) If $s \geq 2$, then $L(G)$ is s-hamiltonian if and only if $\kappa(L(G)) \geq s+2$.
(ii) If $s \geq 1$, then $L(G)$ is s-hamiltonian-connected if and only if $\kappa(L(G)) \geq s+3$.

In this talk, we present some recent progresses towards these conjectures. (Received January 16, 2018)

1136-05-229 **David Galvin*** (dgalvin1@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Chordal graphs, Stirling numbers and total non-negativity.* Preliminary report.

I'll talk about some recent work with Adrian Păcurar concerning Stirling numbers and their generalizations. It's well-known that the matrix whose (m,k)-entry is the number of partitions of a set of size m into k non-empty blocks has a nice inverse: the (m,k)-entry of the inverse is (up to sign $(-1)^{m-k}$) the number of partitions of a set of size m into k non-empty *cyclically ordered* blocks.

The same matrix also has the remarkable property of *total non-negativity*: all minors (determinants of square submatrices) are non-negative. I'll present a broad generalization of this result. A connection to graph theory will be provided — as a corollary of the main result, I'll derive the total non-negativity of a class of matrices associated naturally with chordal graphs. (Received January 16, 2018)

1136-05-276 **Cara Monical*** (cmonica2@illinois.edu), **Neriman Tokcan** and **Alexander Yong**. *Newton Polytopes in Algebraic Combinatorics.*

A polynomial has saturated Newton polytope (SNP) if every lattice point in the convex hull of its exponent vectors corresponds to a monomial. We compile instances of SNP in algebraic combinatorics, and show the phenomenon is widespread in many of the polynomial families of interest. We also give explicit inequalities for the Newton polytope of the Schubert polynomials based on the diagram of the permutation. (Received January 18, 2018)

1136-05-303 **Alan M Frieze*** (alan@random.math.cmu.edu), 5000 Forbes Avenue, Pittsburgh, PA 15213, and **Samantha Petti** (spetti3@gatech.edu), Atlanta, GA. *Balanced Allocation Through Random Walk.*

We consider the allocation problem in which $m \leq (1-\epsilon)dn$ items are to be allocated to n bins with capacity d. The items $x_1, x_2, \ldots, x_m$ arrive sequentially and when item x_i arrives it is given two possible bin locations $p_i = h_1(x_i), q_i = h_2(x_i)$ via hash functions h_1, h_2. We consider a random walk procedure for inserting items and show that the expected time insertion time is constant provided $\epsilon = \Omega\left(\sqrt{\frac{\log d}{d}}\right)$. (Received January 19, 2018)

1136-05-304 **Bhargav Narayanan*** (b.narayanan@rutgers.edu). *Long cycles in Hamiltonian graphs.*

We prove that if an n-vertex graph with minimum degree at least 3 contains a Hamiltonian cycle, then it contains another cycle of length $n - o(n)$; in particular, this verifies, in an asymptotic form, a well-known conjecture due to Sheehan from 1975. Joint work with Girão and Kittipassorn. (Received January 19, 2018)

1136-05-312 **Shira Zerbib*** (zerbib@umich.edu) and **Ron Aharoni**. *A generalization of Tuza's conjecture.*

A famous conjecture of Tuza from 1981 is that the minimal number of edges needed to cover all triangles in a graph G is at most twice the maximal number of edge-disjoint triangles in G. We propose a wider setting for this conjecture. Our conjecture is that in the "pair hypergraph" of any 3-uniform hypergraph H, the covering number is at most twice the matching number. Our conjecture specializes to Tuza's conjecture when H is the hypergraph of all triple of vertices that form a triangle in a graph G, but it has many extremal examples that are not of this type. We show that most known bounds on Tuza's conjecture go over to our more general setting. We also prove our conjecture in some special cases. (Received January 19, 2018)

1136-05-323 **Caroline Terry*** (cterry@umd.edu). *Jumps in speeds of hereditary properties of uniform hypergraphs.*

A hereditary graph property is a class of finite graphs closed under isomorphism and induced subgraphs. Given a hereditary graph property $\mathcal{H}$, the *speed* of $\mathcal{H}$ is the function which sends n to the number of distinct elements in $\mathcal{H}$ with underlying set $\{1, \ldots, n\}$. Not just any function can occur as the speed of hereditary graph property. Specifically, there are discrete "jumps" in the possible speeds. Study of these jumps began with work of Scheinerman and Zito in the 90's, and culminated in a series of papers from the 2000's by Balogh, Bollobás, and Weinreich, in which essentially all possible speeds of hereditary graph properties were characterized. In contrast to this, many questions about the speeds of hereditary hypergraph properties have remained open. In this talk we present new hypergraph analogues of most of the jumps from the graph setting, specifically those involving the polynomial, exponential, and factorial speeds. The jumps in the factorial range have surprising connections to model theory, which we also discuss. This is joint work with Chris Laskowski. (Received January 19, 2018)

1136-05-328 **Alexandr Kostochka*** (kostochk@math.uiuc.edu) and **Ruth Luo**. *Turán numbers for short Berge cycles in uniform hypergraphs.* Preliminary report.

We show that for any $k \geq 4$ and $n > r \geq k+1$, every n-vertex r-uniform hypergraph with no Berge cycle of length at least k has at most $\frac{(k-1)(n-1)}{r}$ edges. The bound is exact, and we describe the extremal hypergraphs. This implies and sharpens the theorem of Győri, Katona and Lemons that for $n > r \geq k \geq 3$, every n-vertex r-uniform hypergraph with no Berge path of length k has at most $\frac{(k-1)n}{r+1}$ edges. (Received January 19, 2018)

1136-05-341 **Mikhail Lavrov*** (mlavrov@illinois.edu), **Po-Shen Loh** and **Arnau Messegué**. *Distance-uniform graphs with large diameter.*

An ϵ-distance-uniform graph with critical distance d is one in which from every vertex, all but at most an ϵ-fraction of the remaining vertices are at distance d. We consider the maximum possible value of d in an ϵ-distance-uniform graph with n vertices. We show that for $\frac{1}{n} \leq \epsilon \leq \frac{1}{\log n}$, there exist ϵ-distance-uniform graphs with critical distance $2^{\Omega(\frac{\log n}{\log \epsilon^{-1}})}$, disproving a conjecture of Alon et al. that d can be at most logarithmic in

n. We also show that our construction is best possible, in the sense that an upper bound on d of the form $2^{O(\frac{\log n}{\log \epsilon^{-1}})}$ holds for all ϵ and n. (Received January 19, 2018)

1136-05-346 **Martina Juhnke-Kubitzke**, **Satoshi Murai**, **Isabella Novik** and **Connor Sawaske*** (sawaske@uw.edu). *Lower bound theorems for balanced manifolds.*

Juhnke-Kubitzke and Murai proved a balanced generalized lower bound theorem for simplicial polytopes. We extend their result to balanced triangulations of orientable homology manifolds whose proper links have the weak Lefschetz property. As a corollary, we prove a conjecture of Klee and Novik that if Δ is a balanced triangulation of a connected $(d-1)$-dimensional orientable homology manifold, then $2h_2(\Delta) - (d-1)h_1(\Delta) \geq 4\binom{d}{2}\tilde{\beta}_1(\Delta)$. (Received January 19, 2018)

1136-05-351 **John Maharry**, **Neil Robertson**, **Vaidy Sivaraman** and **Daniel Slilaty*** (daniel.slilaty@wright.edu), Wright State University, Department of Mathematics and Statistics, Dayton, OH 45435. *Flexibility of graph embeddings, matroid isomorphism, and V_8-free graphs.*

Whitney considered the following problem. A labeled graph G has two distinct embeddings in the plane: What is the relationship between these two embeddings? The simple answer to this question is that the two embeddings are related by a sequence of operations called "Whitney flips".

Consider the analogous problem for the projective plane. The answer to this question is far more complicated with a much more difficult proof. Is there any hope of extending such a complicated result to other surfaces? The proof of our result makes use of Robertson and Maharry's theorem characterizing graphs with no V_8-minor. Ding also makes use of this characterization of V_8-free graphs to characterize graphs without an octahedron minor. Could Robertson and Maharry's theorem be a stepping stone to other results?

The problem on flexibility of graph embeddings in the plane is closely related to the following question: When do two graphs with the same edge set have the same cycle matroids? Flexibility of graph embeddings in the projective plane relate to the question of when two signed graphs have the same frame matroid. While the problem for graphs was solved completely by Whitney, the problem for signed graphs shows little hope of a solution anytime soon. (Received January 19, 2018)

1136-05-373 **Huseyin Acan*** (huseyin.acan@rutgers.edu) and **Boris Pittel**. *On the giant component of the intersection graph of a random chord diagram.*

A chord diagram of size n is a pairing of $2n$ points. When the points are placed on a circle, this gives n chords. For a chord diagram D, its intersection graph is formed by taking the chords of D as the vertices of the graph and creating an edge between two vertices whenever the corresponding chords cross each other. We are interested in the largest component of $H_{n,m}$, where $H_{n,m}$ denotes the intersection graph of a uniformly random chord diagram with n chords and m crossings. When $m/(n \log n)$ tends to a limit in $(0, 2/\pi^2)$, we show that the largest component contains almost all the edges and a positive fraction of all the vertices of $H_{n,m}$. On the other hand, when $m \leq n/14$, the size of the largest component is $O(\log n)$.

Thresholds for the appearance of giant (linear size) components are well studied for various random graph models, most famously for Erdős-Rényi graphs. In the case of a random chord intersection graph, it is not known whether or not there is a threshold. However, if there is such a threshold, our results imply that it must be of order $\Omega(n)$ and $O(n \log n)$. (Received January 20, 2018)

1136-05-381 **P. Bennett*** (patrick.bennett@wmich.edu), **L. DeBiasio**, **A. Dudek** and **S. English**. *Large monochromatic components and long monochromatic cycles in random hypergraphs.*

We extend results of Gyárfás and Füredi on the largest monochromatic component in r-colored complete k-uniform hypergraphs to the setting of random hypergraphs. We also study long monochromatic loose cycles in r-colored random hypergraphs. In particular, we obtain a random analog of a result of Gyárfás, Sárközy, and Szemerédi on the longest monochromatic loose cycle in 2-colored complete k-uniform hypergraphs. (Received January 20, 2018)

1136-05-402 **Craig Timmons*** (craig.timmons@csus.edu) and **Michael Tait**. *The Zarankiewicz problem in 3-partite graphs.*

Bipartite Turán problems are some of the most interesting problems in extremal graph theory. They have a rich history dating back to an early paper of Erdős from 1938. While much progress has been made, many questions have not been answered. The case when the forbidden graph is a complete bipartite graph is closely related to the famous Zarankiewicz problem. In this talk, we will discuss a variation of the bipartite Turán problem where the host graph must be 3-partite. The Zarankiewicz problem corresponds to the case when the host graph is

2-partite. We also present some bounds on the maximum number of edges in a 3-partite graph with no subgraph isomorphic to $K_{s,t}$. This is joint work with Michael Tait. (Received January 20, 2018)

1136-05-418 **Stefaan De Winter** and **Zeying Wang*** (zeying@mtu.edu), Michigan Technological University, Houghton, MI 49931. *Partial Difference Sets in Abelian Groups of order* $8p^3$.

Recently we proved a theorem for strongly regular graphs that provides numerical restrictions on the number of fixed vertices and the number of vertices mapped to adjacent vertices under an automorphism. We then used this result to develop some new techniques to study regular partial difference sets in Abelian groups. Our main results so far are the proof of non-existence of PDS in Abelian groups with small parameters, a complete classification of PDS in Abelian groups of order $4p^2$, and a proof that no non-trivial PDS exist in Abelian groups of order $8p^3$.

In this talk I plan to give an overview of these results with a focus on our most recent work on the PDS in Abelian groups of order $8p^3$, where p is a prime number ≥ 3. (Received January 21, 2018)

1136-05-423 **Ryan Gabrys** and **Olgica Milenkovic*** (milenkov@illinois.edu), 311 Coordinated Science Lab, Urbana, IL 61801. *On constructions of codes uniquely reconstructable from substring multisets.*

The problem of reconstructing strings from their substring spectra has a long history and in its most simple incarnation asks for determining under which conditions the spectrum uniquely determines the string. We study the problem of coded string reconstruction from multiset substring spectra, with the strings restricted to lie in some codebook. In particular, we consider binary codebooks that allow for unique string reconstruction and propose a new method, termed repeat replacement, to create the codebook. (Received January 21, 2018)

1136-05-435 **Hanmeng Zhan*** (h3zhan@uwaterloo.ca), Department of Combinatorics and Optimization, University of Waterloo, Waterloo, Ontario N2L 3G1. *Graph covers and equiangular frames.*

We present a graph-theoretic approach to equiangular frames. Let X be a graph. If we replace each vertex u of X by a set of r vertices, called the fiber of u, and replace each edge (u, v) of X by an r-matching between the fiber of u and the fiber of v, then we obtain an r-fold cover of X. Covers of complete graphs are of particular interest as they give rise to equiangular tight frames, under some regularity conditions. We will explore these conditions, and show how to construct equiangular tight frames from graph covers, and vice versa. (Received January 21, 2018)

1136-05-448 **Michael Tait*** (mtait@cmu.edu). *Sets of integers with restrictions on their products.*

A *product-injective labeling* of a graph G is an injection $\chi : V(G) \to \mathbb{Z}$ such that $\chi(u)\chi(v) \neq \chi(x)\chi(y)$ for any distinct edges $uv, xy \in E(G)$. Let $P(G)$ be the smallest $N \geq 1$ such that there exists a product-injective labeling $\chi : V(G) \to [N]$. Let $P(n, d)$ be the maximum possible value of $P(G)$ over n-vertex graphs G of maximum degree at most d. We determine the asymptotic value of $P(n, d)$ for all but a small range of values of d relative to n. Specifically, we show that there exist constants $a, b > 0$ such that $P(n, d) \sim n$ if $d \leq \sqrt{n}(\log n)^{-a}$ and $P(n, d) \sim n \log n$ if $d \geq \sqrt{n}(\log n)^b$. This is joint work with Jacques Verstraete. (Received January 21, 2018)

1136-05-456 **Thanh N. Dang*** (thanh.dang@gatech.edu) and **Robin Thomas** (thomas@math.gatech.edu). *Minors of graphs of large path-width.*

Let P be a graph with a vertex v such that $P - v$ is a forest and let Q be an outerplanar graph. In 1993 Seymour asked if every two-connected graph of sufficiently large path-width contains P or Q as a minor. Define $g(H)$ as the minimum number for which there exists a positive integer $p(H)$ such that every $g(H)$-connected H-minor-free graph has path-width at most $p(H)$. Then $g(H) = 0$ iff H is a forest and there is no graph H with $g(H) = 1$, because path-width of a graph G is the maximum of the path-widths of its connected components. Let A be the graph that consists of a cycle $(a_1, a_2, a_3, a_4, a_5, a_6, a_1)$ and extra edges a_1a_3, a_3a_5, a_5a_1. Let $C_{3,2}$ be a graph of 2 disjoint triangles. In 2014 Marshall and Wood conjectured that a graph H does not have $K_4, K_{2,3}$, $C_{3,2}$ or A as a minor if and only if $g(H) \leq 2$. We answer Seymour's question in the affirmative as well as extend the result to three-connected and four-connected graphs of large path-width. We also prove the conjecture of Marshall and Wood. (Received January 21, 2018)

1136-05-459 **Jiaao Li***, Department of Mathematics, West Virginia University, Morgantown, WV 26505. *Nowhere-zero Flow Problems.*

As a generalization of map-coloring problems, Tutte initiated the study of nowhere-zero flow of graphs in 1950s, and he proposed some intriguing flow conjectures (3-flow, 4-flow, and 5-flow conjectures). The 3-flow theorem of Lovasz-Thomassen-Wu-Zhang, the Snark Theorem of Robertson-Sanders-Seymour-Thomas, and Seymour's

6-flow theorem provide milestones on those problems, respectively. Jaeger and others further extended the integer flow theory to circular flows of graphs. Jaeger conjectured that every $4p$-edge-connected graph admits a circular $(2 + 1/p)$-flow, where the $p = 1$ case is the 3-flow conjecture and the $p = 2$ case implies the 5-flow conjecture. In this talk, we show that every 8-edge-connected graph has circular flow strictly less than 3, which approximates the conjectured value 2.5 and provides evidence to Tutte's 5-flow conjecture. On the other hand, we disprove Jaeger's circular flow conjecture for every $p \geq 3$ and propose some new problems on nowhere-zero flows. (Received January 21, 2018)

1136-05-503 **James A Davis*** (jdavis@richmond.edu), Dept of Math and CS, Univ of Richmond, VA 23173, **John B. Polhill**, Dept of Math, CS, and Stats, Bloomsburg, PA 17815, and **Ken W. Smith**. *Relative and Almost Linking Systems.* Preliminary report.

Collections of difference sets called linking systems have been used to construct new families of linked systems of symmetric designs. In this paper, we define relative and almost linking systems, collections of difference sets and almost difference sets with very similar linking properties to linking systems. These linking systems have connections to bent sets and vectorial bent functions. We construct examples of relative and almost linking systems using a technical lemma. (Received January 22, 2018)

1136-05-512 **John Asplund**, **Thao Do**, **Arran Hamm*** (hamma@winthrop.edu), **László Székely**, **Libby Taylor** and **Zhiyu Wang**. *Biplanar Crossing Number and the Probabilistic Method.*

Given a graph G, its crossing number, denoted $cr(G)$, is the minimum number edge crossings over all drawings of G in the plane. The biplanar crossing number of G, denoted $cr_2(G)$, is the minimum of $cr(G_1) + cr(G_2)$ over all edge partitions $G = G_1 \cup G_2$. E. Czabarka, O. Sýkora, L. Székely, and I. Vrťo proved that for any G, $cr_2(G) \leq (3/8)cr(G)$ using a probabilistic argument. J. Spencer used the probabilistic method to prove that $cr_2(G_{n,p})$ is asymptotically largest possible with high probability. In this talk we will discuss both of these proofs. We will also generalize Spencer's result to the k-planar crossing number of $G_{n,p}$ (analogous to biplanar but with k planes instead of two) . We will conclude by discussing the biplanar crossing number for random regular graphs. (Received January 22, 2018)

1136-05-513 **Jonathan Cutler*** (jonathan.cutler@montclair.edu) and **A. J. Radcliffe**. *Supersaturation in extremal enumeration.*

Turán's theorem states that the maximum number of edges in 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 $\mathrm{ex}(n, K_{r+1})$, the extremal number of K_{r+1}. Supersaturation in graphs asks 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 G, let $\mathrm{ex}_G(n, H)$ be the maximum number of copies of G 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 January 22, 2018)

1136-05-519 **Deepak Bal*** (deepak.bal@montclair.edu), Montclair State University, Department of mathematical Sciences, 1 Normal Ave., Montclair, NJ 07043, and **Patrick Bennett**. *The bipartite $K_{2,2}$-free process and Ramsey numbers.* Preliminary report.

The smallest n such that every red-blue edge-coloring of $K_{n,n}$ contains a red $K_{2,2}$ or a blue $K_{t,t}$ is known as the two color bipartite Ramsey number, $br(2, t)$. In the bipartite $K_{2,2}$-free process, we begin with an empty graph on vertex set $A \cup B$, $|A| = |B| = n$. At each step, a random edge from $A \times B$ is added under the restriction that no $K_{2,2}$ is formed. This step is repeated until no more edges can be added. We use the technique of dynamic concentration to analyze this process and show how the resulting graph can be used to improve the best known lower bound on $br(2, t)$. This is joint work with Patrick Bennett. (Received January 22, 2018)

1136-05-522 **Xingxing Yu*** (yu@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Progress on a conjecture of Hajós on graph coloring.* Preliminary report.

Hajós conjectured that every graph contains no subdivision of K_{k+1} is k-colorable. This conjecture is known to be true when $k \leq 3$, but it is false when $k \geq 6$. We will discuss recent work on the case when $k = 4$. (Received January 22, 2018)

1136-05-563 **Zoltan Furedi*** (z-furedi@math.uiuc.edu), Realtanoda utca 13-15, Budapest, 1053, Hungary, and **Andras Gyarfas** (gyarfas.andras@renyi.mta.hu), Realtanoda utca 13-15, Budapest, Hungary. *The linear Turán number of the sail and the k-fan.*

The *sail*, F, has four triples on seven points, three pairwise intersecting in the same point p and the fourth intersecting all of them in points different from p. More generally, the k-fan F_k has k k-sets pairwise intersecting in the same point p and a crossing edge intersecting all of them in points different from p. Note that F_2 is the graph triangle and $F_3 = F$.

Linear hypergraph: any two edges intersect in at most one point. The linear Turán number of a linear hypergraph L, $\mathrm{ex}_{\mathrm{lin}}(n, L)$, is the maximum number of edges in a linear hypergraph with n points that does not contain L. We proved

— $\mathrm{ex}_{\mathrm{lin}}(n, F_k) = n^2/k^2$, equality is possible only for transversal designs on n points with k groups,

— if $n = 3m + 2$ then $\mathrm{ex}_{\mathrm{lin}}(n, F) = m^2 + m$, equality only in the following cases: removing one point from a transversal design on $3m + 3$ points; extending each factor of a factorization of a graph G to triples, where G is either the Wagner graph (C_8 with long diagonals) or the graph $C_{5,2}$ (obtained from C_5 by doubling its points),

— the case $n = 3m + 1$ remained unsolved. (Received January 22, 2018)

1136-05-568 **Jason S Williford*** (jwillif1@uwyo.edu), Department of Mathematics and Statistics, Dept. 3036, 1000 E. University Ave., Laramie, WY 82072. *Balanced set type conditions.*

In Paul Terwilliger's papers "A characterization of P- and Q-polynomial association schemes" and "Balanced sets and Q-polynomial association schemes," he introduced certain conditions on sets of unit vectors which, in the context of association schemes, are equivalent to the scheme having a nontrivial sparse representation diagram (specifically a tree with possible loops, an augmented tree or tree).

In this talk we will discuss recent work from the thesis of Gavin King on such sets of vectors, including new examples and partial classification results. We will conclude with conjectures concerning the relationship between sets of vectors with these conditions and the Q-polynomial property. (Received January 22, 2018)

1136-05-580 **Anton Dochtermann*** (dochtermann@txstate.edu), San Marcos, TX. *Chordal graphs, linear quotients, and spanning complexes for data clustering.* Preliminary report.

Notions of chordal graphs and complexes have played a central role in combinatorial commutative algebra. Recently Culberson, Guralnik, and Stiller give a new characterization of chordal graphs in terms of sequences of 'edge-erasures'. Their motivation came from data clustering and algorithms for finding minimal spanning complexes that generalize the minimal spanning trees involved in 'single-linkage clustering'. We give a simple algebraic proof of their result and illustrate some consequences of this new perspective. We discuss how the algebraic approach may provide insight into spanning complexes for other clustering methods. (Received January 22, 2018)

1136-05-585 **Matthew Barnes** and **Bogdan Oporowski*** (bogdan@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Unavoidable Immersions of Large* 3- *and* 4-*Edge-Connected Graphs.* Preliminary report.

A graph H is *immersed* in a graph G if there is an injection φ from the vertex-set of H to the vertex-set of G such that each edge of H incident with vertices u and v is mapped to a path in G so that its ends are $\varphi(u)$ and $\varphi(v)$, the path avoids other elements of $\varphi(V(H))$, and every two such paths are edge-disjoint. We show a Ramsey-type theorem stating that every sufficiently large 3-edge-connected graph admits an immersion of a large well-known 3-edge-connected graph. We also discuss progress towards proving an analogous result for 4-edge-connected graphs. (Received January 22, 2018)

1136-05-595 **William J. Martin*** (martin@wpi.edu), Department of Mathematical Sciences, 100 Institute Road, Worcester Polytechnic Institute, Worcester, MA 01609, and **Douglas R. Stinson** (dstinson@uwaterloo.ca), David R. Cheriton School of Computer Science, University of Waterloo, Waterloo, ON N2L 3G1, Canada. *Polynomial ideals for combinatorial t-designs.* Preliminary report.

Let X be a finite set and let $(X, \mathcal{D})$ be a k-uniform hypergraph on point set X. We call the elements of $\mathcal{D}$ *blocks* and identify each $B \in \mathcal{D}$ with its incidence vector $\mathbf{c}_B$. We seek a nice description of the ideal $I(\mathcal{D})$ of all polynomials F in $|X|$ variables which vanish on the point set $\{\mathbf{c}_B \mid B \in \mathcal{D}\}$. The pair $(X, \mathcal{D})$ is a t-design if every t-element subset of X is contained in exactly λ blocks B in $\mathcal{D}$ for some constant λ. In this joint work, Doug Stinson and I explore the relationship between t and two parameters: $\gamma_1(\mathcal{D})$ is the smallest degree of a non-trivial polynomial in the ideal $I(\mathcal{D})$ and $\gamma_2(\mathcal{D})$ is the smallest integer s such that $I(\mathcal{D})$ is generated by a set of polynomials all having total degree at most s. For a t-design $(X, \mathcal{D})$, we prove $\gamma_1(\mathcal{D}) \geq t/2$ and, for a Steiner system (where $\lambda = 1$), we prove $\gamma_2(\mathcal{D}) \leq t$. We explore some important examples of designs and discuss the connection between these parameters and those of the Q-polynomial association schemes they form. (Received January 22, 2018)

1136-05-603 **Robert E. Jamison** (rejam@clemson.edu) and **Alan P. Sprague*** (sprague@uab.edu), 234 Oakland Park Ave., Columbus, OH 43214. *Multithreshold Graphs.*

A graph is a *threshold graph* if every vertex v has a real *rank* $r(v)$ such that two vertices v and w are adjacent precisely when $r(v) + r(w) \geq 0$. The class of threshold graphs was introduced by Chvatal and Hammer in 1977, and has become one of the most well-studied graph classes. We define a graph to be a *k-threshold graph* if every vertex v has a real *rank* $r(v)$ and there exist k real numbers called *thresholds* such that two vertices v and w are adjacent precisely when $r(v) + r(w)$ is greater than or equal to an odd number of thresholds. The 1-threshold graphs are precisely the threshold graphs of Chvatal and Hammer.

The class of 2-threshold graphs is intermediate between the class of bipartite permutation graphs and the class of permutation graphs.

We will report on graph classes such that few thresholds suffice, classes requiring many thresholds, and show an upper bound on the number of thresholds for all graphs on n vertices. (Received January 22, 2018)

1136-05-608 **Yuqing Chen*** (yuqing.chen@wright.edu). *Bent functions from hyperovals and partial difference sets from semifields.*

By exploiting a connection between certain relative difference sets fixed by inversion and certain partial difference sets, we obtain relative difference sets and partial difference sets. These relative difference sets are described in terms of bent functions (or perfect non-linear functions) which are essentially o-polynomials of hyperovals in $\mathrm{PG}(2, 2^m)$. The partial difference sets are in non-abelian p-groups of exponent p and p^2, where p is an odd prime, and these groups are constructed from semifields. (Received January 22, 2018)

1136-05-616 **Arthur L Gershon*** (arthur.gershon@case.edu). *A Path Through the StArrs: Using Walks on Graphs to Compute Generating Functions for Strip Arrangements on Chessboards.* Preliminary report.

For positive integers m and n, let $T(m, n)$ be the number of ways to arrange non-overlapping strips on an $m \times n$ chessboard with at most one horizontal strip in each row and at most one vertical strip in each column. We show how to use the transfer matrix method to compute, for a fixed positive integer m, the generating function for the sequence $T(m, n) : n \geq 0$. This technique can be generalized to strip arrangements that allow up to h horizontal strips in a row and k vertical strips in a column; the case $h = k = 1$ that we will focus on is of interest due to an apparent connection with the eight-vertex model of statistical physics. Time permitting, we will also discuss results for strip arrangements that allow any number of strips in each row and column (i.e., the case $h = k = \infty$). (Received January 22, 2018)

1136-05-620 **Christopher Park Mooney*** (christopher.mooney@westminster-mo.edu), 501 Westminster College, Fulton, MO 65251. *On Edge Graceful Labelings of Zero-Divisor Graphs.* Preliminary report.

In this talk, we discuss edge graceful labelings of zero-divisor graphs. This continues a previous study in which graceful and harmonious labelings were investigated. These graphs arise naturally out of commutative rings with zero-divisors where the vertex set is the collection of non-zero zero-divisors and there is an edge between distinct vertices $x, y \in Z(R)^*$ if $xy = 0$. These graphs are simple, undirected, connected graphs which makes them very nice candidates for labeling problems. We are able to find infinite classes of rings which admit an edge graceful labeling as well as infinite classes of rings which have no edge graceful labeling. If time permits we will also show tables of which zero-divisor graphs on a small number of vertices are edge graceful for all zero-divisor graphs up to size 14. This is a natural place to begin trying to exhaustively answer the question for all possible commutative rings with finite zero-divisor graphs. (Received January 23, 2018)

06 ► Order, lattices, ordered algebraic structures

1136-06-628 **Artur Elezi***, American University, 4400 Mass Ave, NW, Washington, DC 20016, and **Tony Shaska**. *Reduction of binary forms via the hyperbolic centroid.*

In this paper we introduce a reduction theory of binary forms based on the hyperbolic center of mass. This reduction is different from the one introduced by Julia (1917), but seems to give similar results. (Received January 24, 2018)

1136-06-632 **Jean B Nganou*** (nganouj@uhd.edu), Department of Mathematics & Statistics, University of Houston-Downtown, One Main Street, Room S705, Houston, TX 77002.
Profinite completions of MV-algebras.

In the first part, we prove that the profinite completion of an MV-algebra is the direct product of all its finite simple homomorphic images. As immediate byproducts of our description, we obtain simpler proofs of some previously known results such as the profinite completion of a Boolean algebra, the action of profinite completions on the Boolean center of regular MV-algebras, the characterization of MV-algebras that are isomorphic to their own profinite completions. We also deduce the functoriality of the profinite completion defined on **MV**.

In the second part, we use the description of the profinite completion found to characterize profinite MV-algebras that are isomorphic to profinite completions of some MV-algebras. Among other things, we prove that a profinite MV-algebra $A := \prod_{x\in X} \text{Ł}_{n_x}$ is isomorphic to the profinite completion of an MV-algebra if and only if there exists a compact Hausdorff space Y containing X as a dense subspace and a separating subalgebra A' of $\mathrm{Cont}(Y)$ satisfying:
(i) For every $x \in X$, J_x has rank n_x in A', where $J_x := \{f \in A' : f(x) = 0\}$; and (ii) For every $y \in Y \setminus X$, J_y has infinite rank in A'. (Received January 24, 2018)

08 ► General algebraic systems

1136-08-212 **Travis Alan Baumbaugh*** (tbaumba@clemson.edu), 112 Appletree Avenu, Apt. 128, Central, SC 29630, and **Yariana Diaz**, **Sophia Friesenhahn**, **Felice Manganiello** and **Alexander Vetter**. *Batch Codes from Hamming and Reed-Müller Codes.*

Batch codes, introduced by Ishai *et al.*, encode a string $x \in \Sigma^k$ into an m-tuple of strings, called buckets. In this talk we consider multiset batch codes wherein a set of t-users wish to access one bit of information each from the original string. We introduce a concept of optimal batch codes. We first show that binary Hamming codes are optimal batch codes. The main body of this work provides batch properties of Reed-Müller codes. We look at locality and availability properties of first order Reed-Müller codes over any finite field. We then show that binary first order Reed-Müller codes are optimal batch codes when the number of users is 4 and generalize our study to the family of binary Reed-Müller codes which have order less than half their length. (Received January 16, 2018)

1136-08-256 **Heide Gluesing-Luerssen** and **Tefjol Pllaha*** (tefjol.pllaha@uky.edu). *On Quantum Stabilizer Codes derived from Local Frobenius Rings.*

Quantum stabilizer codes form the most important class of quantum error-correcting codes. In this talk we define quantum stabilizer codes over Frobenius rings and establish a correspondence with self-orthogonal submodules $C \leq R^{2n}$ under a certain bilinear form, called stabilizer codes. The equivalence of stabilizer codes is discussed via symplectic isometries. Next, we compare stabilizer codes over local Frobenius rings with stabilizer codes over fields and conjecture that they perform equally well. (Received January 17, 2018)

1136-08-270 **Sergio R López-Permouth*** (lopez@ohio.edu), Athens, OH 45701, and **Isaac Owusu Mensah** and **Asiyeh Rafieipour**. *Algebraic structures on the set of all magmas over a fixed set.* Preliminary report.

In recent years, the word *magma* has been used to designate a pair of the form $(S, *)$ where $*$ is a binary operation on the set S. Inspired by that terminology, we use the notation $M(S)$ (the magma of S) to denote the set of all binary operations on the set S (i.e. all magmas with underlying set S.) In [1], distributivity hierarchy graphs of a set are introduced. Given a set S, its hierarchy graph has $M(S)$ as vertices and there is an edge from one operation, $*$, to another one, $\circ$, if $*$ distributes over $\circ$. Given $* \in M(S)$, the set $\mathrm{out}(*) = \{\circ \in M(S) | *$ distributes over $\circ\}$ is called the *outset* of $*$. We define an operation that make $M(S)$ a monoid in such a way that each outset is a submonoid. This endowment gives us a possibility to compare the various elements of $M(S)$ with respect to the monoid structure of their outsets. Various properties of the operation mentioned above are considered, including multiple additive structures on $M(S)$ that have it as the multiplicative part of a nearring.

[1] López-Permouth and L. H. Rowen, Distributive hierarchies of binary operations, to appear, Contemporary Mathematics series, American Math Soc. (Received January 18, 2018)

11 ► Number theory

1136-11-29 **Huy Dang*** (hqd4bz@virginia.edu), 2021 Ivy Road, Apt A-1, Charlottesville, VA 22903.
Connectedness of the moduli space of Artin-Schreier curves.

In this talk, the connectedness of the moduli space of Artin-Schreier curves with fixed genus over an algebraically closed field will be discussed. Pries and Zhu introduce a combinatorial description that partitions the moduli space into irreducible strata and tells us partially how they fit together within the moduli space. We continue their work of studying the relations between the geometry of the strata and their combinatorial data. As an application, when the characteristic is equal to 3, the moduli space is connected for every possible genus. When the characteristic is greater than 3, we show that the moduli space is connected when the genus is sufficiently large, and the bound depends on the characteristic. (Received November 30, 2017)

1136-11-74 **Tony Shaska*** (shaska@oakland.edu). *Isogenies among Abelian varieties.*

In this talk we will give a brief review of the main definitions of isogenies among Abelian varieties and then focus on some of the computational aspects of isogenies among Jacobian varieties of low dimension. If time permits we will consider isogenies of Abelian varieties over number fields and some of the main conjectures in the area. (Received January 01, 2018)

1136-11-246 **Scott Guest*** (sguest@oakland.edu), Rochester Hills, MI 48306, and **Lubjana Beshaj**.
Weighted moduli space of binary sextics.

In this talk we will introduce the weighted moduli space $\mathbb{WP}^3_{(2,4,6,10)}(\mathbb{Q})$ of binary sextics and create a database of points in $\mathbb{WP}^3_{(2,4,6,10)}(\mathbb{Q})$ of small weighted moduli height. We will use this database to study how many of the points with bounded moduli height are fine moduli points and how many are obstruction points. (Received January 17, 2018)

1136-11-532 **Marcus Appleby**, University of Sydney, **Steven Flammia***, University of Sydney, **Gary McConnell**, Imperial College London, and **Jon Yard**, University of Waterloo. *Zauner's Conjecture and Algebraic Number Theory.*

Zauner's conjecture asks whether d^2 complex equiangular lines exist in every d-dimensional complex vector space, a number which saturates known upper bounds. Such a set of lines is known in the quantum information literature as a SIC. In this talk, we will discuss a substantial strengthening of Zauner's conjecture that makes surprising connections to explicit algebraic number theory. In particular, every known SIC family yields explicit unit generators for specific ray class fields of a real quadratic number field. The examples in low dimensions suggest a general recipe for producing unit generators in infinite towers of ray class fields above arbitrary real quadratic number fields, and we summarize this in a conjecture. arXiv:1604.06098. (Received January 22, 2018)

1136-11-537 **Marcus Appleby***, University of Sydney, and **Tuan Chien**, **Steven Flammia** and **Shayne Waldron**. *A number-theoretic technique for constructing exact sets of complex equiangular lines.*

Sets of d^2 complex equiangular lines in a d-dimensional vector space are called SICs and are the subject of Zauner's conjecture. Recently several intriguing conjectures have been proposed connecting SICs and algebraic number theory (see S. Flammia's talk in this session). Testing and developing these conjectures requires that the SICs are expressed exactly, rather than as numerical approximations. While many exact solutions have been constructed using Groebner bases this method has probably been taken as far as is possible using current computer technology (except in special cases—see recent work by Grassl and Scott). In this talk it is shown how the same number theoretic considerations which create the demand for more exact solutions also provide the means for satisfying it. Specifically, it is shown how the conjectured Galois symmetries of a SIC can be used in conjunction with an integer relation algorithm to convert a high-precision numerical solution into an exact solution. Using this method 69 new exact solutions have been constructed. arXiv:1703.05981. (Received January 22, 2018)

1136-11-597 **Caleb McKinley Shor*** (cshor@wne.edu), WNE Math Dept, Box H-5156, 1215 Wilbraham Rd, Springfield, MA 01119. *Numerical semigroups with evenly distributed gaps.* Preliminary report.

For $\mathbb{N}_0$ the set of non-negative integers, a numerical semigroup is a submonoid of $\mathbb{N}_0$ with finite complement. Numerical semigroups arise naturally in the context of algebraic curves, for instance as the set of pole orders of functions on a curve that have poles only at a particular point. In this talk, we will see how elements of the complement of a numerical semigroup, which are called gaps, are distributed among various congruence classes in $\mathbb{Z}$. In particular, we will describe moduli for which the gaps of a numerical semigroup are evenly distributed among each congruence class. We will also provide examples of curves with points that lead to numerical semigroups with these properties. (Received January 22, 2018)

1136-11-621 **Kathryn Haymaker**, **Beth Malmskog*** (beth.malmskog@gmail.com) and **Gretchen Matthews**. *Locally Recoverable Codes with Many Recovery Sets from Fiber Products.*

A locally recoverable code (LRC) is an error correcting code such that the value of any position in a codeword can be recovered from some relatively small "helper set" of other positions. These were developed to meet needs in distributed data storage, where information may be stored on large banks of servers. It is desirable that any given codeword be distributed over many servers so that the information can be recovered if a single server fails. However, if many servers fail, it might be desirable to have multiple recovery sets for each position in order to recover it. In this talk, I will briefly present a general construction of LRCs for which each coordinate has several disjoint recovery sets, based on curves over finite fields (generalizing work of Barg, Tamo, and Vladut). The codes will be discussed in the context of parameter bounds for LRCs and viability for additional application in private information retrieval. This construction is joint work with Kathryn Haymaker and Gretchen Matthews. (Received January 23, 2018)

12 ► Field theory and polynomials

1136-12-281 **June Huh*** (junehuh@ias.edu), 1 Einstein Drive, Princeton, NJ 08540. *The correlation constant of a field.*

Let G be a finite connected graph, let i, j be distinct edges, and let T be a random spanning tree of G. The probability that i is in T can only decrease by assuming that j is in T:

$$\Pr(i \in T) \geq \Pr(i \in T \mid j \in T).$$

In other words, the number b_{-} of spanning trees containing given edges satisfies

$$1 \geq \frac{b\, b_{ij}}{b_i b_j}.$$

Now let E be a finite spanning subset of a vector space V, let i, j be distinct nonzero vectors in E, and write b_{-} for the number of bases in E containing given vectors. Do we still have

$$1 \geq \frac{b\, b_{ij}}{b_i b_j}?$$

If not, how large can the ratio be?

The supremum, called the correlation constant, may be an interesting invariant of a field. While studying Hodge-Riemann relations for the intersection cohomology of certain projective varieties, Botong Wang and I noticed that

$$2 > \frac{b\, b_{ij}}{b_i b_j}$$

for any vector configuration. Thus the correlation constant of any field is at most 2. What is the correlation constant of, say, $\mathbb{Z}/2\mathbb{Z}$? Does the correlation constant really depend on the field? We discuss these and other questions. (Received January 18, 2018)

13 ► Commutative rings and algebras

1136-13-21 **Naoki Taniguchi*** (naoki.taniguchi@aoni.waseda.jp), 1-6-1 Nishi-Waseda, Shinjuku-ku, Tokyo 169-8050, Japan. *On Ratliff-Rush closure of modules.*

In this talk, we introduce the notion of Ratliff-Rush closure of modules and explore the question of when the Ratliff-Rush closure coincides with the integral closure. This question has been strongly inspired by the works of Shiro Goto and Naoyuki Matsuoka. The main purpose of this talk is to generalize their results in terms of modules. As a consequence, we shall give concrete examples of the Buchsbaum multi-Rees algebras. (Received November 06, 2017)

1136-13-81 **Dan Anderson*** (dan-anderson@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242, and **Kevin Bombardier**, Department of Mathematics, The University of Iowa, Iowa City, IA 52242. *Small Cohen-Kaplansky Domains.* Preliminary report.

A Cohen-Kaplansky domain is an integral domain with a finite number of nonassociate irreducible elements in which every nonzero nonunit is a finite product of irreducibles. We focus on local Cohen-Kaplansky domains with a small number of nonassociate atoms. We give an example of a local Cohen-Kaplansky domain with eight atoms, two of which are in the square of the maximal ideal. (Received January 03, 2018)

1136-13-83 **Luchezar Avramov**, **Courtney Gibbons** and **Roger Wiegand*** (rwiegand1@unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130. *Poincaré series and Betti tables over short Gorenstein algebras.* Preliminary report.

Let k be a field and $R = R_0 \oplus R_1 \oplus R_2$ be a short Gorenstein graded k-algebra. "Short Gorenstein" means that $\dim_k R_0 = 1 = \dim_k R_2$. We assume that the embedding dimension $e = \dim_k R$ is at least three. The category of finitely generated graded R-modules is known to be wild, but nonetheless we can characterize and classify Betti tables over R. In this talk we will discuss the monoid of Betti tables over R. In particular, we will identify the atoms and strong atoms, and demonstrate the dramatic failure of factoriality. (Received January 03, 2018)

1136-13-97 **Hannah Altmann*** (haltmann@bemidjistate.edu), **Eloisa Grifo**, **Jonathan Montano**, **William Sanders** and **Thanh Vu**. *Lower Bounds on Projective Levels of Complexes.*

For an associative ring R, the projective level of a complex F is the smallest number of mapping cones needed to build F from the projective R-modules. We will discuss finding lower bounds on the projective level of a complex. In particular, we will show that the length of the largest gap in the homology of a complex F gives a lower bound for the projective level of F. We will then discuss an application of this result to the New Intersection Theorem. (Received January 04, 2018)

1136-13-132 **Robert M. Walker*** (robmarsw@umich.edu), 530 East Church Street, 2070 East Hall, Ann Arbor, MI 48109. *Uniform Symbolic Topologies in Normal Toric Rings.*

A Noetherian ring R has the uniform symbolic topology property (USTP) if there's an integer $D := D(R) > 0$ such that the symbolic power $P^{(DN)} \subseteq P^N$ for all prime ideals P in R and all integers $N > 0$. For instance, all excellent finite-dimensional regular rings have USTP, and a large class of isolated singularities also have USTP (Ein-Lazarsfeld-Smith, Hochster-Huneke, Huneke-Katz-Validashti, Ma-Schwede). A toric ring is a domain of finite type over a field, generated by Laurent monomials. In this talk, we present a formula for the multiplier $D(R)$ such that any normal toric ring R has USTP on the set of monomial primes: this is one of the conditional USTP results my dissertation affords for rings whose singular locus may have positive dimension. (Received January 08, 2018)

1136-13-133 **Zachary J. Flores*** (floresza@colostate.edu), Colorado State University, Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523-1874, and **Christopher Peterson** and **Gioia Failla**. *Lefschetz Properties for Certain Graded Modules.*

In 2002, it was shown that complete intersections over $k[x,y,z]$ have the Weak Lefschetz Property by utilizing properties of semistable vector bundles on $\mathbb{P}^2$. By combining previous techniques with a recent theorem of M. Kunte, we discuss what numerical constraints we must place on a graded module of finite length over $k[x,y,z]$ with $n \times (n+2)$ relation in order for it to have the Weak Lefschetz Property. (Received January 08, 2018)

1136-13-135 **Parangama Sarkar*** (sarkarp@missouri.edu), 810 E. Rollins Street, 202 Math Sciences Building, University of Missouri, Columbia, MO 65211, and **Jugal Verma** (jkv@math.iitb.ac.in), 101-C, Department of Mathematics, Indian Institute of Technology Bombay, Mumbai, India. *Local cohomology of multi-Rees algebras, joint reduction vectors and product of complete ideals.*

We find conditions on the local cohomology modules of multi-Rees algebras of admissible filtrations which enable us to predict joint reduction vectors. As a consequence we are able to prove a generalization of a result of Reid-Roberts-Vitulli in the setting of analytically unramified local rings for completeness of power products of complete ideals. (Received January 17, 2018)

1136-13-136 **Giuseppe Favacchio*** (favacchio@dmi.unict.it), Dipartimento Matematica e Informatica, Università Degli Studi Di Catania, Viale Andrea Doria 6, 95125 Catania, CT, Italy. *The Betti Weak Lefschetz Property.*

We study the Hilbert functions and the graded Betti numbers of linear quotients of Artinian k-algebras. It is known that Weak Lefschetz algebras are characterized by the Hilbert function of their generic linear quotient. This result give us the hint to introduce and investigate a new property, called the Betti Weak Lefschetz Property, which encodes a "good behavior" of the graded Betti numbers of generic linear quotients of Weak Lefschetz algebras. Based on a joint work with A. Ragusa and G. Zappalà. (Received January 09, 2018)

1136-13-137 **Jesse Elliott*** (jesse.elliott@csuci.edu). *Multiplicative ideal theory of rings with zerodivisors.*

This talk will outline general strategies for generalizing multiplicative ideal theory of integral domains to rings with zerodivisors. This project continues the work many esteemed researchers in the field, including Tom Lucas, to whom this talk is dedicated on the occasion of his retirement. (Received January 09, 2018)

1136-13-148 **Alessandra Costantini*** (costanta@purdue.edu). *Cohen-Macaulay property of Rees algebras of modules.* Preliminary report.

In this talk we provide a class of modules whose Rees algebra is Cohen-Macaulay. This work generalizes known results of Goto, Nakamura and Nishida, and of Johnson and Ulrich on the Cohen-Macaulayness of Rees algebras of ideals. (Received January 10, 2018)

1136-13-152 **Richard Erwin Hasenauer*** (hasenaue@nsuok.edu) and **Jim Coykendall** (jcoyken@clemson.edu). *Factorization properties of Prüfer domains.*

We construct a norm on the elements of a Prüfer domain. We generalize this norm, to construct a norm on the set of ideals of a one-dimensional Prüfer domain. Using the constructed norms we discuss factorization properties in one-dimension Prüfer domains. (Received January 10, 2018)

1136-13-162 **William J Heinzer***, 150 N University St, West Lafayette, IN 47907-2067, **K. Alan Loper** (lopera@math.ohio-state.edu), Newark, OH 43055, and **Bruce Olberding**, Las Cruces, NM 88003. *Intersections of regular local rings of dimension two.* Preliminary report.

Let D be a regular local ring of dimension two. Among the overrings of D inside the field of fractions of D, the rings that are 2-dimensional regular local rings form a lattice Q(D) with respect to inclusion.

This lattice reflects ideal-theoretic properties of D. Alan Loper, Bruce Olberding and I have been examining and classifying in various ways the rings in the set R(D) of rings obtainable as an intersection of rings in Q(D).

Many of the rings in R(D) are Noetherian and others are not Noetherian. The representation of a ring in R(D) as an intersection of rings in Q(D) is somewhat similar to the representation of a Krull domain as the intersection of its essential valuation rings. Among the rings in R(D) that are not Noetherian, some are almost Krull domains, but others fail to be almost Krull. (Received January 11, 2018)

1136-13-170 **Giulio Peruginelli*** (gperugin@math.unipd.it), Department of Mathematics, University of Padova, Via Trieste, 63, Padova, Italy. *Prüfer domains of integer-valued polynomials over subsets.*

Let V be a rank one valuation domain with quotient field K. Recently, Loper and Werner characterized the pseudo-convergent sequences $E = \{s_n\}_{n\in\mathbb{N}} \subset V$ in the sense of Ostrowski for which the ring of integer-valued polynomials over E, that is $\mathrm{Int}(E,V) = \{f \in K[X] \mid f(E) \subseteq V\}$, is a Prüfer domain. In particular, their result shows that there are subsets E of V which are not precompact but $\mathrm{Int}(E,V)$ is Prüfer (e.g.: take E to be a pseudo-convergent sequence of transcendental type and non-zero breadth ideal). In this talk we give a complete characterization of those subsets S of V such that $\mathrm{Int}(S,V)$ is Prüfer. The result uses the notion of pseudo-monotone sequence introduced by Chabert, which generalizes pseudo-convergent sequences. We show that $\mathrm{Int}(S,V)$ is Prüfer if and only if no element of the algebraic closure of K is a pseudo-limit of a pseudo-monotone sequence of elements of S, with respect to some extension of V. (Received January 12, 2018)

1136-13-172 **Adam Van Tuyl*** (vantuyl@math.mcmaster.ca), Department of Mathematics and Statistics, McMaster University, 1280 Main Street West, Hamilton, ON L8S 4L8, Canada. *Some results on f-ideals.* Preliminary report.

Given a square-free monomial ideal I, there are two natural ways to associate to I a simplicial complex. The first way is the non-face construction of Stanley-Reisner to create the non-face simplicial complex $\delta_{\mathcal{N}}(I)$. The second way is the construction of Faridi to create the facet simplicial complex $\delta_{\mathcal{F}}(I)$. Following Abbasi, Ahmad, Anwar, and Baig, we say that I is an f-ideal if these two simplicial complexes have the same f-vector. We will summarize some of the known results and present some new results on f-ideals. This is based upon joint work with Sam Budd. (Received January 12, 2018)

1136-13-177 **Matthew Mastroeni*** (mastroe2@illinois.edu). *Koszul almost complete intersections.*

Let $R = S/I$ be a quotient of a standard graded polynomial ring S by an ideal I generated by quadrics. If R is Koszul, a question of Avramov, Conca, and Iyengar asks whether the Betti numbers of R over S can be bounded above by binomial coefficients on the minimal number of generators of I. Motivated by previous results for Koszul algebras defined by three quadrics, we give a complete classification of the structure of Koszul almost complete intersections and, in the process, give an affirmative answer to the above question for all such rings. (Received January 12, 2018)

1136-13-178 **Carmelo Antonio Finocchiaro*** (carmelo@math.unipd.it), Via Trieste 63, 35121 Padova, Italy. *A construction of Prüfer rings involving quotients of Rees algebras.*

Starting with a ring A and an ideal $\mathfrak{a}$ of A, it is possible to define a family of rings $A_{a,b}(\mathfrak{a})$, where $a, b \in A$, arising as quotients of the Rees algebra $\oplus_{n\in\mathbf{N}}\mathfrak{a}^n T^n$. In this talk we will classify rings of this family that satisfy certain Prüfer-like properties and, as a particular case, we will extend results obtained for amalgamated duplications and Nagata idealizations. (Received January 13, 2018)

1136-13-185 **Sara Faridi*** (faridi@mathstat.dal.ca) and **Mina Bigdeli**. *Chordality and ideals with linear resolution.* Preliminary report.

This talk will be about various concepts of chordality that have been developed to produce monomial ideals with linear free resolution. In 1990 Froeberg completely characterized ideals generated by degree 2 monomials having linear resolution in terms of graphs. For monomial ideals generated in any degree this task is not as easy since the free resolution depends on the characteristic of the base field.

In this talk we will review higher dimensional versions of chordality that have been developed for hypergraphs and simplicial complexes. and the combinatorial and algebraic properties that result from them.

The main part of the talk is based on joint work with Mina Bigdeli. (Received January 14, 2018)

1136-13-188 **Fabrizio Zanello*** (zanello@mtu.edu). *The Gorenstein Interval Conjecture in low socle degree.*

Roughly ten years ago, I proposed some so-called "Interval Conjectures" for graded artinian level algebras, which, if true, would imply a strong (and very natural) structural property for their h-vectors. In general, these conjectures are still wide open. In particular, the Gorenstein Interval Conjecture (GIC) states that, if $\alpha \geq 2$ and $(1, \dots, h_i, \dots, h_{e-i}, \dots, h_e = 1)$ and $(1, \dots, h_i + \alpha, \dots, h_{e-i} + \alpha, \dots, h_e = 1)$ are Gorenstein h-vectors that only differ in two symmetric degrees i and $e - i$, then $(1, \dots, h_i + \beta, \dots, h_{e-i} + \beta, \dots, h_e = 1)$ is also Gorenstein for all $\beta = 1, \dots, \alpha - 1$.

In this talk, I will outline a proof of the GIC for $e \leq 5$. It combines a few different methods coming from commutative algebra and classical algebraic geometry, where suitable "maximal rank" properties play a key role. (This is part of an upcoming paper with Richard Stanley and my former MIT student Sung Gi Park.) (Received January 14, 2018)

1136-13-189 **Lee Klingler***, 777 Glades Road, Boca Raton, FL 33431, and **Akeel Omairi**. *Unique Decomposition of Direct Sums of Ideals.* Preliminary report.

Let R be a commutative Noetherian ring. We say that R has the *unique decomposition into ideals* (UDI) property if each finite direct sum of ideals of R is uniquely decomposable as a direct sum of indecomposable R-ideals. For integral domain R, Goeters and Olberding showed that R has UDI if and only if R has at most one nonprincipal maximal ideal and has UDI locally at that nonprincipal maximal ideal (if it exists). For local domain R, they gave necessary and sufficient conditions that R have UDI in terms of its integral closure. Their results were extended to reduced (commutative Noetherian) rings by Ay and Klingler. In joint work with Akeel Omairi, we show that if R is any commutative noetherian ring, then R has UDI if and only if R has at most one nonprincipal maximal ideal and has UDI locally at that nonprincipal maximal ideal (if it exists). We also give an example of a ring without UDI but which has UDI modulo its nilradical, so that the UDI property does not lift modulo the nilradical. (Received January 14, 2018)

1136-13-197 **Nicholas R Baeth*** (baeth@ucmo.edu), WCM 213, UCM, Warrensburg, MO 64093, **Courtney Gibbons**, Hamilton College, and **Janet Striuli**, Fairfield University. *Irreducible divisor sequences in Krull semigroups.* Preliminary report.

Let H be a commutative cancellative semigroup and let $h \in H$. For each $n \in \mathbb{N}$, define s_n to be the number of distinct irreducible elements a of H with $a \mid h^n$. The sequence $\mathcal{S}(h) = (s_1, s_2, s_3, \dots)$ is the *irreducible divisor sequence of* h *in* H. If H is free, then factorization in H is unique and $\mathcal{S}(h) = (t, t, \dots)$ where t is the number of distinct irreducible factors of h. As a rule, the more nonunique factorization is in H, the more exotic irreducible divisor sequences can be over H. Of interest are the irreducible divisor sequences of irreducible elements. If $h \in H$ is irreducible, then obviously $s_1 = 1$ and $\mathcal{S}(h)$ is nondecreasing. Moreover, if H is a Krull semigroup, then $s_i = 2$ is impossible and $\mathcal{S}(h)$ eventually stabilizes. In this talk we will discuss preliminary work that describes which eventually constant nondecreasing sequences occur as irreducible divisor sequences of irreducible elements in Krull semigroups. We will also discuss some sequences that are know never to occur. (Received January 15, 2018)

1136-13-214 **Guy R Biyogmam*** (guy.biyogmam@gcsu.edu), Campus Box 17, Office A&S 241, Milledgeville, GA 31061. *Capturing non-relativistic invariants using Leibniz (co)Homology.*

The Schrodinger algebra and the Galilei algebra are among the most important non-relativistic algebras of mathematical physics. In this talk, we show our calculations of their Lie algebra and Leibniz algebra cohomologies using the structure theorem established by Jerry Lodder. We discuss how Leibniz homology captures several non-relativistic invariants. (Received January 16, 2018)

1136-13-224 **Michael C Steward*** (michael.steward@usma.edu) and **K Alan Loper** (lopera@math.ohio-state.edu). *Closures and Semistar Operations in Int*($\mathbb{Z}^2$). Preliminary report.

We consider the ring of integer-valued polynomials in two variables $\mathrm{Int}(\mathbb{Z}^2) := \{f(x,y) \in \mathbb{Q}[x,y] \mid f(c,d) \in \mathbb{Z}\ \forall c,d \in \mathbb{Z}\}$. We define a new closure operation by: given an ideal $J \leq \mathrm{Int}(\mathbb{Z}^2)$, define the operation # by $J^{\#} := \bigcap_{p\in\mathbb{P}} \bigcap_{n\geq 1} (J, p^n)$.

We demonstrate that for finitely generated ideals, # is the same as the Skolem closure. We further consider its relationship to the b and v (semi)star operations. We intend to demonstrate that $\mathrm{Int}(\mathbb{Z}^2)$ is a vacant domain (i.e. has a unique Kronecker function ring) with a non-vacant overring. (Received January 16, 2018)

1136-13-236 **László Fuchs** (fuchs@tulane.edu), Department of Mathematics, Tulane University, New Orleans, LA 70118, and **Bruce Olberding*** (olberdin@nmsu.edu), Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003-8001. *De-noetherizing Cohen-Macaulay rings.*

We introduce a generalization of Cohen-Macaulay rings to rings that are not necessarily non-noetherian. The basic idea is to replace the role artinian rings play in the theory of Cohen-Macaulay rings with that of perfect rings, a well-studied class of semilocal zero-dimensional rings introduced by Bass. This is done by studying the rings R with the following unmixedness property: whenever I is an ideal generated by a regular sequence in R, then the total quotient ring of R/I is perfect. For noetherian rings, such rings are precisely the Cohen-Macaulay rings, but this class of rings is also broad enough to include interesting non-noetherian examples while still exhibiting classical properties of noetherian Cohen-Macaulay rings. We indicate how our generalization connects to other non-noetherian generalizations of Cohen-Macaulay rings in the literature. (Received January 16, 2018)

1136-13-242 **Anthony Iarrobino***, Mathematics Department, 567 Lake Hall, Northeastern University, 360 Huntington Avenue, Boston, MA 02115, and **Pedro Marques** and **Christopher McDaniel**. *Jordan types and the associated graded algebra of an Artinian algebra.* Preliminary report.

Let A be an Artinian Gorenstein [AG] algebra – graded or local – and M a finite dimensional module over A of length n. The Jordan type J_ℓ of a nilpotent multiplication map ℓ on M is the partition of n giving the sizes of the Jordan blocks of m. A standard graded AG algebra A with unimodal Hilbert function H has the strong Lefschetz property when the Jordan type J_ℓ of a suitable linear element is the conjugate of H; and A has the weak Lefschetz property if the number of parts of J_ℓ is Sperner number of A: the maximum value of $H(A)$.

The generic Jordan type of M is J_ℓ for a generic element of the maximum ideal m_A. We discuss properties of the Jordan type, and give examples where the generic Jordan type is not strong Lefschetz.

The associated graded algebra A^* of a local AG algebra has a stratification by ideals whose successive quotients are reflexive A^* modules. Applying this to certain non-standard graded AG algebras, we determine what appear to be new invariants of $\mathrm{Gr}_m(A)$. We show that there are AG algebras that are not strong-Lefschetz, but that have non-homogeneous elements of strong-Lefschetz Jordan type – observed with Shujian Chen on a module arising from invariant theory. (Received January 17, 2018)

1136-13-267 **Hans Schoutens*** (hschoutens@citytech.cuny.edu). *Singular valuations, ideal chains and arrangements.*

How much of a valuation on a Noetherian ring can be recovered from its chain of valuation ideals? Which chains arise and what properties do these have? In answering such questions, we run into singular valuations (of higher rank). The latter also arise as limits of regular valuations (especially in total blowing ups of a fixed valuation). I will describe some preliminary results, mostly in the form of examples. (Received January 18, 2018)

1136-13-268 **Selvi Kara Beyarslan*** (selvi@southalabama.edu), 411 University Boulevard North, Mobile, AL 36688-0002, and **Arindam Banerjee** and **Tai Huy Ha**. *Bounding Regularity of Powers Edge Ideals via Local Conditions.* Preliminary report.

Let $I(G)$ be the edge ideal of a graph G. It is known that local conditions on the regularity of $I(G) : x$, for all vertices of x, result with a global statement on the regularity of G. In this talk, we focus on using these local conditions to obtain bounds for the asymptotic linear function reg $I(G)^s$ for $s \geq 1$. (Received January 18, 2018)

1136-13-274 **Alessandro De Stefani** and **Eloísa Grifo***, eloisa.grifo@virginia.edu, and **Jack Jeffries**. *The Zariski-Nagata Theorem in mixed characteristic.*

In one of its classical versions, the Zariski-Nagata theorem states that if P is a prime ideal in a polynomial ring over the complex numbers, then the n-th symbolic power of P consists of all the polynomial functions that vanish up to order n along the variety defined by P. This can be also stated in terms of differential operators. In this talk, we will discuss analogous results in mixed characteristic, combining properties of differential operators and p-derivations. (Received January 18, 2018)

1136-13-286 **Daniel McGregor*** (mcgregor.36@osu.edu). *Extending Kronecker Function Rings Using Power Series.*

For a given integrally closed ring D, a Kronecker function ring $\mathrm{Kr}(D, *)$ is an overring of the polynomial ring $D[X]$ satisfying certain conditions. These rings have proven to be useful tools in studying the star operations and valuation overrings of D. However, the finite nature of polynomials means that Kronecker function rings mostly reflect finite properties of D, such as the factorizations of finitely generated ideals. I will examine an extension of the classical Kronecker function rings, using overrings of the power series ring $D[[X]]$. These "Kronecker power series rings" were introduced by G.W. Chang in the case where D is Noetherian and (completely) integrally closed, and by B.G. Kang, P.T. Toan, and D. McGregor where D is any completely integrally closed domain. I will compare the properties of these two notions of Kronecker function ring, and discuss some open questions related to this construction. (Received January 18, 2018)

1136-13-288 **H Ananthnarayan**, **E Celikbas** and **Jai Laxmi*** (laxmiuohyd@gmail.com), 210 Saint Pauls Avenue, APT 6L, Jersey City, NJ 07306, and **Z Yang**. *Associated Graded Rings and Connected Sums.*

In 2012, Ananthnarayan, Avramov, and Moore gave a new construction of Gorenstein rings from two Gorenstein local rings, called their connected sum. In this talk, we investigate conditions on the associated graded ring of a Gorenstein Artin local ring Q, which force it to be a connected sum over its residue field. In particular, we recover some results regarding short, and stretched, Gorenstein Artin rings. Finally, we obtain results about the rationality of the Poincaré series of Q.

This is joint work with H. Ananthnarayan, E. Celikbas, and Z. Yang. (Received January 18, 2018)

1136-13-290 **Jim Coykendall*** (jcoyken@clemson.edu), Department of Mathematical Sciences, Clemson, SC 29634. *Rings of (very) strong finite type.*

Let R be a commutative ring with identity. If $I \subseteq R$ is an ideal, we say that I is of strong finite type (SFT) if there is a finitely generated ideal $B \subseteq I$ and a fixed positive integer N such that $x^N \in B$ for all $x \in I$. Additionally, we say that the ring R is SFT if every (prime) ideal of R has the SFT property. The SFT property was conceived in the work of J. Arnold, who showed that if R is a ring such that the Krull dimension of $R[[x]]$ is finite, then R must be SFT.

Given this definition, it is also natural to consider the notion "very strong finite type" (VSFT) by declaring that the ideal I has the VSFT property if there is a finitely generated ideal $B \subseteq I$ and a fixed integer N such that $I^N \subseteq B$ (and we say that R is VSFT if each of its ideals are VSFT).

In this talk we will outline some useful properties of these types of rings, and consider their behavior under standard operations (polynomial and power series adjunction and integral closure in particular). We will also state some open questions. (Received January 18, 2018)

1136-13-294 **Kyouko Kimura*** (kimura.kyoko.a@shizuoka.ac.jp), Department of Mathematics, Faculty of Science, Shizuoka University, 836 Ohya, Suruga-ku, Shizuoka, 422-8529, Japan. *On non-vanishing theorem for Betti numbers of edge ideals.*

The talk is partially based on the joint work with Naoki Terai and Siamak Yassemi. Given a finite simple graph, we can associate an ideal, which is called an edge ideal. It is natural to ask whether we can describe ring invariants of the edge ideal in terms of the combinatorics of the graph. On my talk, we focus on the invariants arising from a minimal free resolution such as the Betti numbers, the Castelnuovo–Mumford regularity, and the projective dimension. The main result of the talk is a non-vanishing theorem for Betti numbers of edge ideals which is an extension of the present work by Katzman. We will introduce some characterization derived from the theorem including the characterization of the projective dimension for an unmixed bipartite graph. Also we generalize the characterization for a very well-covered graph. In the process of the generalization, we construct an explicit minimal free resolution of the Alexander dual ideal of an edge ideal when the graph is a Cohen–Macaulay very well-covered graph. The construction is similar to the present work by Herzog and Hibi for a Cohen–Macaulay bipartite graph. (Received January 18, 2018)

1136-13-297 **Neil Epstein*** (nepstei2@gmu.edu), George Mason University, Fairfax, VA , and **Jay Shapiro** (jshapiro@gmu.edu), George Mason University, Fairfax, VA. *Gaussian elements of semicontent algebras and locally principal content ideals.*

Let R be a commutative ring. When $S = R[x]$, one defines the content of an element $f \in S$ as the ideal of R generated by its coefficients, and f is Gaussian if $c(fg) = c(f)c(g)$ for all $g \in S$. Lucas answered two longstanding questions when he established in 2005 that (a) if $f \in S$ is regular and Gaussian, then the content ideal $c(f) \subseteq R$ is locally principal, and in 2008 that (b) if R is reduced, then for any Gaussian $f \in S$, $c(f)$ is locally principal.

However, the notion of content also makes sense when S is a polynomial extension of R in several variables, or more generally an affine semigroup algebra over R, or a power series extension over R. If R is a K-algebra where K is a field, and L/K is a well-behaved field extension, one may even make sense of content of elements of $S = R \otimes_K L$ over R, with respect to a vector-space basis of L over K. In all of these contexts, and more generally, we show results analogous to (a) and (b) above, provided certain assumptions about Noetherianness, the property of being 'approximately Gorenstein', and module-freeness. This is done by use of the Ohm-Rush content function (which subsumes all the notions of content mentioned above) and the coordinated notion of a semicontent algebra. (Received January 18, 2018)

1136-13-311 **Catalin Ciuperca*** (catalin.ciuperca@ndsu.edu), Department of Mathematics, NDSU Dept 2750, PO Box 6050, Fargo, ND 58108-6050. *Integral closure of strongly Golod ideals.*

Let $A = K[x_1, \dots, x_d]$ be a polynomial ring over a field K of characteristic zero. The strongly Golod ideals in A are defined to be the proper homogeneous ideals I that satisfy the condition $\partial(I)^2 \subseteq I$, where $\partial(I)$ is the ideal generated by the partial derivatives of all the elements of I. They were introduced by Herzog and Huneke who proved that if I is strongly Golod, then the ring A/I is Golod.

We show that the integral closure of a homogeneous strongly Golod ideal is strongly Golod, positively answering a question of Huneke. More generally, the rational power I_α of an arbitrary homogeneous ideal is strongly Golod for $\alpha \geq 2$ and, if I is strongly Golod, then I_α is strongly Golod for $\alpha \geq 1$. This extends work of Herzog and Huneke (in the case of the integral closure of an ideal) and De Stefani (in the case of rational powers) who proved these results for monomial ideals. We also show that all the coefficient ideals of a strongly Golod ideal are strongly Golod. (Received January 19, 2018)

1136-13-321 **José Gómez-Torrecillas**, **Erik Hieta-aho*** (eh991112@ohio.edu), **Javier Lobillo**, **Sergio López-Permouth** and **Gabriel Navarro**. *Error Correcting Codes in a Frobenius Ring Ambient.* Preliminary report.

Cyclic codes are among the most studied error-correcting codes. Constacyclic and polycyclic codes are generalizations of cyclic codes. Their underlying common feature is that they can be considered as ideals of their Ambient ring. Cyclic codes have the appealing property that the dual of a cyclic code is also cyclic code; in fact the duals are ideals of the same ambient ring. While the duals of constacyclic codes are of the same type, a constacyclic code and its dual are not necessarily ideals of the same ambient ring. Noting the fact that the duals of polycyclic codes are not polycyclic and observing the alternative of using annihilators in lieu of dual codes proposed and studied in [1] suggests an alternative approach. We extend the results in [1] by assuming only that the ambient ring is a Frobenius algebra. We have only been successful so far in the context of a Frobenius algebra where the additional structure has allowed us to construct an appropriate balanced non-degenerate bilinear form. We have also obtained analogues to the MacWilliams identities in this setting.

[1] Alahmadi, Dougherty, Leroy, and Solé, On the Duality and the direction of polycyclic codes, Advances in Mathematics of Communications 10, (2016). (Received January 19, 2018)

1136-13-335 **Janet Vassilev*** (jvassil@math.unm.edu), Department of Mathematics and Statistics, University of New Mexico, Albuquerque, NM 87131. *Closures, interiors and related structures.* Preliminary report.

In a recent paper, Epstein and Schwede introduced the tight interior operation which is defined as a dual operation to tight closure. We will discuss interior operations more generally on subsets of ideals of a ring and when there are interior operations which encode similar information to a given closure operation. (Received January 19, 2018)

1136-13-337 **Susan Marie Cooper*** (susan.cooper@umanitoba.ca), Department of Mathematics, 464 Machray Hall, University of Manitoba, Winnipeg, MB R3T 2N2, Canada. *Using Partial Intersections To Understand Fat Points.* Preliminary report.

It is well-known that characterizing Hilbert functions of fat points is an open and challenging problem. One approach is to compare the Hilbert functions of these non-reduced schemes to those of well-known families of reduced point sets. In this talk we will investigate how reduced point sets called partial intersections can be used to gain insight about fat points supported inside grid complete intersections. As an application, we will bound the minimum Hamming distance of a family of linear codes. This is joint work in progress with E. Guardo. (Received January 19, 2018)

1136-13-342 **Susan Morey*** (morey@txstate.edu), **Loiuza Fouli** and **Huy Tài Hà**. *Depth Bounds for Monomial Ideals.*

In this talk, we examine lower bounds for the depths of monomial ideals. Starting with edge ideals of graphs, which are in one-to-one correspondence with square-free monomial ideals generated in degree two, we view lower bounds on the depth of R/I (and in some cases, the depths of R/I^t) in a way that allows the bounds to be extended to bounds that hold for all square-free monomial ideals and in some cases to bounds that hold for general monomial ideals. The techniques used involve a combination of extending known results and creating a new sequence of regular elements. While the sequence is not guaranteed to be a regular sequence on R/I, it provides a lower bound on the length of a maximal regular sequence on R/I, and thus on the depth of R/I. In the square-free case, the argument provides insight through the combinatorial correspondence with clutters on a geometric way to visualize a regular sequence. (Received January 19, 2018)

1136-13-356 **Uwe Nagel***, Dep. of Mathematics, University of Kentucky, 715 Patterson Office Tower, Lexington, KY 40506. *Chains of Symmetric Ideals.*

Ideals in polynomial rings in countably many variables that are invariant under a suitable action of a symmetric group arise in various contexts, including algebraic statistics and representation theory. Any such ideal can be described by an ascending chain of symmetric ideals in an increasing number of finitely many variables. We discuss recent results describing properties of ideals in such chains.

The talk is based on joint work with Tim Römer. (Received January 19, 2018)

1136-13-386 **W Wm. McGovern*** (warren.mcgovern@fau.edu), 5353 Parkside Dr., Jupiter, FL 33458. *The ring of germs of continuous functions.* Preliminary report.

This talk will be a preliminary presentation.

Let X be a Tychonoff space (i.e. completely regular and Hausdorff) and $p \in X$. The ring of real-valued continuous functions, denoted $C(X)$, is an example of a commutative ring with identity with zero Jacobson radical. In particular, letting

$$M_p = \{f \in C(X) : f(p) = 0\}$$

it is easy to check that M_p is a maximal ideal of $C(X)$ and that the intersection of all such ranging over all $p \in X$ equals $\{0\}$. The set of functions which vanish on a neighborhood of p is denoted by O_p and it is the intersection of all primes contained in M_p. The ring of germs at the point p is the (local) factor ring $G_p = C(X)/O_p$. We will discuss some interesting possibilities for such a local ring. (Received January 20, 2018)

1136-13-413 **Chris McDaniel*** (cmcdanie@endicott.edu), **S. Chen**, **A. Iarrobino** and **P. Marques**. *Generic Jordan Types of Twisted Tensor Products.*

Let A be a graded Artinian algebra. The Jordan type of a linear form $\ell \in A_1$ is the partition P_ℓ whose parts are the block sizes in the Jordan canonical form for its multiplication map $\times\ell\colon A \to A$. The generic Jordan type of A is the largest occurring Jordan type P_ℓ among all $\ell \in A_1$ with respect to the dominance order on partitions, and A has the strong Lefschetz property if its generic Jordan type is as large as possible. Given graded Artinian algebras A, B, C, we say C has a twisted tensor product decomposition if it is isomorphic to the tensor product $A \otimes B$ as A modules, but not as rings. We show that the generic Jordan type of the twisted tensor product

C is bounded below by the generic Jordan type of the actual tensor product $A \otimes B$. A corollary is that the strong Lefschetz property for $A \otimes B$ implies the strong Lefschetz property for C. We will also give examples from invariant theory showing this implication is strict. (Received January 20, 2018)

1136-13-416 **Sara Faridi*** (faridi@mathstat.dal.ca). *Lefschetz properties of Gotzmann square-free monomial ideals.* Preliminary report.

This talk is an exploration of Gotzmann square-free monomial ideals with the Weak Lefschetz Property. Hoefel and Mermin classified Gotzmann square-free monomial ideals in a polynomial ring, and showed also that the image of these ideals is Gotzmann in the Kruskal-Katona ring. Wiebe, on the other hand, characterized Hilbert functions of Gotzmann Artinian algebras that have the Weak Lefschetz Property. In this work we examine Wiebe's criterion against that of Hoefel and Mermin. The main motivation is a result of Migliore and Zanello which states that if a Gotzmann algebra has the Weak Lefschetz Property, then so does every Artinian algebra with the same Hilbert function. (Received January 20, 2018)

1136-13-421 **Hailong Dao*** (hdao@ku.edu), 405 Snow Hall 1460 Jayhawk Blvd, Lawrence, KS 66049. *On h-vector of standard graded algebras.*

Abstract: Let R be a standard graded algebra over a field. The h-vector of R is the coefficients vector of the numerator of the (reduced) Hilbert series of R. It is a classical and easy result that if R is Cohen-Macaulay, then the h-vector is non-negative. This talk will focus on how the singularities of R affect the size and shapes of the h-vectors. Based on joint work with Linquan Ma and Matteo Varbaro. (Received January 21, 2018)

1136-13-427 **William J Heinzer**, **Christel Rotthaus** and **Sylvia M Wiegand*** (swiegand1@unl.edu). *Generic formal fiber rings of mixed power series-polynomial rings.*

Let k be a field, let m and n be positive integers, and let $X = \{x_1, \dots, x_n\}$ and $Y = \{y_1, \dots, y_m\}$ be sets of independent variables over k. The completions of the rings $A := k[X]_{(X)}$, $B := k[[X]]\,[Y]_{(X,Y)}$ and $C := k[Y]_{(Y)}[[X]]$, are $\widehat{A} = k[[X]]$, and $\widehat{B} = \widehat{C} = k[[X, Y]]$. We discuss why, for each of these rings R, every ideal P of $\widehat{R}$ that is maximal with respect to $P \cap R = (0)$ has height $P = \dim(\mathrm{GFF}(R))$. ($\mathrm{GFF}(R)$ is the generic formal fiber ring of R.)

Previously Matsumura showed that $\dim(\mathrm{GFF}(B)) = \dim(\mathrm{GFF}(C)) = n + m - 2$ and $\dim(\mathrm{GFF}(A)) = n - 1$; i.e, these are the largest heights possible for prime ideals P of each ring R maximal with respect to $P \cap R = (0)$. Matsumura did not consider whether lesser heights occur for other prime ideals of R maximal in $\mathrm{Gff}(R)$. Examples of Rotthaus and Charters and Loepp show that many excellent RLRs A, with $\widehat{A}$ a complete Noetherian local domain T, have widely varying heights for prime ideals of T maximal in $\mathrm{Gff}(A)$.

We may discuss another generalization of Matsumura's work, inspired by a question of Youngsu Kim, to local domains essentially finitely generated over a field. (Received January 21, 2018)

1136-13-438 **Jack Jeffries*** (jackjeff@umich.edu). *Derived Functors of Differential Operators.*

In their work on differential operators in positive characteristic, Smith and Van den Bergh define and study the derived functors of differential operators; they arise naturally as obstructions to differential operators reducing to positive characteristic. In this talk, we will provide formulas for the ring of differential operators as well as these derived functors of differential operators in terms of local cohomology. One can use this description to relate questions on the behavior of differential operators under base change to questions on p-torsion in local cohomology. We will also connect the vanishing of these functors to some interesting properties of singularities.
(Received January 21, 2018)

1136-13-467 **Federico Galetto*** (galettof@math.mcmaster.ca), **Anthony V. Geramita**, **Yong-Su Shin** and **Adam Van Tuyl**. *The symbolic defect of an ideal.*

We introduce the notion of symbolic defect in relation to containment problems of ordinary and symbolic powers of ideals. Namely, the m-th symbolic defect of an ideal is the minimal number of generators that one needs to add to the m-th ordinary power to generate the m-th symbolic power. We use star configurations and sets of points in the projective plane to provide examples of ideals whose second symbolic defect is 1. (Received January 21, 2018)

1136-13-499 **Alex Dugas*** (adugas@pacific.edu), CA , and **Graham Leuschke**. *On the category of maximal Cohen-Macaulay modules over a branched cover of a hypersurface.*

Let $R = k[[x_0, \dots, x_d]]/(f)$ be an isolated hypersurface singularity over a field k of characteristic zero, and consider the n-fold branched cover $R^\# = k[[x_0, \dots, x_d, y]]/(f + y^n)$ of R. For each $1 \le k < n$ we consider the subcategory Σ_k of $\mathrm{MCM}(R^\#)$ consisting of modules M that arise as direct summands of syzygies of MCM modules over $R^\#/(y^k)$. Generalizing a result of Knörrer (for $n = 2$), Herzog and Popescu have shown that

$\Sigma_{n-1} = \mathrm{MCM}(R^{\#})$. We show that each Σ_k is a functorially finite subcategory of $\mathrm{MCM}(R^{\#})$, yielding a relative Frobenius category structure on $\mathrm{MCM}(R^{\#})$, and that each object of Σ_k can be built out of iterated extensions of objects from Σ_1. We apply these ideas to obtain an upper bound on the dimension of the stable category of MCM $R^{\#}$-modules when $R^{\#}$ is an (iterated) branched cover of a simple singularity. (Received January 22, 2018)

1136-13-507 **Whitney Liske*** (liske.2@nd.edu). *The Rees Algebra for a family of Gorenstien Ideals.* Preliminary report.

Let $R = k[x_1, \ldots, x_d]$ be a polynomial ring in d variables over a field k. Let $m = (x_1, \ldots, x_d)$ be the maximal homogenous ideal of R. Let I be a Gorenstein ideal generated by all the generators of m^2 except for one. For each fixed d these ideals are all equivalent, up to change of coordinates. The goal is to compute the defining equations of the special fiber ring and the Rees ring of these ideals. A secondary goal is to study the algebraic properties of these blowup algebras. To compute the Rees ring, we study the Jacobian dual and the defining equations of the special fiber ring of m^2. (Received January 22, 2018)

1136-13-514 **Claudia Miller**, **Hamid Rahmati** and **Alexandra Seceleanu*** (aseceleanu@unl.edu). *Comparing ranks of maps on graded artinian Gorenstein algebras.* Preliminary report.

We apply ideas from the theory of tensor rank to relate the ranks of certain maps between homogeneous components of graded algebras. Our work has applications to the study of the weak Lefschetz property for artinian Gorenstein rings. (Received January 22, 2018)

1136-13-521 **Huy Tai Ha**, **Selvi Kara** 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 January 22, 2018)

1136-13-557 **Gabriel Sosa***, gsosa@amherst.edu, and **Michael DiPasquale**, **Chris Francisco**, **Jeff Mermin** and **Jay Schweig**. *The Rees algebra of a Two-Borel ideal is Kozsul.*

Let K be a field of characteristic 0 and u and v two monomials of the same degree in $K[X_1, \ldots, X_n]$. We show that the toric ring $K[\mathcal{N}]$, where $\mathcal{N} = \mathcal{B}(u) \cup \mathcal{B}(v)$, is Koszul using the construction of graphs corresponding to fibers of the toric map.

This implies that the Rees Algebra, $\mathcal{R}(I)$, of the two Borel ideal $I = \langle \mathcal{N} \rangle$ is also Koszul, answering a question of Conca. Remarks regarding the normality and Cohen-Macaulayness of these toric rings will be presented.

This is joint work with M. DiPasquale, C. Francisco, J. Mermin and J. Schweig. (Received January 22, 2018)

1136-13-567 **Katie Ansaldi*** (ansaldik@wabash.edu), 301 W. Wabash Avenue, Crawfordsville, IN 47933, and **Kuei-Nuan Lin** and **Yi-Huang Shen**. *Generalized Newton Complementary Duals of Monomial Ideals.*

We define the generalized Newton complementary dual of a monomial ideal in a polynomial ring over a field. We show good properties of such duals including linear quotients and isomorphisms between the special fiber rings. This generalizes the Newton complementary dual that was first introduced by Costa and Simis. We construct the cellular free resolutions of duals of strongly stable ideals generated in the same degree. When the base ideal is generated in degree two, we provide an explicit description of cellular free resolution of the dual of a compatible generalized stable ideal. (Received January 22, 2018)

1136-13-579 **Erin Bela*** (ebela@nd.edu). *Numerical Macaulification.*

An ideal $J \subset k[x_0, \cdots, x_n]$ is said to be *Numerically ACM* (NACM) if R/J has the Hilbert function of some codimension c ACM subscheme of $\mathbb{P}^n$. In this talk, I describe an algorithm which takes an arbitrary ideal and produces, via a finite sequence of basic double links, an ideal which is numerically ACM. An immediate consequence of this result is that every even liaison class of codimension c subschemes of $\mathbb{P}^n$ contains elements which are NACM. This was first proved for the codimension two case by Migliore and Nagel, and I will demonstrate that these results can be extended to higher codimension. In the case of curves in $\mathbb{P}^4$ we also draw conclusions about the NACM property for codimension two even liaison classes on a hypersurface. This is closely related to questions of maximal rank by multiplication by a general linear form of a certain algebra. (Received January 22, 2018)

1136-13-587 **Jason G Boynton*** (jason.boynton@ndsu.edu), Department of Mathematics, Fargo, ND 58102. *Locally Prüfer rings.*

In this talk we consider a class of rings that lies properly between Gaussian rings and Prüfer rings. In particular, we say that a ring R is locally Prüfer if all of its localizations at prime ideals are Prüfer rings. Fortunately for the naive speaker, the locally Prüfer notion is distinct from that of "maximally Prüfer" as defined by Tom Lucas in 1986. At any rate, we give a characterization of this locally Prüfer property in terms of the total quotient ring. It is worth noting that our characterization is in the spirit of the Bazzoni and Glaz characterizations of four well-studied subclasses of Prüfer rings. (Received January 22, 2018)

1136-13-629 **Sema Gunturkun*** (gunturku@umich.edu) and **Mel Hochster**. *A case for Eisenbud-Green-Harris conjecture.* Preliminary report.

Eisenbug-Green-Harris(EGH) conjecture states a generalization of the well-known Macaulay's theorem on the growth of Hilbert functions of homogeneous ideals and the role of lexicographic ideals. In this talk, we will discuss a case of EGH conjecture for the homogeneous ideals generated by $n+2$ quadrics containing a regular sequence. This is a joint work with Mel Hochster. (Received January 24, 2018)

14 ► Algebraic geometry

1136-14-56 **Andrew Obus*** (andrewobus@gmail.com), 141 Cabell Drive, Charlottesville, VA 22904, and **Stefan Wewers**. *Resolution of weak wild quotient singularities.*

Given a smooth projective curve X over a discretely valued field K, it follows from well-known work of Lipman that there is a regular model of X defined over the valuation ring of K. A particularly interesting case is when X has potentially good reduction. In this case, there is a natural model of X with so-called quotient singularities. Resolution of tame quotient singularities is well understood, and we will give a complete picture of the resolution of the simplest case of wild quotient singularities (which we call "weak wild quotient singularities"). Our techniques involve heavy use of deformation theory and valuation theory, in contrast to the techniques that have been used by Lorenzini on related problems.

This is joint work with Stefan Wewers. (Received December 18, 2017)

1136-14-61 **Emma Previato*** (ep@bu.edu), Department of Mathematics and Statistics, Boston University, Boston, MA 02215-2411. *Painlevé equations and integrable hierarchies: Two spectral curves.*

Heuristically, self-similar solutions to "integrable" hierarchies of PDEs satisfy a Painlevé equation. We investigate the equivariance of the correspondence under Darboux transformation, and give an interpretation of the transformation in terms of the moduli of two types of spectral curves. We apply the results to special solutions found in the 1970s by M. Boiti and F. Pempinelli, comparing them to the general algebraic solutions classified in the 1990s by K. Okamoto and by B. Dubrovin jointly with M. Mazzocco. (Received December 22, 2017)

1136-14-71 **Douglas A Torrance*** (dtorrance@piedmont.edu), PO Box 10, Demorest, GA 30535. *The Chow-Waring problem.*

Suppose we have a homogeneous polynomial. We would like to decompose it into a sum where each summand is the product of powers of linear forms, with the powers given by some sequence. On one extreme, the summands are powers of linear forms. This is known as the Waring problem, and the number of summands in a minimal decomposition is well-known in the generic case due to Alexander and Hirschowitz. On the other extreme, the summands are products of linear forms. This is known as the Chow problem, as the summands of this decomposition lie on a Chow variety. The general problem has become known as the Chow-Waring problem. We discuss recent results and conjectures related to this problem. (Received December 31, 2017)

1136-14-99 **David Jensen*** (dave.h.jensen@gmail.com), 109 N Mill St, Apt 201, Lexington, KY 40507. *The Kodaira dimension of M_{22} and M_{23}.*

We discuss new methods for studying tropicalizations of not necessarily complete linear series and proving linear independence of sections. Using these methods, we prove two outstanding cases of the Strong Maximal Rank Conjecture of Aprodu and Farkas and conclude that the moduli spaces of curves of genus 22 and 23 are of general type. This is joint work with Sam Payne. (Received January 04, 2018)

1136-14-106 **Lubjana Beshaj*** (lubjana.beshaj@usma.edu). *Isogenous elliptic subcovers of genus two curves.*

Genus 2 curves with (n, n)-decomposable Jacobians are the most studied type of genus 2. Such curves have received new attention lately due to interest on their use on cryptographic applications and their suggested use on post-quantum crypto-systems and random self-reducibility of discrete logarithm problem.

In this talk we show that for $N = 2$, 3, 5, and 7 there are only finitely many genus two curves C (up to isomorphism) defined over $\mathbb{Q}$ with $(2, 2)$-split Jacobian and automorphism group of order 4, such that their elliptic subcovers are N-isogenous. Also, there are only finitely many genus two curves (up to isomorphism) defined over $\mathbb{Q}$ with $(3, 3)$-split Jacobian such that their elliptic subcovers are 5-isogenous. (Received January 05, 2018)

1136-14-121 **Jaiung Jun*** (jjun@math.binghamton.edu), **Kalina Mincheva** and **Jeffrey Tolliver**. *Picard groups for tropical toric varieties.*

From any monoid scheme X one can pass to a semiring scheme (a generalization of a tropical scheme) X_S by scalar extension to an idempotent semifield S. We prove that for a given irreducible monoid scheme X (with some mild conditions) and an idempotent semifield S, the Picard group $\mathrm{Pic}(X)$ of X is stable under scalar extension to S. In other words, we show that the two groups $\mathrm{Pic}(X)$ and $\mathrm{Pic}(X_S)$ are isomorphic. We also construct the group $\mathrm{CaCl}(X_S)$ of Cartier divisors modulo principal Cartier divisors for a cancellative semiring scheme X_S and prove that $\mathrm{CaCl}(X_S)$ is isomorphic to $\mathrm{Pic}(X_S)$. (Received January 11, 2018)

1136-14-143 **Jonathan Wise*** (jonathan.wise@colorado.edu), Department of Mathematics, Campus Box 395, University of Colorado, Boulder, CO 80309-0395, and **Renzo Cavalieri**, **Melody Chan** and **Martin Ulirsch**. *Tropicalizing logarithmic schemes, particularly curves.*

I will introduce logarithmic structures and explain how they interpolate between algebraic geometry and tropical geometry. The main examples will be curves and their moduli. (Received January 09, 2018)

1136-14-171 **Steffen Marcus*** (marcuss@tcnj.edu), The College of New Jersey, 2000 Pennington Road, Ewing, NJ 08628, and **Jonathan Wise**, University of Colorado, Boulder. *Logarithmic compactification of the Abel–Jacobi section.*

Given a smooth curve with weighted marked points, the Abel-Jacboi map produces a line bundle on the curve. This map fails to extend to the full boundary of the moduli space of stable pointed curves. Using logarithmic and tropical geometry, we describe a modular modification of the moduli space of curves over which the Abel-Jacobi map extends. This recovers the double ramification cycle, as well as variants associated to differentials. (Received January 12, 2018)

1136-14-235 **Alexandru Chirvasitu*** (achirvas@buffalo.edu), **Ryo Kanda** and **S. Paul Smith**. *Noncommutative symmetric powers.*

One particularly fruitful source of noncommutative projective varieties is the construction, due to Artin, Tate and Van den Bergh, of twisted homogeneous coordinate rings. These are algebras $B(X, \sigma, \mathcal{L})$ attached to data consisting of a projective algebraic variety X, an automorphism σ thereof and a line bundle $\mathcal{L}$ on X. They are noncommutative counterparts to the homogeneous coordinate rings familiar from Serre's work on projective varieties, in the sense that $B(X, \sigma, \mathcal{L})$ should be regarded as a noncommutative deformation of X.

The talk focuses on the case when the variety being deformed is a symmetric power of an elliptic curve. The gist of the results is that if the line bundle is "large enough" then the resulting twisted homogeneous coordinate ring has some of the expected or desired properties, i.e. is generated in degree one and defined by relations of degrees two and three.

The proofs rely only on the numerical equivalence class of the bundle; this is in contrast to analogous results for abelian varieties, where generation in degree one seems to depend on the isomorphism class of the bundle (a finer piece of data than its numerical equivalence class).

(joint w/ Ryo Kanda and S. Paul Smith) (Received January 16, 2018)

1136-14-245 **Hirotachi Abo*** (abo@uidaho.edu), 875 Perimeter Drive, MS 1103, Moscow, ID , and **Nick Vannieuwenhoven**. *Taking a Step from the Waring Rank Toward the Chow Rank.*

The main goal of this talk is to present a result related to a conjecture suggested by Catalisano, Geramita, and Gimigliano in 2002, which claims that the secant varieties of tangential varieties to Veronese varieties are non-defective modulo a few known exceptions. (Received January 17, 2018)

1136-14-247 **Colin Crowley**, **Noah Giansiracusa** and **Joshua Mundinger*** (jmundin1@swarthmore.edu). *A module-theoretic approach to matroids.*

Tropical linear spaces provide a bridge between the combinatorics of matroids, the algebra of idempotent semifields, and the geometry of tropical varieties. This began with Speyer's observation that matroids encode the same data as a special class of tropical linear spaces, and Frenk's work in developing the perspective of tropical linear spaces as modules over an idempotent semifield. We expand on this work by further developing idempotent module theory of matroids, finding new formulations of both classical matroid and tropical linear space constructions. (Received January 17, 2018)

1136-14-259 **Daniel Corey*** (daniel.corey@yale.edu), 10 Hillhouse Ave, Floor 4, New Haven, CT 06511. *Initial degenerations of Grassmannians.*

Let $\mathrm{Gr}_0^{d,n}$ denote the open subvariety of the Grassmannian $\mathrm{Gr}^{d,n}$ consisting of $d-1$ dimensional subspaces of $\mathbb{P}^{n-1}$ meeting the toric boundary transversely. We prove that $\mathrm{Gr}_0^{3,7}$ is schön in the sense that all of its initial degenerations are smooth. We use this to show that the Chow quotient of $\mathrm{Gr}^{3,7}$ by the maximal torus $H \subset \mathrm{GL}(n)$ is the log canonical compactification of the moduli space of 7 lines in $\mathbb{P}^2$ in linear general position. This provides a positive answer to a conjecture of Hacking, Keel, and Tevelev from *Geometry of Chow quotients of Grassmannians.* (Received January 18, 2018)

1136-14-264 **Elise Villella*** (emv23@pitt.edu). *Virtual Gelfand-Zetlin Polytopes.* Preliminary report.

The theory of virtual polytopes and convex chains was introduced by Khovanskii and Pukhlikov in 1993. In this talk we describe the virtual Gelfand-Zetlin polytopes. Gelfand-Zetlin polytopes are an important family of polytopes which arise from irreducible representations of SL_n. We interpret Gelfand-Zetlin virtual polytopes both as convex chains, and also as twisted cubes, which were originally defined by Grossberg and Karshon in 1994. (Received January 18, 2018)

1136-14-300 **Alex Küronya*** (kuronya@math.uni-frankfurt.de), Institut für Mathematik, Goethe Universität, Robert-Mayer-Str. 6-10, 60325 Frankfurt am Main, Germany, and **Victor Lozovanu**, Institut für Algebraische Geometrie, Leibniz Universität Hannover, Welfengarten 1, 30167 Hannover, Germany. *Syzygies of abelian varieties via Newton-Okounkov bodies.*

An effective way to study algebraic varieties is through their embeddings into projective space. A projective embedding gives rise to a homogeneous coordinate ring, whose algebraic properties reflect the geometry of the underlying variety.

Syzygies of varieties come from minimal free resolutions of the corresponding coordinate rings, here we study syzygies of abelian surfaces and threefolds. By the work of Green, Inamdar, and Lazarsfeld-Pareschi-Popa, the study of syzygies of abelian varieties can be reduced to the construction of singular divisors. The existence of effective divisors with prescribed singularities and numerical behaviour is a very important question in algebraic geometry with many powerful applications like the classical theorems of MMP and major positivity theorems.

The purpose of this talk is to show how to use Newton-Okounkov bodies, that is, convex bodies associated to divisors, to show the existence of effective divisors with a given numerical equivalence class and multiplier ideal, which leads to strong results about syzygies of abelian varieties of low dimension. (Received January 19, 2018)

1136-14-306 **Frank Sottile*** (sottile@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843-3368, and **Ata Firat Pir**, Department of Mathematics, Texas A&M University, College Station, TX 77843-3368. *Irrational Toric Varieties.*

Classical toric varieties come in two flavours: Normal toric varieties are given by rational fans in $\mathbb{R}^n$. A (not necessarily normal) affine toric variety is given by finite subset A of $\mathbb{Z}^n$. When A is homogeneous, it is projective. Applications of mathematics have long studied the positive real part of a toric variety as the main object, where the points A may be arbitrary points in $\mathbb{R}^n$. For example, in 1963 Birch showed that such an irrational toric variety is homeomorphic to the convex hull of the set A.

Recent work in applications suggested the need for a richer theory, one that starts with an arbitrary fan in $\mathbb{R}^n$. This has been developed in collaboration with Ata Pir. The resulting irrational toric variety is an $\mathbb{R}^n_>$-equivariant cell complex that is dual to the fan. Among many pleasing parallels with the classical theory is that for normal fans to polytopes, the irrational toric variety is homeomorphic to the polytope. (Received January 19, 2018)

1136-14-324 **Matt Stevenson*** (stevmatt@umich.edu). *Topology of Hybrid Analytifications.*

Given a complete normed field k and a variety X over k, one can construct the Berkovich analytification X^{an} of X with respect to the native norm on k; alternatively, one can construct the analytification X^{triv} of X with respect to the trivial norm on k. In fact, Berkovich introduced a "hybrid" analytification of X that interpolates between the two spaces X^{an} and X^{triv}. We will discuss recent results describing how the topology of certain hybrid analytifications compares with that of the usual analytifications. (Received January 19, 2018)

1136-14-330 **Eric Katz*** (katz.60@osu.edu), 231 W. 18th Ave., Columbus, OH 43210. *Curve Arrangements on Surfaces and the Hodge Index Theorem.*

Given a surface, one can ask which possible combinatorial arrangement of curves on it are possible. We will explain how the Hodge index theorem constrains the combinatorics of an abstract tropicalization of the curve arrangement. (Received January 19, 2018)

1136-14-332 **Eric Katz*** (katz.60@osu.edu), 231 W. 18th Ave., Columbus, OH 43210. *Iterated tropical and p-adic integration.*

Coleman's theory of p-adic integration is an important tool in number theory. Its iterated analogue is used in Kim's non-abelian version of the Chabauty method. We will discuss some of the challenges of making sense of the integral on bad reduction curves. A combinatorial analogue of iterated integration will make an appearance. This talk is based on joint work with Daniel Litt and Raymond Cheng. (Received January 19, 2018)

1136-14-345 **Max B. Kutler*** (max.kutler@yale.edu). *Faithful tropicalization of hypertoric varieties.*

A hypertoric variety is a "hyperkähler analogue" of a toric variety. Each hypertoric variety comes equipped with an embedding into a toric variety, called the Lawrence toric variety, and hence has a natural tropicalization. We show that, for every hypertoric variety, the tropicalization map (i) admits a unique continuous section and (ii) is a homotopy equivalence. (Received January 19, 2018)

1136-14-355 **Aida Maraj*** (aida.maraj@uky.edu), Department of Mathematics, 715 Patterson Office Tower, Lexington, KY 40506, and **Uwe Nagel** (uwe.nagel@uky.edu), Department of Mathematics, 715 Patterson Office Tower, Lexington, KY 40506. *Toric Ideals of Hierarchical Models.* Preliminary report.

This talk will be about toric ideals which correspond to Hierarchical Models in Algebraic Statistics. We will start by introducing these ideals, then explaining a formula for Krull dimension. To describe generating sets of these ideals one can use a symmetric group action. Using this tool, we will describe generating sets for some classes of these ideals as decomposable and non-reducible Models. (Received January 19, 2018)

1136-14-362 **Brian Harbourne*** (bharbourne1@unl.edu). *Line arrangement problems: a unifying perspective on Lefschetz, postulation and containment problems in commutative algebra and algebraic geometry.*

Recent work on certain Lefschetz problems, on postulation problems (related to the number of conditions imposed on forms of given degree by points in the plane) and on containment problems (related to containment of symbolic powers of ideals of points in regular powers of those ideals) has in all three cases led to the same central longstanding problem on line arrangements in the plane. I will discuss what this central problem is and how it relates to the problems in the other three areas. (Received January 19, 2018)

1136-14-380 **Mihai Fulger*** (mihai.fulger@uconn.edu), Department of Mathematics, University of Connecticut, 341 Mansfield Rd, Storrs, CT 06268. *Local volumes as limits.*

If $\pi : Y \to X$ is a proper birational morphism over X normal, and if $x \in X$ is a closed point, then for all divisors D on Y, the local volume of D around x is defined as the asymptotic $\limsup$ of the cohomology with supports $\dim H^1_x(X; \pi_*\mathcal{O}_Y(mD))$ as m grows. Particular cases include the Hilbert-Samuel multiplicity of X at x, or Wahl's volume of an isolated normal surface singularity. We prove that $\limsup$ in the definition of the local volume can be replaced by $\lim$, and that the local volume naturally measures the volume of a difference of nested convex bodies. For this we employ Newton-Okounkov semigroup techniques. A difficulty is the apparent impossibility of reducing the question to a study of linear series of multiples of a fixed divisor on a projective variety. (Received January 20, 2018)

1136-14-425 **Bea Schumann*** (bschumann@math.uni-koeln.de), Mathematical Institute, University of Cologne, Weyertal 86-90, Cologne, Germany. *Cones and Polytopes arising from potential functions on cluster varieties.* Preliminary report.

In this talk we discuss potential functions on the base affine space of a simply-connected, simple algebraic group over the complex numbers. These are certain regular functions on the associated cluster variety whose tropicalizations cut out interesting cones and polytopes. We discuss the relation to the string parametrization of Lusztig's canonical bases. This is joint work with Volker Genz and Gleb Koshevoy. (Received January 21, 2018)

1136-14-428 **Giuliano Gagliardi** and **Johannes Hofscheier*** (hofschej@mcmaster.ca), Dept. of Mathematics & Statistics, McMaster University, Hamilton, Ontario L8S 4K1, Canada. *A geometric proof of the generalized Mukai conjecture for horospherical varieties.*
Horospherical varieties naturally generalize toric and flag varieties and thus form a rich class of algebraic varieties admitting an action by a reductive group with an open dense orbit. In this talk, I will present recent joint work with Giuliano Gagliardi on a geometric proof of the generalized Mukai conjecture (an inequality involving the pseudo-index, the dimension, and the Picard number of a smooth Fano variety) for the horospherical case. In our approach, we combine the theory of toric degenerations of spherical varieties using representation theory with a recent result by Brown-McKernan-Svaldi-Zong which characterizes toric varieties using log pairs. (Received January 21, 2018)

1136-14-440 **Jihyeon Jessie Yang*** (jyang@marian.edu). *Bott canonical basis.* Preliminary report.
I will report on a work in progress with Yael Karshon. This work is motivated by an old idea from Raoul Bott to geometrically construct bases for unitary representations of compact Lie groups. His main idea was to use large torus actions on Bott-Samelson manifolds, which are birational models of flag manifolds. We introduce a new torus action that may lead to the success of his problem. This torus action was motivated by certain deformations of Bott-Samelson manifolds with their Newton-Okounkov Bodies. (Received January 21, 2018)

1136-14-443 **Christopher A Manon*** (christopher.manon@uky.edu). *Newton-Okounkov bodies of rational complexity 1 varieties.*
For a connected reductive group G, the complexity 1 G-varieties form a natural class of spaces which generalize toric varieties and spherical varieties. I'll describe a few constructions of Newton-Okounkov bodies for these spaces and a relationship with their associated tropical varieties, generalizing known results from the toric and spherical cases. Much of this is joint work with with Nathan Ilten. (Received January 21, 2018)

1136-14-444 **Christopher A Manon*** (christopher.manon@uky.edu). *Results on Khovanskii bases of graded algebras.* Preliminary report.
For an algebra R of finite type equipped with a discrete valuation v, a Khovanskii basis is a set of elements of R whose equivalence classes in the associated graded algebra $gr_v(R)$ constitute an algebra generating set. A result with Kaveh shows that finite Khovanskii bases are related to structures called prime cones in an associated tropical variety. I will talk about recent work with Kaveh and Takuya Murata on the existence of Khovanskii bases for positively graded algebras of finite type over an algebraically closed field of characteristic zero. We show that any such algebra of dimension d always has a valuation of rank $\leq d-1$ with finite Khovanskii basis. As consequence we show that any Hilbert function of a positively graded ring is always the Hilbert function of an affine semigroup algebra. (Received January 21, 2018)

1136-14-453 **Gregory G Smith*** (ggsmith@mast.queensu.ca), Department of Mathematics and Statistics, Queen's University, Kingston, Ontario , Canada. *Combinatorics of Toric Vector Bundles.* Preliminary report.
To each torus-equivariant vector bundle over a smooth complete toric variety, we associate a finite collection of line bundles indexed by vectors in a finite-dimensional vector space. In this talk, we will describe how the combinatorics of this data encodes a resolution of the toric vector bundle. We will also indicate some applications of these resolutions. (Received January 21, 2018)

1136-14-460 **Andreas Gross** and **Farbod Shokrieh***, farbod@math.cornell.edu. *A non-Archimedean Poincaré formula for theta divisors.*
Let X be a curve over $\mathbb{C}$. The classical Poincaré formula for theta divisors compares the fundamental classes of Θ (the theta divisor) and W_d (the subset of $\mathrm{Pic}^d(X)$ of line bundles with nonempty linear systems). I will discuss a non-Archimedean/tropical version of this formula. (Joint work with Andreas Gross at Imperial College London) (Received January 21, 2018)

1136-14-463 **Hiraku Abe**, **Lauren DeDieu**, **Federico Galetto*** (galettof@math.mcmaster.ca) and **Megumi Harada**. *Towards Newton-Okounkov bodies of Hessenberg varieties.*
The theory of Newton-Okounkov bodies provides a method to associate useful combinatorial data to an algebraic variety. We are interested in Newton-Okounkov bodies of Hessenberg varieties, certain subvarieties of the flag variety. I will describe a flat family with reduced fibers degenerating a regular semisimple Hessenberg variety to a regular nilpotent Hessenberg variety. This degeneration leads to a degree formula for regular nilpotent Hessenberg varieties with respect to a Plücker embedding and, in the special case of the two-dimensional Peterson variety, to the computation of Newton-Okounkov bodies corresponding to such embeddings. (Received January 21, 2018)

1136-14-476 **Emily Clader**, **Samuel Grushevsky**, **Felix Janda**, **Martin Ulirsch** and **Dmitry Zakharov*** (dvzakharov@gmail.com). *The double ramification cycle, relations in the tautological ring, and tropical geometry.*

The double ramification cycle is a natural class in the Chow ring of the moduli space $\overline{\mathcal{M}}_{g,n}$ of stable marked curves, parametrizing curves admitting a meromorphic function with prescribed singularities. Recently, a formula for the double ramification cycle, conjectured by Pixton, was proved by Janda, Pandharipande, Pixton and Zvonkine. A related family of relations in the Chow ring of $\overline{\mathcal{M}}_{g,n}$, also conjectured by Pixton, were proved by Clader and Janda.

I will discuss the consequences of the relations of Clader and Janda, and show that they naturally reproduce classical vanishing results in the tautological ring of $\overline{\mathcal{M}}_{g,n}$. Furthermore, they give an effective algorithm for computing boundary formulas for classes that vanish on $\mathcal{M}_{g,n}$. I will also discuss possible tropical extensions of the double ramification cycle. (Received January 21, 2018)

1136-14-477 **Askold Khovanskii*** (askold@math.toronto.edu). *Good compactification theorem for $(\mathbf{C}^*)^n$.*

Let X be an algebraic subvariety in $(\mathbf{C}^*)^n$. According to the good compactification theorem there is a complete toric variety $M \supset (\mathbf{C}^*)^n$ such that the closure of X in M does not intersect orbits in M of codimension bigger than $\dim_{\mathbf{C}} X$. This theorem allows to defined the tropicalization of the subvariety X. All proofs of the good compactification theorem I met in literature are rather involved.

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-th. It is a version of intersection theory for algebraic cycles in H. Its construction for $(\mathbf{C}^*)^n$ is based on the good compactification theorem.

I will present a new constructive and elementary proof of the good compactification theorem. In particular it allows to give a constructive description of the tropicalization of subvarieties in $(\mathbf{C}^*)^n$. (Received January 21, 2018)

1136-14-479 **Dori Bejleri*** (dbejleri@math.brown.edu). *Combinatorial and tropical geometry of Hilbert schemes of points.* Preliminary report.

The Hilbert scheme of points has been a rich source of interplay between combinatorics and geometry. In this talk I will survey some recent work in this direction, focusing on the role of partition combinatorics, as well as pose some open questions. I will also introduce the tropical Hilbert scheme (joint work in progress with A. Fink and D. Maclagan) and discuss how it should encode some of the relevant partition combinatorics. (Received January 21, 2018)

1136-14-491 **Leonid Monin*** (leonid.monin@gmail.com), 40 St George St, Rm 6290, Toronto, On M5S2E4, Canada. *Discrete Invariants of Generically Inconsistent Systems of Linear Series.*

Consider a collection of linear series $L_1, \dots, L_k$ on an irreducible algebraic variety X such that the system $f_1 = \dots = f_k = 0$ does not have zeroes on X for generic k-tuple $f_1 \in L_1, \dots, f_k \in L_k$. How to compute discrete invariants of $Y \subset X$ defined by a system of equations which is generic **in the set of consistent systems**? In my talk I will answer this question in the case of $X = (\mathbb{C}^*)^n$ and more generally in the case $X = G/H$ is a spherical homogeneous space by reducing it to the study of discrete invariants of generically solvable collections of linear series. The main reduction theorem is true in the general case of inconsistent linear systems on an algebraic variety. (Received January 21, 2018)

1136-14-501 **Gretchen L. Matthews*** (gmatthe@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634-0975. *Quantum error-correcting codes from curves.*

With the advent of quantum computing comes the need to protect quantum information from errors. The scenario is quite different from the classical one, where redundancy may be used to correct errors introduced by noise. According to the No Cloning Theorem, quantum information may not be replicated. Even so, as demonstrated by Peter Shor in 1994, quantum error-correcting codes do exist. In this talk, we discuss the use of algebraic curves in the construction of quantum error-correcting codes. (Received January 22, 2018)

1136-14-508 **Laura Escobar*** (lescobar@illinois.edu), **Megumi Harada** and **Kristin Shaw**. *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 January 22, 2018)

1136-14-516 **Brian G Kodalen*** (bgkodalen@wpi.edu). *Linked Simplices.*

Let X and Y be sets of unit vectors corresponding to regular simplices in $\mathbb{R}^v$ ($v+1$ vectors with pairwise inner product $-\frac{1}{v}$). We call X and Y a pair of *linked simplices* if, for every $x \in X$ and $y \in Y$, we have $\langle x, y\rangle \in \{\gamma, \zeta\}$ for some fixed values of γ and ζ. We ask the question of when you can find large sets of simplices for which every pair of them are linked using the same inner products γ and ζ. In this talk, we show that any set of w linked simplices corresponds to a linked system of symmetric designs (LSSD) on w fibers. Using the Q-polynomial structure of LSSDs, we then construct linked simplices showing the equivalence between these two objects. Finally we review known examples such as the Cameron-Seidel association scheme and, in restricted cases, use the linked simplices to construct real mutually unbiased bases. (Received January 22, 2018)

1136-14-528 **Rohini Ramadas*** (ramadas@math.harvard.edu), Harvard University Department of Mathematics, 1 Oxford Street, Cambridge, MA 02138. *Dynamics on the moduli space of pointed rational curves.*

Hurwitz correspondences are a special family of algebraic discrete dynamical systems on the moduli space $\mathcal{M}_{0,n}$ parametrizing configurations of n points on $\mathbb{P}^1$. Hurwitz correspondences arise in the study of the topological dynamics of self-maps of $\mathbb{P}^{\Bbbk}$. I will introduce Hurwitz correspondences, discuss their algebraic dynamics, and briefly describe their tropical analogs. (Received January 22, 2018)

1136-14-545 **Brian Lehmann*** (lehmannb@bc.edu), Math Department – Maloney Hall, 140 Commonwealth Ave, Chestnut Hill, MA 02467. *Convexity and Zariski decompositions.*

The Zariski decomposition is an important tool for understanding the properties of linear series on algebraic varieties. I will describe how abstract convex analysis can be used to analyze Zariski's original construction. One then obtains a dual theory for curves which has surprising geometric properties. (Received January 22, 2018)

1136-14-548 **Dhruv Ranganathan*** (dhruvr@mit.edu), 77 Massachusetts Avenue, Building 2, Cambridge, MA 02138. *Tropical geometry of stable maps and elliptic singularities.*

I will outline a framework based on tropical and logarithmic methods to study curve singularities of genus one. I will focus on the application of these methods to the construction of nonsingular moduli spaces of elliptic curves in toric varieties, generalizing a well-known result of Vakil and Zinger. This is based on joint work with Santos-Parker and Wise, building on prior work of Speyer, Smyth, Vakil, Viscardi, and Zinger. (Received January 22, 2018)

1136-14-549 **Philip Engel*** (engel@math.harvard.edu). *Cusp Singularities.*

In 1884, Klein initiated the study of rational double points (RDPs), a special class of surface singularities which are in bijection with the simply-laced Dynkin diagrams. Over the course of the 20th century, du Val, Artin, Tyurina, Brieskorn, and others intensively studied their properties, in particular determining their adjacencies—the other singularities to which an RDP deforms. The answer: One RDP deforms to another if and only if the Dynkin diagram of the latter embeds into the Dynkin diagram of the former. The next stage of complexity is the class of elliptic surface singularities. Their deformation theory, initially studied by Laufer in 1973, was largely determined by the mid 1980's by work of Pinkham, Wahl, Looijenga, Friedman and others. The exception was a conjecture of Looijenga's regarding smoothability of cusp singularities—surface singularities whose resolution is a cycle of rational curves. I will describe a proof of Looijenga's conjecture which connects the problem to symplectic geometry via mirror symmetry, and summarize some recent work with Friedman determining adjacencies of a cusp singularity. (Received January 22, 2018)

1136-14-552 **Rajesh S. Kulkarni** (kulkarni@math.msu.edu), Michigan State University, Department of Mathematics, 619 Red Cedar Road, East Lansing, MI 48824, and **Charlotte Ure*** (urecharl@math.msu.edu), Michigan State University, Department of Mathematics, 619 Red Cedar Road, East Lansing, MI 48824. *Splitting the Generic Binary Cubic Clifford Algebra.*

Let V be a 2-dimensional vector space, and let $k\langle V\rangle$ be its tensor algebra. The binary cubic generic Clifford algebra A is the quotient of $k\langle V\rangle$ by the ideal generated by elements of the form $[X, Y^3]$ with X and Y in V. Note that for any binary cubic form f, the Clifford algebra associated to f is a homomorphic image of A. We show that A is Azumaya over an open subset of its center and determine when its Brauer class is trivial. We exhibit an explicit étale cover of the center that splits the algebra. This is joint work in progress. (Received January 22, 2018)

1136-14-564 **Bill Trok*** (`william.trok@uky.edu`). *Lefschetz Failure and Hyperplane Arrangements.* Preliminary report.

Macaulay-Matlis duality gives a relationship between the Lefschetz properties of quotients of polynomial rings by powers of linear forms and the geometry of fat point schemes. We discuss a further relationship relating certain properties of fat points, to properties of the dual Hyperplane arrangement, generalizing a relationship already known for the projective plane. We will also discuss some new results in the planar case, and connections with Lefschetz properties. (Received January 22, 2018)

1136-14-572 **Monika Polak*** (`mkp@cs.rit.edu`). *A database for genus 3 hyperelliptic curves.* Preliminary report.

We study the genus 3 hyperelliptic moduli via the weighted projective space of binary octavics. This enables us to create a database of all genus 3 hyperelliptic curves with field of moduli $\mathbb{Q}$ and weighted moduli height ≤ 3. Each point in the database is represented by a absolutely minimal tuple of Shioda invariants $J_2, \ldots, J_8$. For each point in the database we determine the automorphism group and an equation of the curve defined over $\mathbb{Q}$ whenever possible. (Received January 22, 2018)

1136-14-600 **Padmavathi Srinivasan***, 686 Cherry Street NW, Atlanta, GA 30313. *Conductors and minimal discriminants of hyperelliptic curves.*

Conductors and minimal discriminants are two measures of degeneracy of the singular fiber in a family of hyperelliptic curves. We will explain how these invariants can be computed from the combinatorics of explicit regular models, and present a proof of an inequality relating these two invariants under suitable hypotheses. (Received January 22, 2018)

1136-14-610 **Matthew Satriano*** (`msatrian@uwaterloo.ca`) and **Dan Edidin**. *Towards an Intersection Chow Cohomology Theory for GIT Quotients.*

The Hirzebruch-Riemann-Roch Theorem allows one to compute the Euler characteristic of a coherent sheaf in terms of the degree of a 0-cycle. It has been generalized by Toen to the case of Deligne-Mumford stacks. Using toric methods, we prove that (a naive version of) Hirzebruch-Riemann-Roch fails for Artin stacks. We discuss the extent to which the problem can be rectified, leading us to a closely connected problem of constructing an intersection Chow cohomology theory. (Received January 22, 2018)

1136-14-614 **Maitreyee C Kulkarni***, 3942 Gourrier Ave, Baton Rouge, LA 70808. *Dimer models on cylinders over Dynkin diagrams and cluster algebras.*

In 2013, Baur, King and Marsh used dimer models to categorify the cluster structure on the coordinate ring of Grassmannians (partial flag varieties G/P where G is the general linear group and P is a maximal parabolic). On the other hand, Pressland recently introduced a method to construct Frobenius categorifications of cluster algebras with frozen variables. In this talk, I will give an analog of dimer models for partial flag varieties G/P for general G and P, by introducing a technique called "constructing cylinders over Dynkin diagrams"—together with a variant of Pressland's work, this can (conjecturally) be used to give a categorification of cluster algebras from double Bruhat cells. (Received January 22, 2018)

15 ► Linear and multilinear algebra; matrix theory

1136-15-378 **John I Haas*** (`terraformthedreamscape@gmail.com`), 105 Redwood Rd, Columbia, MO 65203, and **Peter G Casazza**, **Tin Tran** and **Joshua Stueck** (`jss4yf@mail.missouri.edu`). *Optimally packed fusion frames via symmetric and quasi-symmetric block designs.* Preliminary report.

In a previous work, maximally orthoplectic fusion frames (OFFs) – sequences of subspaces with minimized chordal coherence equal to the orthoplex bound – were constructed in every complex Hilbert space with dimension of even prime power and in every real Hilbert space with dimension that is a power of four. These constructions rely on the existence of maximal sets of mutually unbiased bases (MUBs) and certain block designs, and we note that the maximality condition requires that the subspaces be precisely half that of their ambient vector spaces.

In this talk, we further exploit the existence of MUBs along with other types of block designs to construct more families of optimally packed fusion frames, achieving both the Welch and orthoplex bounds. These families include real OFFs where the subspaces are not necessarily half-dimension and complex OFFs in every complex Hilbert space of prime power dimension. (Received January 20, 2018)

1136-15-498 **Sarah Bockting-Conrad*** (sarah.bockting@depaul.edu). *Three bases associated with a thin tridiagonal pair of q-Racah type.*

Let $\mathbb{K}$ denote an algebraically closed field and let V denote a vector space over $\mathbb{K}$ with finite positive dimension. Let A, A^* denote a tridiagonal pair on V which has q-Racah type. We consider the linear transformations $\psi : V \to V$, $\Delta : V \to V$, and $\mathcal{M} : V \to V$, each of which acts on the split decompositions of V in an attractive way. In earlier work, we showed that Δ can be factored into a q^{-1}-exponential in ψ times a q-exponential in ψ and discussed how this factorization relates to $\mathcal{M}$. In this talk we focus on the situation when the tridiagonal pair A, A^* is thin. For this case, we use the above transformations to obtain three attractive bases for the underlying space V. We discuss these bases in detail. In particular, for each of the linear transformations associated with A, A^*, we describe its action on each basis. In addition, we give the transition maps between these bases. (Received January 22, 2018)

16 ► Associative rings and algebras

1136-16-8 **James Mixco*** (james.mixco@slu.edu), Saint Louis University, 220 North Grand Blvd, Ritter Hall 331, Saint Louis, MO 63103, and **Ashish Srivastava**, **Li Li** and **Biswajit Ransingh**. *An introduction to cluster superalgebras.*

In this paper we propose the notion of cluster superalgebras which is a supersymmetric version of the classical cluster algebras introduced by Fomin and Zelevinsky. We show that the symplectic-orthogonal superalgebra $SpO(2|1)$ admits a cluster superalgebra structure and as a consequence of this, we also deduce that the supercommutative superalgebra generated by all the entries of a superfrieze is a cluster superalgebra. We also discuss some basic properties of cluster superalgebras and observe their similarities and differences with the classical set up. (Received August 25, 2017)

1136-16-9 **Daniel P. Bossaller*** (db684513@ohio.edu) and **Sergio R. Lopez-Permouth** (lopez@ohio.edu). *Algebras With Bases Consisting Solely of Strongly Regular Elements.* Preliminary report.

Various recent papers deal with the so-called "invertible algebras", those algebras over arbitrary (not necessarily commutative) unital rings which have bases that consist solely of invertible elements. Somewhat surprisingly, many familiar algebras satisfy this property, including all finite dimensional algebras over fields other than $\mathbb{F}_2$. A characterization of invertible Leavitt Path Algebras was obtained by López-Permouth and Pilewski. We introduce the concept of a locally invertible algebra, that is, an algebra A having a basis $\mathcal{B}$ such that, for every $b \in \mathcal{B}$, there exists some idempotent e such that b is a unit in the corner ring eAe. We show that this property is equivalent to the property that A has a basis consisting solely of strongly von Neumann regular elements. Among other results, we show that this family of algebras is strictly larger than that of invertible algebras and includes all finite dimensional algebras over arbitrary fields, as well as all clean algebras. Most importantly, the new notion opens this type of inquiry to the consideration of non-unital algebras; we will show various examples of non-unital locally invertible algebras. (Received August 28, 2017)

1136-16-35 **Pinar Aydogdu*** (paydogdu@hacettepe.edu.tr), Department of Mathematics, Hacettepe University, 06800 Beytepe, Ankara, Turkey, and **Sergio Roberto Lopez-Permouth** and **Martha Lizbeth Shaid Sandoval-Miranda**. *On the weakly-injective profile of a ring.* Preliminary report.

Following [1], a module M is called weakly N-injective if for each homomorphism f from N to the injective hull $E(M)$ of M, there exists a submodule X of $E(M)$ such that $f(N) \subset X \cong M$. If M is N-injective, then it is weakly N-injective. In [2], López-Permouth and Simental introduced the injectivity profile of a ring to be the collection of all domains of injectivity of modules over said ring. In this work, we deal with the investigation of weak-injectivity profile.

References: [1] S.K. Jain and S.R. López-Permouth, Rings whose cyclics are essentially embeddable in projective modules, J. Algebra, 128, 257-269, 1990. [2] S.R. López-Permouth and J.E. Simental, Characterizing rings in terms of the extent of the injectivity and projectivity of their modules, J. Algebra, 362, 56-69, 2012. (Received December 06, 2017)

1136-16-37 **Kulumani M Rangaswamy***, 1420 Austin Bluffs Parkway, Colorado Springs, CO 80918. *Cotorsionness of modules by extension of homomorphisms.*

Let R be an integral domain and let k be an infinite cardinal. Let P denote the direct product of k copies of R and let S denote the direct sum of k copies of R. In his investigation of homomorphic images of P, George Bergman

(Pacific J. Math, vol. 274 (2015)) raised the question of describing, when R is ring of integers, the R-modules A having the property that every homomorphism from S to A extends to a homomorphism from P to A. We show that, when R is a Dedekind domain, the R-modules A with the stated property are precisely the cotorsion modules. When R is an arbitrary integral domain, generalization to cotorsion theories of R-modules leads to the consideration of the three well-known types of cotorsionnesss- the Enochs, the Matlis and the Warfield cotorsion modules (Received December 05, 2017)

1136-16-38 **Mauricio Gabriel Medina Barcenas**, **Lorena Morales Callejas** and **Martha Lizbeth Shaid Sandoval Miranda*** (marlisha@gmail.com), Center or Rings and Its Aplications, 414 Morton Hall , Department of Mathematics, Ohio University, Athens, OH 45701, and **Luis Angel Zaldivar Corichi**. *On quasiquantales and topological spaces associated to a module.*

In the study of modules, in (1) it was introduced a lattice structure as a generalization of meet-continuous lattices and quantales, and so we apply this to study a module throught some associated frames. In particular, we give a module counterpart of the well known result that in a commutative ring the set of semiprime ideals, that is, radical ideals is a frame. In a recent work (2), we define semiprimitive submodules and we prove that they form an spatial frame canonically isomorphic to the topology of Max(M). We characterize the soberness of Max(M) in terms of the point space of that frame. Beside of this, we study the regularity of an spatial frame associated to M given by annihilator conditions.

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(Received December 05, 2017)

1136-16-42 **Louis H Rowen*** (rowen@math.biu.ac.il). *Representability of relatively free affine algebras over an arbitrary field.*

(Joint work with Alexei Belov and Uzi Vishne)

This is part of the revisionist program in PI-theory. In an earlier series of papers, we used full quivers as tools in describing PI-varieties of algebras and providing a complete proof of Belov's solution of Specht's problem for affine algebras over an arbitrary Noetherian ring. In this talk, based on that work, we sketch the full proof of the Kemer-Belov theorem that relatively free affine PI-algebras over an arbitrary field are representable, emphasizing "hiking" to guarantee that nonzero substitutions of polynomials are in the appropriate Wedderburn components. (Received December 09, 2017)

1136-16-44 **Jan Trlifaj*** (trlifaj@karlin.mff.cuni.cz). *Faith's problem on R-projectivity is undecidable.*

In Algebra II, Carl Faith asked for a characterization of the rings R such that the Dual Baer Criterion holds in Mod-R. Such rings were called right testing. Sandomierski proved that each right perfect ring is right testing. Puninski et al. have recently proved for a number of non-right perfect rings that they are not right testing, and noticed the consistency with ZFC of the statement 'each right testing ring is right perfect.'

We prove the complementing consistency result: the existence of a right testing, but not right perfect ring is also consistent with ZFC. Thus the answer to the Faith's question above is undecidable in ZFC. Moreover, we provide examples of non-right perfect rings R such that the Dual Baer Criterion holds (in ZFC) for all countably generated right R-modules. (Received December 12, 2017)

1136-16-46 **V. V. Bavula*** (v.bavula@sheffield.ac.uk), Hounsfield Road, Hicks Building, Sheffield, S3 7RH, United Kingdom. *Localizable and weakly left localizable rings.* Preliminary report.

Two new classes of rings are introduced - the class of left localizable and the class of weakly left localizable rings. Characterizations of them are given. (Received December 14, 2017)

1136-16-53 **Jae Keol Park** and **Syed Tariq Rizvi*** (rizvi.1@osu.edu), Department of Mathematics, The Ohio State University, 4240 Campus Drive, Lima, OH 45804. *On Extending and (Quasi-)Baer Module Hulls.*

Let M_R be a module. We fix an injective hull $E(M_R)$ of M_R. Let $\mathfrak{M}$ be a class of modules. We call a module H_R, when it exists, the $\mathfrak{M}$ hull of M_R if H_R is the smallest extension of M_R in $E(M_R)$ that belongs to $\mathfrak{M}$. It is well-known that the Baer, the quasi-Baer, the extending, and the FI-extending hulls of a module M do not exist in general. On the other hand, we show that for any nonsingular cyclic module M over a commutative ring all of these module hulls of M do exist and coincide with the quasi-continuous hull of M.

Furthermore, when A is an intermediate domain between a commutative domain R and the field of fractions F of R, we can describe the extending hull of $M_R \oplus A_R^{(n)}$ for any R-module M with $\mathrm{Ann}_R(M) \neq 0$ (n, any positive integer) if A is Prüfer. Indeed, A is a Prüfer domain if and only if $E(M_R) \oplus A_R^{(n)}$ is the extending hull of $M_R \oplus A_R^{(n)}$ for any R-module with $\mathrm{Ann}_R(M) \neq 0$ and for any positive integer n. We will discuss examples in which the extending hull, the (quasi-)Baer hull and the Rickart module hull of a module differ among other hulls. (Received December 16, 2017)

1136-16-58 **Chelsea Walton** and **Xingting Wang*** (xingting@temple.edu), Department of Mathematics, Wachman Hall (038-16), 1805 N. Broad St, Philadelphia, PA 19122, and **Milen Yakimov**. *Irreducible representations of the 4-dimensional Slyanin algebra at points of finite order.*

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. By exploring a compatible Poisson structure on the central affine variety of $A(E, \tau)$ obtained by formal deformation, we are able to describe the Azumaya locus and prove that it coincides with the smooth locus of $A(E, \tau)$. We also relate these irreducible representations to the fat point modules of intermediate multiplicity classified by Smith. This is a joint work of Chelsea Walton and Milen Yakimov. (Received December 18, 2017)

1136-16-64 **Alexander H Sistko*** (alexander-sistko@uiowa.edu), 14 MacLean Hall, Iowa City, IA 52242-1419, and **Miodrag C Iovanov**. *Maximal Subalgebras of Finite-DImensional Algebras and Applications.*

We present a classification for maximal subalgebras of finite-dimensional associative algebras over a field K. If K is nice (ex. algebraically closed), the classification can be understood directly in terms of the bimodule structure of the Jacobson radical. In particular, this gives us nice presentations of subalgebras for bound quiver algebras. We discuss the role of separable functors in our classification, and the problem of determining isomorphism classes of maximal subalgebras. (Received December 28, 2017)

1136-16-79 **Daniel Bulacu**, St. Academiei 14, Bucharest, Romania, and **Blas Torrecillas*** (btorreci@ual.es), 04071 Almería, Spain. *Morita contexts for cowreaths.*

A cowreath in a monoidal category is a generalization of entwining structures. A Morita context for preGalois and coFrobenius cowreath is constructed. Using this context, we characterize Galois cowreath and when the maps of the context are bijective. Moreover, the separability of the extension associated to the cowreath is studied. Finally, we apply these results to several examples of cowreaths. (Received January 03, 2018)

1136-16-87 **Mee Seong Im*** (meeseongim@gmail.com). *On a construction of the affine VW supercategory.*

A construction of the affine VW supercategory arose from our study of the representation theory of periplectic Lie superalgebras $\mathfrak{p}(n)$. Letting V to be a superspace with $\mathbb{Z}/2\mathbb{Z}$-grading and M to be a $\mathfrak{p}(n)$-module, we construct a super version of the degenerate BMW algebra in the process of examining higher Schur-Weyl duality for the tensor product of M with finitely-many copies of V. I will discuss affine VW superalgebras (the signed version of the affine VW algebra and an affine version of the Brauer superalgebra) and their center, and the affine VW supercategory and its connection to Brauer supercategory. This is joint with M. Balagovic, Z. Daugherty, I. Entova-Aizenbud, I. Halacheva, J. Hennig, G. Letzter, E. Norton, V. Serganova, and C. Stroppel. (Received January 03, 2018)

1136-16-95 **Allen Herman***, 3737 Wascana Parkway, Regina, SK S4S 0A2, Canada. *How to find Hopf algebra comultiplications on Bose-Mesner algebras of association schemes.* Preliminary report.

A bialgebra A is both an associative algebra with unity (A, μ, η) and a coassociative coalgebra with counit (A, Δ, δ) satisfying the extra condition that its counit δ and comultiplication Δ are algebra homomorphisms. A bialgebra becomes a Hopf algebra when it is equipped with an antipode S satisfying $\mu \circ (id \otimes S) \circ \Delta =$

$\mu \circ (S \otimes id) \circ \Delta = \eta \circ \delta$. Bose-Mesner algebras of association schemes are naturally associative algebras over C with unity, and have natural candidates for their counit (valency map) and antipode (transpose). So one can ask what are the comultiplications that extend the Bose-Mesner algebra to a Hopf algebra? Fortunately the finite-dimensional Hopf algebras over C have been classified in prime, prime-squared, and small dimensions up to 80. In this talk I wlll show how to apply this classification to produce calculate all Hopf algebra comultiplications for Bose-Mesner algebras of prime dimension. Included will be examples giving new Hopf algebra structures new complete graphs and some small strongly regular graphs. This is a preliminary report on joint work with Gurmail Singh. (Received January 04, 2018)

1136-16-108 **Alberto Facchini*** (facchini@math.unipd.it), Dipartimento di Matematica, Università di Padova, Via Trieste 63, I-35121 Padova, Italy. *Factorizations of ideals in noncommutative rings similar to factorizations of ideals in commutative Dedekind domains.*

Dedekind domains were one of the propulsive forces, one of the propulsive ideas, at the origins of the study of rings: there is no uniqueness of factorization for non-zero elements, but there is uniqueness of factorization for non-zero ideals. Well, ... for every non-zero ideal I in a Dedekind domain R, the module R/I is direct sum of finitely many uniserial R-modules, and this seems to be the motivation because of which Dedekind domains have such a good behavior as far as product decompositions of ideals is concerned. Thus we have studied the right ideals I in a (non-commutative) ring R for which the right R-module R/I is a direct sum of finitely many uniserial right R-modules. For such a right ideal I, there is a product decomposition of I, which is unique .... (Received January 06, 2018)

1136-16-109 **Nicholas J Werner*** (wernern@oldwestbury.edu) and **Eric Swartz**. *Zero Pattern Matrix Rings.*

Let R be a commutative ring with unity and $M_n(R)$ the ring of $n \times n$ matrices with entries from R. A *zero pattern matrix ring* (zpmr) is a subring of $M_n(R)$ defined by the location of zero and nonzero entries of matrices in the subring. The *weight* of a zpmr $\mathcal{P}$ is the maximum number of nonzero entries of a matrix in $\mathcal{P}$, which is the rank of $\mathcal{P}$ as an R-module. The set of possible weights of $n \times n$ zpmrs is denoted by $W(n)$. It is clear that $W(n) \subseteq \{x \in \mathbb{N} \mid n \leq x \leq n^2\}$, but for $n \geq 3$ we have $W(n) \neq \{x \in \mathbb{N} \mid n \leq x \leq n^2\}$, which means that not every integer between n and n^2 occurs as a weight.

In this talk, we will discuss zero pattern matrix rings and the sets $W(n)$. We will present known results on determining which patterns of zeros produce subrings of $M_n(R)$, and show how zpmrs are closely related to directed graphs and topologies on finite sets. We will then focus on the weight sets $W(n)$. We will show that $W(n)$ can be determined recursively and that most of the values in $W(n)$ lie in an interval of $\mathbb{N}$ that can be computed recursively and independently of $W(n)$ itself. We also give effective bounds on $|W(n)|$. (Received January 06, 2018)

1136-16-157 **Henrik Holm*** (holm@math.ku.dk), , Denmark. *Cotorsion pairs in categories of quiver representations.*

A cotorsion pair in an abelian category is a pair of Ext-orthogonal subcategories. For example, the maximal Cohen-Macaulay modules and the class of modules with finite injective dimension constitute a (complete) cotorsion pair in the category of finitely generated modules over a Cohen-Macaulay ring. This fact relies on the existence of maximal Cohen-Macaulay approximations and of hulls of finite injective dimension, proved by Auslander and Buchweitz. The flat modules and the so-called cotorsion modules also constitute a cotorsion pair; and the flat cover conjecture was settled affirmatively by Enochs by proving that this cotorsion pair is complete.

Cotorsion pairs are abundant in categories of modules and in other abelian categories, and they have connections to relative homological algebra and to model categories (due to a result of Hovey).

In this talk I will report on joint work with Peter Jørgensen. We explain how a cotorsion pair of modules can be transferred, in two different ways, to the category of module-valued representations of some fixed quiver. Our main result is akin to a theorem of Gillespie which asserts that any cotorsion pair of modules induces two canonical cotorsion pairs in the category of chain complexes. (Received January 10, 2018)

1136-16-183 **Daniel Yee*** (dyee@fsmail.bradley.edu). *Comparing Global Dimension of Connected Hopf Algebras and their Enveloping Algebra.* Preliminary report.

In the paper "Properties of Pointed and Connected Hopf Algebras of Finite Gelfand-Kirillov Dimension" by Zhuang contains the result: if A is a Hopf subalgebra of a connected Hopf algebra H, where GK.dim(H) = GK.dim(A) and are finite, it follows that $H = A$. In this talk, we replace GK dimension with global dimension and ask if the result still holds. We obtain a positive answer in the case where A is the enveloping algebra. (Received January 14, 2018)

1136-16-186 **Nguyen Viet Dung*** (nguyend2@ohio.edu), Department of Mathematics, Ohio University, Zanesville Campus, Zanesville, OH 43701, and **José Luis García** (jlgarcia@um.es), Department of Mathematics, University of Murcia, 30100 Murcia, Spain. *Tilting cotorsion pairs and pure semisimple rings.*

A ring R is called left pure semisimple if every left R-module is a direct sum of finitely generated left R-modules. It is still unknown if left pure semisimple rings always have finite representation type. Several results in the literature have shown that, if R is a left pure semisimple hereditary ring, there is an abundance of tilting modules in the category R-mod of finitely generated left R-modules. In particular, a result of L. Angeleri Hügel in [A key module over pure-semisimple hereditary rings, J. Algebra 307 (2007), 361-376] asserts that if R is a left pure semisimple hereditary ring, then every cotorsion pair in R-Mod is generated by a finitely generated tilting module. In this talk, we present a new characterization of left pure semisimple hereditary rings by showing that the converse of Angeleri Hügel's result is true. (Received January 14, 2018)

1136-16-196 **Dan Bossaler** and **Feroz Siddique*** (feroz.siddique@uwc.edu), University of Wisconsin Colleges, 1800 College Dr, Rice Lake, WI 54868. *A Generalization of Exchange Rings.*

We define and explore a new class of rings called unit-exchange rings that strictly contain the class of exchange rings. An element $a \in R$ is *left unit-exchange* if there exists a unit u and an idempotent e in R such that $e - ua \in R(a - aua)$. An element $a \in R$ is defined to be *right unit-exchange* if for some unit v and an idempotent f we have $f - av \in (a - ava)R$. We will show that the definition of unit-exchange is left-right symmetric for each element. We will show several classes of rings that are unit-exchange but not exchange. It is known, due to Kaplansky, that a von Neumann regular ring R is unit regular if and only if it has stable range one. Later Camillo and Yu extended this result to exchange rings. We first show that the property of stable range one is equivalent to the property that every left (right) unit lifts modulo every left (right) principal ideal. Using this property, we show that for a unit-exchange ring the notion of stable range one is equivalent to the property that the ring is partially unit-regular which is equivalent to the property that the ring is left (right) uniquely generated. (Received January 15, 2018)

1136-16-205 **Adel Alahmadi**, **Hamed Alsulami**, **Surender Jain** and **Efim Zelmanov*** (efim.zelmanov@gmail.com), La Jolla, CA 92130. *ON MATRIX WREATH PRODUCTS OF ALGEBRAS.* Preliminary report.

We introduce a new construction of matrix wreath products of algebras that is similar to the construction of wreath products of groups introduced by L. Kaloujnine and M. Krasner. We then illustrate its usefulness by proving embedding theorems into nitely generated algebras and constructing nil algebras with prescribed Gelfand-Kirillov dimension. (Received January 15, 2018)

1136-16-225 **Sergio López-Permouth**, **Jeremy Moore*** (jmoore@otterbein.edu), **Nicholas Pilewski** and **Steve Szabo**. *Units and Linear Independence.* Preliminary report.

We deal with the property that sets of inverses of linearly independent invertible elements be also linearly independent. We refer to algebras with this property as fluid algebras. We will characterize which single-variable polynomials over a field yield fluid quotient algebras of the F-algebra $F[x]$. As a consequence to this we establish when finite field extensions are fluid algebras. Also infinite field extensions are never fluid. For any commutative ring R, $M_2(R)$ is fluid. However, this does not extend to larger matrices. We define the *mojo* of an R-algebra A to be the largest number of linearly independent units in A, and denote this cardinal as $mojo(A)$. We then define the fluidity of an R-algebra A to be the integer $n \leq mojo(A)$, such that for every set of n or less linearly independent invertible elements, their inverses are also linearly independent. The fluidity of several families of algebras such will be explored. We call an algebra σ-fluid if the direct sum of a finite number of copies of itself is fluid, and π-fluid if the direct product of copies of itself is fluid. Various algebras will be examined under these notions. (Received January 16, 2018)

1136-16-255 **Rafail Alizade**, **Engİn Büyükaşık**, **Sergio R López-Permouth*** (lopez@ohio.edu) and **Liu Yang**. *Poor modules with no proper poor direct summands.*

As a mean to provide intrinsic characterizations of poor modules, the notion of a pauper module is introduced. A module is a pauper if it is poor and has no proper poor direct summand. We show that not all rings have pauper modules and explore conditions for their existence. In addition, we ponder the role of paupers in the characterization of poor modules over those rings that do have them by considering two possible types of ubiquity: one according to which every poor module contains a pauper direct summand and a second one according to which every poor module contains a pauper as a pure submodule. The second condition holds for the ring of integers and is just as significant as the first one for Noetherian rings since, in that context, modules having poor pure submodules must themselves be poor.

Among other results, It is shown that the existence of paupers is equivalent to the Noetherian condition for rings with no middle class. (Received January 17, 2018)

1136-16-280 **Paul M Terwilliger*** (terwilli@math.wisc.edu), Department of Mathematics, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706, and **Kazumasa Nomura**. *Totally bipartite tridiagonal pairs.*

We discuss a linear algebraic object called a tridiagonal pair. The concept originated in Algebraic Graph Theory, on the subject of Q-polynomial distance-regular graphs. We will focus on a special case called totally bipartite. We will cover the following topics: (i) Tridiagonal pair background (ii) TB tridiagonal pairs and systems (iii) The standard basis and matrix representations (iv) The classification of TB tridiagonal systems (v) The Askey-Wilson relations (vi) Some automorphisms and antiautomorphisms (vii) The $\mathbb{Z}_3$-symmetric Askey-Wilson relations (vii) An action of the modular group $\mathrm{PSL}_2(\mathbb{Z})$. This is joint work with Kazumasa Nomura. (Received January 18, 2018)

1136-16-445 **Lars Winther Christensen*** (lars.w.christensen@ttu.edu) and **Peder Thompson**. *Pure-minimal chain complexes.*

Let R be an associative unital ring. A chain complex M of R-modules is called *minimal* if every homotopy equivalence $M \to M$ is an isomorphism. Many homological invariants of modules, such as their injective and projective dimension, can be read off from minimal resolutions—provided that they exist. Minimal injective and minimal flat resolutions exist for every R-module; in fact, any resolution constructed from injective envelopes or flat covers is a minimal complex.

While minimal flat resolutions exist, they do not quite behave as one would want them to: They are not even unique! To remedy the situation, we introduce the notion of a *pure-minimal* chain complex and show that it coincides the usual notion of (homotopy) minimality in standard settings, while being a more useful notion of minimality for complexes of flat modules. (Received January 21, 2018)

1136-16-458 **Philipp S. Rothmaler*** (philipp.rothmaler@bcc.cuny.edu), The CUNY Graduate Center, Dept. of Math., 365 Fifth Avenue, Room 4208, New York, NY 10016. *Endoproperties of direct products of strict Mittag-Leffler modules.*

Properties of products of strict Mittag-Leffler (=locally pure-projective) modules will be discussed that guarantee the product to be sum-like in the sense that every element has the same pp type as its restriction to some finite support (which is an element of the direct sum, whence the name). Any sum-like submodule is strict Mittag-Leffler, hence the endoproperties in question will make the entire product strict Mittag-Leffler. Applying the results to powers of the regular representation of the ring we obtain that every such power is sum-like iff the countable power is sum-like iff the elements of finite pp-support form an additive subgroup, which is the case precisely when the ring is noetherian on the other side. (Received January 21, 2018)

1136-16-488 **Yevgenia Kashina***, Department of Mathematical Sciences, DePaul University, Chicago, IL 60614. *On a family of semisimple Hopf algebras.* Preliminary report.

In this talk we will discuss a family of semisimple Hopf algebras of dimension 2^n with a large abelian group of grouplike elements. All Hopf algebras in this family can be obtained as abelian extensions. We will classify these extensions up to equivalence. (Received January 21, 2018)

1136-16-496 **Jonas T Hartwig*** (jth@iastate.edu). *Gelfand-Zeitlin modules over Galois orders.*

Galois orders form a class of noncommutative algebras introduced by Futorny and Ovsienko in 2010. Examples include enveloping algebras, truncated Yangians, finite W-algebras, and orthogonal Gelfand-Zeitlin algebras of type A. In this talk we present new techniques which allows us to prove that quantum analogs as well as parabolic generalizations of the mentioned examples are also Galois orders. In addition, the new approach provides a natural way to construct canonical simple Gelfand-Zeitlin modules over these algebras, generalizing recent results by several different authors. (Received January 22, 2018)

1136-16-546 **Dennis Keeler*** (keelerds@miamioh.edu) and **Daniel Rogalski**. *Twisted Cox rings.* Preliminary report.

When a normal variety X has a finitely generated divisor class group, one can define the Cox ring R of X via the global sections of all Weil divisors. In the projective case, any homogeneous coordinate ring is a subring of R. We examine the effect of twisting the multiplication of R by automorphisms of X. (Received January 22, 2018)

1136-16-554 **Anthony Giaquinto*** (agiaqui@luc.edu). *Twists as deformations and their applications to quantum groups and noncommutative algebra.*

In this talk we will consider Drinfel'd Twists and show how they provide algebraic deformations and, in some cases, applications to quantum groups and algebras of interest in noncommutative algebraic geometry. Throughout the talk, examples will be presented to illustrate the results. (Received January 22, 2018)

1136-16-586 **Rajesh S Kulkarni*** (kulkarni@math.msu.edu), Department of Mathematics, Wells Hall, 619 Red Cedar Rd., East Lansing, MI 48864. *Minimal model program for orders on projective varieties.* Preliminary report.

The minimal model program for maximal orders on surfaces was developed and studied by several authors including Artin-deJong, Chan-Ingalls and Chan-Kulkarni. Recently, this program was developed for orders on arbitrary (smooth) projective varieties with ideas from the recent developments in minimal model program of higher dimensional algebraic varieties. We will review these developments and time permitting, discuss more recent developments in joint work with Nathan Grieve. (Received January 22, 2018)

1136-16-630 **Timothy Hodges*** (thodges@nsf.gov). *Algebraic Structure of Belvin-Drinfeld non-standard Quantum Groups.*

Belavin and Drinfeld classified certain non-standard Poisson structures on semi-simple Lie groups. A concrete algebraic quantization of these Poisson groups was described by Etingof, Schedler and Schiffler. We shall discuss various conjecture about the algebraic structure of these algebras and describe progress on these conjectures. (Received January 24, 2018)

17 ▶ Nonassociative rings and algebras

1136-17-23 **Garrett Johnson*** (gjohns62@nccu.edu). *Subprime solutions of the classical Yang-Baxter equation.*

We introduce a new family of r-matrices for the Lie algebra $\mathfrak{sl}_n$ that lies in the Zariski boundary of the Belavin-Drinfeld space $\mathcal{M}$ of quasi-triangular solutions to the classical Yang-Baxter equation. In this setting $\mathcal{M}$ is a finite disjoint union of components; exactly $\phi(n)$ of these components are SL_n-orbits of single points. These points are the generalized Cremmer-Gervais r-matrices $r_{i,n}$ which are naturally indexed by pairs of positive coprime integers, i and n, with $i < n$. A conjecture of Gerstenhaber and Giaquinto states that the boundaries of the Cremmer-Gervais components contain r-matrices having maximal parabolic subalgebras $\mathfrak{p}_{i,n} \subseteq \mathfrak{sl}_n$ as carriers. We prove this conjecture in the cases when $n \equiv \pm 1 \pmod{i}$. The subprime linear functionals $f \in \mathfrak{p}^*_{i,n}$ and the corresponding principal elements $H \in \mathfrak{p}_{i,n}$ play important roles in our proof. Since the subprime functionals are Frobenius in the cases when $n \equiv \pm 1 \pmod{i}$, this partly explains our need to require these conditions on i and n. We conclude with a proof of the GG boundary conjecture in an unrelated case, namely when $(i, n) = (5, 12)$. (Received November 10, 2017)

1136-17-39 **Katherine Radler*** (katie.radler@slu.edu), **Ashish Srivastava** and **K.M. Rangaswamy**. *Supersymmetric Analogue of Leavitt Path Algebras.* Preliminary report.

We propose a supersymmetric analogue to Leavitt Path Algebras called Leavitt path superalgebras. We discuss their structure and basic properties. (Received December 06, 2017)

1136-17-85 **Tathagata Basak*** (tathagat@iastate.edu), Department of Mathematics, 396 Carver Hall, Ames, IA 50011. *Octonions as a twisted group algebra.*

Abstract: We show that the octonions can be defined as a real algebra with basis $\{e^x : x \in \mathbb{F}_8\}$ and multiplication defined by $e^x e^y = (-1)^{\varphi(x,y)} e^{x+y}$, where $\varphi(x, y) = \mathrm{tr}(yx^6)$. The basic properties of octonions follow quickly from this definition. We obtain an uniform description of the sixteen orders of integral octonions containing the Gravesian integers and a quick definition of the Lie algebra $\mathfrak{g}_2$ by writing down an explicit Chevalley basis. (Received January 03, 2018)

18 ► Category theory; homological algebra

1136-18-60 **C.C. Cheng** and **Karimah Sweet*** (ksweet@oakland.edu). *Small Cancellative Categories of Homological Dimension One.*

Let $\mathbf{C}$ be a small category and R be a ring with identity, and let $\mathbf{M}$ denote the category of left R-modules. The R-cohomological dimension of $\mathbf{C}$ is defined by $\mathrm{cd}_R\mathbf{C} = \mathrm{pd}\ \Delta R$, where where ΔR denotes the constant R-valued functor $\mathbf{C} \to \mathbf{M}$, and $\mathrm{pd}\Delta R$ denotes the projective dimension of ΔR in the functor category $\mathbf{M}^{\mathbf{C}}$. The R-homological dimension of $\mathbf{C}$ is defined by $\mathrm{hd}_R\mathbf{C} = \mathrm{wd}\Delta R$, where $\mathrm{wd}\Delta R$ denotes the weak (or flat) dimension of ΔR. We prove that if $\mathbf{C}$ is cancellative and $\mathrm{hd}_R\mathbf{C} \leq 1$, then $\mathbf{C}$ is embeddable in a groupoid, and furthermore, if $\mathrm{cd}_R\mathbf{C} \leq 1$ and $\mathbf{C}$ is connected, then $\mathbf{C}$ is embeddable in a groupoid which is equivalent to a free group. (Received December 22, 2017)

1136-18-62 **Manuel Cortés-Izurdiaga*** (mizurdia@ual.es). *Maximal ideals in module categories.*

An ideal $\mathcal{I}$ in a preadditive category $\mathbf{C}$ is an additive subfunctor of the Hom bifunctor. As in the case of rings, one can consider maximal and minimal ideals in the category $\mathbf{C}$. We are interested in maximal ideals in the category Mod-R of modules over a ring R.

While minimal ideals in Mod-R are well understood, as a consequence of a result, proved by A. Facchini, which establishes a one-to-one correspondence between minimal ideals in Mod-R and simple modules, there is no such description of maximal ideals. The main goal of the talk is to prove that actually there do not exist maximal ideals in Mod-R (in fact, there do not exist in Grothendieck categories).

The main idea to prove this result is to relate the order inclusion between ideals in $\mathbf{C}$ with a new preorder, $\preceq$, between objects in the category, in such a way that the existence of maximal ideals implies the existence of maximal objects with respect to $\preceq$. Now, noting that big direct sums of copies of a module M are greater than M with respect to $\preceq$, we conclude that there do not exist maximal ideals in the category of modules over a ring.

The talk is based on joint work with A. Facchini. (Received December 23, 2017)

1136-18-102 **Keith A Pardue*** (pardue@member.ams.org) and **Aaron P Gray**. *Products in a Category with One Object.*

We study monoids equipped with a second binary operation that captures the structure of the endomorphisms of an object X such that $X = X \times X$. We construct a universal monoid of this type and examine some of its rich combinatorial structure. We show that if X has a nontrivial endomorphism and $X = X \times X$, then every finite monoid has a faithful action on X. (Received January 04, 2018)

1136-18-134 **Alexei Davydov*** (davydov@ohio.edu), Department of MAthematics, Ohio University, Athens, OH 45701. *Fine structure of third cohomology.*

The interpretation of the third cohomology group as the group of minimal extensions gives a new way of looking at cohomology. In particular it provides the cohomology with a natural filtration. The members of the filtration are defined by certain categorical triviality conditions. (Received January 08, 2018)

1136-18-161 **Joshua R. Edge*** (joshredge@gmail.com), Rawles Hall, 831 East 3rd St, Bloomington, IN 47405. *Simple virtual skein theories.* Preliminary report.

We give a skein theory classification of all quotients of the planar algebra of virtual tangles with n-box space dimensions $1, 0, 1, 0, k, ...$, where $k \leq 3$. Most examples that appear are elementary but a few interesting examples arise, including the virtual Jones polynomial and most notably $\mathrm{Rep}(O(2))$. (Received January 11, 2018)

1136-18-181 **Yuan-Ming Lu*** (lu.1435@osu.edu), 191 W Woodruff Ave, Columbus, OH 43210. *Protected edge states in symmetry enriched topological orders: criteria and realizations.* Preliminary report.

The interplay of symmetry and two-dimensional (2d) topological orders lead to the "symmetry-enriched topological orders" (SETOs), mathematically described by a G-crossed braided tensor category where G is the symmetry group. This work is motivated by the following question: when will a 2d SETO support a gapless energy spectrum on an open boundary, which provides a sharp signature in experimental measurements?

Focusing on 2d Abelian SETOs, we propose two sufficient conditions for the existence of robust gapless edge states. We further demonstrate both criteria in a simple model. (Received January 13, 2018)

1136-18-190 **Daniel Bravo**, **Sergio Estrada**, **Alina Iacob*** (aiacob@georgiasouthern.edu) and **Marco Perez**. *FP_n-injective and FP_n-flat covers and preenvelopes; Gorenstein AC-flat covers.*

We prove that, for any $n \geq 2$, the classes of FP_n-injective modules and of FP_n-flat modules are both covering and preenveloping over any ring R. Then we define a generalization of the class of Gorenstein flat modules - the Gorenstein AC-flat modules. Assuming closure under extensions for Gorenstein AC-flat modules, we construct a model structure on $R - Mod$ in which these modules are the cofibrant objects. (Received January 14, 2018)

1136-18-231 **Sergio Estrada*** (sestrada@um.es), Facultad de Matemáticas, Campus de Espinardo, 30100 Murcia, Spain, **Marco A. Pérez** (mperez@fing.edu.uy), Instituto de Matemática y Estadística, "Prof. Ing. Rafael Laguardia", 11300 Montevideo, Uruguay, and **Haiyan Zhu** (hyzhu@zjut.edu.cn), College of Science, Hangzhou, Peoples Rep of China. *Balanced pairs and cotorsion triplets.* Preliminary report.

It is well-known that the right derived functors Ext^n can be computed either using projective or injective resolutions. In other words, the pair of classes $(\mathrm{Proj}(R), \mathrm{Inj}(R))$ is balanced. The question of balance appears naturally in relative homological algebra by replacing the absolute Ext^n functors with other relative functors obtained from resolutions with respect to an arbitrary class $\mathcal{F}$ or coresolutions with respect to $\mathcal{G}$. In the talk we will present a new and short proof of the absence of balance for relative right derived functors computed using flat covers with potential new application to more general categories. We will also summarize the relation between balance and cotorsion triplets, an algebraic tool that encompasses simultaneously two cotorsion pairs. (Received January 16, 2018)

1136-18-392 **Alexei Davydov** and **Chris Renner*** (cr287915@ohio.edu). *Fine Structure of Third Cohomology of Metabelian Groups.* Preliminary report.

Modular categories are essentially linked with classical group theory. One connection is exhibited in the Drinfeld center $Z(G, \alpha)$ with different twists $\alpha \in H^3(G, k^*)$ the third group cohomology. Recently, an isomorphism between elements α and $Z(G, \alpha)$ was exhibited by using the so-called minimal extensions. The interpretation of $H^3(G, k^*)$ as $Mex(Rep(G))$ provides a filtration on $H^3(G, k^*)$ such that $Z(G, \alpha)$ has the same rank and dimension function, fusion rules, S-matrix, and modular data as $Z(G)$ for different choices of α correspondingly. We examine conditions for when any of the modular data coincide between $Z(G, \alpha)$ and $Z(G)$ in the case when G is a metabelian group. (Received January 20, 2018)

1136-18-410 **Marcel Bischoff*** (bischoff@ohio.edu). *A Notion of Quantum Symmetry.* Preliminary report.

A G-crossed braided extension of a unitary modular tensor category $\mathcal{C}$ can be seen as a G-symmetry of a topological phase of matter associated with $\mathcal{C}$. Motivated by finite index inclusions of rational local conformal nets, I'll give a purely categorical notion of a more general "quantum symmetry". In particular, any finite index subnet of a rational local conformal net A gives rise to such a quantum symmetry for the representation category of A and the existence of a quantum symmetry is necessary for the existence of a finite index subnet. (Received January 20, 2018)

1136-18-439 **Peter J. Webb*** (webb@math.umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55057. *The Burnside ring of a finite category.* Preliminary report.

In the context of representation theory and cohomology, many things that can be done for groups can also be done for categories. There is a trivial representation, a tensor product, a notion of cohomology with interpretations of the low dimensional groups, including extensions of categories and the Schur multiplier. I will describe competing notions for the Burnside ring of a finite category, indicating why some should be preferred over others. An important criterion for a good definition of the Burnside ring is that it should be projective as a biset functor, in a theory of bisets for categories that extends the usual notion for groups. It should give a ring that seems to be reasonable in terms of our intuition of what the Burnside ring might be. The top candidates for the Burnside ring have their structure described to some extent by an extension of Burnside's marks homomorphism. (Received January 21, 2018)

1136-18-468 **Paul Gustafson*** (pgustafs@math.tamu.edu), **Eric Rowell** and **Yuze Ruan**. *Classifying even metaplectic modular categories via gauging.* Preliminary report.

A metaplectic modular category is a unitary modular category with the fusion rules of $SO(N)_2$ for some positive integer N. These categories provide some of the simplest non-trivial examples of gauging. In particular, any metaplectic modular category $SO(N)_2$ with N odd is a gauging of the particle-hole symmetry of a $\mathbb{Z}_N$-cyclic modular category.

The even N case is more complicated. In particular, the structure of these categories depends on the greatest power of 2 dividing N. Bruillard, Gustafson, Plavnik, and Rowell recently gave a characterization for the $4 \mid N$ case parallel to the odd case. In this talk, we provide evidence for an alternative characterization when N is a power of 2. We conjecture every metaplectic modular category $SO(2^k)_2$ for $k \geq 4$ is a $\mathbb{Z}_2$-gauging of a metaplectic modular category $SO(2^{k-2})_2$. If $k < 4$, the metaplectic modular category $SO(2^k)$ is also a $\mathbb{Z}_2$ gauging of a one of a few simple modular categories. (Received January 21, 2018)

1136-18-483 **Nima Rasekh***, Department of Mathematics, Altgeld Hall, 1409 W. Green Street, Urbana, IL 61801. *A Theory of Elementary Higher Toposes.*

Topos theory was developed by Grothendieck in order to be able to study schemes in their proper categorical context, by applying the language of sheaves. Later people realized that it can be generalized to a theory of elementary toposes, which allows us to study sets from a categorical perspective and even give a categorical characterization of sets. The theory of Grothendieck toposes was later generalized by Lurie and Rezk to the context of higher categories, giving rise to higher toposes. This theory has been successfully used in derived algebraic geometry. However, as of now, we still lack an analogous theory of elementary higher toposes. The goal of this talk is to introduce such a definition of elementary higher toposes and show this definition satisfies some common sense conditions that we would expect of any such theory. (Received January 21, 2018)

1136-18-581 **Yu Tsumura*** (tsumura.2@osu.edu), 231 West 18th Avenue, Coloumbus, OH 43210, and **Thomas Kerler** and **Yilong Wang**. *Braided Hopf algebra structures on the duals of coends of metaplectic categories.* Preliminary report.

Metaplectic categories are examples of weakly integral fusion categories. These categories are $\mathbb{Z}_2$-graded and the zero-graded parts have the same fusion rules as the classical fusion rules of dihedral groups. In this work, we identify concrete quasi-triangular structures on the group algebras of dihedral groups whose representation categories are isomorphic to these sub-categories. Next, we discuss the coend $\int^X X \otimes X^*$ of a metaplectic category with applications to TQFTs in mind. As an example, we determine the braided Hopf algebra structure on the dual of the coend of the Ising modular category. (Received January 22, 2018)

1136-18-607 **Scott Morrison** and **Emily Peters*** (epeters3@luc.edu), Department of Math and Stats, 1032 W. Sheridan Rd., Chicago, IL 60660-1537, and **Noah Snyder**. *Categories generated by a trivalent vertex.*

Classifying all fusion categories is (with current technology) completely impossible; nevertheless, we can take a step in this direction by classifying small "trivalent" fusion categories. Instead of judging the size of the category by the number of simple objects it has, we fix a generating simple object X and say that the sequence of dimensions of the Hom spaces from $X^{\otimes n}$ to 1 determines the size of the category. We classify small categories whose Hom spaces are generated by a rotationally symmetric morphism τ from $X \otimes X \otimes X$ to 1 – this τ is the trivalent vertex – and discuss generalizations. (Received January 22, 2018)

19 ► K-theory

1136-19-213 **Elden Elmanto***, 2033 Sheridan Road, Evanston, IL 60208, and **Håkon Kolderup**, Ullevål Stadion, Sognsveien 77B, Oslo, Norway. *Motivic Module Categories and their Classification.*

A theorem of Østvær and Röndigs show that modules over the motivic cohomology spectrum recovers Voevodsky's category of motives, at least after inverting residual characteristics. We give a general framework for identifying categories of "motives," including Voevodsky's category and the more recent iteration of Milnor-Witt motives due to Déglise-Fasel, as modules over a motivic E_∞-ring spectrum. The main ingredients are Lurie's Barr-Beck theorem and recent results identifying compact objects in p-inverted stable motivic homotopy category. (Received January 16, 2018)

20 ► Group theory and generalizations

1136-20-55 **Jonathan D.H. Smith*** (jdhsmith@iastate.edu). *Top-down Sylow theory for quasigroups and Latin squares.*

There are three current approaches to the problem of extending Sylow theory from finite groups to quasigroups. One possible approach, which has not yet been explored, is to use the Sylow theory for association schemes. A second bottom-up approach uses a labeled version of the Burnside algebra of a quasigroup, the Grothendieck ring of the category of permutation representations of that quasigroup. In this talk, we will outline the third, top-down approach, which is based on Wielandt's treatment of Sylow theory for finite groups. Because of the non-associativity inherent to quasigroups, this top-down approach comes in two flavors, based either on the action of the full group generated by the set of left multiplications by elements of a subquasigroup, or just based on the actions of the left multiplications themselves. The theory offers powerful and readily computed isomorphism invariants, capable, for example, of distinguishing all eighty Steiner triple systems of order fifteen. (Received December 17, 2017)

1136-20-88 **J.P. Cossey*** (cossey@uakron.edu), Department of Mathematics, University of Akron, Akron, OH 44325-4002. *Blocks of small defect in simple groups and Brauer character degrees in finite groups.*

Let G be a finite group. Lewis and Gagola showed that G is nilpotent if and only if $\chi(1)^2$ divides $|G : \ker(\chi)|$ for every ordinary irreducible character χ of G. In this talk we examine the analogous question for Brauer characters, and prove a similar result. Along the way, we prove an interesting result about blocks of relatively small defect for symmetric and alternating groups, and use this to prove the existence of blocks of relatively small defect for all simple groups.

This is joint work with Xiaoyou Chen, Mark Lewis, and Hung Tong-Viet. (Received January 03, 2018)

1136-20-90 **Nham V Ngo*** (nvngo@ung.edu), University of North Georgia - Gainesville, Department of Mathematics, 3820 Mundy Mill Rd, Oakwood, GA 30566, and **Paul Levy** (p.d.levy@lancaster.ac.uk) and **Klemen Sivic** (klemen.sivic@fmf.uni-lj.si). *On the complexities of Frobenius kernels and finite Chevalley groups.*

Let G be a simple algebraic group defined over an algebraically closed field k of prime characteristic p. For a positive integer r, let $F^r : G \to G$ be the r-th iteration of the Frobenius morphism, let $G_r = \mathrm{Ker}(F^r)$ the r-th Frobenius kernel of G and $G(\mathbb{F}_{p^r}) = G^{F^r}$ the finite Chevalley group. In this talk, we will present our results on the complexity $c_{G_r}(M)$ of a finite dimensional G-module M over G_r and then introduce an inequality between $c_{G_r}(M)$ and $c_{G(\mathbb{F}_{p^r})}(M)$. (Received January 17, 2018)

1136-20-92 **Hung P Tong-Viet*** (tongviet@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University (SUNY), Binghamton, NY 13902-6000. *2-parts of real class sizes.* Preliminary report.

An element x in a finite group G is said to be real if x and its inverse are G-conjugate. A conjugacy class is real if it contains a real element. Many important results in group theory admit real versions. In this talk, I will discuss some recent results concerning real class sizes. In particular, I will outline the proof that a finite group has 2-length one if all its non-central real class sizes have the same 2-part. As a consequence, it follows that a finite group is solvable if it has two real class sizes. This confirms a conjecture due to G. Navarro. (Received January 04, 2018)

1136-20-94 **Ronald Solomon*** (solomon.1@osu.edu) and **Richard Lyons**. *Update on the GLS Project.* Preliminary report.

I will report on the current status of the GLS Revision Project for the Classification of the Finite Simple Groups. Volume 7 of GLS has recently been published by the A.M.S., and Volume 8 is near completion. This will complete the proof of the following theorem.

Theorem. *Let G be a finite $\mathcal{K}$-proper simple group of odd type. Then either G is an alternating group of degree $n \geq 5$ (but not 8 or 12) or G is a group of Lie type defined over a finite field of odd order or G is one of the following sporadic simple groups: M_{11}, M_{12}, J_1, Mc, $O'N$, or Ly.*

It will also complete the identification of generic simple groups of even type modulo certain results, notably p-uniqueness theorems for odd primes p.

I will explain the terminology and describe what remains to be done in our series. (Received January 04, 2018)

1136-20-101 **C. Ryan Vinroot*** (vinroot@math.wm.edu), Department of Mathematics, College of William and Mary, P. O. Box 8795, Williamsburg, VA 23187-8795. *Totally orthogonal finite simple groups.* Preliminary report.

A group G is said to be totally orthogonal if every irreducible complex representation of G may be realized over the real numbers. We prove that if q is a power of 2, then the symplectic and (full) orthogonal groups over the field with q elements are totally orthogonal. From this and previous results, we obtain the statement that a finite simple group G is totally orthogonal if and only if every element of G is a product of two involutions in G. (Received January 04, 2018)

1136-20-124 **Harvey I. Blau*** (hblau@niu.edu), Department of Mathematical Sciences, Northern Illinois University, DeKalb, IL 60115. *On dimension 6.* Preliminary report.

We study the existence/non-existence of various non-commutative table algebras of dimension 6; and discuss implications for the existence/non-existence of non-commutative association schemes of the same rank, a topic of great recent interest. (Received January 08, 2018)

1136-20-223 **Stephen P. Humphries*** (steve@mathematics.byu.edu), Department of Mathematics, Brigham Young University, Provo, UT 84602. *Schur rings over Symmetric and other groups.*

A Schur ring over a group G is a subring of the group ring $\mathbb{Z}G$ that is determined by a partition of G by finite sets, this partition being invariant under inversion of group elements. We detail results about commutative Schur rings over symmetric groups S_n, where the sum of all the transpositions in S_n is in the Schur ring. This amounts to determining the partition of the set of transpositions that the Schur ring gives. We also give results on Schur rings over other classes of groups. (Received January 16, 2018)

1136-20-317 **Paul-Hermann Zieschang***, School of Mathematical and Statist. Sciences, The University of Texas Rio Grande Valley, 1201 West University Drive, Edinbug, TX 78539. *Metathin Association Schemes.* Preliminary report.

An association scheme S is called *metathin* if $O^{\vartheta}(S) \subseteq O_{\vartheta}(S)$. Metathin schemes have been investigated first in 2003 (Sufficient conditions for a scheme to originate from a group, J. Combin. Theory A **104**, 17–27). Since then they have attracted increasing attention. I will discuss recent work on metathin schemes of C. French, M. Hirasaka, K. Kim, and I. Ponomarenko and contribute recent observations. (Received January 19, 2018)

1136-20-347 **Cihan Bahran*** (bahra004@umn.edu). *Categorifying induction formulae via divergent series.* Preliminary report.

We show that Brauer's induction formula for complex characters and its generalizations can be obtained by summing a divergent series over Dwyer's subgroup decomposition category. The same method, applied to Dwyer's centralizer decomposition category, yields a new induction formula. (Received January 19, 2018)

1136-20-361 **Michael Geline*** (mgeline@niu.edu), Department of Mathematical Sciences, Northern Illinois University, DeKalb, IL 60115. *A case of Alperin's weight conjecture.*

We will show that Alperin's conjecture holds for finite groups in which the Sylow p-subgroups are TI and the endomorphism algebra of the Sylow permutation module is self-injective. The argument is very short, given some work of Green, but appears not to have been noticed before. (Received January 19, 2018)

1136-20-391 **Mandi A. Schaeffer Fry*** (aschaef6@msudenver.edu). *Galois Action on Characters and Navarro's Sylow 2-Normalizer Conjectures.*

We discuss the proofs of Navarro's and Navarro-Tiep-Vallejo's conjectures relating the character theory of a finite group G to structural properties of its Sylow 2-normalizers. We also discuss the action of Galois automorphisms on characters of groups of Lie type, which is a crucial aspect of these proofs. (Received January 20, 2018)

1136-20-394 **Alexandre Turull***, Department of Mathematics, University of Florida, Gainesville, FL 32611. *Calculating the Brauer invariant of an irreducible character of a finite group.* Preliminary report.

Suppose that χ is an irreducible character of a finite group G, and that the values of χ are all in some finite extension F of the field of p-adic numbers for some prime p. Then χ determines uniquely an element b of the Brauer group of F. As is well known, b is canonically characterized by an element $f \in \mathbf{Q}/\mathbf{Z}$, the quotient of the additive group of the rational numbers by the additive group of the integers. This element is called the *invariant* of b, so we also call it, the *invariant* of χ. If we represent f by an element $n/m \in \mathbf{Q}$ such that $0 \leq n/m < 1$, $m > 0$, and m is as small as possible, then it is known that m is the Schur index of χ over F. We will discuss some methods to calculate the invariant (including both numerator and denominator) of χ explicitly. (Received January 20, 2018)

1136-20-399 **Adriana Nenciu*** (anenciu@otterbein.edu), Department of Mathematical Sciences, Otterbein University, 1 S Grove Street, Westerville, OH 43081. *2–generator p–groups of class 2 of central type.* Preliminary report.

Let G be a finite group and let $f \in Z^2(G, \mathbb{C}^*)$. The *twisted group algebra* over $\mathbb{C}$, denoted by $\mathbb{C}^f G$, is an associative algebra with basis $\{u_g\}_{g \in G}$ and multiplication $u_g \cdot u_h = f(g,h)u_{gh}$.

It is well–known that if G is non–trivial then $\mathbb{C}G$ is not simple. However, it is possible to find $f \in Z^2(G, \mathbb{C}^*)$ such that $\mathbb{C}^f G$ is simple. In that case the group G is said to be of *central type.* The classification of abelian groups of central type is known. It is much harder to understand the non–abelian groups of central type. In this talk I will give some preliminary results regarding which 2–generator p–groups of class 2 are of central type. (Received January 20, 2018)

1136-20-454 **Rob Carman*** (wcarman@ucsc.edu). *Units of the Trivial Source Ring.* Preliminary report.
The trivial source ring of a finite group is an intermediate representation ring, connecting the Burnside ring to the character ring and Brauer character ring. The units of the trivial source ring, in particular the units of finite order, are of interest because they can be used to define p-permutation equivalences on blocks of the group algebra. The theory of biset functors introduced by Serge Bouc has been instrumental for understanding the structure of the unit group of the Burnside ring, and so I will show how the unit groups of the trivial source ring and its ghost ring define biset functors as well. I will then also describe progress towards determining the structure of the group of units of finite order. (Received January 21, 2018)

1136-20-509 **Talia Fernos*** (t_fernos@uncg.edu). *Group Actions on CAT(0) Cube Complexes.*
CAT(0) cube complexes have interesting interconnections between geometry, analysis, and algebra. They played a key roll in Agol's proof of the Virtually Haken Conjecture in 2012. In this talk, we discuss a variety of aspects of groups acting on CAT(0) cube complexes. The following notions will be visited: rank-1 isometries, Haagerup property, property FC, and random walks. (Received January 22, 2018)

1136-20-530 **Robert Boltje*** (boltje@ucsc.edu). *Analyzing tensor products of p-permutation bimodules.*
Let k be a field of characteristic $p > 0$ and G a finite group. A finitely generated kG-module is called a p-permutation module if its restriction to a Sylow p-subgroup of G is a permutation module. Similarly, one defines p-permutation (kG, kH)-bimodules by identifying them with $k[G \times H]$-modules. Such bimodules play a central role in the strongest version of Broué's Abelian Defect Group Conjecture. We present three different ways to analyze the tensor product of two p-permutation bimodules. (Received January 22, 2018)

1136-20-533 **Jamison Blair Barsotti*** (jbarsott@ucsc.edu), 5085 Wilder Dr, Apt C, Soquel, CA 95073. *On the unit group of the Burnside ring as, a biset functor, for some solvable groups.*
The theory of bisets has been very useful in progress towards settling the longstanding question of determining units for the Burnside ring. In 2006 Bouc used bisets to settle the question for p-groups. In this talk, we will investigate the units of the Burnside ring for the class of finte groups G, where G contains a normal subgroup N of odd index, and N contains an abelian subgroup of index at most 2. Additionally, we will discuss the structure of the units of the Burnside ring as a biset functor, over this same class of groups. (Received January 22, 2018)

1136-20-543 **Jeffrey M Riedl*** (riedl@uakron.edu), Department of Mathematics, 302 Buchtel Common, University of Akron, Akron, OH 44325-4002. *Orbits and stabilizers for base normal subgroups in some wreath product 2-groups.*
Let G be the regular wreath product group $C \wr E$ where E is elementary abelian of order 4 and C is cyclic of order 2^e for some positive integer e. We wish to apply our knowledge of the structure of the automorphism group $\mathrm{Aut}(G)$ (obtained in an earlier work) to the study of the automorphism group $\mathrm{Aut}(H)$ for various subgroups H of G. It is natural to consider the subgroups H that satisfy $BH = G$ where B is the base group of G. There is a natural homomorphism from the stabilizer subgroup $N(H) = \{\, \sigma \in \mathrm{Aut}(G) \mid H^\sigma = H \,\}$ to $\mathrm{Aut}(H)$ whose kernel we denote by $C(H)$. The factor group $N(H)/C(H)$ is isomorphic to a subgroup of $\mathrm{Aut}(H)$, and any knowledge of the structure of $N(H)/C(H)$ that we obtain might contribute to understanding $\mathrm{Aut}(H)$ and its structure in case the former is not too small compared to the latter. To calculate $N(H)$ it is helpful to calculate $N(H \cap B)$ for the normal subgroup $H \cap B$ of G. Motivated by this, I will describe my ongoing efforts to study the orbits and the stabilizer subgroups in the natural action of $\mathrm{Aut}(G)$ on the set consisting of all the normal subgroups of G that are contained in B, for small values of e. (Received January 22, 2018)

1136-20-551 **Radha Kessar***, Department of Mathematics, City, University of London, Northampton Square, London, EC1V0HB, United Kingdom. *Rationality of blocks of finite simple groups.*
Let G be a finite group and p a prime number. The modular group algebra $\bar{\mathbb{F}}_p G$ decomposes uniquely into a product of indecomposable factors, the *blocks* of kG. We are interested in the following question. Given a block B what is the minimal finite subfield F of $\bar{\mathbb{F}}_p$ such that B has an F-form? The finiteness conjectures of block theory predict that the size of F is locally controlled. In her PhD thesis, Niamh Farrell provided evidence of a much stronger phenomenon: for blocks of finite simple groups, there should be an absolute bound on the size of F. I will report on recent results around this theme (joint work with Farrell). (Received January 22, 2018)

1136-20-559 **Markus Linckelmann***, Department of Mathematics, City, University of London, Northampton Square, London, EC1V 0HB, United Kingdom. *On Picard groups of block algebras of finite groups.*

We investigate structural and finiteness properties of the Picard group of self Morita equivalences of a block algebra of a finite group over a complete discrete valuation ring. We describe a 'large' subgroup of the Picard group in terms of fundamental block theoretic invariants including source algebras, fusion systems, and Dade groups. This is based on joint work with Robert Boltje and Radha Kessar. (Received January 22, 2018)

1136-20-565 **Matthew Welz*** (mwelz@fortlewis.edu), Department of Mathematics, 1000 Rim Drive, Durango, CO 81301. *2-Fusion Systems with a Standard Component of type $L_2(q)$.*

In the Classification of Finite Simple Groups, the simple groups are split between those of *characteristic 2-type* and those of *component type* (which, save a few exceptions, posses a *standard* component). Aschbacher laid out a major program of research: work toward a classification of fusion systems of component type in order to establish a new proof of the Classification for groups of component type. In this talk we consider the case where a 2-fusion system contains subgroups and fusion maps that arise in the Classification with standard components of type $L_2(q)$. (Received January 22, 2018)

1136-20-569 **Mark B Greer*** (mgreer@una.edu), University of North Alabama, One Harrison Plaza, Florence, AL 35632. *Loop constructions from finite groups.*

Loops are magmas (or groupoids) which contain an identity element and both left and right translations are bijections. Since groups are precisely associative loops, many problems in loop theory are motivated by group theory. In this talk, we will discuss several constructions of loops from finite groups. The talk will focus on constructions for Bruck and automorphic loops, their connections, as well as several open problems stated purely in terms of groups. (Received January 22, 2018)

1136-20-576 **Stephen Trefethen*** (sjtrefethen@wm.edu). *Finite Groups with Cyclotomic Fields of Values.*

Let G be a finite group. The field of values of G is the extension of $\mathbb{Q}$ defined by $\mathbb{Q}(G) := \mathbb{Q}(\{\chi(g) | g \in G, \chi \in \mathrm{Irr}(G)\})$, where $\mathrm{Irr}(G)$ is the set of complex irreducible characters of G. We say that G has a cyclotomic field of values if $\mathbb{Q}(G) \subseteq \mathbb{Q}(\zeta_p)$ for some prime p, where ζ_p is a primitive p-th root of unity. Joan Tent has classified the possible cyclic composition factors of solvable groups with cyclotomic fields of values. In this talk, we discuss the possible non-abelian composition factors of non-solvable groups with cyclotomic fields of values. (Received January 22, 2018)

1136-20-605 **Tullia Dymarz***, dymarz@math.wisc.edu. *BiLipschitz vs Quasi-isometric equivalence.*

The foundational premise of geometric group theory is that a finitely generated group can be endowed with a canonical metric, unique up to equivalence. This equivalence class should contain all word metrics (those metrics given by fixing a finite generating set and counting the number of generators it takes to transform one element to the other). Gromov started the field of geometric group theory by suggesting that the right equivalence to study is *quasi-isometry.* In this talk we will examine *biLipschitz* equivalence, another equivalence that contains all word metrics. Then we will compare the two types of equivalences for finitely generated groups and for more general discrete metric spaces. (Received January 22, 2018)

26 ► Real functions

1136-26-163 **Douglas R Anderson*** (andersod@cord.edu), Department of Mathematics, 901 8th Street S., Moorhead, MN 56562. *Caputo-Fabrizio fractional derivatives without singular kernel and proportional derivatives: connections.*

A direct connection will be made between the new Caputo-Fabrizio definition of fractional derivatives without singular kernel (2015, 2017) and proportional derivatives (2015), which are motivated by proportional-derivative controllers in control theory. The definition and properties of proportional derivatives will be explored, particularly the kind of calculus that they generate. (Received January 11, 2018)

1136-26-252 **Paul W. Eloe** and **Jeffrey T. Neugebauer*** (jeffrey.neugebauer@eku.edu). *Concavity in Fractional Calculus.*

We discuss a concavity like property for functions u satisfying $D^{\alpha}_{0+} u \in C[0,b]$ with $u(0) = 0$ and $-D^{\alpha}_{0+} u(t) \geq 0$ for all $t \in [0,b]$. We develop the property for $\alpha \in (1,2]$, where D^{α}_{0+} is the standard Riemann-Liouville fractional derivative. We observe the property is also valid in the case $\alpha = 1$. (Received January 17, 2018)

1136-26-370 **Pablo Jimenez-Rodriguez*** (pjimene1@kent.edu), 299, Dale Drive, Kent, OH 44240.
Structures in inequalities with convex functions.

In this talk we will analyze some inequalities convex functions verify. We will use the property of midconvexity and its relationship with convexity as a frame to set some questions (and answers) these inequalities propose. In particular, we will examine those questions under the prism of the theories of lineability and spaceability. (Received January 20, 2018)

32 ► Several complex variables and analytic spaces

1136-32-82 **Alan R Legg*** (leggar01@ipfw.edu). *Quadrature Domains for the Bergman Space in Several Complex Variables.*

A quadrature domain is a domain on which integrating functions of a prescribed class coincides with a finite linear combination of point evaluations of the functions and their derivatives. For example, integrating an analytic function on a planar disc involves evaluating the function at the center of the disc.

Quadrature domains using harmonic and analytic functions as the test class have been well studied in the plane, and have an appealing theory. But the situation in several complex dimensions is undeveloped.

In this talk, I will present results that highlight some elegant planar properties of quadrature domains which extend (or not) into several dimensions. Among these will be the result that every smooth bounded convex domain in C^n is biholomorphic to a quadrature domain. (Received January 03, 2018)

1136-32-117 **Debraj Chakrabarti*** (chakr2d@cmich.edu), Department of Mathematics, Central Michigan University, Mt Pleasant, MI 48859, and **Sonmez Sahutoglu**. *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 January 07, 2018)

1136-32-123 **Phillip S. Harrington** and **Andrew S. Raich*** (araich@uark.edu), Department of Mathematical Sciences, SCEN 327, 1 University of Arkansas, Fayetteville, AR 72701.
Boundary invariants and the closed range property for $\bar{\partial}$.

The main goal of this talk is to show that geometric information captured by certain invariant CR tensors provides sufficient information to establish the closed range property for $\bar{\partial}$ on a domain in $\mathbb{C}^n$. A secondary goal of the talk is to provide a general construction method for establishing when a domain (or its boundary) satisfies weak $Z(q)$. (Received January 08, 2018)

1136-32-156 **Laszlo Lempert***, Department of Mathematics, Purdue University, 150N University Street, West Lafayette, IN 47906. *Noncommutative potential theory.*

We propose to view hermitian metrics on trivial holomorphic vector bundles $E \to \Omega$ as noncommutative analogs of functions defined on the base Ω, and curvature as the notion corresponding to the Laplace operator or $\partial\bar{\partial}$. We discuss noncommutative generalizations of basic results of ordinary potential theory, mean value properties, maximum principle, Harnack inequality, and the solvability of Dirichlet problems. (Received January 10, 2018)

1136-32-191 **Zeljko Cuckovic*** (zcuckovi@math.utoledo.edu), Department of Mathematics and Statistics, University of Toledo, 2801 W. Bancroft St., Toledo, OH 43606, **Sonmez Sahutoglu**, Department of Mathematics and Statistics, University of Toledo, 2801 W. Bancroft St., Toledo, OH 43606, and **Yunus Zeytuncu**, Department of Mathematics and Statistics, University of Michigan-Dearborn, Dearborn, MI 48128. *Compactness of Toeplitz and Hankel operators on domains in $\mathbb{C}^n$.*

In this talk we will discuss compactness of Toeplitz and Hankel operators acting on weighted Bergman spaces on pseudoconvex domains. (Joint work with Sonmez Sahutoglu and Yunus Zeytuncu) (Received January 14, 2018)

1136-32-239 **Philip S. Harrington** and **Yunus E. Zeytuncu*** (zeytuncu@umich.edu), 4901 Evergreen Road, Dearborn, MI 48128. *L^p mapping properties for the Cauchy-Riemann equations on Lipschitz domains admitting subelliptic estimates.*

In this talk we look at the L^p mapping properties of some canonical operators on general pseudoconvex domains. In particular, we show that on bounded Lipschitz pseudoconvex domains that admit good weight functions the $\overline{\partial}$-Neumann operators N_q, $\overline{\partial}^* N_q$, and $\overline{\partial} N_q$ are bounded on L^p spaces for some values of p greater than 2. (Received January 16, 2018)

1136-32-244 **Loredana Lanzani***, llanzani@syr.edu, and **Elias M. Stein**. *The Szego projection for the worm domain.* Preliminary report.

I will give an overview of joint work with E. M. Stein (Princeton U.) concerning the analysis of the Szego Projection for the worm domain. (Received January 17, 2018)

1136-32-310 **John P. D'Angelo*** (jpda@illinois.edu). *Hermitian invariant groups for holomorphic and CR maps.*

We discuss Hermitian invariant groups associated with holomorphic mappings, giving examples and proving a regularity theorem for holomorphic mappings between balls. This talk is based on joint work with Ming Xiao. (Received January 19, 2018)

1136-32-322 **Emil J. Straube*** (straube@math.tamu.edu). *On the vexing question of* a priori *estimates for the Bergman projection.* Preliminary report.

Whether or not the Bergman projection on a smooth bounded domain in $\mathbb{C}^n$ has to satisfy *a priori* estimates is open. We will discuss several aspects of this question. (Received January 19, 2018)

1136-32-340 **Martino Fassina*** (fassina2@illinois.edu). *A remark on two notions of order of contact.*

To every point of a real hypersurface in the complex space, one can attach an invariant which measures the maximum order of contact of the hypersurface with complex q-dimensional varieties. This number is called the q-type, and was first introduced by D'Angelo. When the hypersurface is the boundary of a domain, the work of Catlin shows how the type is connected with the local regularity of the Cauchy Riemann equations. In Catlin's work, however, for q at least 2, an a priori different measurement of the order of contact is used. In this talk we present some situations in which the two numbers differ, and we show that the crucial point is the distinction between an infimum and a generic value. We also provide some inequalities between the two invariants. (Received January 19, 2018)

1136-32-348 **Herve Gaussier** (herve.gaussier@univ-grenoble-alpes.fr), Univ. Grenoble Alpes, CNRS, IF, F - 38000 Grenoble, France, and **Xianghong Gong*** (gong@math.wisc.edu), Department of Mathematics, 480 Lincoln Dr / Van Vleck Hall, University of Wisconsin - Madison, Madison, WI 53706. *Smooth equivalence of deformations of domains in complex euclidean spaces.*

We prove that two smooth families of 2-connected domains in $\mathbf{C}$ are smoothly equivalent if they are equivalent under a possibly discontinuous family of biholomorphisms. We construct, for $m \geq 3$, two smooth families of smoothly bounded m-connected domains in $\mathbf{C}$, and for $n \geq 2$, two families of strictly pseudoconvex domains in $\mathbf{C}^n$, that are equivalent under discontinuous families of biholomorphisms but not under any continuous family of biholomorphisms. Finally, we give sufficient conditions for the smooth equivalence of two smooth families of domains. (Received January 19, 2018)

1136-32-366 **Kuang-Ru Wu*** (wu739@purdue.edu). *A Dirichlet problem for flat hermitian metrics.*

Let $\bar{\Omega}$ be a compact Riemann surface with boundary, and V a Hilbert space . We consider the existence of flat hermitian metrics on $\bar{\Omega} \times V$ with given boundary values. Under some assumptions on $\bar{\Omega}$, we show this Dirichlet problem can be solved. 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 January 19, 2018)

1136-32-368 **Dror Varolin*** (dror@math.stonybrook.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794-3651. *Extension of jets and of singular Hermitian metrics with non-negative curvature current.*

Using standard, twisted estimates together with the relatively new technique of Berndtsson and Lempert, we prove extension theorems with Hilbert space estimates for normal jets to complex hypersurfaces in Stein manifolds. The key new idea is to degenerate the Stein manifold to a thin neighborhood of the hypersurface and then make use of a new observation about the existence of special weights on such thin neighborhoods. Once an estimate is obtained on the thin neighborhood, monotonicity of the estimates is established via Berndtsson's positivity theorem. We then apply the result to obtain a theorem on extension of singular Hermitian metrics for pseudoeffective line bundles on projective manifolds, yielding a partial generalization of a result of Coman-Guedj-Zeriahi (later reproved by Collins-Tosatti by different methods) on extension of metrics of ample line bundles. This is joint work with Jeff McNeal. (Received January 20, 2018)

1136-32-371 **Zhenghui Huo*** (huo@math.wustl.edu), One Brookings Dr., Department of Mathematics, Washington University in St. Louis, 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 $\{|z_1|^2 + |z_2|^p < 1\}$. We will discuss several results about Toeplitz operators, Hankel operators, and operators in the Toeplitz algebra. This work is joint with Brett Wick. (Received January 20, 2018)

1136-32-374 **Wanke Yin** (wankeyin@whu.edu.cn), **Yuan Yuan** (yyuan05@syr.edu) and **Yuan Zhang*** (zhangyu@ipfw.edu), 2101 E Coliseum Blvd, Fort Wayne, IN 46805. *CR immersions between spheres with degenerate CR Gauss maps.*

In this talk we study smooth CR immersions between spheres $\partial\mathbf{B}^n$ and $\partial\mathbf{B}^N, n \geq 3$. It is well-known that when $N - n \leq n - 2$, any such map is necessarily totally geodesic. The rigidity phenomenon fails in general when the codimension gets bigger unless additional assumptions are imposed. I will discuss our recent progress on rigidity phenomenon with degenerate CR Gauss maps. This is based on a joint work with Wanke Yin and Yuan Yuan. (Received January 20, 2018)

1136-32-390 **David E. Barrett*** (barrett@umich.edu) and **Luke D. Edholm** (edholm@umich.edu). *Projective dual coordinates and the Leray transform.*

The talk will examine systems of "projective dual coordinates" (depending on the choice of an invertible matrix M) for real hypersurfaces that are locally projectively equivalent to strongly convex hypersurfaces. With the use of these coordinates the Leray transform (the most basic type of Cauchy-Fantappiè operator) takes on a universal form such as

$$\mathbf{L}f(z) = \frac{1}{(2\pi i)^2} \int\limits_{\zeta \in S} f(\zeta) \, \frac{(w_2 \, dw_1 - w_1 \, dw_2) \wedge d\zeta_1 \wedge d\zeta_2}{(1 - z_1 w_1 - z_2 w_2)^2}$$

or

$$\mathbf{L}f(z) = \frac{i}{4\pi^2} \int\limits_{\zeta \in S} f(\zeta) \, \frac{dw_1 \wedge d\zeta_1 \wedge d\zeta_2}{(2iz_1 w_1 + w_2 - z_2)^2}$$

depending on the choice of M; here the dimension has been set equal to 2 for brevity, the z_j are the standard coordinates and the $w_j = w_j(\zeta)$ are the projective dual coordinates.

In the respective special cases of the sphere and the Heisenberg group, the dual coordinates are given by $w_j(\zeta) = \overline{\zeta_j}$ and the formulas above coincide with those for the Szegő projection.

Consequences for the structure of the Leray transform will be presented. (Received January 20, 2018)

1136-32-412 **Damin Wu*** (damin.wu@uconn.edu), 341 Mansfield Road U1009, Storrs, CT 06269. *Invariant metrics on negatively pinched complete Kähler manifolds.*

I will discuss the recent joint work with S. T. Yau on the study of invariant metrics, in particular the complete Kähler-Einstein metric of negative scalar curvature on complete Kähler manifolds whose holomorphic sectional curvature is bounded between two negative constants. (Received January 20, 2018)

1136-32-441 **Berit Stensones*** (berit.stensones@ntnu.no), Trondheim, Norway. *D-bar in dimension 3.*

We will study the Henkin kernel on finite type domains in $\mathbb{C}^3$. We shall show how one can construct such a kernel which converges even when the type is changing in different tangential directions . This is known when the domain is also convex ,but there are several difficulties when it is not convex. Our construction is inspired by Range's work in $\mathbb{C}^2$. (Received January 21, 2018)

1136-32-455 **Jian Xiao*** (jianxiao@math.northwestern.edu). *Positivity in the inverse σ_k equations.*

We discuss some positivity results in the conjecture proposed by Lejmi-Székelyhidi, which is a numerical criterion on the solvability of inverse σ_k equations over a compact Kähler manifold. In particular, we partially verify their conjecture by obtaining the desired positivity results for cohomology classes of bidegree $(n-1, n-1)$ when $k = n-1$ or when the manifold is a 3-fold. (Received January 21, 2018)

1136-32-464 **Luke D Edholm*** (edholm@umich.edu). *The Leray transform on two-dimensional model domains.*

One major difference between complex analysis in one and several variables is the lack of a true analogue to the one-variable Cauchy transform, **C**. By looking at domains satisfying a convexity condition, however, we are able to construct the Leray transform, **L**, an operator which shares many familiar properties with **C**. A significant amount of recent work has been done to study the mapping properties of **L** in various settings. I will focus on a family of model domains in $\mathbb{C}^2$, and discuss new techniques used in the analysis of the Leray operator. These models can be used to locally approximate a very general class of domains, and it is expected that the theorems in the model case will carry over to the general case. I will also discuss what these results mean in terms of dual CR structures on hypersurfaces in projective space. This is joint work with Dave Barrett. (Received January 21, 2018)

1136-32-493 **Purvi Gupta*** (purvi.gupta@rutgers.edu). *Embeddings of even-dimensional manifolds with constrained hulls.*

In this talk we will discuss a few related questions regarding the minimum embedding dimension of compact manifolds — where some constraints are imposed on the polynomial hull of the embedding. In particular, we will discuss a perturbation result for even-dimensional manifolds that improves previously known bounds. (Received January 22, 2018)

34 ► Ordinary differential equations

1136-34-6 **Shawn D Ryan*** (s.d.ryan@csuohio.edu), 2121 Euclid Ave., RT 1538, Cleveland State University, Cleveland, OH 44115. *Coupled ODE/PDE Models for Active Biosystems.*

We start by introducing two discrete coupled PDE/ODE models capable of exhibiting remarkable collective behavior. First, a bacterium is represented as a point dipole subject to hydrodynamic and excluded volume interactions. Simulations and analysis of the corresponding kinetic theory reveal the physical mechanisms behind the striking decrease in effective viscosity and the nontrivial correlations emerging during collective swimming. Second a model for foraging ants is introduced illustrating a transition to a collective state and local lane formation. Both are unified by the fact that a kinetic approach provides additional insight into the self-organization of these biosystems into mesoscopic groups possessing capabilities beyond that of an individual. (Received August 01, 2017)

1136-34-57 **Joseph E. Paullet*** (jep7@psu.edu), School of Science, Penn State Behrend, Erie, PA 16563, and **Joseph P. Previte**. *A Nonexistence Result for a BVP from Fluid Mechanics.*

Several recent papers investigate the boundary value problem

$$f''(t) + \lambda f'(t) + f(t)^2 = 0, \quad t \geq 0$$

subject to

$$f(0) = 1, \quad f(\infty) = 0,$$

which arises in certain situations of boundary layer flow. It is known that no solution exists for $\lambda \leq 0$ and that there exists $\lambda_{crit} \approx 1.07913$ such that solutions exist for $\lambda \geq \lambda_{crit}$. For $0 < \lambda < \lambda_{crit}$ the question remains open. We partially resolve this open question by proving that no solution exists for $0 < \lambda < \lambda_1 \approx .96105$. The proofs will involve integral expressions on f and f' as well as an application of Green's Theorem to the vector field defined by the phase plane for the ODE. (Received December 18, 2017)

1136-34-174 **Paul Eloe*** (peloe1@udayton.edu) and **Tyler Masthay**. *Uniqueness implies existence of solutions for a two-point boundary value problem for a Caputo fractional differential equation.*

Lasota and Opial (1967) showed that global existence and uniqueness of solutions of initial value problems and uniqueness of solutions of two-point conjugate boundary value problems implies existence of solutions of two-point conjugate boundary value problems for second order ordinary differential equations. We obtain the analogous result for a Caputo fractional differential equation of order α where $1 < \alpha \leq 2$. (Received January 12, 2018)

1136-34-250 **Ting-Hao Hsu*** (hsut1@mcmaster.ca), Department of Mathematics and Statistics, McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4K1, Canada.
Number and Stability of Relaxation Oscillations for Predator-Prey Systems with Small Death Rates.

In this talk, we will discuss predator-prey systems $\dot{x} = rx(1 - x/K) - yp(x)$, $\dot{y} = y(-\epsilon + cp(x))$ for small $\epsilon > 0$, with $r, K, c > 0$, and functional response $p(x)$ satisfying $p(0) = 0$, $p'(0) > 0$ and $p(x) > 0$ for $x > 0$. When the function $F(x) = rx(1 - x/K)/p(x)$, $x \in [0, K]$, has a single interior local extremum, I will show that there is a unique nontrivial periodic orbit ℓ_ϵ for all sufficiently small $\epsilon > 0$. Moreover, ℓ_ϵ forms a relaxation oscillation, that is, the period of ℓ_ϵ tends to infinity as $\epsilon \to 0$, and the trajectory of ℓ_ϵ approaches a certain configuration.

When $F(x)$ has exactly two interior local extrema, assuming the convexity of $F(x)$ on the right of the local maximum and that $c > 0$ is small enough, I will show that either the positive equilibrium is globally stable for all sufficiently small $\epsilon > 0$, or the system has exact two periodic orbits. In particular, for the Holling type IV functional response $p(x) = mx/(ax^2 + 1)$, I will derive a threshold value $K_* > 0$ of K that separates these two outcomes. This result supports the so-called paradox of enrichment. The main tools are geometric singular perturbation theory and the theory of Floquet multipliers. (Received January 17, 2018)

1136-34-251 **Sougata Dhar***, sougata.dhar@maine.edu, and **Qingkai Kong**. *Fractional Lyapunov-type Inequalities with order $\alpha \in (2, 3]$ and fractional integral boundary conditions.*

In this talk, We study linear fractional boundary value problems consisting of an α-th order Riemann-Liouville fractional differential equation with $2 < \alpha \leq 3$ and certain fractional boundary conditions. We derive several Lyapunov-type Inequalities and apply them to establish nonexistence, uniqueness, and existence-uniqueness for solutions of related homogeneous and nonhomogeneous linear fractional boundary value problems. As a special case, our work covers and improves some existing results for the third-order linear boundary value problems. (Received January 17, 2018)

1136-34-260 **Anna Maltsev***, annavmaltsev@gmail.com. *Landscape functions on quantum graphs.* Preliminary report.

I will discuss localization and other properties of eigenfunctions of the Schrödinger operator on quantum graphs. The motivation is to understand how graph structure impacts eigenfunction behavior. I will present adaptations of the landscape function approach, well-established for $\mathbb{R}^n$, to quantum graphs and its limitations. In our context, a "landscape function" $\Upsilon(x)$ is a function that controls the localization properties of normalized eigenfunctions $\psi(x)$ through a pointwise inequality of the form $|\psi(x)| \leq \Upsilon(x)$. The connectedness of a graph can present a barrier to the existence of universal landscape functions in the high-energy régime, as we demonstrate with simple examples. However, at low and moderate energies landscape functions can be made explicit. This talk is based on joint work with Evans Harrell. (Received January 18, 2018)

1136-34-262 **Muhammad N Islam*** (mislam1@udayton.edu), 300 College Park Ave, Dayton, OH 45469-0001. *A fractional differential equation of Riemann-Liouville type.* Preliminary report.

The existence of solutions along with certain qualitative properties of a scalar fractional differential equation of Riemann-Liouville type

$$D^q x(t) = f(t, x(t)), \lim_{t \to 0^+} t^{1-q} x(t) = x_0, \ 0 < q < 1$$

has been studied in this paper. Fixed point theorems have been employed as the tools of analysis.
(Received January 18, 2018)

1136-34-266 **Youssef Naim Raffoul*** (yraffoul1@udayton.edu), 300 College PARK, DAYTON, OH 45469-2316. *Boundedness and Stability of Solutions in Nonlinear Volterra Integro-Differential Equation.*

We use Lyapunov functionals combined with Laplace transform and obtain boundedness and stability results regarding the solutions of the nonlinear Volterra integro-differential equation

$$y'(t) = A(t)y + f(y) + \int_0^t C(t, s)h(y(s))ds + p(t).$$

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1136-34-298 **JABR ALJEDANI*** (jabr.15358@hotmail.com), 300 college park, Dayton, OH 45469, and **Paul Eloe** (peloe1@udayton.edu), 300 college park, Dayton, OH 45469. *Uniqueness and existence of solutions of boundary value problems at resonance for ordinary differential equations.*

A quasilinearization algorithm is developed for a specific boundary value problem at resonance. To do so, a standard monotonicity condition is assumed to obtain uniqueness of solutions for the boundary value problem at resonance. Then the method of upper and lower solutions and a shift method is applied to obtain the existence of solutions. A quasilinearization algorithm is developed and sequences of approximate solutions are constructed that converge monotonically and quadratically to the unique solution of the boundary value problem at resonance. (Received January 19, 2018)

1136-34-333 **Aghalaya S Vatsala*** (vatsala@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504, and **Yunxiang Bai**, Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504. *Caputo Fractional Impulsive Differential Equations with Mixed Monotone Functions and Mixed Monotone impulses.*

Abstract: In this work, initially we compute the solution of the linear impulsive differential Equations equation explicitly. This is obtained by applying Laplace transform method and by method of mathematical induction. We develop a comparison results using the coupled lower and upper solution for the nonlinear Caputo impulsive differential equation with mixed monotonicity. Using this as a tool we develop generalized monotone iterative technique for nonlinear Caputo Fractional Impulsive Differential Equation. We present some numerical results for linear problems. (Received January 19, 2018)

1136-34-403 **Zhen Jin** and **Chunhua Shan*** (chunhua.shan@utoledo.edu), The University of Toledo, and **Xiaoguang Zhang** and **Huaiping Zhu**. *Complex Dynamics of Epidemic Models on Adaptive Networks.*

There has been a substantial amount of well-mixing epidemic models devoted to characterizing the observed complex phenomena (such as bistability, hysteresis, oscillations, etc.) during the transmission of many infectious diseases. A comprehensive explanation of these phenomena by epidemic models on complex networks is still lacking. In this paper we study epidemic dynamics in an adaptive network model proposed by Gross et al, where the susceptibles are able to avoid contact with the infected by rewiring their network connections. Such rewiring of the local connections changes the topology of network, and inevitably has a profound effect on the transmissions of infectious diseases, which in turn influences the rewiring process. We rigorously prove that such adaptive epidemic network model exhibits degenerate Hopf bifurcation, homoclinic bifurcation and Bogdanov-Takens bifurcation. Our study shows thathuman adaptive behaviors to the emergence of an epidemic may induce complex dynamics of diseases transmission, including bistability, transient and persistent oscillations, which contrast sharply to the dynamics of classic network models. Our results yield deeper insights into the interplay between topology of networks and the dynamics of disease transmission on networks. (Received January 20, 2018)

1136-34-404 **Rodica D Costin*** (costin.10@osu.edu), 100 Math Tower, 231 W 18th Ave, Columbus, OH 43210. *Truncated solutions of Painlevé equations.*

After a brief review of truncated solutions of Painlevé equations P1-P5, it is shown that they can be represented as re-summed transseries in the pole free sectors. The transseries are then used to determine the location of the first array of poles. All these representations can be used for efficient numeric calculations. (Received January 20, 2018)

1136-34-449 **Milena Stanislavova*** (stanis@ku.edu), University of Kansas, Department of Mathematics, Lawrence, KS 66045, and **Satbir Malhi**. *Energy decay rate for the one-dimensional fractional Klein-Gordon equation.*

In this paper, we prove that the energy of the solution for the one dimensional fractional Klein-Gordon equation decays at a rate $t^{-\frac{s}{4-2s}}$ for $q < 2$, while the decay rate is exponential for $q \geq 2$. Our approach is based on the asymptotic theory of C_0-semigroups, in particular the results by Gearhart-Pruss, and later Borichev and Tomilov, in which they relate the decay rate of energy in terms of the the resolvent growth of the semigroup generator. A key ingredient of our proof is an improved observability estimate for the fractional Laplacain. We then estimate the resolvent of the semigroup via the new observability estimate for the fractional Laplacain. (Received January 21, 2018)

1136-34-472 **Yangyang Wang*** (wang.9737@mbi.osu.edu), **Jonathan Rubin**, **Catherine Czeisler** and **Jose Otero**. *Mathematical modeling of astrocyte-potentiated chemosensation.* Preliminary report.

The retrotrapezoid nucleus (RTN) has previously been identified as a CO_2/pH sensor system. Neurons located in RTN are activated by increased CO_2 or decreased pH and couple with the respiratory oscillations generated by the kernel of the respiratory central pattern generator. There is evidence showing that RTN neurons are intrinsically sensitive to CO_2/pH. However, recent experimental work shows that the ablation of RTN astrocytes will result in a deficiency in CO_2 chemosensory control of breathing, suggesting a neuronal-astrocyte unit is involved in the regulation of the chemosensory control of breathing. In this work, we describe a mathematical model of the RTN neurons to explore the mechanisms responsible for their chemosensitivity. We not only consider the intrinsic pH sensitivity of the RTN neurons but also investigate how the RTN neurons attain their chemosensitivity indirectly from local pH-sensitive astrocytes. (Received January 21, 2018)

1136-34-480 **Wenjing Zhang*** (wenjing.zhang@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Broadway and Boston, Lubbock, TX 79409-1042. *Dynamical Studies on an Recurrent Disease Model via Model Reduction.*

In this paper, we apply order reductions and parameter reductions on an recurrent autoimmune disease model to reveal rich dynamics. The reduced models not only inherit the intrinsic recurrent patterns, but also allow sophisticated mathematical analyses to reveal complex dynamical behaviors such as multiple limit cycles. Our analyses show that the quasi-steady-state assumption (QSSA) is able to keep the intrinsic dynamical behaviors of the original system and is easier to use in practice than iterative methods for asymptotic expansion of the slow invariant manifold. However, it may alter the determining parameter ranges, which is acceptable if analyses are focused on qualitative behaviors. Moreover, the formulas for the parameter reductions can be used to identify complex dynamics such as multiple limit cycles bifurcation in the original model. (Received January 21, 2018)

35 ► *Partial differential equations*

1136-35-11 **Qiliang Wu*** (wuq@ohio.edu), Morton Hall RM 552, 1 Ohio University, Athens, OH 45701, and **Keith Promislow** (kpromisl@math.msu.edu), 619 Red Cedar Road, East Lansing, MI 48824. *Quenched flow in symmetric multi-component FCH.*

Multicomponent mixtures support bilayers with a diversity of lipid compositions. We study a two-component FCH model with a radial symmetric potential which admits a family of quasi-bilayers with various compositional ratios between amphiphile A and B. In the absence of pearling, the compositional and geometric evolution of quasi-bilayers decouples, in the sense that the former evolution takes place in a slow time scale when the normal velocity of interface is still zero. More specifically, the composition ratio satisfies a nonlocal equation accommodating rich dynamics. Depending on the competition between the phase separation and the quenching of the background, the composition ratio evolves into, (1) a homogeneous profile; (2) a phase separation profile where the bilayer consists of pure A regions and pure B regions; or, (3) a quenched profile in a co-dim two manifold. In last two cases, a rapid spatial variation of the composition promotes surface diffusion terms from lower orders. While the evolution of phase separation profiles mimics Allen-Cahn type coarse graining, novel dynamics emerges from rapid varying profiles in a neighborhood of the quenched manifold: compositional profiles stay nearby the quenching manifold and evolve into periodic profiles with large periods. (Received October 09, 2017)

1136-35-14 **Thinh Kieu*** (thinh.kieu@ung.edu), 3820 Mundy Mill Rd., Oakwood, GA 30019. *A MIXED FINITE ELEMENT APPROXIMATION FOR NON-DARCY FLOWS OF SLIGHTLY COMPRESSIBLE FLUIDS IN POROUS MEDIA.* Preliminary report.

We consider the generalized Forchheimer flows for slightly compressible fluids in porous media. Using Muskat's and Ward's general form of Forchheimer equations, we describe the flow of a single-phase fluid in by a nonlinear degenerate system of density and momentum. A mixed finite element method is proposed for the approximation of the solution of the above system. The stability of the approximations are proved; the error estimates are derived for the numerical approximations for both continuous and discrete time procedures. The continuous dependence of numerical solutions on physical parameters are demonstrated. Experimental studies are presented regarding convergence rates and showing the dependence of the solution on the physical parameters. (Received October 13, 2017)

1136-35-17 **Atanas Stefanov***, 1460, Jayhawk Blvd., Lawrence, KS 66045, and **Iurii Posukhovskyi**, 1460 Jayhak Blvd, Lawrence, KS 66045. *Ground states for the Kawahara and a fourth order NLS.*

We consider the Kawahara model and two fourth order semi-linear Schroedinger equations in any spatial dimension. We construct the corresponding normalized ground states, which we rigorously show to be spectrally stable.

For the Kawahara model, our results provide a significant extension in parameter space of the current rigorous results. At the same time, we verify and clarify recent numerical simulations of the stability of these solitons. For the fourth order NLS models, we improve upon recent results on stability of very special, explicit solutions in the one dimensional case. (Received November 02, 2017)

1136-35-26 **Yaqin Feng*** (fengy@ohio.edu), Ohio university, Athens, OH 45701. *Functional equations with rescaling and applications to mathematical model of plankton.* Preliminary report.

We consider the time evolution of the super-critical Galton-Watson model of branching particles with extra parameter (mass). In the moment of the division the mass of the particle (which is growing linearly after the birth) is divided in random proportion between two offspring (mitosis). Using the technique of moment equations, we study asymptotically the mass-space distribution of the particles. Mass distribution of the particles is the solution of the special functional-differential equation with linearly transformed argument. We proved several limit theorems describing the fluctuations of the density of the particles. (Received December 22, 2017)

1136-35-27 **Anna Ghazaryan*** (ghazarar@miamioh.edu), Miami University, Department of Mathematics, 301 Patterson Ave, Oxford, OH 45056, and **Yuri Latushkin** and **Xinyao Yang**. *On the stability of planar fronts with marginally unstable essential spectra.*

We study a planar front solution for a class of reaction-diffusion equations in the case when the essential spectrum of the linearization about the front touches the imaginary axis. The spectrum of the wave is stabilized by an exponential weight. 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 November 23, 2017)

1136-35-31 **Alaa Haj Ali*** (ep3983@wayne.edu) and **Peiyong Wang**. *The one-phase bifurcation for the p-Laplacian.* Preliminary report.

We prove a bifurcation about the uniqueness of a solution of a singularly perturbed free boundary problem of phase transition associated with the p-Laplacian, subject to given boundary condition. We show this phenomenon by proving the existence of a third solution through the Mountain Pass Lemma when the boundary data decreases below a threshold. We also prove that the minimizer solution and the trivial p-harmonic solution are stable, while the Mountain Pass solution is unstable. Here the stability of a solution u is in the sense that starting with initial data near u, the evolution will convergence to u. This is a joint work with professor Peiyong Wang.
(Received December 04, 2017)

1136-35-40 **Gro Hovhannisyan*** (ghovhann@kent.edu), 6000 Frank Ave NW, North Canton, OH 44720. *Multi soliton solutions to Sin-Gordon equation on a time scale.* Preliminary report.

Using Hirota's direct approach we describe the multi soliton solutions to Sin-Gordon equation on a time scale.
(Received December 08, 2017)

1136-35-41 **Anna Ghazaryan** and **Yuri Latushkin*** (latushkiny@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, and **Roland Schnaubelt** and **Xinyao Yang**. *Stability of one-dimensional and multi-dimensional fronts in exponentially weighted norms for a class of reaction diffusion equations.*

We study fronts for systems of reaction diffusion equations of a special type that often appear in combustion theory and chemical reaction models. The spectrum of the linearized operator touches the imaginary axis and therefore the system is studied in the intersection of the original Sobolev space and the space with an exponential weight. In the one-dimensional case we prove the existence of a stable foliation in vicinity of the front and thus explain orbital stability. In the multidimensional case we prove algebraic decay of perturbations of the planar front. (Received December 09, 2017)

1136-35-52 **Hong Cai**, **Anna Ghazaryan** and **Vahagn Manukian***, manukive@miamioh.edu. *Front solutions of modified Rosenzweig-MacArthur model.*

We will show existence of front solutions in diffusive modified Rosenzweig-MacArthur reaction diffusion system in the limits when prey diffuses at the rate much smaller than that of the predator and both the predator and the prey diffuse very slowly. Stability properties of some of these waves will also be discussed. (Received December 15, 2017)

1136-35-65 **Siyuan Lu***, siyuan.lu@math.rutgers.edu, and **Yanyan Li**. *Exterior problem for Monge-Ampere equation.*

We consider exterior problem for Monge-Ampere equation.

In 2003, Caffarelli and Li proved that there exists a unique solution for exterior problem with fixed asymptotic behavior.

In this talk, we will discuss the relation between existence/nonexistence of solution and its asymptotic behavior. In particular, we give sharp characterization for the existence/nonexistence of the exterior problem.

This is based on joint work with Yanyan Li. (Received December 29, 2017)

1136-35-73 **Shaohua George Chen*** (george_chen@cbu.ca), 1250 Grand Lake Road, Sydney, NS B1M1A6, Canada. *Blow-up of positive solutions to a singular Gierer-Meinhardt system.* Preliminary report.

This talk discusses the blow-up of positive solutions for a singular Gierer-Meinhardt system subject to zero Dirichlet boundary conditions. We first prove the existence of a local solution and then show blow-up solutions under certain conditions for parameters. We use a functional method to obtain a local solution which is bounded by the first eigenfunction both from upper and from below and then obtain the bound of a ratio of two solutions. This method is completely different than the traditional methods of sub and super solutions. (Received January 01, 2018)

1136-35-77 **Peter V Gordon*** (gordon@math.kent.edu), Department of Mathematical Sciences, Kent State Univerity, Kent, OH 44242. *Gelfand type problems for reactive jets: autoignition of turbulent jets.*

Gelfand problem is one of the canonical problems in the theory of non-linear parabolic and elliptic partial differential equations (PDEs). This problem naturally arises in the Frank-Kamenetskii theory of thermal explosion (autoignition) and describes an initial stage of evolution of a temperature field in reactive materials and mixtures.

In this talk I will present a generalization of Gelfand problem for analysis of autoignition of reactive turbulent jets. I will present both derivation of this new model and its analysis. The latter is performed using a combination of rigorous, formal asymptotic and numerical techniques. It will be shown that similar to the classical Gelfand problem an autoignition in jets occur exclusively owing to the absence of self-similar temperature distribution which, in mathematical terms, leads to loss of regularity (blow-up) of underlying PDE. The detailed analysis of self-similar temperature profiles will be presented and a sharp characterization of an autoignition event in terms of principal geometric and physical parameters of the problem will be given.

This a joint work with U.G. Hegde and M.C. Hicks. (Received January 02, 2018)

1136-35-78 **Panayotis Kevrekidis*** (kevrekid5@gmail.com), 710 N. Pleasant Street, Amherst, MA 01003. *Nonlinear Waves in Granular Crystals.*

In this talk, we will provide an overview of results in the setting of granular crystals, consisting of beads interacting through Hertzian contacts. In 1d we show that there exist three prototypical types of coherent nonlinear waveforms: shock waves, traveling solitary waves and discrete breathers. The latter are time-periodic, spatially localized structures. For each one, we will analyze the existence theory, presenting connections to prototypical models of nonlinear wave theory, such as the Burgers equation, the Korteweg-de Vries equation and the nonlinear Schrodinger (NLS) equa- tion, respectively. We will also explore the stability of such structures, presenting some explicit stability criteria analogous to the famous Vakhitov-Kolokolov criterion in the NLS model. Finally, for each one of these structures, we will complement the mathematical theory and numerical computations with state-of-the-art experiments, allowing their quantitative identification and visualization. Finally, time permitting, ongoing extensions of these themes will be briefly touched upon, most notably in higher dimensions, in heterogeneous or disordered chains and in the presence of damping and driving; associated open questions will also be outlined. (Received January 02, 2018)

1136-35-86 **David P. Nicholls***, Dept of Math, Stat, and CS, 851 South Morgan Street, Chicago, IL 60607. *Well-Posedness and Analyticity of Solutions to a Water Wave Problem with Viscosity.*

The water wave problem models the free-surface evolution of an ideal fluid under the influence of gravity and surface tension. The governing equations are a central model in the study of open ocean wave propagation, but they possess a surprisingly difficult and subtle well-posedness theory. In this talk we establish the existence and uniqueness of solutions to the water wave equations augmented with physically inspired viscosity suggested in the recent work of Dias, Dyachenko, and Zakharov (Phys. Lett. A, 372, 2008). As we show, this viscosity (which can be arbitrarily weak) not only delivers an enormously simplified well-posedness theory for the governing equations, but also justifies a greatly stabilized numerical scheme for use in studying solutions of the water wave problem. (Received January 03, 2018)

1136-35-89 **Alex A. Himonas*** (himonas@nd.edu), Department of Mathematics, 274 Hurley, University of Notre Dame, Notre Dame, IN 46556. *The Cauchy Problem for Camassa-Holm equations.*

Over the last two decades, much progress has been made on the well-posedness of the initial value problem for Camassa-Holm type equations with data in spaces of functions with various smoothness. In this talk we shall discuss some of our collaborative contributions towards this progress with an emphasis on our most recent results. (Received January 03, 2018)

1136-35-93 **Tatiana Savina*** (savin@ohio.edu), **Lanre Akinyemi** and **Avital Savin**. *On a two-fluid flow in a Hele-Shaw cell with a time-dependent gap.*

A Hele-Shaw cell is a pair of parallel plates separated by a small gap. The motion of the fluids sandwiched between the plates could be driven by a pressure gradient, gravity, fluid injection, and an external potential fields. This has been the subject of numerous investigations. The reason for the intense interest is the mathematical relation to modeling of several applied problems in material science and fluid dynamics, as well as to modeling of biological processes involving moving fronts of populations or tumors. These latter processes include cancer, biofilms, wound healing, granulomas, and atherosclerosis.

In this talk we consider two fluids with different viscosities in a Hele-Shaw cell. The evolution of the interface, separating the fluids, is driven by a uniform change in the gap width of the cell as well as by the presence of some special distributions of sinks and sources located in both the interior and exterior domains The effect of surface tension is neglected.

Using the Schwarz function approach, we give examples of exact solutions when the interface belongs to a certain family of algebraic curves. (Received January 04, 2018)

1136-35-100 **Ryan Cole Thompson*** (ryan.thompson@ung.edu), Department of Mathematics, University of North Georgia, 82 College Circle, Dahlonega, GA 30597, and **John Holmes**. *Well-posedness and Continuity Properties of The Fornberg-Whitham Equation in Besov Spaces.*

In this talk, we exhibit a well-posedness of the Fornberg-Whitham equation in Besov spaces $B^s_{2,r}$ in both the periodic and non-periodic cases. This will imply the existence and uniqueness of solutions in the aforementioned spaces along with the continuity of the data-to-solution map provided that the initial data belongs to $B^s_{2,r}$. We also establish sharpness of continuity on the data-to-solution map by showing that it is not uniformly continuous from any bounded subset of $B^s_{2,r}$ to $C([-T,T];B^s_{2,r})$. Time permitting, we will exhibit a Cauchy-Kowalevski type theorem for this equation that establishes the existence and uniqueness of real analytic solutions and also provide blow-up criterion for solutions. (Received January 04, 2018)

1136-35-104 **Mathew Johnson**, **Gregory Lyng** and **Connor Smith*** (c406s460@ku.edu). *Metastable Traveling Fronts Arising in Nanoscale Pattern Formation.*

We study an equation that models ripple formation when a flat surface is bombarded by an ion beam. The experimentally observed ripples consist of parts with a certain positive slope, parts with a certain negative slope, and transitions between the two slopes. The transitions admit a solitary wave solution with stable point spectrum but unstable essential spectrum. At first glance this may be written off as "unstable." However numerical results suggest that the instability has two parts; a convecting part that saturates to some value and an exponentially decaying part that slightly modulates the underlying transition. We define an exponential weight that decays in the direction the first part of the instability travels in, allowing us to focus on the second part of the instability. In this exponentially weighted space we obtain a linear stability result. Inspired by the "repeating" part of the experimental results, we also consider "gluing" together solitary waves in an ad hoc periodic pattern. For some specific methods of gluing the entire spectrum is stable, with the implication that while an individual transition is unstable, the instability is benign enough that it can be stabilized by repeating the transition. (Received January 05, 2018)

1136-35-107 **King-Yeung Lam*** (lam.184@math.ohio-state.edu), **Xueying Wang** and **Tianran Zhang**. *Traveling waves for a class of diffusive disease-transmission models with network structures.*

In this paper, the necessary and sufficient conditions for the existence of traveling wave solutions are derived for a class of diffusive disease-transmission models with network structures. The existence of traveling semi-fronts is obtained by Schauder's fixed-point theorem and these traveling semi- fronts are shown to be bounded by transforming the boundedness problem into the classification problem of non-negative solutions to a linear elliptic system on $\mathbb{R}$. To overcome the reducibility problem arising in the proofs, a Harnack's inequality for positive supersolutions on $\mathbb{R}$ is proved. (Received January 05, 2018)

1136-35-120 **Aslihan Demirkaya*** (demirkaya@hartford.edu), West Hartford, CT 06119. *ϕ^4 Solitary Waves With a Parabolic Potential: Existence, Stability, and Collisional Dynamics.* Preliminary report.

We explore a ϕ^4 model with an added external parabolic potential term. This term dramatically alters the spectral properties of the system. We identify single and multiple kink solutions and examine their stability features; importantly, all of the stationary structures turn out to be unstable. We complement these with a dynamical study of the evolution of a single kink in the trap, as well as of the scattering of kink and anti-kink solutions of the model. We see that some of the key characteristics of kink-antikink collisions, such as the critical velocity and the multi-bounce windows highly depend on the trap strength parameter, as well as importantly also the initial displacement of the kink and antikink. (Received January 07, 2018)

1136-35-126 **Robin Ming Chen*** (mingchen@pitt.edu), Department of Mathematics, University of Pittsburgh, Pittsburgh, PA 15260, and **Samuel Walsh** and **Miles Wheeler**. *Asymptotic behavior of deep water solitary waves with localized vorticity.*

We consider free-surface solitary waves of an infinitely deep two- or three-dimensional fluid with a localized distributed vorticity, with or without surface tension. We are able to obtain precise asymptotics at infinity, given a very mild algebraic decay assumption. Moreover using these asymptotic information we can prove several qualitative properties of the wave. This is a joint work with S. Walsh and M. Wheeler. (Received January 08, 2018)

1136-35-128 **Gerard Misiolek*** (gmisiole@nd.edu). *Continuity properties of the solution map of the incompressible Euler equations.*

Continuity properties of the solution map of the incompressible Euler equations. (Received January 08, 2018)

1136-35-147 **Lianzhang Bao*** (lzbao@jlu.edu.cn), Room 628 Mathematical building, Jilin University, Changchun, Jilin 130012, Peoples Rep of China. *New population model from probability and its traveling wave solution.*

In this talk, we first derive a new backward forward parabolic equation from population dynamics. The existence of infinitely many traveling wave solutions is proven. These traveling waves are parameterized by their wave speed and monotonically connect the stationary states. (Received January 09, 2018)

1136-35-179 **Zhijun (George) Qiao*** (zhijun.qiao@utrgv.edu), SMSS UTRGV, 1210 W Univ Drive, Edinburg, TX 78539. *Negative order flows from integrable hierarchy.*

In this talk, we will show how to generate a negative order integrable flow from the Lenard recursion operators, and then find the Lax pair for the entire hierarchy to guarantee the integrability. Interesting thing is that the peakon equation would be coming from the negative hierarchy. Amazing examples include the negative AKNS, Negative KdV, CH, DP, cubic CH, inhomogeneous Burgers, and two-component short pulse equations etc. Particularly, real and complex short pulse equations can be derived from the negative AKNS. Some of this work is joint with Dr. Zhaqilao and Dr. Qiaoyi Hu. (Received January 13, 2018)

1136-35-207 **Leandro Lichtenfelz*** (llichte1@nd.edu). *Singularities of the L^2 exponential map on diffeomorphism groups.*

In this talk, we will discuss some results on conjugate points and normal forms for the L^2 Riemannian exponential map on the diffeomorphism group of a compact 2D manifold. This map is strongly tied to the motion of a perfect incompressible fluid on the manifold. (Received January 15, 2018)

1136-35-219 **Marcelo Mendes Disconzi*** (marcelo.disconzi@vanderbilt.edu), 1326 Stevenson Center, Vanderbilt University, 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 study the compressible free boundary Euler equations in three spatial dimensions with surface tension. We show that when the sound speed tends to infinity, solutions to the compressible equations converge to solutions of the incompressible free boundary Euler equations. (Received January 16, 2018)

1136-35-228 **Jacek Szmigielski*** (szmigiel@math.usask.ca), Department of Mathematics/Statistics, UofS, Saskatoon, SK S7N 5E6, Canada. *The inverse problem for the modified Camassa-Holm peakon equation.*

In this talk I will concentrate on showing how to solve the inverse problem that arrises for peakon solutions of the modified Camassa-Holm equation. I will discuss the following aspects of the problem: a) distributional formulation of the Lax pair, b) the boundary value problem and the characterization of its spectrum, c) a certain interpolation problem and its role in the solution of the inverse problem, d) examples of exact peakon formulas. This talk is based on a joint work with Xiangke Chang (Beijing). (Received January 16, 2018)

1136-35-257 **Ralph Saxton*** (rsaxton@uno.edu), Department of Mathematics, University of New Orleans, New Orleans, LA 70148, and **Katarzyna Saxton** (saxton@loyno.edu), Dept. of Mathematics and Computer Science, Loyola University, 6363 St Charles Ave, New Orleans, LA 70118. *L^∞ Blowup of Solutions to the $N \times N$ Keyfitz and Kranzer System.* Preliminary report.

We consider the Cauchy problem for the system of conservation laws $U_t + (\Phi(U)U)_x = 0$, $U : R_t \times R_x \to R^n$, $n \geq 2$, where $\Phi(U) = \phi(r, \Theta) : R^n \to R$, $r = |U|$ and $\Theta = U/|U| \in S^{n-1}$. We find a wide class of functions ϕ for which the amplitude of solutions can blow up in finite time provided $\nabla_\Theta \phi \neq 0$ in regions of phase space where 'strict hyperbolicity' fails. (Received January 17, 2018)

1136-35-261 **Angela Alberico*** (a.alberico@iac.cnr.it), Via P. Castellino, 111, I-80131 Napoli, Italy, **Giuseppina di Blasio**, Italy, and **Filomena Feo**, Italy. *A priori bounds for solutions to fully anisotropic elliptic equations.*

We are concerned with a priori estimates, in rearrangement form, for solutions to fully anisotropic elliptic equations with lower-order terms.

Our estimates extend well known results that can be traced back to the contributions [Maz'ya, 1969] and [Talenti, 1976] for linear problems, to [Talenti, 1979] for nonlinear problems, to [Díaz, 1992] for lower-order terms, and [Cianchi, 2007] for anisotropic equations.

The results to be presented in this talk are the subject in the paper [Alberico, di Blasio, Feo, preprint arXiv:1711.10559]. (Received January 18, 2018)

1136-35-271 **Timur Akhunov** and **Lyudmila Korobenko***, korobenko@reed.edu, and **Cristian Rios**. *Hypoellipticity without loss of derivatives for Fediĭ's type operators.*

The talk is concerned with hypoellipticity of second order degenerate elliptic operators. Starting with the famous Hormander bracket condition given in 1967, there has been a lot of theory built trying to classify hypoelliptic operators. It is known that subelliptic operators are hypoelliptic, however the latter class is much wider. For example, it includes operators of the form $\partial_x^2 + g(x)\partial_y^2$, where function $g(x)$ is allowed to vanish at a point together with all its derivatives. It has been shown by Fediĭ that such operators are hypoelliptic independent of the order of vanishing of $g(x)$. We consider a generalization of this construction where the second partials are replaced by second order operators satisfying a certain logarithmic criterion introduced by Morimoto in 1987. We show that such operators are hypoelliptic independent of the order of degeneracy. To our knowledge this gives the widest class of hypoelliptic operators of such construction. A simple example also shows necessity of the logarithmic condition for hypoellipticity. (Received January 18, 2018)

1136-35-272 **Pierre Magal**, **Glenn F Webb** and **Yixiang Wu*** (yixiang.wu@vanderbilt.edu). *On a Vector-host Epidemic Model with Spatial Structure.*

In this talk, we consider a reaction-diffusion vector-host epidemic model. We define the basic reproduction number R_0 and show that R_0 is a threshold parameter: if $R_0 \leq 1$ the disease free steady state is globally stable; if $R_0 > 1$ the model has a unique globally stable positive steady state. We then write R_0 as the spectral radius of the product of one multiplicative operator $R(x)$ and two compact operators with spectral radius equalling one. Here $R(x)$ corresponds to the basic reproduction number of the model without diffusion and is thus called local basic reproduction number. We study the relationship between R_0 and $R(x)$ as the diffusion rates vary. (Received January 18, 2018)

1136-35-285 **Alin Pogan*** (pogana@miamioh.edu), 301 S. Patterson Ave., 123 Bachelor Hall, Oxford, OH 45056, and **Kevin Zumbrun** (kzumbrun@indiana.edu), Rawles Hall, 831 E. Third St, Bloomington, IN 47405. *Center Manifolds for a Class of Degenerate Evolution Equations and Existence of Small Amplitude Kinetic Shocks.*

We construct center manifolds for a class of degenerate evolution equations including the steady Boltzmann equation and related kinetic models, establishing in the process existence and behavior of small-amplitude kinetic shock and boundary layers. Notably, for Boltzmann's equation, we show that elements of the center manifold decay in velocity at near-Maxwellian rate, in accord with the formal Chapman-Enskog picture of near-equilibrium ow as evolution along the manifold of Maxwellian states, or Grad moment approximation via Hermite polynomials in velocity. Our analysis is from a classical dynamical systems point of view, with a number of interesting modifications to accommodate ill-posedness of the underlying evolution equation. (Received January 18, 2018)

1136-35-295 **Shu Wang*** (wangshu@bjut.edu.cn). *Quasineutral limit of drift-diffusion-Poisson models for semiconductors.* Preliminary report.

We will discuss the quasineutral limit of drift-diffusion-Poisson models for semiconductors and the coupled system of drift-diffusion-Poisson and hydrodynamic equations. Some recent new results will be given. (Received January 18, 2018)

1136-35-302 **Stephane Lafortune*** (lafortunes@cofc.edu), Department of Mathematics, College of Charleston, Charleston, SC 29424, and **Thomas Ivey** (iveyt@cofc.edu), Department of Mathematics, College of Charleston, Charleston, SC 29424. *Stability of solutions to the VFE and its hierarchy.*

The Vortex Filament Equation (VFE) is part of an integrable hierarchy of filament equations. Several equations in this hierarchy have been derived to describe vortex filaments in various situations. Inspired by these results, we develop a general framework for studying the existence and the linear stability of closed solutions of the VFE hierarchy. The framework is based on the correspondence between the VFE and the nonlinear Schrodinger (NLS) hierarchies. Our results establish a connection between the AKNS Floquet spectrum and the stability properties of the solutions of the filament equations. We apply our machinery to solutions of the filament equation associated to the Hirota equation. We also discuss how our framework applies to soliton solutions. (Received January 19, 2018)

1136-35-318 **Jerry L. Bona*** (jbona@uic.edu), Dept. Math., Statistics and Computer Sci., University of Illinois at Chicago, 851 S. Morgan Street MC 249, Chicago, IL 60607. *A Hamiltonian, higher-order unidirectional model for surface water waves.*

A second-order correct model for the propagation of surface water waves will be discussed. Both theoretical results and numerical simulations will be presented. (Received January 19, 2018)

1136-35-331 **Qiliang Wu*** (wuq@ohio.edu) and **Arnd Scheel**. *The effect of impurities on stripes.*

We study the effect of algebraically localized impurities on striped phases in one and higher space-dimension. We therefore develop a functional-analytic framework which allows us to cast the perturbation problem as a regular Fredholm problem despite the presence of essential spectrum, caused by the soft translational mode. Our 1-d results establish the selection of jumps in wavenumber and phase, depending on the location of the impurity and the average wavenumber in the system. We also show that, for select locations, the jump in the wavenumber vanishes. (Received January 19, 2018)

1136-35-339 **Xiulan Lai*** (xiulanlai@ruc.edu.cn) and **Avner Friedman**. *Mathematical modeling of exosomal microRNAs as biomarkers for lung cancer.* Preliminary report.

Lung cancer, primarily non-small-cell lung cancer (NSCLC), is the leading cause of cancer deaths in the United States and worldwide. While early detection significantly improves five-year survival, there are no reliable diagnostic tools for early detection. Several exosomal microRNAs (miRs) are overexpressed in NSCLC, and have been suggested as potential biomarkers for early detection. In this talk, I want to talk about a mathematical model for early stage of NSCLC with emphasis on the role of the three highest overexpressed miRs, namely miR-21, miR-205 and miR-155. Simulations of the model provide quantitative relationships between the tumor volume and the total mass of each of the above miRs in the tumor. Because of the positive correlation between these miRs in the tumor tissue and in the blood, the results may be viewed as a step toward establishing miRs 21, 205 and 155 as reliable serum biomarkers for early detection of NSCLC. (Received January 19, 2018)

1136-35-352 **Ling Xiao*** (ling.2.xiao@uconn.edu). *Optimal Regularity of Degenerate PDE.*
The equation that a constant curvature graph in hyperbolic space satisfies is degenerate at the boundary. Therefore, it's very interesting to study the regularity of the graph at the boundary. In this talk, we will discuss the optimal regularity of constant curvature graphs in hyperbolic space. This is a joint work with Xumin Jiang. (Received January 19, 2018)

1136-35-358 **Jeremy S LeCrone*** (jlecrone@richmond.edu), 28 Westhampton Way, Univ. of Richmond, VA 23173, and **Gieri Simonett** (gieri.simonett@vanderbilt.edu). *Stability of cylinders in surface diffusion flow under general perturbations.*
The surface diffusion flow is a geometric evolution equation which prescribes the normal velocity of points on immersed, oriented manifolds to equal the Laplace-Beltrami operator acting on the mean curvature at the point. Given a parameterization for the manifold, the morphological evolution of the parameterization is expressed by a fourth-order, quasilinear, parabolic pde. In this talk, I will discuss results regarding well–posedness of surface diffusion under weak regularity assumptions on initial data and stability of unbounded cylinders (as stationary solutions to surface diffusion flow) under general perturbations with periodicity along the cylindrical axis. (Received January 19, 2018)

1136-35-359 **Duong Phong** and **Sebastien Picard***, Department of Mathematics, Columbia University, 2990 Broadway, New York, NY 10027, and **Xiangwen Zhang**. *The Anomaly flow and the Hull-Strominger system.*
The Anomaly flow is a geometric flow which implements the Green-Schwarz anomaly cancellation mechanism originating from superstring theory, while preserving the conformally balanced condition of Hermitian metrics. Its stationary points satisfy the Hull-Strominger system of partial differential equations. The Anomaly flow allows metrics with torsion, and we hope to use it to study non-Kahler complex geometry. I will discuss general features of this flow, and describe its behavior on certain examples. This is joint work with D.H. Phong and X.-W. Zhang. (Received January 19, 2018)

1136-35-360 **Xiaolong Li*** (xiaololo1@uci.edu), **Lei Ni** and **Kui Wang**. *Shrinking Ricci Solitons with Positive Isotropic Curvature.*
We show that a four-dimensional complete gradient shrinking Ricci soliton with positive isotropic curvature is either a quotient of

$$S^4$$

or a quotient of

$$S^3 \times R$$

. This is joint work with Lei Ni and Kui Wang. (Received January 19, 2018)

1136-35-363 **Efstathios Georgios Charalampidis*** (charalamp@math.umass.edu), Department of Mathematics and Statistics, Lederle Graduate Research Tower, University of Massachusetts 710 N. Pleasant S, Amherst, MA 01003-9305. *Formation of rogue waves in continuum and discrete models: Theory and Computation.*
In this talk, we will discuss the dynamics of rogue waves in nonlinear Schrödinger (NLS) equations and discrete variants thereof. Initially, we will consider NLS equations with variable coefficients which can be converted into their integrable siblings by utilizing suitable transformations. Then, the Peregrine soliton will be fed to the transformation employed. Using direct numerical simulations, the formation of such soliton solutions will be presented. Subsequently, and in the realm of atomic Bose-Einstein Condensates (BEC), the IBVP with Gaussian wavepacket initial data for the scalar (NLS) will be discussed where some novel features will be presented. In particular, it will be shown that as the width of the relevant Gaussian is varied, large amplitude excitations strongly reminiscent of Peregrine solitons or regular solitons appear to form. This analysis will be complemented by considering the Salerno model interpolating between the discrete NLS (DNLS) and Ablowitz-Ladik (AL) models where similar phenomenology is observed. The findings presented in this talk might be of particular importance towards realizing experimentally extreme events in BECs. (Received January 19, 2018)

1136-35-365 **Michael Goldberg*** (goldbeml@ucmail.uc.edu). *Exotic weighted Strichartz estimates.* Preliminary report.
We introduce time-weighted Strichartz estimates for the free Schrödinger equation in $\mathbb{R}^n$ that provide more rapid decay at large times than the standard inequalities. In order to achieve this, some trade-offs are necessary. In one example, the initial data belongs to weighted $L^2(\mathbb{R}^n)$, so it requires faster decay in space in order to

extract the additional time-decay. In another example, we show that the time-weighted evolution $te^{-it\Delta}f$ can be approximated by an unweighted solution $e^{-it\Delta}g$, and it is the remainder that satisfies a Strichartz-like bound.

This is joint work with Dmitriy Stolyarov. (Received January 19, 2018)

1136-35-372 **Tuoc Phan*** (phan@math.utk.edu). *Regularity gradient estimates for weak solutions of quasi-linear parabolic equations with singular divergence-free drifts.*

In this talk, we consider a general class of quasi-linear parabolic equations with singular divergence-free drifts. Several results on existence and regularity estimates of Calderón-Zygmund type for gradients of weak solutions will be reported. In particular, results on interior, local boundary, and global regularity estimates in Lorentz spaces for gradients of weak solutions are established. The results are even new when the drifts are identically zero because they do not require solutions to be bounded as in the available results. Some main ideas and outlines of the proofs are also given in the talk. (Received January 20, 2018)

1136-35-393 **Benjamin F. Akers** (benjamin.akers@afit.edu), Department of Mathematics and Statistics, Air Force Institute of Technology, 2950 Hobson Way, WPAFB, OH 45433, **David M. Ambrose** (dma68@drexel.edu), Department of Mathematics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, and **David W. Sulon*** (dws57@drexel.edu), Department of Mathematics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104. *Periodic traveling interfacial hydroelastic waves with or without mass.*

We study the hydroelastic wave problem. First, we prove the existence of families of periodic traveling waves in a global bifurcation theorem; these curves of solutions may terminate with a self-intersecting wave, return to the trivial solution, or alternatively be unbounded. In our formulation, we parametrize the interface in a manner that allows for waves of multivalued height. Given the presence of elastic bending terms, and by using this traveling wave formulation, we are able to apply an "identity plus compact" type of abstract global bifurcation theorem. This theorem requires that our mapping's linearization have a one-dimensional kernel; yet, this kernel may instead be two-dimensional for some parameter values. For the non-resonant case of two-dimensional kernel, we prove the existence of traveling waves by applying an implicit function theorem argument. An approach for the resonant case (i.e. Wilton ripples), which is the subject of current work, is also discussed. (Received January 20, 2018)

1136-35-407 **Yuji Kodama*** (kodama.1@osu.edu), Department of Mathematics, 231 West 18th Ave, Columbus, OH 43210. *On the stability of soliton solution of the KP equation.* Preliminary report.

I will discuss the transversal stability of the KdV soliton in terms of the KP equation. Based on a simple perturbation argument, one can show that an amplitude modulation generates a local phase shift which propagates along the soliton crest. This implies that the soliton is unstable in any norm with the entire $\mathbb{R}^2$. However the phase shift eventually escapes from any compact space in $\mathbb{R}^2$. This result is consistent with the recent result of the stability problem by Mizumachi. (Received January 20, 2018)

1136-35-408 **Yuji Kodama*** (kodama.1@osu.edu), Department of Mathematics, 231 West 18th Ave, Columbus, OH 43210. *On soliton resolution for the KP equation.* Preliminary report.

I will start to give a brief summary of a combinatorial aspect of soliton solutions of the KP equation, the KP solitons. Then I demonstrate numerical results of the KP equation with certain class of initial waves. The goal of the talk is to show how one can predict the asymptotic solutions based on the combinatorial properties of the KP solitons. As a specific example, I will discuss the Mach reflection problem which describes a resonant interaction of solitary waves appearing in the reflection of an obliquely incident wave onto a vertical wall. (Received January 20, 2018)

1136-35-426 **Korobenko Lyudmila** and **Cristian Rios*** (crios@ucalgary.ca), 2500 University Dr. NW, Calgary, AB T2N1N4, Canada, and **Eric Sawyer** and **Ruipeng Shen**. *Infinitely degenerate elliptic equations, Orlicz-Sobolev inequalities, and regularity.*

We implement the DeGiorgi iteration for certain infinitely degenerate elliptic equations under Orlicz-Sobolev a-priori estimates. We obtain boundedness of solutions, maximum principles, and continuity of solutions under stronger structural assumptions. (Received January 21, 2018)

1136-35-462 **Logan F. Stokols*** (lstokols@math.utexas.edu), TX , and **Alexis Vasseur**. *De Giorgi Method: Applications to Highly Non-linear Equations.*

De Giorgi's method was pioneered to attack a linear heat equation with rough (discontinuous) coefficients. The key ingredient, so it seemed, was that the equation was coercive, meaning the second order term could be treated essentially as a Laplacian. This talk, based on joint work with A. Vasseur, will demonstrate how this method can be applied to highly non-linear equations without coercivity. Specifically, we obtain Holder estimates for solutions to second-order Hamilton-Jacobi equations with super-quadratic growth in the gradient and unbounded source term. The estimates are uniform with respect to the smallness of the diffusion and the smoothness of the Hamiltonian. Our work is in the spirit of a result by P. Cardaliaguet and L. Silvestre, and a continuation of a project began by A. Vasseur and C.-H. Chan. (Received January 21, 2018)

1136-35-474 **Leandro A. Lichtenfelz**, **Gerard K. Misiolek** and **Stephen C. Preston*** (`stephen.preston@brooklyn.cuny.edu`). *Axisymmetric ideal fluids on Riemannian 3-manifolds.*

In 3-dimensional Euclidean space, there are three symmetries one can impose to reduce the Euler equations to a manageable system: translational symmetry (which decouples into 2-D Euler and a transported third component); rotational symmetry (to get the axisymmetric equations with swirl); and a "screw" symmetry which combines both. However all these situations are either too simple (due to decoupling) or too complicated (due to singular behavior on the axis and nonconstant coefficients).

In this talk we will present the analogue of axisymmetric fluid flows on Riemannian 3-manifolds, in particular the eight Thurston geometries that have the most symmetries. Some of these geometries even have stagnation-point solutions which reduce to one-dimensional PDEs that are simpler than those appearing in the axisymmetric case. As one example, the reduced equation on $SL_2(\mathbb{R})$ becomes the system

$$\Delta f_t + \{f, \Delta f\} - \{f, g\} = 0, \quad g_t + \{f, g\} = 0$$

for a stream function f and swirl g on $\mathbb{R}^2$, which is analogous to the 2D Boussinesq equation. (Received January 21, 2018)

1136-35-478 **Peter D Miller*** (`millerpd@umich.edu`). *Exact Direct Scattering for the Benjamin-Ono Equation and Applications to Small Dispersion Theory.*

Building on an example calculation described by Kodama, Ablowitz, and Satsuma, we present a general scheme for explicitly solving the direct scattering problem appearing in the solution of the Benjamin-Ono equation by an inverse scattering transform under the dense assumption that the initial condition is a rational function. The resulting explicit formulae for the scattering data exhibit a complexity that grows with the degree of the rational initial data, but that significantly is independent of the dispersion parameter in the Benjamin-Ono equation. It therefore becomes possible to calculate the scattering data for the Benjamin-Ono equation in the small-dispersion limit with great accuracy. This is an essential first step toward a complete understanding of the dynamics of the Benjamin-Ono equation in the small-dispersion limit, for which previous work at various levels of accuracy and rigor suggests the formation of dispersive shock waves that are described by the multi-sheeted solution of the inviscid Burgers equation. This is joint work with Alfredo Wetzel. (Received January 21, 2018)

1136-35-482 **Robert Buckingham*** (`buckinrt@uc.edu`), Department of Mathematical Sciences, The University of Cincinnati, Cincinnati, OH 45221. *Coherent structures in semiclassical soliton ensembles.*

Lax and Levermore showed that solutions of the Korteweg-de Vries equation in the small-dispersion limit exhibit rapid oscillations within slowly modulated envelopes. Similar behavior was shown for the focusing integrable nonlinear Schrodinger equation by Kamvissis, McLaughlin, and Miller using so-called semiclassical soliton ensembles, which are pure soliton intial data intended to approximate more general initial data in the zero-dispersion limit. We will present recent results on soliton ensembles for the three-wave resonant interaction equations. We will also show how the analysis of this system of non-dispersive equations has shed new light on solutions of the nonlinear Schrodinger equation. This is joint work with Robert Jenkins and Peter Miller. (Received January 21, 2018)

1136-35-486 **Jeremy Marzuola**, **Sarah Raynor*** (`raynorsg@wfu.edu`) and **Gideon Simpson**. *Nonlinear Bound States in a Schrödinger-Poisson System with External Potential.*

We consider radial solutions to the Schrödinger-Poisson system in three dimensions with an external smooth potential with Coulomb-like decay. Such a system can be viewed as a model for the interaction of dark matter with a bright matter background in the non-relativistic limit. We find that there are infinitely many critical points of the Hamiltonian, subject to fixed mass, and that these bifurcate from solutions to the associated linear problem at zero mass. As a result, each branch has a different topological character defined by the number of zeros of the radial states. We construct numerical approximations to these nonlinear states along the first several branches. The solution branches can be continued, numerically, to large mass values, where they become asymptotic, under a rescaling, to those of the Schrödinger-Poisson problem with no external potential. Our numerical computations indicate that the ground state is orbitally stable, while the excited states are linearly unstable for sufficiently large mass. (Received January 21, 2018)

1136-35-487 **David M. Ambrose*** (dma68@drexel.edu), 3141 Chestnut St., Philadelphia, PA 19104. *Nonexistence of small doubly periodic waves for dispersive PDE.*

We study the question of existence (more specifically, nonexistence) of spatially periodic, time-periodic solutions for dispersive PDE. Most existence theory for time-periodic solutions of dispersive equations is via small divisor methods, yielding existence of solutions at small amplitudes for certain temporal periods. In joint work with J. Douglas Wright, we have developed a framework to complement existence theory, showing that in other regions of the amplitude-period plane, time-periodic solutions may not exist. This nonexistence theory combines a small divisor estimate for the linear part of the evolution with an estimate for the Duhamel integral for the nonlinearity. In some cases, such as equations with strong dispersion, the estimate for the Duhamel integral can be found by making use of dispersive smoothing estimates. More generally, interpolation may be used instead. The abstract framework is applied to the KdV equation, nonlinear Schrödinger equation, and generalizations. (Received January 21, 2018)

1136-35-489 **Dehua Wang*** (dwang@math.pitt.edu), University of Pittsburgh. *Martingale solutions to the 3D stochastic compressible Navier-Stokes equations.*

Stochastic problems arise in many applications including fluid dynamics and are challenging in mathematical modeling, analysis and computations. The talk will focus on the stochastic partial differential equations for incompressible and compressible flows in fluid dynamics. The known results on the stochastic partial differential equations in fluid dynamics will be surveyed, and new recent results will be presented. (Received January 21, 2018)

1136-35-531 **Mathew Johnson*** (matjohn@ku.edu), Lawrence, KS. *Spectral Stability of Inviscid Roll Waves.* Preliminary report.

In this talk, I will discuss recent progress concerning the spectral stability of roll waves, which are well observed hydrodynamic instabilities occurring in inclined thin film flow. In particular, I will present results from a recent systematic analytical and numerical study of spectral stability of discontinuous roll waves solutions of the inviscid St. Venant equations, based on a periodic Evans-Lopatinski determinant analogous to the periodic Evans function of Gardner in the (smooth) visor case. This is joint work with Pascal No bel, Miguel Rodrigues, Zhao Yang, and Kevin Zumbrun. (Received January 22, 2018)

1136-35-539 **Gino Biondini** and **Dionyssios Mantzavinos*** (mantzavinos@ku.edu). *Long-time asymptotics for the focusing nonlinear Schrödinger equation and the nonlinear stage of modulational instability.*

The long-time asymptotic behavior for the focusing nonlinear Schrödinger equation with nonzero boundary conditions at infinity is characterized via the Deift-Zhou nonlinear steepest descent method for oscillatory Riemann-Hilbert problems. In particular, the growing jumps in the Riemann-Hilbert problem — which are the signature of the modulational instability — are regularized via the Deift-Zhou method by appropriate deformations in different regions of the xt-plane. The various kinds of deformations correspond to different asymptotic behavior for the solution. More specifically, the xt-plane decomposes into three regions: a left far-field and a right far-field, in which the solution equals the boundary condition to leading order, and a central region in which the asymptotic behavior is described by slowly modulated periodic oscillations. This is joint work with Gino Biondini. (Received January 22, 2018)

1136-35-544 **Hongqiu CHEN*** (hchen1@memphis.edu), University of Memphis, Department of Mathematical Sciences, 373 Dunn Hall, Memphis, TN 38152, and **Xiaojune Wang**. *Stability of solitary wave solutions to a coupled system.*

Considered here is a system

$$U_t + U_x - U_{xxt} + (\nabla H(U))_x = 0 \tag{1}$$

of nonlinear dispersive equations, where $U = U(x,t)$ is an $\mathbb{R}^2$-valued function, and ∇H is the gradient of a homogeneous polynomial function $H : \mathbb{R}^2 \to \mathbb{R}$ of degree $p \geq 3$. We present existence of explicit solitary wave solutions. Using the idea by Bona, Chen and Karakashian and exploiting the accurate point spectrum information of the associated Schrödinger operator, we derive a simple algebraic condition for stability of the explicit solitary wave solutions, which improves the stability results previously obtained by Pereira and also observe the criteria for instability of solitary wave solutions. (Received January 22, 2018)

1136-35-560 **Alim Sukhtayev*** (sukhtaa@miamioh.edu), Department of Mathematics, 123 Bachelor Hall, 301 S. Patterson Ave., Oxford, OH 45056, and **Margaret Beck**, **Graham Cox**, **Chris Jones** and **Yuri Latushkin**. *A dynamical approach to semilinear elliptic equations.*

We describe a procedure for reducing a semilinear elliptic PDE to an (infinite-dimensional) dynamical system on the boundary of some fixed bounded domain $\Omega \subset \mathbb{R}^n$.

Suppose u satisfies the equation $\Delta u + F(x,u) = 0$ on $\mathbb{R}^n$. When the domain is deformed through a one-parameter family $\{\Omega_t\}$, it is shown that the Cauchy data of u on $\partial\Omega_t$ satisfies a Hamiltonian evolution equation. If Ω is deformed smoothly to a point, this equation admits an exponential dichotomy, with the unstable subspace at time t corresponding to the Cauchy data of weak solutions to the PDE on Ω_t. (Received January 22, 2018)

1136-35-573 **Annalisa M. Calini*** (calinia@cofc.edu) and **Constance M. Schober**. *Linear Instability of the Peregrine Breather: Numerical and Analytical Investigations.*

We study the linear stability of the Peregrine breather both numerically and with analytical arguments based on its derivation as the singular limit of a single-mode spatially periodic breather as the spatial period becomes infinite. By constructing solutions of the linearization of the nonlinear Schrödinger equation in terms of quadratic products of components of the eigenfunctions of the Zakharov-Shabat system, we show that the Peregrine breather is linearly unstable. A numerical study employing a highly accurate Chebychev pseudo-spectral integrator confirms exponential growth of random initial perturbations of the Peregrine breather. (Received January 22, 2018)

1136-35-577 **Jae Min Lee*** (jlee10@gradcenter.cuny.edu), 365 Fifth Avenue, Room 4208, New York, NY 10016. *Geometric approach on the global conservative solutions of the Camassa-Holm equation.*

We construct global weak conservative solutions of the Camassa-Holm equation on the periodic domain. We first express the equation in Lagrangian flow variable η and then transform it using a simple change of variable $\rho = \sqrt{\eta_x}$. The new variable removes the singularity of the Camassa-Holm equation, and we obtain both global weak conservative solutions and global spatial smoothness of the Lagrangian trajectories, which were originally discovered by Bressan-Constantin and McKean, respectively. This work is inspired by J. Lenells who proved similar results for the Hunter-Saxton equation using the geometric interpretation. (Received January 22, 2018)

1136-35-582 **Robert L Pego*** (rpego@cmu.edu). *Weakly singular shock profiles for a regularized shallow water system.* Preliminary report.

This is a preliminary report describing weakly singular traveling waves for a Green-Naghdi type conservative regularization of the shallow water equations as recently derived by D. Clamond and D. Dutykh. (Received January 22, 2018)

1136-35-596 **Jared C. Bronski*** (bronski@illinois.edu), University of Illinois, Department of Mathematics, Urbana, IL 61801. *Stability of Quasiperiodic solutions to equations of nonlinear Schrodinger type.*

We present some recent progress on the modulational stability of quasi-periodic solutions to evolution equations of nonlinear Schrodinger type. The quasi-periodic solutions can be viewed as relative critical points of the energy subject to four constraints: fixed period, mass, momentum and Floquet exponent. From the point of view of Whitham theory the modulational stability reduces to computing the eigenvalues of a four by four matrix that can be built up out of the four previously mentioned quantities. This is joint work with Robert Marangell and Mat Johnson. (Received January 22, 2018)

1136-35-624 **Barbara Lee Keyfitz***, 231 W 18th Avenue, Columbus, OH 43210. *L^2 stability for conservation laws.*

We show by and example that it is unlikely that we will be able to prove classical L^2 stability for hyperbolic conservation laws. (Received January 23, 2018)

1136-35-631 **David V. Cruz-Uribe*** (dcruzuribe@ua.edu), **Scott Rodney** and **Emily Rosta**. *Poincare inequalities and Neumann problems for the p-Laplacian.*

We explore the equivalence between weighted Poincare inequalities and the existence of weak solutions to Neumann problems related to a p-Laplacian with rough coefficients. We work in the setting of degenerate Sobolev spaces where the degeneracy of the gradient is controlled by a symmetric matrix. (Received January 24, 2018)

37 ► Dynamical systems and ergodic theory

1136-37-36 **Paul G Cornwell***, 120 E Cameron Ave, 329 Phillips Hall, Chapel Hill, NC 27599, and **Christopher K.R.T. Jones**. *Calculating the Maslov index for traveling waves in singularly perturbed systems.*

The Maslov index is a powerful tool in the stability analysis of nonlinear waves. As a generalization of Sturm-Liouville theory, it provides the ideal result of stability analyses; spectral information is encoded in qualitative properties of the wave itself. Although theorems exist relating the Maslov index to stability, calculating the index is difficult in practice. In this talk, we provide a framework for calculating the index for traveling waves in singularly perturbed reaction-diffusion equations. The key insight is (the general fact) that the index is encoded in the twisting of an unstable manifold for the traveling wave equation. Using Fenichel theory, the index can then be calculated by following this manifold around phase space. We perform this calculation for a doubly-diffusive FitzHugh-Nagumo equation and prove that fast traveling waves are stable. (Received December 05, 2017)

1136-37-67 **Veronica Ciocanel*** (ciocanel.1@mbi.osu.edu), 1735 Neil Ave, Columbus, OH 43210, and **Bjorn Sandstede**. *Modeling Microtubule-based Transport in the Frog Egg Cell.*

In the development of egg cells into embryos, spatial differentiation is essential in determining the role of the new embryo cells in the growing organism. This spatial patterning often relies on asymmetric accumulations and transport of proteins in the egg cell. In the frog, messenger RNA (mRNA) dynamically switches between diffusion and active transport states in its journey to the periphery of the egg cell, where it accumulates and creates a spatial axis of development. Using dynamical systems modeling and analysis, we investigate the transport of mRNA and its dependence on cytoskeleton in the egg cells consisting of microtubules. Numerical studies using model microtubule structures allow us to predict that an anchoring mechanism at the cell periphery may be key in healthy development. (Received December 30, 2017)

1136-37-619 **Aaron W Brown***, 5734 S University Ave, Chicago, IL 60637. *Recent progress in the Zimmer program.*

The Zimmer program refers to a number of questions and conjectures about actions of certain discrete groups, namely, lattices in higher-rank simple Lie groups. The primary example example of a such a group is $\mathrm{SL}(n,\mathbb{R})$.

In the past few years, there has been significant progress in the Zimmer program. In my talk, I will discuss a recent proof of Zimmer's conjecture which shows that (cocompact and certain non-uniform) higher-rank lattices do not act on manifolds with low dimension. I will also discuss recent results and work in progress that classify all possible non-trivial actions under certain dynamical or dimension assumptions. (Received January 22, 2018)

39 ► Difference and functional equations

1136-39-10 **Gro Hovhannisyan*** (ghovhann@kent.edu), 6000 Frank Ave NW, North Canton, OH 44720. *Schwarzian equation on a time scale.* Preliminary report.

We introduce the Schwarzian on a time scale invariant under the fractional linear transformations. As an application we establish the invariant disconjugacy condition for second order dynamic equations on a time scale. We consider also Ermakov dynamic equations, and the Ermakov-Lewis adiabatic invariant on a time scale. (Received September 28, 2017)

1136-39-211 **Ferhan M. Atici*** (ferhan.atici@wku.edu), Western Kentucky University, Department of Mathematics, Bowling Green, KY 42101, **Mustafa Atici** (mustafa.atici@wku.edu), Western Kentucky University, Computer Science, Bowling Green, KY 42101, **Dana Marshall**, Meharry Medical College, Nashville, TN , and **Ngoc Nguyen** (ngoc.nguyen@wku.edu), Western Kentucky University, Department of Mathematics, Bowling Green, KY 42101. *Discrete Fractional Models of Tumor Growth in Mice.* Preliminary report.

Describing tumor growth in mice with mathematical models can be categorized in two groups: Tumor growth in untreated mice and tumor growth in treated mice with anticancer therapeutics. For each group, we formulate the models with fractional difference equations and estimate the parameters for data fitting. (Received January 16, 2018)

41 ► Approximations and expansions

1136-41-30 **Winfried Sickel*** (winfried.sickel@uni-jena.de), Institute of Mathematics, University of Jena, Ernst-Abbe-Platz 2, D-07743 Jena, Germany. *Approximation Numbers of Embeddings of Anisotropic Sobolev Spaces of Dominating Mixed Smoothness – Preasymptotics and Asymptotics.*

We investigate the approximation of d-variate periodic functions in anisotropic Sobolev spaces of dominating mixed (fractional) smoothness $(s_1, \ldots, s_d)$ on the d-dimensional torus, where the approximation error is measured in the L_2-norm.

As it is well-known, in high dimensions functions from isotropic Sobolev spaces can not be approximated sufficiently fast (in the sense of approximation numbers of corresponding embeddings). One needs to switch to smaller spaces. A way out is to sort the variables in dependence of there importance. We associate to each variable different smoothness assumptions. This philosophy is reflected in the choice of the function space - the periodic anisotropic Sobolev spaces of dominating mixed smoothness. It will be the main aim of my talk to describe the behaviour of corresponding approximation numbers in dependence of $n, s_1, \ldots, s_d, \nu$ and d.

This is joined work with Thomas Kühn (Leipzig) and Tino Ullrich (Bonn). (Received December 01, 2017)

1136-41-80 **Walter Van Assche*** (walter@wis.kuleuven.be), Department of Mathematics, KU Leuven, Celestijnenlaan 200B box 2400, 3001 Leuven, Belgium. *Simultaneous Gauss quadrature and multiple Hermite polynomials.*

Multiple Hermite polynomials are an extension of the classical Hermite polynomials for which orthogonality conditions are imposed with respect to $r > 1$ normal (Gaussian) weights with different means c_i, $1 \leq i \leq r$. These polynomials have a number of properties, such as a Rodrigues formula, recurrence relations (connecting polynomials with nearest neighbor multi-indices), a differential equation, etc. The asymptotic distribution of the (scaled) zeros is well understood and an interesting new feature happens: depending on the distance between the means c_i, $1 \leq i \leq r$, the zeros may accumulate on s disjoint intervals, where $1 \leq s \leq r$. We will use the zeros of these multiple Hermite polynomials to approximate integrals of the form $\int_{-\infty}^{\infty} f(x) \exp(-x^2 + c_j x)\, dx$ simultaneously for $1 \leq j \leq r$. (Received January 03, 2018)

1136-41-105 **Archil Gulisashvili*** (gulisash@ohio.edu), Department of Mathematics, Ohio University, Athens, OH 45701. *Asymptotic approximations in the theory of stochastic volatility models.*

Asymptotic approximations play an important role in financial mathematics. Since there is often a lack of simple explicit expressions for various quantities arising in the mathematical theory of finance, e.g., asset price densities, option pricing functions, and the implied volatility, finding sharp asymptotic approximations to these quantities becomes an important practical problem. In the talk, we present recent results concerning applications of asymptotic analysis to the theory of stochastic volatility models. In such models, the random dynamics of the volatility are described by a stochastic process. We will discuss sharp approximation formulas with error estimates for asset price densities, option pricing functions, and the implied volatility in stochastic volatility models. The following asymptotic regimes are employed in our work: small-noise, small-time, and extreme strike regimes. Approximation formulas for the above-mentioned quantities are obtained using diverse techniques, which include methods of asymptotic and stochastic analysis, Tauberian theorems, self-similarity, and large deviation principles. (Received January 05, 2018)

1136-41-308 **Petr Gurka*** (gurka@tf.czu.cz), Department of Mathematics, Czech University of Life Sciences in Prague, 16521 Prague, Czech Rep. *Asymptotic estimates of s–numbers of Hardy-type operators.*

In a quite recent paper of D. E. Edmunds and J. Lang, Asymptotic formulae for s-numbers of a Sobolev embedding and a Volterra type operator published in Rev. Mat. Complut., 29(1), 2016) the authors obtained sharp upper and lower estimates of the approximation numbers of a Sobolev embedding involving second derivatives and of a corresponding integral operator of Volterra type. Possible extensions of these results for higher order derivatives will be discussed. (Received January 19, 2018)

1136-41-400 **Ovidiu Costin*** (costin.9@osu.edu), The Ohio State University, Mathematics Department, 231 W 18th Ave, Columbus, OH 43210, and **Rodica D Costin** and **Gerald Dunne**. *New techniques of global approximation of special functions.*

Most special functions admit asymptotic expansions as combinations of exponentials, asymptotic power series and sometimes logs. The asymptotic power series involved are most often divergent. It turns out, perhaps surprisingly, that these series can be replaced with geometrically convergent rational function series throughout the domain of asymptoticity. The new representations are numerically efficient as well. (Received January 20, 2018)

1136-41-504 **Amos Ron*** (amos@cs.wisc.edu) and **Shengnan Wang**. *Acyclic resolutions of multivariate splines.*

Cone polynomials are the polynomials that appear in the local structure of the truncated powers, hence in the local structure of box splines, simplex splines, partition functions, character formulas and moment maps. The underlying geometry is determined by a real linear matroid, i.e., a real matrix X. The cone polynomial space itself is defined as the kernel of an ideal $J(X)$ of differential operators. As of today, the algebraic structure of the cone polynomial space is considered to be hopelessly involved: basis constructions for it are scarce, and provide neither an insight nor an aid in pertinent applications.

We study the above setup when X is the incidence matrix of a graph G. We first resolve the ideal $J(X)$ by representing it as the intersection of complete intersection (CI) ideals. Each CI ideal J_i is induced by an acyclic directed version with one source G_i of the graph G. Kernels of CI ideals have 1-dimensional socles, and the final outcome is a resolution of the cone polynomial space into a direct sum of these 1-dimensional socles. This decomposition is an algebraic realization of a combinatorial graph identity: the number of trees of the graph with 0 external activity equals the number of acyclic orientations with one source. (Received January 22, 2018)

42 ► Fourier analysis

1136-42-127 **Desai Cheng*** (chengdesai@yahoo.com), 311 Hamilton Rd., Ridgewood, NJ 07450, and **Peter Casazza**, **Sara Botelho-Andrade** and **Tin T Tran**. *The solution to the frame Quantum Detection Problem.*

We will give a complete solution to the frame quantum detection problem. We will solve both cases of the problem: the quantum injectivity problem and quantum state estimation problem. We will answer the problem in both the real and complex cases and in both the finite dimensional and infinite dimensional cases.
(Received January 08, 2018)

1136-42-216 **Mark Magsino*** (mmagsino@math.umd.edu). *Constructing Tight Gabor Frames Using CAZAC Sequences.*

The construction of finite tight Gabor frames plays an important role in many applications which include signal and image processing. We explore when constant amplitude zero autocorrelation (CAZAC) sequences can be used to generate tight Gabor frames. The main theorem uses Janssen's representation and the zeros of the discrete periodic ambiguity function to give necessary and sufficient conditions for determining whether a Gabor frame is tight. The relevance of the theorem depends significantly on the construction of examples. These examples are necessarily intricate, and depend on CAZAC sequences. To conclude, we present an alternate method for determining when Gabor frames are tight. This alternate method uses the Gram matrix of the Gabor system instead. (Received January 16, 2018)

1136-42-226 **Matthew Fickus*** (matthew.fickus@afit.edu). *Equiangular tight frames and combinatorial designs.*

An equiangular tight frame (ETF) is a type of optimal packing of lines in a real or complex Euclidean space. ETFs arise in several applications, involving waveform design for communications, compressed sensing, quantum information theory and algebraic coding theory. In the complex case, many fundamental problems concerning the existence of ETFs remain glaringly open. All known positive existence results are by explicit construction. In particular, beyond orthonormal bases and regular simplices, all known infinite families of ETFs arise from combinatorial designs. We give an overview of these constructions, and then use them to formulate some plausible conjectures regarding ETF existence. (Received January 16, 2018)

1136-42-279 **Lenka Slavíková*** (slavikoval@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *An optimal criterion for $L^2 \times L^2 \to L^1$ boundedness.*

In the absence of Plancherel's identity on L^1, we obtain a nearly sharp condition for bilinear multiplier operators to be bounded from $L^2 \times L^2 \to L^1$. We discuss applications concerning bilinear rough singular integrals and spherical maximal functions. This is a joint work with L. Grafakos and D. He. (Received January 18, 2018)

1136-42-442 **X Chen**, **E Goodman**, **V Gonzales** and **K Okoudjou*** (kasso@math.umd.edu), 2111 Kirwan Hall, Department of Mathematics, University of Maryland, College Park, MD. *New results in minimizing the p-frame potentials.* Preliminary report.

Given $d \geq 2$, $p \in (0, \infty]$, and $N \geq 2$, let

$$\mu_{p,d,N} = \min\left\{ \sum_{k,\ell=1}^{N} |\langle \varphi_k, \varphi_\ell \rangle|^p : \{\varphi_k\}_{k=1}^{N} \subset S^{d-1} \right\}$$

where S^{d-1} is the unit sphere in $\mathbb{R}^d$. Of the many questions one can ask about this function, two are of interest to us in this talk:

- For fixed d and N, find an explicit formula for the function $\mu_{p,d,N}$.
- For fixed d and N, what are the optimal configurations $\{\varphi_k\}_{k=1}^{N} \subset S^{d-1}$?

Answers to these questions are known in certain cases, e.g., when $p = 2$ Benedetto and Fickus proved that FUNTFs are the optimal configurations. In addition, for certain values of p, the optimal configurations are related to ETFs or Grassmannian frames.

In this talk, we shall report on recent progress made in finding in answering these question for $d = 2$ and $N \geq 4$. In addition we shall present some numerical results for the case $d \geq 3$, and $N = d + 1$.

This talk is based on joint work with X. Chen, E. Goodman, and V. Gonzales. (Received January 21, 2018)

1136-42-447 **Li-An Daniel Wang*** (daniel.wang@shsu.edu), 1900 Ave I, LDB Suite 420, Huntsville, TX 77340, and **Marcin Bownik**. *A PDE characterization of anisotropic Hardy spaces.* Preliminary report.

Classically, real Hardy spaces were characterized by the heat equation and the Poisson equation, and in recent decades, these have generalized into Hardy spaces associated with differential operators. Anisotropic Hardy spaces, motivated by wavelet theory, has an inherent discrete structure that does not seem compatible with differential operator formulation. In this talk, we see how such a characterization does exist, and see how this approach naturally give rise to potentially new Hardy spaces. (Received January 21, 2018)

45 ► Integral equations

1136-45-409 **Christopher S. Goodrich*** (cgood@prep.creighton.edu), Creighton Preparatory School, 7400 Western Ave., Omaha, NE 68114. *Coercivity Conditions and their Application to Nonlocal Boundary Value Problems.*

I will consider perturbed Hammerstein integral equations, of which one example is

$$y(t) = \gamma(t)H\big(\varphi(y)\big) + \lambda \int_0^1 G(t,s)f\big(s, y(s)\big)\, ds.$$

In the above equation $\varphi(y)$ is a linear functional, and so, solutions of this type of integral equation can be related to solutions of nonlocal boundary value problems. I will demonstrate that by requiring the coercivity-type condition $\varphi(y) \geq C_0\|y\|$ for a constant $C_0 > 0$ and all y in a particular cone, the existence-type results associated to the above problem can be improved. A particular application will be to show that under reasonable assumptions the above problem can admit a positive solution even if $f(t,y) < 0$ for all (t,y) and $\lim_{y\to\infty} f(t,y) = -\infty$. (Received January 20, 2018)

46 ► Functional analysis

1136-46-15 **Zead Mustafa*** (zead@qu.edu.qa), Department of Mathematics, Statistics and Phy, Doha, 2713, Qatar. *Some common fixed point results on D^*-metric spaces using (E.A) property.*

In this paper, we introduce some new types of pairs of mappings (f, g) on D^*-metric spaces called D^*-weakly commuting of type D_f^* and D^*-R-weakly commuting of type D_f^*. Also we obtain several common fixed point results by using these types of mappings and (E.A) property. Further examples are presented to show that D^*-metric is totaly different from G-metric. (Received October 22, 2017)

1136-46-28 **Dorothee D. Haroske*** (dorothee.haroske@uni-jena.de), Friedrich Schiller University Jena, Institute of Mathematics, 07737 Jena, Germany. *Morrey spaces on domains.*

We deal with Morrey spaces on bounded domains Ω obtained by different approaches. We study their connections and diversities, as well as their growth envelopes. Then we report about recent related results for smoothness

Morrey spaces, and indicate some applications. This is joint work with Susana Moura (Coimbra), Cornelia Schneider (Erlangen-Nuremberg) and Leszek Skrzypczak (Poznań). (Received January 10, 2018)

1136-46-72 **Menita Carozza** and **Andrea Cianchi*** (andrea.cianchi@unifi.it), Viale Morgani 67/A, 50134 Firenze, Italy. *Smooth approximation of Orlicz-Sobolev maps between manifolds.*

The problem of density of smooth functions in Orlicz-Sobolev spaces of maps between compact manifolds, without topological restrictions, is addressed. Our contribution refines earlier results in the literature via ad hoc Orlicz space techniques. (Received January 01, 2018)

1136-46-76 **Lubos Pick*** (pick@karlin.mff.cuni.cz), KMA MFF UK Sokolovska 83 18675 Praha 8, 18675 Prague, Czech Rep. *Sobolev embeddings, rearrangement-invariant spaces and Frostman measures.*

We study Sobolev embeddings into rearrangement-infariant (r.i.) spaces in an open subset Ω in $\mathbb{R}^n$ endowed with a Borel measure. We say that a Borel measure μ is a Frostman measure on Ω provided that it obeys the decay condition

$$\sup_{x\in\mathbb{R}^n, r>0} \frac{\mu(B_r(x)\cap\Omega)}{r^d} < \infty$$

for some $d \in (0, n]$. Here, $B_r(x)$ denotes the ball centered at x, with radius r. Given a couple of r.i. spaces $X(\Omega)$ and $Y(\overline{\Omega}, \mu)$, we consider Sobolev-type embeddings of the form

$$W^m X(\Omega) \to Y(\overline{\Omega}, \mu).$$

A very important special case of such embedding is the trace embedding which is achieved by taking for μ the d-dimensional Hausdorff measure concentrated on a (nonempty) intersection of Ω with a d-dimensional hyperplane. It turns out that the cases $d < n-m$ and $d \geq n-m$ are quite different in nature and have to be treated separately. (Received January 02, 2018)

1136-46-149 **Zdeněk Mihula*** (mihulaz@karlin.mff.cuni.cz), Sokolovská 83, 186 75 Praha 8, Czech Rep. *On Compactness of Sobolev Trace Embeddings.*

We investigate compactness of Sobolev trace embeddings in the scope of rearrangement–invariant spaces. We show that compactness of a Sobolev trace embedding is equivalent to compactness of a one-dimensional Hardy type operator. We also show that compactness of Sobolev trace embeddings has an intimate connection with optimal spaces and the concept of almost-compact embeddings. (Received January 10, 2018)

1136-46-150 **Dorothee D. Haroske*** (dorothee.haroske@uni-jena.de), Friedrich Schiller University Jena, Institute of Mathematics, Jena, Germany. *Embeddings of weighted spaces of Morrey type.*

We consider embedding theorems within the scale of weighted Morrey spaces $\mathcal{M}_{u,p}(\mathbb{R}^n, w)$, where the weight w belongs to the Muckenhoupt class $\mathcal{A}_\infty$ and $0 < p \leq u < \infty$. This includes, in particular, the classical setting of weighted Lebesgue spaces. We study some typical examples for the weight like $w(x) = |x|^\alpha$, $\alpha > -n$, but also deal with quite general assumptions. Finally, we shall also consider weighted embeddings of smoothness spaces of Morrey type.

This is joint work with Leszek Skrzypczak (Poznań). (Received January 10, 2018)

1136-46-182 **Alexandru Chirvasitu*** (achirvas@buffalo.edu). *Quantum isometries.* Preliminary report.

Compact quantum groups are the non-commutative geometer's version of a compact group, and their actions on geometric or algebraic objects capture extended notions of symmetry, generalizing the concept of a structure-preserving automorphism.

The talk will explain what it means for a compact quantum group action on a compact metric measure space to preserve the entirety of the structure (metric as well as measure-theoretic). The main result is then a reflection of the general intuition that most objects are not very symmetric: upon topologizing the set of isomorphism classes of metric measure spaces, it transpires that a "large" collection of them admit no symmetry, even when relaxing the notion of symmetry to allow for its quantum counterpart.

(partly joint w/ Martino Lupini, Laura Mančinska and David Roberson) (Received January 13, 2018)

1136-46-284 **Kaifeng Bu**, **Arthur Jaffe** and **Zhengwei Liu*** (zhengweiliu@fas.harvard.edu), 17 Oxford Street, Cambridge, MA 02138, and **Jinsong Wu**. *A de Finetti theorem on parafermion algebras.* Preliminary report.

The de Finetti theorem is a powerful tool relating symmetry and independence of random variables. It also plays a significant role in quantum information theory. We prove a new de Finetti theorem on non-commutative parafermion algebras, with respect to the natural braid-group symmetry. We show that a braid-invariant state is extremal if and only if it is a product state. Furthermore, we provide an explicit characterization of braid-invariant states, such that the parafermion algebra generates a factor under the Gelfand-Naimark-Segal construction. (Received January 18, 2018)

1136-46-289 **Lauren C. Ruth*** (ruth@math.ucr.edu). *Two new settings for examples of von Neumann dimension.*

Let $G = PSL(2,\mathbb{R})$, let Γ be a lattice in G, and let $\mathcal{H}$ be an irreducible unitary representation of G with square-integrable matrix coefficients. A theorem in Goodman–de la Harpe–Jones (1989) states that the von Neumann dimension of $\mathcal{H}$ as a $W^*(\Gamma)$-module is equal to the formal dimension of the discrete series representation $\mathcal{H}$ times the covolume of Γ, calculated with respect to the same Haar measure. We will present two results inspired by this theorem. First, we show there is a representation of $W^*(\Gamma)$ on a subspace of cuspidal automorphic functions in $L^2(\Lambda\backslash G)$, where Λ is any other lattice in G, and $W^*(\Gamma)$ acts on the right; and this representation is unitarily equivalent to one of the representations in [GHJ]. Next, we calculate von Neumann dimensions when G is $PGL(2,F)$, for F a local non-archimedean field of characteristic 0 with residue field of order not divisible by 2; Γ is a torsion-free lattice in $PGL(2,F)$, which, by a theorem of Ihara, is a free group; and $\mathcal{H}$ is the Steinberg representation, or a depth-zero supercuspidal representation, each yielding a different dimension. (Received January 18, 2018)

1136-46-327 **Richard M Aron*** (aron@math.kent.edu), Department of Mathematical Sciences, Kent State University, Kent, OH 44242. *Restrictions of surjective mappings.*

This will be a brief synopsis of recent work with J. Jaramillo, Enrico Le Donne, and Thomas Ransford on the following problem: *Let $f : X \to Y$ be a "good"* surjective *mapping between Banach or complete metric spaces.* **Question:** *When is there a subspace $Z \subset X$ having the same "size" as X such that $f|_Z$ is surjective?* When X and Y are Banach spaces and f is a bounded linear operator, the answer is "yes, always" (Bartle-Graves). However, we will see that the situation is much more interesting for non-linear mappings. (Received January 19, 2018)

1136-46-502 **Ales Nekvinda*** (ales.nekvinda@cvut.cz), Faculty of Civil Engineering, Department of Mathematics, Thákurova 7, 166 29 Prague 6, Czech Rep. *A characterization of functions with zero trace.*

Let $X(\Omega)$ be a Banach function space of certain properties defined on a slightly regular domain Ω. Consider a Sobolev space $W^k(X)$. A characterization of $W^k_0(X(\Omega))$ (a subspace of all functions vanishing at the boundary) will be given by a distance function. (Received January 22, 2018)

1136-46-538 **Michael Brannan***, Texas A&M University, College Station, TX 77843, and **Benoit Collins**, **Hun-Hee Lee** and **Sang-Gyun Youn**. *Quantum groups, quantum channels, and the quantum 6j-symbols.*

I will discuss an application of the representation theory of a class of free orthogonal quantum groups to the construction and analysis of interesting examples of quantum channels. I will explain how the (planar) structure of their representation categories can be used to gain a great deal of insight into the algebraic and geometric properties of the channels under consideration. I will, in particular, highlight how the quantum 6j-symbols come into play in the analysis. (Received January 22, 2018)

1136-46-575 **O Mendez*** (osmendez@utep.edu), 500 W University Ave., 124 Bell Hall, El Paso, TX 79968. *A Sobolev embedding theorem for Sobolev spaces of Musielak-Orlicz type and Applications.* Preliminary report.

The compactness of the Sobolev embedding for Musielak-Orlicz spaces by way of simple conditions will be presented. Applications to partial differential equations are given. (Received January 22, 2018)

47 ► Operator theory

1136-47-66 **Maxim Derevyagin*** (derevyagin.m@gmail.com), University of Mississippi, Department of Mathematics, Hume Hall 305, P. O. Box 1848, University, MS 38677-1848. *Complex Jacobi matrices and zeroes of hypergeometric functions.*

At first, it will be shown how ratios of hypergeometric functions arise as m-functions of complex Jacobi matrices. Then, we will see how one can use the theory of non-Hermitian Jacobi matrices to get new insights on the problem of determining zeroes of hypergeometric functions, which goes back to Klein, Hurwitz, and Van Vleck. (Received December 29, 2017)

1136-47-113 **Nihat Gokhan Gogus** (nggogus@sabanciuniv.edu), Istanbul, Turkey, and **Sonmez Sahutoglu*** (sonmez.sahutoglu@utoledo.edu), Department of Mathematics and Statistics, Toledo, OH 43606. *Schatten class Hankel and $\overline{\partial}$-Neumann operators.*

Let Ω be a C^2-smooth bounded pseudoconvex domain in $\mathbb{C}^n$ for $n \geq 2$ and let φ be a holomorphic function on Ω that is C^2-smooth on the closure of Ω. We prove that if $H_{\overline{\varphi}}$ is in Schatten p-class for $p \leq 2n$ then φ is a constant function. As a corollary, we show that the $\overline{\partial}$-Neumann operator on Ω is not Hilbert-Schmidt. This is joint work with Nihat Gökhan Göğüş (Received January 06, 2018)

1136-47-263 **Plamen Iliev*** (iliev@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332-0160. *Krall commutative algebras of partial differential operators.*

In 1938, Krall posed the problem to determine all families of orthogonal polynomials which are eigenfunctions of a differential operator of arbitrary order. General bispectral techniques, based on the Darboux transformation, were used to construct a large collection of solutions to Krall's problem. I will discuss another method motivated by solitons, which allows to characterize the commutative algebra of all differential operators for each family of Krall polynomials, and which leads to multivariable extensions. (Received January 18, 2018)

1136-47-301 **Vit Musil*** (musil@karlin.mff.cuni.cz), Charles University, Faculty of Mathematics and Physics, Prague, Czech Rep, and **Jan Lang** (lang@math.osu.edu), Ohio State University, Columbus, OH. *Strict s-numbers of non-compact Sobolev embeddings into continuous functions.*

For limiting non-compact Sobolev embeddings into continuous functions we study behavior of Approximation, Gelfand, Kolmogorov, Bernstein and Isomorphism s-numbers. In the one dimensional case the exact values of the above-mentioned strict s-numbers were obtained and in the higher dimensions sharp estimates for asymptotic behavior of strict s-numbers were established. As all known results for s-numbers of Sobolev type embeddings are studied mainly under the compactness assumption then our work is an extension of existing results and reveal an interesting behavior of s-numbers in the limiting case when some of them (Approximation, Gelfand and Kolmogorov) have positive lower bound and others (Bernstein and Isomorphism) are decreasing to zero. From our results also follows that such limiting non-compact Sobolev embeddings are finitely strictly singular maps. (Received January 19, 2018)

1136-47-336 **Boris S Mityagin*** (boris.mityagin@gmail.com). *"Arcsine" law for anharmonic operators.* Preliminary report.

Consider a Schrödinger operator $A = -\frac{d^2}{dx^2} + Q(x)$, where $Q(x) \in C^2(\mathbb{R})$ is a real, even, convex, slowly changing potential. Let $A\psi_k = \lambda_k \psi_k$, $\|\psi_k\| = 1$, $k \in \mathbb{N}$ be a complete system of eigenfunctions, and let the turning points $x_k > 0$ be defined by $Q(x_k) = \lambda_k$. Assume that $Q(x)$ satisfies

$$\lim_{x\to\infty} \frac{Q(tx)}{Q(x)} = t^\beta, \quad \beta \geq 2.$$

Rescale measures, or their densities, on $\mathbb{R}$ by

$$\varphi_k(x) = x_k \psi_k^2(x_k x).$$

Then for any f in the Schwartz space on $\mathbb{R}$,

$$\lim_{k\to\infty} \int_{-\infty}^{\infty} f(x)\varphi_k(x)\,dx = c(\beta)\int_{-1}^{1} f(x)\frac{dx}{(1-|x|^\beta)^{1/2}}$$

where $c(\beta) = \frac{\Gamma(\frac{1}{2}+\frac{1}{\beta})}{2\pi^{1/2}\Gamma(1+\frac{1}{\beta})}$. Such statements, in the context of the theory of orthogonal polynomials, are well known (Rakhmanov, Mhaskar, Saff, Lubinsky).

These are preliminary results of a joint work of the speaker, Petr Siegl (Queen's University, Belfast, UK) and Joseph Viola (University of Nantes, France). (Received January 19, 2018)

1136-47-602 **Jan Lang*** (lang@math.osu.edu), Department of Mathematical Sciences, The Ohio State University, Columbus, OH 43210-1174, and **Lyonell Boulton**, Department of Mathematics and, Maxwell Institute for Mathematical Sciences, Edinburgh, Sctland EH14 4AS, United Kingdom. *A non-linear biharmonic operator, higher order Sobolev embeddings and generalized trigonometric functions.* Preliminary report.

We study a non-linear p,q-biharmonic eigenvalue problem on the unit segment subject to Navier boundary condition. We determine a variational formulation of this problem, which relates it with the s-numbers of higher order Sobolev embeddings. In the case q =p/(p-1) , we show that all eigenvalues and eigenfunctions can be expressed in terms of generalized trigonometric functions. Joint work with L. Boulton. (Received January 22, 2018)

49 ► Calculus of variations and optimal control; optimization

1136-49-19 **Phong Luu*** (phong.luu@ung.edu), Department of Mathematics, University of North Georgia, 3820 Mundy Mill Rd., Oakwood, AL 30566, and **Jingzhi Tie** and **Qing Zhang**. *A Numerical Method for an Optimal Trading Rule with a Mean-Reverting Asset.*

A mean-reverting asset is expected to fluctuate around an equilibrium level several times. We can make profit by trading a mean-reverting stock by buying low and selling high. It has been shown in Zhang and Zhang (2008) that two threshold levels buy and sell can be obtained to maximize the overall return when the slippage cost is present in each transaction in term of the stock price's percentage. Like Zhang and Zhang, this work is concerned with an optimal trading (buy and sell) rule for an asset price governed by a mean-reverting model; however, a fixed slippage cost is considered for each transaction, and three threshold levels are used. The associated HJB equations are used to characterize the value functions. The solution to the optimal stopping problem can be obtained by solving two quasi-algebraic equations. Sufficient conditions are given in the form of a verification theorem. A numerical example is reported to demonstrate the results. (Received November 04, 2017)

1136-49-556 **Ganesh Sundaramoorthi*** (ganesh.sundaramoorthi@kaust.edu.sa) and **Anthony Yezzi**. *Accelerated Optimization on Manifolds and Application to Motion Estimation and Segmentation.*

Accelerated optimization methods have gained wide applicability within the machine learning and optimization communities. They are known for leading to optimal convergence rates among first order schemes in the convex case. In the non-convex case they appear to provide robustness to shallow local minima. The intuition comes from considering a mass particle moving in an energy landscape. The particle gains momentum to surpass shallow local minimum and settles within a wider, deeper extremum in the energy landscape. Although these techniques have been widely used, only within the last few years have theoretical attempts been made to understand them in a mathematical framework. Recent work has shown how accelerated methods may be formulated with variational principles, although in finite dimensions. Motivated by the success of accelerated methods in finite dimensions, we generalize them to infinite dimensional manifolds of diffeomorphisms. We note large speed-ups in optical flow computation compared with standard approaches and robustness to local minima. Finally, we adapt our approach to video applications in motion-based segmentation, which require diffeomorphisms to be optimized over evolving regions of interest that encompass the domains of each object in the scene. (Received January 22, 2018)

51 ► Geometry

1136-51-167 **Jane Ivy Coons*** (jicoons@ncsu.edu), 2311 Stinson Drive, SAS Hall - Office 4123, Raleigh, NC 27606, and **Seth Sullivant**. *The Cavender-Farris-Neyman Model with a Molecular Clock.*

We prove results about the polytope associated to the toric ideal of invariants of the Cavender-Farris-Neyman model with a molecular clock on a rooted phylogenetic tree. For instance, the number of vertices of this polytope is a Fibonacci number and the facets of the polytope can be described using the combinatorial structure of the underlying rooted tree. The toric ideal of invariants of this model has a quadratic Gröbner basis, and we use this Gröbner basis in special cases to give a unimodular triangulation of the associated polytope with number of simplices equal to an Euler zig-zag number. Finally, we show that the Ehrhart polynomial of these polytopes

depends only on the number of leaves of the underlying tree, and not on the topology of the tree itself. (Received January 11, 2018)

1136-51-204 **Blake C Stacey***, 100 Morrissey Blvd, Boston, MA 02125. *Symmetric Informationally Complete quantum measurements: Where sphere packing meets quantum information.* Preliminary report.

The problem of complex equiangular line sets—"SICs", to the quantum information community—has a similar feel to sphere packing. It is easy to state, being only a mild "mathematician-izing" of everyday experience, yet a decisive resolution has proven quite recalcitrant. A major difficulty is that a solution in dimension N provides little help finding one in dimension $N+1$. SICs in dimensions 2 and 3, along with one of the solutions in $N=8$, stand out in some ways from the rest and have earned the term "sporadic SICs". These structures relate to exceptional objects known from other areas of mathematics. In particular, the three nicest of the sporadic SICs (known as the qubit, Hesse and Hoggar solutions) have a surprising link with sphere packing and integer lattices in the normed division algebras. (Received January 15, 2018)

1136-51-249 **Anusha M. Krishnan*** (anushakr@math.upenn.edu), University of Pennsylvania, Department of Mathematics, DRL, 209 South 33rd Street, Philadelphia, PA 19104. *Ricci flow on cohomogeneity one manifolds.*

We study the Ricci flow in the setting of cohomogeneity one manifolds, i.e. a Riemannian manifold M with a group G acting isometrically such that the orbit space M/G is one-dimensional. Since isometries are preserved under the flow, the evolving metrics continue to have a large isometry group. In several past works, this structure has been utilized to gain new information about the Ricci flow. In joint work with R. Bettiol, we give examples of $sec \geq 0$ metrics on some 4-manifolds, which immediately lose this property under the flow. This result indicates certain limitations of the flow in dimensions above 3, since $sec \geq 0$ is preserved under Ricci flow for 3-manifolds.

We will describe the challenges in systematically studying Ricci flow on cohomogeneity one manifolds arising from both the nature of the Ricci flow PDE (degenerate parabolic) and the structure of invariant metrics on a cohomogeneity one manifold. We will also present a strategy to overcome these. (Received January 17, 2018)

1136-51-388 **pedro ontaneda*** (pedro@math.binghamton.edu). *A semi flow on the space of polygonal curves of a space of curvature $< \infty$.*

We construct a semi flow on the space of polygonal loops of a space of curvature $< \infty$. The semi flow decreases energy outside the set of closed geodesics. (Received January 20, 2018)

1136-51-431 **Y. Berest**, **A Eshmatov*** (alimjon.eshmatov@utoledo.edu) and **W Yeung**. *Knot contact homology.*

In a series of papers, L. Ng introduced a new algebraic invariant of a link L in $\mathbf{R}^3$ represented by a semi-free differential graded (DG) algebra A_L. The structure of this DG algebra is determined by an element of a braid group B_n representing the link L. The homology of A_L is called the knot contact homology. We present a universal construction, called homotopy braid closure, that produces invariants of links in $\mathbf{R}^3$. As an application, we obtain a differential graded (DG) category that gives knot contact homology in the sense of L. Ng. (Received January 21, 2018)

1136-51-591 **Facundo Memoli** and **Osman Berat Okutan*** (okutan.1@osu.edu). *Reeb Posets and Tree Approximations.*

A well known result in the analysis of finite metric spaces due to Gromov says that given any (X, d_X) there exists a *tree metric* t_X on X such that $\|d_X - t_X\|_\infty$ is bounded above by twice $\mathrm{hyp}(X)\cdot\log(2\,|X|)$. Here $\mathrm{hyp}(X)$ is the *hyperbolicity* of X, a quantity that measures the *treeness* of 4-tuples of points in X. This bound is known to be asymptotically tight.

We improve this bound by restricting ourselves to metric spaces arising from filtered posets. By doing so we are able to replace the cardinality appearing in Gromov's bound by a certain poset theoretic invariant (the maximum length of fences in the poset) which can be much smaller thus significantly improving the approximation bound.

At the core of our results lies the adaptation of the Reeb graph and Reeb tree constructions and the concept of hyperbolicity to the setting of posets, which we use to formulate and prove a tree approximation result for any filtered poset. (Received January 22, 2018)

52 ► Convex and discrete geometry

1136-52-50 **Bo Lin** (bolin@math.utexas.edu), Dpeartment of Mathematics, UT Austin, Austin, TX 78712, and **Ngoc Mai Tran*** (ntran@math.utexas.edu), Department of Mathematics, UT Austin, Austin, TX 78723. *Linear and rational factorization of tropical polynomials.*

Already for bivariate tropical polynomials, factorization is an NP-Complete problem. In this paper, we give an efficient algorithm for factorization and rational factorization of a rich class of tropical polynomials in n variables. Special families of these polynomials have appeared in economics, discrete convex analysis, and combinatorics. Our theorems rely on an intrinsic characterization of regular mixed subdivisions of integral polytopes, and lead to many open problems of interest in discrete geometry. (Received December 15, 2017)

1136-52-84 **Steven D Hoehner*** (steven.hoehner@farmingdale.edu) and **Gil Kur** (gil.kur@weizmann.ac.il). *Approximating convex bodies by random polytopes and the connection to sphere covering.*

This paper aims to add new insights about the approximation of convex bodies by polytopes by illuminating the connection between random sphere "covering" and approximating a convex body in the symmetric difference metric. Our main contribution is an almost sharp concentration inequality for the symmetric volume difference of the Euclidean unit ball and a random circumscribed polytope with a restricted number of facets. This is a "dual" analogue of a result of Vu, in the case the body is the ball, and the concentration also holds for the arbitrarily positioned polytopes that were defined by Kur.

As a corollary, we derive a variance estimate for the facets case that is a dual analogue of a result of Reitzner, in the case the body is the ball. This work is a follow-up to a paper of Böröczky and Reitzner, where one of the results is an asymptotic formula for the expectation of the volume difference between a circumscribed random polytope and a convex body.

As a second contribution, we provide a simple proof and improve a result of Zador on the Dirichlet-Voronoi tiling numbers.

This paper also provides a new result and an interesting open conjecture about random sphere "covering", both of which are related to results of Few, Rogers, and Erdős. (Received January 21, 2018)

1136-52-159 **Oleg R. Musin*** (oleg.musin@utrgv.edu), 1900 University Blvd #15F, Brownsville, TX 78520. *Densest sphere packing in four dimensions.*

The main goal of this talk is to discuss reasonable approaches for solutions to problems related to densest sphere packings in 4-dimensional Euclidean space. We consider two long-standing open problems: the uniqueness of maximum kissing arrangements in 4 dimensions and the 24-cell conjecture. Note that a proof of the 24-cell conjecture also proves that the lattice packing D4 is the densest sphere packing in 4 dimensions. (Received January 16, 2018)

1136-52-227 **Yiming Zhao*** (zhaoy@stjohns.edu), St. John's University, 8000 Utopia Parkway, SJH 334, Queens, NY 11439. *The Aleksandrov problem and its recent development.* Preliminary report.

The Aleksandrov problem, after a constant rescaling, can be viewed as a problem that connects probability measure with a convex body. In particular, it asks for necessary and sufficient conditions on a given probability measure so that it is exactly the (normalized) Aleksandrov's integral curvature of a convex body. Recently, the Lp Aleksandrov problem which includes the classical problem was posed. Recent results in this direction will be discussed. (Received January 16, 2018)

1136-52-282 **Ohad Giladi**, **Joscha Prochno** and **Carsten Schuett*** (schuett@math.uni-kiel.de), Mathematisches Seminar, University of Kiel, 24098 Kiel, Germany, and **Nicole Tomczak-Jaegermann** and **Elisabeth Werner**. *On the geometry of projective tensor products.*

In this work, we study the volume ratio of the projective tensor products $\ell_p^n \otimes_\pi \ell_q^n \otimes_\pi \ell_r^n$ with $1 \le p \le q \le r \le \infty$. The asymptotic formulas we obtain are sharp in almost all cases. As a consequence of our estimates, these spaces allow for an almost Euclidean decomposition of Kashin type whenever $1 \le p \le q \le r \le 2$ or $1 \le p \le 2 \le r \le \infty$ and $q = 2$. Also, from the Bourgain-Milman bound on the volume ratio of Banach spaces in terms of their cotype 2 constant, we obtain information on the cotype of these 3-fold projective tensor products. Our results naturally generalize to the k-fold products $\ell_{p_1}^n \otimes_\pi \cdots \otimes_\pi \ell_{p_k}^n$ with $k \in \mathbb{N}$ and $1 \le p_1 \le \cdots \le p_k \le \infty$. (Received January 18, 2018)

1136-52-291 **Matthew Alexander**, **Matthieu Fradelizi** and **Artem Zvavitch*** (zvavitch@math.kent.edu), Department of Mathematical Sciences, Kent State University, Kent, OH 44242. *Polytopes of Maximal Volume Product.*

For a convex body $K \subset \mathbb{R}^n$, let $K^z = \{y \in \mathbb{R}^n : \langle y - z, x - z\rangle \leq 1, \text{ for all } x \in K\}$ be the polar body of K with respect to the center of polarity $z \in \mathbb{R}^n$. The goal of this talk is to present a study the maximum of the volume product $\mathcal{P}(K) = \min_{z \in \text{int}(K)} |K||K^z|$, among convex polytopes $K \subset \mathbb{R}^n$ with a number of vertices bounded by some fixed integer $m \geq n + 1$. In particular, we will show that the supremum is reached at a simplicial polytope with exactly m vertices and we provide a new proof of a result of Meyer and Reisner showing that, in the plane, the regular polygon has maximal volume product among all polygons with at most m vertices. Finally, we treat the case of polytopes with $n + 2$ vertices in $\mathbb{R}^n$. (Received January 18, 2018)

1136-52-316 **Megan Owen*** (megan.owen@lehman.cuny.edu). *Computing the Frechet Mean in Billera-Holmes-Vogtmann Treespace.* Preliminary report.

Data generated in such areas as evolutionary biology and medical imaging are frequently tree-shaped, and thus non-Euclidean in nature. As a result, standard techniques for analyzing data in Euclidean spaces become inappropriate, and new methods must be used. One such framework is the Billera-Holmes-Vogtmann continuous space of metric trees. This space is a non-positively curved, or CAT(0), polyhedral cone complex, with a unique geodesic (shortest path) between any two trees, and a well-defined and unique Frechet mean. The Frechet mean can be approximated using an iterative algorithm, but no known exact polynomial algorithm exists. Using the log map, we derive inequalities on the input tree edge lengths that the mean tree must satisfy. These inequalities lead to an algorithm that is fixed-parameter tractable in the number of different splits in the set of input trees. This is joint work with M. Anaya, O. Anipchenko-Ulaj, A. Ashfaq, J. Chiu, M. Kaiser, M. Shoji Ohsawa, E. Pavlechko, K. St. John, S. Suleria, K. Thompson, and C. Yap as part of the Fall 2015 Treespace REU at Lehman College, CUNY. (Received January 19, 2018)

1136-52-320 **Galyna Livshyts***, 686 Cherry st NW, Atlanta, GA 30332. *On the dimensional Brunn-Minkowski inequality.*

In the recent years, a number of conjectures has appeared, concerning the improvement of the inequalities of Brunn-Minkowski type under the additional assumptions of symmetry; this includes the B-conjecture, the Gardner-Zvavitch conjecture of 2008, the Log-Brunn-Minkowski conjecture of 2012, and some variants. The conjecture of Gardner and Zvavitch, also known as dimensional Brunn-Minkowski conjecture, states that even log-concave measures in $\mathbb{R}^n$ are in fact $\frac{1}{n}$-concave with respect to the addition of symmetric convex sets. In this talk we shall establish the validity of the Gardner-Zvavitch conjecture asymptotically, and prove that the standard Gaussian measure enjoys $\frac{0.3}{n}$ concavity with respect to centered convex sets. Some improvements to the case of general log-concave measures shall be discussed as well. This is a joint work with A. Kolesnikov. (Received January 19, 2018)

1136-52-329 **Susanna Dann** (susanna.dann@tuwien.ac.at), **Alexander Koldobsky** (koldobskiya@missouri.edu) and **Dmitry Ryabogin*** (ryabogin@math.kent.edu). *Some Fourier transform formulas related to the simplex mean width conjecture.* Preliminary report.

This is a joint work with Susanna Dann and Alexander Koldobsky. I will present some formulas that might be helpful in the solution of the mean width conjecture. (Received January 19, 2018)

1136-52-382 **Henry Cohn*** (cohn@microsoft.com). *Why are packing problems much easier in some cases than others?*

One might expect that the difficulty of solving a packing problem would simply depend on the size and complexity of the problem: higher dimensions or more complicated shapes would increase the difficulty. Instead, the difficulty is far more subtle to predict. For example, Viazovska's solution of the sphere packing problem in eight dimensions is enormously simpler than Hales's solution in three dimensions, and several dozen similar cases can be found in the literature. How can we understand why such phenomena occur? Sadly, I can't give a definitive answer to this question, but in this talk I'll discuss what I understand and what I wish I understood. (Received January 20, 2018)

1136-52-424 **Florian Besau*** (besau@math.uni-frankfurt.de), Institut für Mathematik, Goethe Universität Frankfurt, Robert-Mayer-Str. 10, 60054 Frankfurt, Hessen, Germany. *Floating bodies and random approximation.*

It is a classic result that the expected volume difference between a convex body and a random polytope, i.e., the convex hull of i.i.d. random points chosen uniformly from the convex body, converges to the affine surface area of the convex body as the number of points goes to infinity. Furthermore, if the convex body is actually a polytope, then the affine surface area vanishes and the first term in the asymptotic expansion of the volume difference depends on the number of (complete) flags of the polytope. Remarkably, a similar behavior is exhibited by the volume difference between a convex body and its floating body.

In this talk I consider recent generalizations of the above notions obtained together with M. Ludwig and E. M. Werner, where we consider the non-uniform case. This naturally gives rise to weighted floating bodies and a notion of weighted affine surface area for general convex bodies.

More recently, in joint work with C. Schütt and E. M. Werner, we were able to give extensions also for the first term in the asymptotic expansion of the volume difference of a polytope and its weighted floating body, which now depends on weighted sum of the (complete) flags of the polytope. (Received January 21, 2018)

1136-52-437 **Tom Needham*** (needham.71@osu.edu) and **Facundo Mémoli**. *Injectivity Properties of Local Distance Distributions.* Preliminary report.

The local distance distribution h_X is a simple invariant of a metric measure space X which gives for each $(p, r) \in X \times \mathbb{R}_+$ the volume of the corresponding metric ball. The function h_X serves as a proxy for scalar curvature in the mm-space setting and the L^1-distance between local distance distributions can be used to give a lower bound on Gromov-Wasserstein distance between mm-spaces. In this talk we will discuss the discriminative properties of the function h_X itself when restricted to subclasses of mm-spaces such as weighted metric graphs or plane curves. (Received January 21, 2018)

1136-52-475 **Ben Li***, bxl292@case.edu, and **Carsten Schuett** and **Elisabeth Werner**. *Floating functions.*

We introduce floating bodies for convex, not necessarily bounded subsets of Rn. This allows us to define floating functions for convex and log concave functions and log concave measures. We establish the asymptotic behavior of the integral difference of a log concave function and its floating function. This gives rise to a new affine invariant which bears striking similarities to the Euclidean affine surface area. This is joint work with C. Schuett and Elisabeth Werner. (Received January 21, 2018)

1136-52-506 **Susanna Dann** and **Grigorios Paouris*** (grigorios.paouris@gmail.com), Department of Mathematics, Texas A&M University, College Statiom, TX 77843-3368, and **Peter Pivovarov**. *Affine isoperimetric inequalities on flag manifolds.* Preliminary report.

I will present extensions of classical results on affine invariance due to Grinberg and their corresponding inequalities due to Busemann-Strauss and Grinberg to the setting of flag manifolds. I will also present some inequalities for the dual quantities in the setting of convex bodies as well as extensions in the set of functions. The talk will be based on a joint work with S. Dann and P. Pivovarov. (Received January 22, 2018)

1136-52-524 **Beatrice-Helen Vritsiou*** (vritsiou@ualberta.ca), Dept. of Math. and Stat. Sciences, University of Alberta, CAB 632, Edmonton, Alberta T6G 2G1, Canada. *Selberg-type integrals and the variance conjecture for the operator norm.*

The variance conjecture in Asymptotic Convex Geometry stipulates that the Euclidean norm of a random vector uniformly distributed in a (properly normalised) high-dimensional convex body $K \subset \mathbb{R}^n$ satisfies a Poincaré-type inequality, implying that its variance is much smaller than its expectation. In this talk we discuss the conjecture in the case of unit balls of p-Schatten norms on spaces of square matrices and on their subspaces of self-adjoint matrices. In particular, we show how to settle the conjecture when K is the unit ball of the operator norm in these spaces (in the case of subspaces of self-adjoint matrices, this improves upon previous joint work with J. Radke).

By Random Matrix Theory results, the question can be reduced to estimation of integrals of highly symmetric distributions, which may be more amenable to analytic or combinatorial techniques. In the case of the operator norm, integrals of the corresponding symmetric distributions (at least some specific instances of them) have been analysed by Selberg and others, and we manage to use the nice expressions they have found for them. (Received January 22, 2018)

53 ► Differential geometry

1136-53-96 **Pavan Turaga***, School of Arts, Media, Engineering, PO Box 875802, Tempe, AZ 85287, and **Suhas Lohit**. *Leveraging Riemannian Geometry and Deep-Learning for Invariant Representations in Computer Vision.*

Non-Euclidean constraints are inherent in many kinds of representations in computer vision and machine learning, typically as a result of specific invariance requirements that need to be respected during high-level inference. While deep learning has made revolutionary advances, its ability to learn truly invariant representations is quite limited. To address this issue, we propose a general framework for manifold-aware training of deep neural networks that also respects application-specific invariance requirements. We describe two applications to demonstrate this approach: prediction of probability distributions for multi-class image classification, and prediction of illumination-invariant subspaces from a single face-image. These applications show the generality of the proposed framework, and result in improved performance over baselines that ignore the geometry of the output space. (Received January 04, 2018)

1136-53-122 **Ricardo A. E. Mendes** and **Marco Radeschi*** (mradesch@nd.edu), 255 Hurley, Notre Dame, IN 46556. *Virtual immersions, and symmetric space.*

Virtual immersions generalize isometric immersions in Euclidean and Lorentzian spaces. Most of the extrinsic geometry is still valid, however the most important new feature is that the second fundamental form (which still exists) is not necessarily symmetric anymore. In fact, we will prove that there are virtual immersions with skew-symmetric second fundamental form. Remarkably enough, however, this existence completely characterizes symmetric spaces. (Received January 08, 2018)

1136-53-131 **Chris Connell** and **Shi Wang*** (wang679@iu.edu). *The barycenter method in nonpositively curved manifolds.*

The barycenter method was originally developed by Besson, Courtois and Gallot, to show the minimal entropy rigidity theorem of rank one symmetric spaces. Since then, people have extended the method in various context and have made fruitful applications in areas of differential geometry, topology and dynamical system.

In this talk, we will introduce the barycenter map in general, and the barycentric straightening on nonpositively curved manifolds. We show positivity of simplicial volume of certain nonpositively curved geometric rank one manifolds. This gives a positive answer in special cases to a conjecture attributed to Gromov. (Received January 08, 2018)

1136-53-155 **Kevin Schreve*** (schreve@umich.edu). *Action dimension of lattices in Euclidean buildings.*

The action dimension of G is the minimal dimension of contractible manifold with a proper G-action. I will compute the action dimension of groups that act properly and cocompactly on Euclidean buildings, which will turn out to be twice the dimension of the building. This will also compute the action dimension for some S-arithmetic groups. (Received January 10, 2018)

1136-53-198 **Christopher Connell** and **Thang Nguyen*** (tnguyen@nyu.edu), Courant Institute of Mathematical Science, New York, NY 10012, and **Ralf Spatzier**. *Hyperbolic rank rigidity for quarter-pinched manifolds.*

Motivated by the question about (Euclidean) rank rigidity, whether a closed non-positively curved manifold with every geodesic locally contained in a flat is locally symmetric, we consider the question where flat is replaced by hyperbolic plane. The question about Euclidean rank rigidity was answered positive by Ballmann-Brin-Eberline and Burns-Spatzier in 80s'. For the later one, it has not been completely solved yet. It was achieved in many cases by Hamenstadt and Constantine. We give a positive answer for the case quarter-pinched manifolds, which we use different technique with the ones of Hamenstadt or Constantine. The main tools are from dynamics of Lyapunov distributions and a lemma by Foulon. This is a joint work with C. Connell and R. Spatzier. (Received January 15, 2018)

1136-53-208 **Tom Needham*** (needham.71@osu.edu) and **Sebastian Kurtek**. *Comparing Elastic Metrics on Plane Curves.* Preliminary report.

The elastic metrics are a two-parameter family of Riemannian metrics on the shape space of planar curves which have been used extensively in shape analysis applications. Statistical analysis of plane curve shapes is simplified by a change of coordinates called the Square Root Velocity Transform, which identifies the space of fixed length curves with a Hilbert sphere. Moreover, the SRVT is an isometry with respect to a particular choice of elastic metric and the round metric on the sphere. We show that there is a general family of transforms which can be used to simplify statistical analysis with respect to the elastic metrics for any choice of parameters. We will describe some of the technical issues that arise and compare the performance of elastic metrics for shape classification. (Received January 15, 2018)

1136-53-248 **Barry Minemyer*** (bminemyer@bloomu.edu). *Real hyperbolic hyperplane complements in the complex hyperbolic plane.*

Let M be a complete four dimensional Riemannian manifold with finite volume which is modeled on the complex hyperbolic plane $\mathbb{CH}^2$, and let S be a compact totally geodesic codimension two submanifold of M that is modeled on the real hyperbolic plane $\mathbb{H}^2$. In the paper to be presented we write the metric on M in polar coordinates about S, compute formulas for the components of the curvature tensor in terms of arbitrary warping functions, and prove that there exist warping functions that yield a complete finite volume Riemannian metric on $M \setminus S$ whose sectional curvature is bounded above by a negative constant. The cases of $M \setminus S$ modeled on $\mathbb{H}^n \setminus \mathbb{H}^{n-2}$ and $\mathbb{CH}^n \setminus \mathbb{CH}^{n-1}$ were previously studied by Belegradek. (Received January 17, 2018)

1136-53-405 **Longzhi Lin***, 1156 High Street, Santa Cruz, CA 95064, and **Paul Laurain**. *Energy convexity of intrinsic bi-harmonic map and its heat flow.*

In this talk, we will discuss an energy convexity for weakly intrinsic bi-harmonic map and its heat flow with small bi-energy from the four dimensional unit ball into spheres. This in particular yields the uniqueness of weakly intrinsic bi-harmonic maps from the 4-ball into spheres with small bi-energy. Moreover, it yields the long time existence and uniform convergence of the intrinsic bi-harmonic map heat flow on the 4-ball with small initial bi-energy. Every harmonic map is an intrinsic bi-harmonic map as an absolute minimizer of the intrinsic bi-energy functional, and thus intrinsic bi-harmonic map and its heat flow are more geometrically natural to study than their extrinsic counterparts, but they are also analytically more difficult. Prior to our results, the intrinsic bi-harmonic map heat flow is only known to exist for short time unless the target manifold is special (e.g. non-positively curved). This is a recent joint work with Paul Laurain. (Received January 20, 2018)

1136-53-414 **Xin Fu** and **Bin Guo*** (bguo@math.columbia.edu), 2990 Broadway, New York, NY 10027, and **Jian Song**. *Geometric estimates for complex Monge-Ampere equations.*

We prove uniform gradient and diameter estimates for a family of geometric complex Monge-Ampère equations. Such estimates can be applied to study geometric regularity of singular solutions of complex Monge-Ampère equations. We also prove a uniform diameter estimate for collapsing families of twisted Kähler-Einstein metrics on Kähler manifolds of nonnegative Kodaira dimensions. (Received January 20, 2018)

1136-53-429 **Renato G Bettiol***, University of Pennsylvania, David Rittenhouse Lab., 209 South 33rd Street, Philadelphia, PA 19104, and **Paolo Piccione** and **Yannick Sire**. *Non-uniqueness of conformal metrics with constant Q-curvature.*

The problem of finding (complete) metrics with constant Q-curvature in a prescribed conformal class is a famous fourth-order cousin of the Yamabe problem. In this talk, I will provide some background on Q-curvature and discuss how several non-uniqueness results for the Yamabe problem can be transplanted to this context. However, special emphasis will be given to multiplicity phenomena for constant Q-curvature that have no analogues in the Yamabe problem, confirming expectations raised by the lack of a maximum principle. (Received January 21, 2018)

1136-53-432 **Renato G Bettiol***, University of Pennsylvania, David Rittenhouse Lab., 209 South 33rd Street, Philadelphia, PA 19104, and **Ricardo Mendes**. *Manifolds with strongly positive curvature and many symmetries.*

Closed manifolds with positive sectional curvature are notoriously mysterious and difficult to construct, while those with positive-definite curvature operator are known (via Ricci flow) to be diffeomorphic to space forms. We consider an intermediate curvature condition between the latter, strongly positive curvature, whose definition is motivated by an observation of Thorpe in the 1970s. In the spirit of the Grove Symmetry Program, we endeavor to understand manifolds with strongly positive curvature by imposing symmetries assumptions; in particular, we completely classify simply-connected homogeneous spaces with this property. (Received January 21, 2018)

1136-53-470 **Yueh-Ju Lin*** (yuehjul@math.princeton.edu) and **Wei Yuan** (gnr-x@163.com). *Deformations of Q-curvature.*

Stability (local surjectivity) and rigidity of the scalar curvature have been studied in an early work of Fischer-Marsden on "vacuum static spaces". Inspired by this line of research, we seek similar properties for Q-curvature by studying "Q-singular spaces", which were introduced by Chang-Gursky-Yang.

In this talk, we investigate deformation problems of Q-curvature on closed Riemannian manifolds with dimensions $n \geq 3$. In particular, we prove local surjectivity for non-Q-singular spaces and local rigidity of flat manifolds.

For global results, we show that any smooth functions can be realized as a Q-curvature on generic Q-flat manifolds. However, a locally conformally flat metric on n-tori with nonnegative Q-curvature has to be flat.

This is joint work with Wei Yuan. (Received January 21, 2018)

1136-53-473 **Jean-François Lafont** and **Gangotryi Sorcar*** (sorcar.1@osu.edu), 2243 Antigua Drive Apt 3B, Columbus, OH 43235, and **Fangyang Zheng**, OH. *How diffeomorphisms affect the total Chern class of complex Bott manifolds. (Joint work with Jean Lafont and Fangyang Zheng).*

Complex Bott manifolds are defined iteratively by taking a CP^1 bundle over a CP^1 bundle over a CP^1 bundle over a... you get the idea. A 1-step Bott manifold is CP^1 and an n-step Bott manifold is what you get after performing these iterations n times. In this joint work with Jean Lafont and Fangyang Zheng, we show that for complex Bott manifolds diffeomorphic to a product of CP^1, the total Chern class is a diffeomorphism invariant. (Received January 21, 2018)

1136-53-550 **Gregory J Edwards*** (gedwards@math.northwestern.edu), 2033 Sheridan Rd., Evanston, IL 60208. *A scalar curvature bound along the conical Kähler-Ricci flow.*

Kähler-Einstein metrics with conical singularities along a divisor have been of recent interest to complex geometers. The conical Kähler-Ricci flow was introduced as a parabolic flow of conical Kähler metrics which preserves the conical singularities along the cone divisor, and is expected to converge to a conical Kähler-Einstein metric, when one exists. In the case when no conical Kähler-Einstein metrics exists, the behavior of the flow is related to the log minimal model program with respect to the cone divisor. We show that when (X,D) is a log minimal model and satisfies a semi-ampleness condition, the solution to the conical Kähler-Ricci flow exists for all time, and the scalar curvature is uniformly bound along the flow. This supports the conjecture that the solution converges to a canonical metric on the log canonical model of (X,D). (Received January 22, 2018)

1136-53-561 **Jason Cantarella***, Boyd GSRC, 102 D.W. Brooks Drive, Athens, GA 30602, and **Clayton Shonkwiler**. *The symplectic structure on the space of polygons and curves in $\mathbb{R}^3$ and some applications to random polygons and shape analysis.*

In this talk we'll give a concrete and approachable version of a description of the space of space polygons as a Grassmannian analogous to the paper of Younes-Michor-Shah-Mumford for plane curves. This picture was first proposed by Knutson-Haussmann, and ties in with work of many other authors, including Millson-Kapovich and Mandini.

This description gives us a symplectic structure on space polygons and a natural way to talk about distances and volumes in shape space. We present some theorems about polygons which follow naturally from these coordinates. We have (so far) mostly used these methods to prove theorems about random polygons, but they may have applications in shape analysis as well. (Received January 22, 2018)

1136-53-570 **Patricia Cahn*** (pcahn@smith.edu), **Herman Gluck** and **Haggai Nuchi**. *Deformation and Extension of Fibrations of Spheres by Great Circles.*

In 1983, Gluck and Warner proved that the space of all oriented great circle fibrations of the three-sphere deformation retracts to the subspace of Hopf fibrations, and so has the homotopy type of a pair of disjoint two-spheres. Since that time, no generalization of this result to higher dimensions has been found, so we instead show that in a certain infinitesimal sense, the space of oriented great circle fibrations of the (2n+1)-sphere deformation retracts to the subspace of Hopf fibrations. The tools developed to prove this result also show that every germ of a fibration of the (2n+1)-sphere by great circles extends to such a fibration of all of S^{2n+1}, a result previously only known for S^3. (Received January 22, 2018)

1136-53-571 **Jacob Bernstein** (bernstein@math.jhu.edu), 3400 N. Charles Street, Baltimore, MD 21218, and **Lu Wang*** (luwang@math.wisc.edu), 480 Lincoln Drive, Madison, WI 53706. *The space of asymptotically conical self-expanders of mean curvature flow.*

We show that the space of asymptotically conical self-expanders of the mean curvature flow is a smooth Banach manifold. An immediate consequence is that non-degenerate self-expanders – that is, those self-expanders that admit no non-trivial normal Jacobi fields that fix the asymptotic cone – are generic in a certain sense. This is joint work with Jacob Bernstein. (Received January 22, 2018)

1136-53-593 **Zhe Su** (zsu@math.fsu.edu), **Martin Bauer** (bauer@math.fsu.edu) and **Eric Klassen*** (klassen@math.fsu.edu). *A New Method for Comparing Shapes of Surfaces Immersed in R^3.* Preliminary report.

We describe a new method of putting a metric on the set of immersions of a fixed closed surface in R^3. This metric is invariant under reparametrizations, so it induces a metric on the "shape space", i.e., on the space of immersions modulo reparametrization. We discuss the problem of obtaining geodesics in these spaces, and exhibit some numerical implementations. (Received January 22, 2018)

54 ► General topology

1136-54-326 **Robin Gaudreau*** (gaudreau@tutamail.com), **Hans U. Boden** and **Micah Chrisman**. *Concordance invariants of virtual knots I.*

Virtual knot theory concerns knots in thickened surfaces, and Turaev introduced virtual concordance and several useful invariants of them. This talk is based on joint work with Hans Boden and Micah Chrisman. It introduces various equivalent approaches to virtual knot cobordisms. The multiplicity of approaches becomes a strength of the theory and is used to compute the sliceness and the 4-genus for virtual knots with fewer than 6 crossings. Moreover, we use the topology of the supporting surfaces to investigate the structure of the virtual concordance group. (Received January 19, 2018)

1136-54-553 **Sarah Seger*** (seger@rice.edu). *0.5-solvability, Seifert forms, and Blanchfield forms of links.*

It is known for knots that 0.5-solvability, being algebraically slice, and having a hyperbolic Blanchfield form are all equivalent. We wish to generalize this result to links. We outline some partial results for the special case of boundary links, and the more general case of links with pairwise linking numbers zero. (Received January 22, 2018)

55 ► Algebraic topology

1136-55-138 **Michael Ching*** (mching@amherst.edu). *Operads and Day convolution in Goodwillie calculus.*

We prove two theorems about Goodwillie calculus, and we use those theorems to describe new models for Goodwillie derivatives of functors between pointed compactly-generated ∞-categories. The first theorem say that the construction of higher derivatives for spectrum-valued functors is a Day convolution of copies of the first derivative construction. The second theorem says that the derivatives of any functor can be realized as natural transformation objects for derivatives of spectrum-valued functors.

Together these results allow us to construct an ∞-operad that models the derivatives of the identity on any pointed compactly-generated ∞-category. The derivatives of a functor between such ∞-categories then form a bimodule over the relevant ∞-operads. (Received January 09, 2018)

1136-55-146 **Bena Tshishiku*** (tshishikub@gmail.com). *Cohomology of arithmetic groups and characteristic classes of manifold bundles.*

A basic problem in the study of fiber bundles is to compute the ring $H^*(BDiff(M))$ of characteristic classes of bundles with fiber a smooth manifold M. When M is a surface, this problem has ties to algebraic topology, geometric group theory, and algebraic geometry. Currently, we know only a very small percentage of the total cohomology. In this talk I will explain some of what is known and discuss some new characteristic classes (in the case dim $M \gg 0$) that come from the unstable cohomology of arithmetic groups. (Received January 09, 2018)

1136-55-222 **Mark W. Johnson*** (mwj3@psu.edu), Penn State Altoona, 3000 Ivyside Dr., Altoona, PA 16601, and **David Blanc** and **James M. Turner**. *A constructive approach to higher homotopy operations.*

Higher homotopy operations, especially Toda brackets and Massey products, have long been important computational tools in homotopy theory. The current project proposes a very explicit way to construct higher homotopy operations associated to finite, directed, homotopy commutative diagrams, using grids of homotopy pullbacks and a refinement of the Reedy matching construction. This allows us to present the construction in completely general terms, in some cases not requiring base points, or allowing "hybrid" situations where some portions of a diagram are required to respect base points and others are not. Our hope is to eventually use this approach to study any algebraic structure on the collection of higher homotopy operations, but we have only a few small results in that direction so far. (Received January 16, 2018)

1136-55-238 **J. D. Quigley*** (jquigle2@nd.edu), 255 Hurley, Notre Dame, IN 46556. *The Mahowald invariant in motivic, equivariant, and classical stable homotopy theory.*

The Mahowald invariant is a method for constructing nontrivial classes in the stable homotopy groups of spheres from lower dimensional classes. I will recall this construction and some classical computations, then discuss analogs in the motivic and C_2-equivariant settings. In particular, I will explain how functors between the motivic, equivariant, and classical stable homotopy categories can be leveraged to make computations across contexts. (Received January 16, 2018)

1136-55-287 **Nicholas J. Meadows*** (nmeadows@uwo.ca), Department of Mathematics, Middlesex College, 1151 Richmond St., Western University, London, Ontario N6A 5B7, Canada. *Local Higher Category Theory.*

We describe local presheaf theoretic extensions of three of the main extant models of higher category theory: the Joyal, Bergner and Rezk model structures, in which the weak equivalences are defined 'stalkwise'. There is a zig-zag of Quillen equivalences between them, which extends the Quillen equivalences linking the various models of higher category theory.

The local Bergner model structure is right proper. This leads to an attractive theory of cocycles and torsors, which generalizes classical non-abelian H^1.

The local Joyal model structure leads to potential new perspectives on descent theory, which will be briefly discussed. (Received January 18, 2018)

1136-55-353 **Anna Marie Bohmann***, am.bohmann@vanderbilt.edu, and **Angélica M. Osorno**. *Comparing K-theory functors multiplicatively.*

Algebraic K-theory is a method for building spectra out of suitable categorical data. There are several different versions of algebraic K-theory that take as starting points different types of categorical data. Two oft-cited versions are Segal's K-theory machine, which starts with symmetric monoidal categories, and Waldhausen's $S_\bullet$-construction, which starts with Waldhausen categories. Waldhausen himself constructs a functor comparing the $S_\bullet$-construction with Segal's machine. For many uses, one wants a K-theory construction that is "multiplicative." Both Segal's and Waldhausen's constructions have lifts to multiplicative constructions, due to Elmendorf–Mandell and Blumberg–Mandell respectively. In this talk, I will discuss a comparison of these multiplicative constructions that lifts Waldhausen's original functor. This requires the language of multicategories. (Received January 19, 2018)

1136-55-375 **Eva Belmont*** (ebelmont@mit.edu). *Localizing the E_2 page of the Adams spectral sequence.*

The Adams spectral sequence is one of the central tools for calculating the stable homotopy groups of spheres, one of the motivating problems in stable homotopy theory. In this talk, I will discuss an approach for computing the Adams E_2 page at $p = 3$ in an infinite region, by computing its localization by the non-nilpotent element b_{10}. This approach relies on computing an analogue of the Adams spectral sequence in Palmieri's stable category of comodules, which can be regarded as an algebraic analogue of stable homotopy theory. This computation fits in the framework of chromatic homotopy theory in the stable category of comodules. (Received January 20, 2018)

1136-55-376 **Cary Malkiewich** and **Mona Merling*** (mmerling@jhu.edu), 1931 17th St apt 302, Washington, DC 20009. *Toward the equivariant parametrized stable h-cobordism theorem.* Preliminary report.

Waldhausen's introduction of A-theory of spaces revolutionized the early study of pseudo-isotopy theory. Waldhausen proved that the A-theory of a manifold splits as its suspension spectrum and a factor Wh(M) whose first delooping is the space of stable h-cobordisms, and its second delooping is the space of stable pseudo-isotopies. I will describe a joint project with C. Malkiewich aimed at telling the equivariant story if one starts with a manifold M with group action by a finite group G. (Received January 20, 2018)

1136-55-384 **Daniel A. Ramras*** (danramras@gmail.com), 420 N Blackford Rd, LD 270, Indianapolis, IN 46202. *Coassembly for representation spaces.*

The deformation K-theory of a space X is the K-theory spectrum of the category of finite-dimensional unitary representations of $\pi_1(X)$. This is a ring spectrum, and in fact an algebra over the connective K-theory spectrum

ku. I will give a hands-on description of the universal coassembly map linking deformation K-theory and topological K-theory, along with some geometric applications. (Received January 20, 2018)

1136-55-385 **Gabe Angelini-Knoll*** (angelini@math.msu.edu), Michigan State University, Department of Mathematics, 619 Red Cedar Road, C207 Wells Hall, East Lansing, MI 48824, and **J.D. Quigley**. *Chromatic complexity of topological periodic cyclic homology of y(n).* Preliminary report.

The Thom spectra $y(n)$ were defined by Mahowald-Ravenel-Shick in their paper on the telescope conjecture. They interpolate between the sphere spectrum and the Eilenberg-Mac Lane spectrum of a finite field of order p and they can be considered "infinite complexes of type n." Work of Hesselholt-Madsen and Nikolaus-Scholze shows that topological periodic cyclic homology of the Eilenberg-Mac Lane spectrum of the field with p elements is a wedge of suspensions of integral Eilenberg Maclane spectra, demonstrating a shift in chromatic height. In work in progress with J.D. Quigley, we construct Thom spectra $z(n)$ that filter between the sphere and the integral Eilenberg Maclane spectrum and we give evidence that topological periodic cyclic homology of $y(n)$ can be described in terms of these spectra. Our approach is based on the one outlined by Bruner and Rognes in their paper on homological homotopy fixed point spectral sequences. The goal is to give an analog of the Hesselholt-Madsen result at all chromatic heights. (Received January 20, 2018)

1136-55-398 **Sune Precht Reeh** (sune@reeh.dk), **Tomer M Schlank** (tomer.schlank@mail.huji.ac.il) and **Nathaniel Stapleton*** (nat.j.stapleton@uky.edu). *A formula for p-completion by way of the Segal conjecture.*

The Segal conjecture describes stable maps between classifying spaces in terms of (virtual) bisets for the finite groups in question. Along these lines, Reeh, Schlank, and I gave an algebraic formula for the p-completion functor applied to stable maps between classifying spaces purely in terms of fusion data and Burnside modules. (Received January 20, 2018)

1136-55-450 **Jacobson R. Blomquist***, 100 Math Tower, 231 W 18th Ave, Columbus, OH 43210. *Higher stabilization and completion with respect to stable homotopy.*

We will explain how estimates from a higher stabilization theorem show that the stable homotopy completion studied by Carlsson, and subsequently in Arone-Kankaanrinta (S-localization), fits into a derived adjunction via the Arone-Ching theory that can be turned into a derived equivalence by restricting to simply connected spaces. If time permits, the analogous results from finite suspensions of spaces, and their analogs and duals in structured ring spectra, will be discussed. (Received January 21, 2018)

1136-55-481 **Brenda Johnson*** (johnsonb@union.edu), Department of Mathematics, Union College, Schenectady, NY 12308. *Functor Calculus and Cartesian Differential Categories.*

The abelian functor calculus associates to a functor between abelian categories a tower of functors that has properties analogous to those of a Taylor series for functions. We will discuss connections between this functor calculus and cartesian differential categories as defined by Blute, Cockett, and Seely. In particular, we define a directional derivative in the abelian functor calculus, and prove that this directional derivative endows a particular category of functors of abelian categories with the structure of a cartesian differential category. As a consequence, we obtain a higher order chain rule for abelian functor calculus. This is joint work with Kristine Bauer, Christina Osborne, Emily Riehl, and Amelia Tebbe. If time permits, we will discuss extensions of these results stemming from work with K. Bauer and S. Yeakel. (Received January 21, 2018)

1136-55-492 **Luis Pereira*** (luisalexandrepereira@outlook.com), 1120 Welbek Drive, South Bend, IN 46637. *Genuine Equivariant Operads.*

A fundamental result in equivariant homotopy theory due to Elmendorf states that the homotopy theory of G-spaces, with w.e.s measured on all fixed points, is equivalent to the homotopy theory of G-coefficient systems in spaces, with w.e.s measured at each level of the system. Furthermore, Elmendorf's result is rather robust: analogue results can be shown to hold for, among others, the categories of (topological) categories and operads. However, it has been known for some time that in the G-operad case such a result does not capture the "correct" notion of weak equivalence, a fact made particularly clear in work of Blumberg and Hill discussing a whole lattice of "commutative operads with only some norms" that are not distinguished at all by the notion of w.e. suggested above. In this talk I will talk about part of a joint project which aims at providing a more diagrammatic understanding of Blumberg and Hill's work using a notion of G-trees, which are a generalization of the trees of Cisinski-Moerdijk-Weiss. More specifically, I will describe a new algebraic structure, which we dub a "genuine equivariant operad", which naturally arises from the study of G-trees and which allows us to state the "correct" analogue of Elmendorf's theorem for G-operads. (Received January 21, 2018)

1136-55-500 **Paul VanKoughnett*** (pvankoug@math.northwestern.edu). *Localizations of E-theory.*
Height n Morava E-theory is a representation in homotopy theory of the deformation space of a height n formal group. In the $K(t)$-localizations of E-theory, for $t < n$, the height of this formal group is forced to decrease; we present a modular description of these localizations, using ideas from the theory of higher local fields. This leads to a theory of the behavior of power operations under chromatic localization. (Received January 22, 2018)

1136-55-510 **Iris Yoon*** (irishryoon@gmail.com). *Persistence of Sheaf Cohomology: Studying Data Evolving Over Time.* Preliminary report.
Persistent homology is a widely used tool in Topological Data Analysis (TDA) that infers topological features from data. I will discuss the extension of persistence to cellular sheaf cohomology. Cellular sheaves are useful tools for extracting global structure from local data and relations. By virtue of being cellular, one can take advantage of sheaf theory in a computable manner. Persistent cellular sheaf cohomology then allows one to examine global changes that result from local changes of time-varying data. While there are many applications of persistent sheaf cohomology to be explored, I will focus on its application to distributed computation of persistent homology. It turns out, such distributed computation can be useful in studying multi-density data by recovering information that gets lost by persistent homology. (Received January 22, 2018)

1136-55-511 **Jonathan A Campbell*** (j.campbell@vanderbilt.edu). *Fixed Point Theory and the Cyclotomic Trace.*
In this talk I'll describe some results relating classical invariants in fixed point theory (such as the Lefschetz number, Reidemeister trace, and Reidemeister zeta function) to the cyclotomic trace in algebraic K-theory. (Received January 22, 2018)

1136-55-520 **Woojin Kim***, 100 Math Tower, The Ohio State University, Columbus, OH 43210, and **Facundo Memoli**, 100 Math Tower, The Ohio State University, Columbus, OH 43210. *Stable signatures for dynamic metric spaces via persistent homology.*
When studying flocking/swarming behaviors in animals one is interested in quantifying and comparing the dynamics of the clustering induced by the coalescence and disbanding of animals in different groups. Motivated by this we study the problem of obtaining persistent homology based summaries of time dependent metric data. In particular, we study the stability of this construction under a suitable variant of the Gromov-Hausdorff distance. (Received January 22, 2018)

1136-55-534 **Crichton Ogle*** (ogle.1@osu.edu), Columbus, OH 43210, and **Tom Needham** (needham.71@osu.edu). *On the structure of modules indexed by partially ordered sets.* Preliminary report.
A $\mathcal{C}$-module (over a field k) is a functor $M : \mathcal{C} \to (v.s./k)$ from the categorical representation $\mathcal{C}$ of a finite partially ordered set to the abelian category of finite dimensional vector spaces over k. We show:

Theorem To any $\mathcal{C}$-module M one may associate a collection of indecomposable submodules of M referred to as generalized bar codes (GBC). The GBCs are isomorphism invariants of M, from which M may be recovered as a direct sum if and only if the module is tame.

This collection of GBCs is determined by the *local structure of* M, which allow one to associate to each vertex space $M(x)$ a non-negative integer called the *excess*. This set of integers - referred to collectively as the *excess of* M - provides a complete obstruction to tameness, in that one can show that the module is tame precisely when its excess is zero.
(Received January 22, 2018)

1136-55-547 **Matthew Kahle**, **Frank H. Lutz**, **Andrew Newman*** (newman.534@osu.edu) and **Kyle Parsons**. *Cohen–Lenstra heuristics for torsion in homology of random complexes.*
Experimental evidence suggests that there is a moment in the discrete-time stochastic process version of the Linial–Meshulam random simplicial complex model in which there is torsion in homology. This torsion, which we refer to as the "torsion burst", tends to be enormous and short-lived. As an example, a single instance of the stochastic Linial–Meshulam process in 2-dimensions on 50 vertices had the group $\mathbb{Z}/10{,}819{,}621\mathbb{Z}$ appear in the first homology group and persist for two steps, but it had no torsion throughout the rest of the process. Here, we examine the torsion burst experimentally to explore questions about the size of the groups within the torsion burst, the duration of the torsion burst, and, most importantly, the distribution of the groups which appear within the torsion burst. In particular, we conjecture certain Cohen–Lenstra heuristics which model the torsion burst. We also establish a hitting-time conjecture which relates the torsion burst to a surprising

higher-dimensional generalization of the classical "giant component" in the Erdős–Rényi random graph. This is joint work with Matthew Kahle, Frank H. Lutz, and Kyle Parsons. (Received January 22, 2018)

1136-55-555 **Tasos Moulinos*** (tmouli2@uic.edu). *Derived Azumaya algebras and twisted K-theory.*
Topological K-theory of dg-categories is a localizing invariant of dg-categories over $\mathbb{C}$ taking values in the ∞-category of KU-modules. In this talk I describe a relative version of this construction; namely for X a quasi-compact, quasi-separated $\mathbb{C}$-scheme I construct a functor valued in $Shv_{Sp}(X(\mathbb{C}))$, the ∞-category of sheaves of spectra on $X(\mathbb{C})$. For inputs of the form $\mathrm{Perf}(X, A)$ where A is an Azumaya algebra over X, I characterize the values of this functor in terms of the twisted topological K-theory of $X(\mathbb{C})$. From this I deduce a certain decomposition for X, a finite CW-complex equipped with a bundle of projective spaces $\pi : P \to X$, of $KU(P)$ in terms of the twisted topological K-theory of X ; this is a topological analogue of a result of Quillen's on the algebraic K-theory of Severi-Brauer schemes. (Received January 22, 2018)

1136-55-562 **Nathan Alvarez Olson** (nathanalvarezolson@utexas.edu), **Zoe Margaret Himwich*** (zhimwich@stanford.edu) and **Indraneel Tambe** (indraneel.tambe.1@gmail.com). *The Finite Group TQFT for S_3.*
An explicit construction of the 3D TQFT of Dijkgraaf and Witten for the finite group S_3, a discussion of the algebraic objects assigned to manifolds by the TQFT and how to get link invariants from simple modules of $D(S_3)$. Further discussion of a few interesting properties of the link invariant for $V_{s,0}$, a simple module to be specified later in the paper, and an explanation of why this is the only interesting link invariant given by S_3. (Received January 22, 2018)

1136-55-574 **Phillip Jedlovec*** (pjedlove@nd.edu). *The generalized homology of $BU\langle 2k\rangle$.*
In their 2001 paper, "Elliptic spectra, the Witten genus and the theorem of the cube," Ando, Hopkins, and Strickland use an algebro-geometric perspective to give a partial description of the generalized homology of the connective covers of BU. For any complex-orientable cohomology theory E they define homology elements $b_{i_1,\ldots,i_k}$ in $E_*BU\langle 2k\rangle$, prove the so called "cocycle relations" and "symmetry relations" on these elements, and show that when $E = H\mathbb{Q}$ or $k = 1, 2$, or 3, these are in fact the defining relations for $E_*BU\langle 2k\rangle$. In this talk, I will sketch a new proof of these results that uses no algebraic geometry, but instead uses facts about Hopf rings and the work of Ravenel and Wilson on the homology of the spaces in the Ω-spectrum for Brown-Peterson cohomology. (Received January 22, 2018)

1136-55-598 **Krzysztof K. Putyra** and **Alexander N. Shumakovitch*** (shurik@gwu.edu), 801 22nd St. NW, Phillips Hall, Suite 739, Department of Mathematics, The George Washington University, Washington, DC 20052. *On algebraic structure of the unified Khovanov homology.* 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 $\mathbb{Z}\mathbb{Z}_2$. The goal of this talk is to show how to find these modules and to compare unified Khovanov homology for different knots and links. We start with a convenient pullback presentation of these modules to show that they are always separated. Consequently, there exist an explicit algorithmic procedure for representing them as a direct product of indecomposables. The algorithm relies on the classification of indecomposable $\mathbb{Z}\mathbb{Z}_2$-modules due to Lawrence S. Levy. Finally, we present numeric evidence that the unified Khovanov homology is a stronger knot invariant than the even and odd Khovanov homology combined. (Received January 22, 2018)

1136-55-601 **Calvin D Woo*** (calwoo@indiana.edu), 831 E 3rd Street, Rawles Hall, Bloomington, IN 47405. *THH and semi-stable reduction.*
In contrast 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.

The speaker constructs a relative version of log THH via a Mokrane-Steenbrink complex and uses it to suggest that the localization sequences reflect the geometry of schemes with semi-stable reduction. (Received January 22, 2018)

1136-55-612 **Calvin Woo*** (calwoo@indiana.edu). *On a candidate for a relative log THH.* Preliminary report.

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 January 22, 2018)

1136-55-617 **Shaun Harker**, **Miroslav Kramar**, **Rachel Levanger*** (levanger@seas.upenn.edu) and **Konstantin Mischaikow**. *A Comparison Framework for Interleaved Persistence Modules.*

In this talk, we'll take a look at a recent result in the theory of persistent homology that can be used to rigorously track noise introduced during the computation of a barcode or a persistence diagram. We'll then illustrate the use of this framework by looking closely at a number of examples, including common approximation techniques such as sub-sampling and discretization. (Received January 22, 2018)

57 ► Manifolds and cell complexes

1136-57-49 **Nick Salter*** (salter.n@gmail.com), Department of Mathematics, 1 Oxford St, Cambridge, MA 02138. *Vanishing cycles via the mapping class group.*

A fundamental phenomenon in the study of families of Riemann surfaces is that of "nodal degeneration", whereby smooth Riemann surfaces limit onto one with a nodal singularity. Associated to such a degeneration is a special simple closed curve called a "vanishing cycle". For various applications appearing in symplectic geometry, algebraic geometry, and low-dimensional topology, one would like to have an answer to the following question: which simple closed curves can be vanishing cycles? In this talk I will survey some recent work providing a complete answer to this question whenever the family of Riemann surfaces arises from a linear system on a toric surface. The key idea is to reformulate the problem in terms of the mapping class group. (Received December 15, 2017)

1136-57-115 **Mustafa Hajij*** (mhajij@usf.edu), University of South Florida, Tampa, **Mohammed Elhamdadi**, Tampa, and **Sam Nelson**. *Singular Knots and Quandles.*

We give a generating set of the generalized Reidemeister moves for oriented singular links. We use it to introduce an algebraic structure arising from the study of oriented singular knots: Quandles on singular knots. We show that the set of colorings of a singular knot by this new structure is an invariant of oriented singular knots and use it to distinguish some singular links. (Received January 07, 2018)

1136-57-142 **Charles Livingston*** (livingst@indiana.edu), Mathematics, Rawles Hall, 831 E. Third St., Bloomington, IN 47405. *Signature functions of knots and the unknotting number.*

The signature function of a knot is an integer-valued step function on the unit circle in the complex plane. Its discontinuities can occur only at roots of the Alexander polynomial. There are relationships between the values of the jumps at these discontinuities, and these lead to a complete characterization of knot signature functions. These relationships also provide new bounds on the unknotting number. (Received January 09, 2018)

1136-57-180 **Zhenghan Wang*** (zhenghwa@math.ucsb.edu). *Fracton (3+1)-TQFTs.* Preliminary report.

We discuss a program of constructing generalized (3+1)-TQFTs as inspired by fracton models in physics such as the X-cube and Haah code. (Received January 13, 2018)

1136-57-199 **Nicolas Petit*** (petitnicola@gmail.com), Oxford, GA 30054. *Index polynomials of virtual tangles.* Preliminary report.

We will briefly discuss the Henrich-Turaev polynomial, a Vassiliev finite-type invariant of virtual knots, then go over a few generalizations of it to the field of virtual tangles. Time permitting, we will go over the generalization of the smoothing invariant as well. (Received January 15, 2018)

1136-57-215 **Ruiyi Zhang*** (ruiyi.zhang@stat.fsu.edu), Department of Statistics, Florida State Univ, 214 Rogers Building (OSB), 117 N. Woodward Av, P.O. Box 3064330, Tallahassee, FL 32306-4330, and **Robert T Ogden**, **Martin Picard** and **Anuj Srivastava**. *Nonparametric k-Sample Test on Shape Space of Planar Contours with Application on Mitochondria.*

This paper develops a nonparametric framework for k-sample test on manifold where the response is shape of objects with factors from experiment design. The goal is to test on a guess that exercise might affect the mitochondrial morphology imaged from skeletal muscles of mice. Restricted by the experiment design, we also need to test on factor cell and type of mitochondria (SS/IMF).

The fact that shape space is non-Euclidean, infinite-dimensional rules out standard ANOVA decomposition and requires new ideas. Here we extend a metric-based approach developed for Euclidean space in Rizzo and Szekely, 2010, termed DISCO analysis, to the shape space of planar closed curves with different shape metrics. The adaptation leads to a statistic for testing equality of distributions. We prove the theoretical validation for Full Procrustes metric in Kendall's shape space and run the test with 5 shape metrics. Since the data have a nested structure, we also develop a procedure to test on the factor while it includes another significant factor.

The results show that under the elastic scaled metric, we are able to detect the change of SS while factor cell is significant which verifies our initial guess. (Received January 16, 2018)

1136-57-234 **Samantha Allen*** (allensam@indiana.edu). *Nonorientable surfaces bounded by knots.*
A common theme among results concerning nonorientable surfaces in 4-space is a relationship between the first Betti number and the normal Euler number of a surface. Fix a knot $K \subset S^3$. For each nonorientable surface $F \subset B^4$ bounded by K, one can compute these two values: its normal Euler number $e(F)$ and its first Betti number $b_1(F)$. The minimum value of b_1 among all such surfaces is called the nonorientable 4-genus $\gamma_4(K)$.

In this talk, I will introduce these definitions. I will then present some of the current methods for bounding $\gamma_4(K)$ involving the Euler number and an interplay between classical knot invariants and the more recently defined Upsilon invariant arising from Heegaard Floer theory.

To conclude, I will explain how another Heegaard Floer invariant, the d-invariant, can provide finer details about the set of pairs (e, b_1) that can occur for a given knot. (Received January 16, 2018)

1136-57-243 **Thomas Kerler*** (kerler.2@osu.edu). *Computing Quantum Group Valued Invariants of Knots and Links.*
Universal invariants of knots associated to quantum sl2 and other quasi-triangular Hopf algebras have been described by Lawrence and Reshetikhin in the last 1980's. We discuss the formalization of the respective calculus including general higher rank quantum groups with particular attention to the involved restrictions from formal power series to Laurent polynomials. Time permitting we will also explain applications of the algorithm in recent work with A. Borland on monodromy dependent invariants and M. Harper on the square nilpotent invariants. (Received January 17, 2018)

1136-57-253 **Hans U. Boden*** (boden@mcmaster.ca), **Micah Chrisman** and **Robin Gaudreau**. *Concordance invariants of virtual knots II.*
This talk will focus on virtual knot concordance and is a based on joint work with Micah Chrisman and Robin Gaudreau. The goal is to extend classical concordance invariants to the virtual setting and apply them to determine the sliceness and the 4-genus for low crossing virtual knots. One of the obstacles is the absence of Seifert surfaces for virtual knots, and for that reason we focus on the subclass of almost classical (AC) knots, which consist of virtual knots which can be represented as homologically trivial knots in thickened surfaces. Such knots admit Seifert surfaces, which can be used to define Seifert matrices, Alexander-like polynomials, signatures, and twisted signatures. For round AC knots, the resulting invariants will depend on the choice of Seifert surface, but for long virtual knots, they are independent. In either case, they give obstructions to slicing AC knots and we apply them to determine sliceness and 4-ball genus for AC knots up to 6 crossings. Parity projection, and the fact that it preserves virtual knot concordance, allows one to extend the invariants to all virtual knots. (Received January 17, 2018)

1136-57-258 **Marco Bonatto**, **Michael K. Kinyon**, **David Stanovsky**, **Petr Vojtechovsky** and **Seung Yeop Yang*** (seungyeop.yang@du.edu). *Set-theoretic Yang-Baxter (co)homology theory for bijective rumples and rumple cocycle invariants.* Preliminary report.
A groupoid $(X, \cdot)$ is called a *left quasigroup* if all its left translations $L_x : X \to X$ defined by $L_x(y) = xy$ are bijective. A left quasigroup satisfying the left Rump identity $(xy)(xz) = (yx)(yz)$ is called a *rumple*. It is known that there is a one-to-one correspondence between involutive solutions of the Yang-Baxter equation and bijective rumples. In 2004, Carter, Elhamdadi, and Saito introduced homology theory for set-theoretic Yang-Baxter equations, and defined state-sum invariants for knots and knotted surfaces using cocycles. In this talk, we construct set-theoretic Yang-Baxter (co)homology theory for bijective rumples, and define rumple cocycle invariants of links. (Received January 18, 2018)

1136-57-265 **J. Scott Carter*** (carter@southalabama.edu), ILB 325, Department of Mathematics and Statistics, 307 N. University Blvd., Mobile, AL 36608. *A 2-categorical description of embedded surfaces in 3-space.*

I am pretty sure this is folklore, but I have been asked about this recently. Namely, What is the 2-categorical description of (oriented) surfaces that are embedded in 3-dimensional space? Objects are oriented points. 1-morphisms are identities, $\cup$, and $\cap$. Of course, in the oriented case, there are $\overleftarrow{\cup}$, $\overrightarrow{\cup}$, $\overleftarrow{\cap}$, and $\overrightarrow{\cap}$. By asserting inveritibility at the object level, the 2-morphisms births, deaths, and saddles are automatic. The 2-morphisms that are cusps are described as adjointness or duality via (invertible) zig-zags. The assertion that zig-zags are invertible forces invertible beak-to-beak and lips 3-morphisms. One further asserts some critical cancellation as 3-morphisms as well as swallow-tail identities.

Despite the categorical nature, the talk is envisioned to be elementary. It will involve slides and a globular worksheet. I'll give a 2-categorical functor between the 2-category of 2-tangles in 3-space and this combinatorial description. I aim for a freeness result. (Received January 18, 2018)

1136-57-275 **Sujoy Mukherjee*** (sujoymukherjee@gwu.edu) and **Jozef H. Przytycki** (przytyck@gwu.edu). *Graphic quandles.* Preliminary report.

Quandles are algebraic structures with axioms motivated by the three Reidemeister moves in knot theory. After a brief introduction to basic quandle theory, we will focus on the family of quandles satisfying the graphic axiom. Then, we will study the rack homology of some of the quandles in this family. (Received January 18, 2018)

1136-57-305 **Juanita Pinzon-Caicedo*** (jpinzon@ncsu.edu). *Cable-like satellites are not homomorphisms.* Preliminary report.

A satellite knot $P(K)$ with pattern $P \sqcup J$ (J an unknot) and companion K is obtained as the image of P under the identification of the solid tori $S^3 \setminus N(J)$ and $N(K)$. Fixing the pattern P and letting K vary gives a function on $\mathcal{C}$, the set of smooth concordance classes of knots. It is not known if in general the function $P : \mathcal{C} \to \mathcal{C}$ is a homomorphism. In this talk I will show that if a pattern P can be transformed into a cable $C_{w,1}$ by a sequence of positive-to-negative crossing changes, then the function $P : \mathcal{C} \to \mathcal{C}$ is not a homomorphism. (Received January 19, 2018)

1136-57-364 **Radmila Sazdanovic*** (rsazdan@ncsu.edu), Deparment of Mathematics, NC State PO Box 8205, Raleigh, NC 27695, and **Vladimir Baranovsky**. *On factorization, Khovanov link, and chromatic graph homology.* Preliminary report.

Factorization homology, introduced by Ayala, Francis, and Tanaka, generalizes Hochschild homology. Chromatic homology, a comultiplication-fee Khovanov-type theory for graphs constructed by Helme-Guizon and Rong, approximates Hochschild homology when applied to a circle. We complete this picture by relating factorization and chromatic homology to each other, and conjecturally to Khovanov link homology. (Received January 19, 2018)

1136-57-419 **Jozef H. Przytycki*** (przytyck@gwu.edu), Columbian College of Arts and Sciences, Phillips Hall, Room 739, Washington, DC 20052. *Geometric realization of transition Khovanov homology.*

For a link diagram whose A-state graph has large girth, the Khovanov homology is "easy" in comultiplication free part and difficult if multiplication is mixed with comultiplication. We discuss a geometric realization of Khovanov homology in gradings between easy and difficult parts. (Received January 21, 2018)

1136-57-420 **Liang Chang** and **Shawn X Cui***, 382 Via Pueblo Mall Varian Laboratory, Stanford, CA 94305. *On Two Invariants of Three Manifolds from Hopf Algebras.*

We prove a 20-year-old conjecture concerning two quantum invariants of three manifolds that are constructed from finite dimensional Hopf algebras, namely, the Kuperberg invariant and the Hennings-Kauffman-Radford invariant. The two invariants can be viewed as a non-semisimple generalization of the Turaev-Viro-Barrett-Westbury (TVBW) invariant and the Witten-Reshetikhin-Turaev (WRT) invariant, respectively. By a classical result relating TVBW and WRT, it follows that the Kuperberg invariant for a semisimple Hopf algebra is equal to the Hennings-Kauffman-Radford invariant for the Drinfeld double of the Hopf algebra. However, whether the relation holds for non-semisimple Hopf algebras has remained open, partly because the introduction of framings in this case makes the Kuperberg invariant significantly more complicated to handle. We give an affirmative answer to this question. An important ingredient in the proof involves using a special Heegaard diagram in which one family of circles gives the surgery link of the three manifold represented by the Heegaard diagram. (Received January 21, 2018)

1136-57-422 **J.-F. Lafont*** (jlafont@math.ohio-state.edu) and **C. Neofytidis**. *Sets of degrees of maps between SU(2)-bundles over the 5-sphere.*

We compute the sets of degrees of maps between the two principal SU(2)-bundles over the 5-sphere. We show that the only obstruction to the existence of a mapping degree between those manifolds is derived by the Steenrod squares. We construct explicit maps realizing each integer that occurs as a mapping degree between these bundles. (Received January 21, 2018)

1136-57-505 **Heather A Dye***, heatheranndye@gmail.com. *The Tiered Bracket Polynomial.* Preliminary report.

In this talk, we use information about the parity of the crossings to introduce additional variables. (Received January 22, 2018)

1136-57-566 **Patricia Cahn*** (pcahn@smith.edu) and **Alexandra Kjuchukova**. *Ribbon obstructions and dihedral branched covers of four-manifolds.*

Consider a four-manifold Y which is presented as a p-fold dihedral branched cover of S^4, with one singularity on the branching set, modeled on the cone on a knot K. Kjuchukova showed that the signature of Y is an invariant of K. We show that this signature is a ribbon obstruction, and give an algorithm for computing this signature from a p-colored knot diagram of K. We use trisections to identify the diffeomorphism type of the cover for given families of singularities. In particular, we construct infinitely many singular dihedral covers of S^4 by CP^2. We conclude by giving a classification of singular dihedral branched covering maps from CP^2 to S^4, and explain the implications of this classification for finding potential counterexamples to the Slice-Ribbon Conjecture. (Received January 22, 2018)

1136-57-584 **Bakul Sathaye*** (sathaye.2@osu.edu). *Obstructions to Riemannian smoothings of locally CAT(0) manifolds.*

In this talk I will focus on obstructions in dimension = 4 to Riemannian smoothings of a locally CAT(0) manifold. I will discuss the obstruction given by Davis-Januszkiewicz-Lafont and show how their methods can be extended to construct more examples of locally CAT(0) 4-manifolds M that do not support Riemannian metric with non-positive sectional curvature. The universal cover of the manifolds we construct satisfy the isolated flats condition and contain a collection of 2-dimensional flats with the property that their boundaries at infinity form non-trivial links in the boundary 3-sphere. (Received January 22, 2018)

1136-57-627 **Fedor Manin***, manin.4@osu.edu. *Quantitative and computational immersion theory.*

Many quantitative and computational problems that we would like to resolve for embeddings of manifolds are more easily done for immersions. I will survey some results and explain some of the challenges of extending them to the embedding world. (Received January 23, 2018)

58 ► Global analysis, analysis on manifolds

1136-58-4 **Shu-Cheng Chang**, **Yuxin Dong** and **Yibin Ren***, allenryb@outlook.com. *Compactness of Closed Pseudo-Einstein Manifolds.*

Based on uniform CR Sobolev inequality and Moser iteration, the paper estimate the pseudo-Hermitian curvature, the pseudo-Hermitian torsion and its first covariant derivative on pseudo-Einstein manifolds under some integral conditions. By Cheeger-Gromov compactness theorem, the set of normalized closed pseudo-Einstein manifolds with some integral conditions is $C^{1,\alpha}$ compact. Moreover, the set of normalized closed Sasakian-Einstein manifolds are C^∞ compact. (Received June 22, 2017)

1136-58-129 **Gerard Misiolek*** (gmisiole@nd.edu). *Information Geometry on diffeomorphism groups.*

Information Geometry on diffeomorphism groups and, time permitting, connections with Hydrodynamics and Optimal transport. (Received January 08, 2018)

1136-58-164 **Laurent Younes*** (laurent.younes@jhu.edu). *Riemannian Metrics Associated with Metamorphoses on Spaces of Curves.*

We consider a class of metrics on length-normalized curves in $\mathbb{R}^d$, represented by their tangent angle expressed as a function of arc-length, $T : \Omega \to S^{d-1}$, where Ω is the unit interval and S^{d-1} the unit sphere. These metrics are derived from the combined action of diffeomorphisms (change of parameters) and rotation acting on the function T, represented infinitesimally as $\delta T = -vT' + z$, where v is a scalar-valued function associated with an infinitesimal change of parameter and z a small variation perpendicular to T. Minimizing a Riemannian metric combining a squared Sobolev norm on v and a weighted L^2 norm on z leads to a special case of "metamorphosis", which provide a general framework adapted to situations when a Lie group acts on a Riemannian manifold.

When the norm on v is Sobolev with order 1, the resulting problem is identical to that introduced by Mio and Srivastava for the study of plane curves. Our presentation will offer a new angle for the analysis on this family of metrics, for which we will present new results and experiments. (Received January 11, 2018)

1136-58-220 **Mengmeng Guo** (mengmeng.guo@ttu.edu), Lubbock, TX 79409, and **Jingyong Su*** (jingyong.su@ttu.edu), Lubbock, TX 79409. *Elastic Regression Analysis of Ozone Hole Contours.*

We develop a multivariate regression model when response variable is on nonlinear manifolds, rather than on Euclidean space. This nonlinear constraint makes the problem challenging and needs to be studied carefully. By performing principal component analysis on tangent space of manifolds, we use the principal directions as our response variables instead. Then, the ordinary regression tools are utilized. We apply the framework to the problem of ozone depletion and its influencing factors. Particularly, these ozone hole contours are considered as response observations on manifold, where the manifold is equipped with a parametrization-invariant metric. Experimental results have shown that we can not only find the most significant factors, but also predict ozone hole contours by the constructed model. (Received January 16, 2018)

1136-58-299 **Gabriel Khan*** (khan.375@osu.edu). *Estimates on the Principle Eigenvalue of a Hermitian Manifold.*

One of the central questions in complex geometry seeks to understand the moduli space of complex structures on a given manifold. In this talk, we consider a modified version of this problem, where we first specify a Riemannian metric and then study the moduli space of the complex structures compatible with it. Under some assumptions, we can derive a lower bound on the principle eigenvalue of the complex Laplacian using the Riemannian geometry alone, independent of the particular choice of complex structure. Along the way, we encounter non-self-adjoint drift Laplacians and show how the classic Li-Yau estimate can be adapted to this setting. (Received January 19, 2018)

1136-58-529 **Jason Cantarella** and **Clayton Shonkwiler*** (clay@shonkwiler.org), Colorado State University, Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523. *Equilateral Polygons, Shapes of Ring Polymers, and an Application to Frame Theory.*

Random flights in $\mathbb{R}^3$ forming a closed loop, or *random polygons*, are a standard simplified model of so-called ring polymers like bacterial DNA. Equilateral random polygons, where all steps are the same length, are particularly interesting (and challenging) in this context. In this talk I will describe an (almost) toric Kähler structure on the moduli space of equilateral polygons and show how to exploit this structure to get a fast algorithm to directly sample the space.

Using work of Hausmann–Knutson, the Kähler structure on the space of equilateral polygons can be realized as the Kähler reduction of the standard Kähler structure on the Grassmannian $G_2(\mathbb{C}^n)$. This means that equilateral polygons in $\mathbb{R}^3$ can be lifted to Finite Unit-Norm Tight Frames (FUNTFs) in $\mathbb{C}^2$. I will describe how to modify the polygon sampler to produce a FUNTF sampler and show that optimal packings in the 2-sphere lift to FUNTFs with low coherence. (Received January 22, 2018)

1136-58-578 **Jakob Moeller-Andersen***, 1017 Academic Way, 208 Love Building, Tallahassee, FL 32306. *Varifold-based Curve Matching with Elastic Sobolev Metrics.*

We present a flexible method to obtain numerical solutions for both exact and inexact matchings between open or closed curves based on Sobolev-type Riemannian metrics on shape space and a varifold discrepancy term. The method does not use a metric specific transform, so the metric on shape space can be chosen in a larger class of metrics than in previous work, including all elastic and scale-invariant metrics. Instead, an Augmented Lagrangian scheme is employed to solve the resulting optimization problem. To demonstrate the method, we will show examples of how matchings change as the metric is varied. (Received January 22, 2018)

1136-58-583 **Casey Lynn Kelleher*** (ckelleher@math.princeton.edu) and **Jeffrey Streets**. *Recent developments for symplectic curvature flow.* Preliminary report.

The symplectic curvature flow was introduced by Streets and Tian as a natural extension of Kahler Ricci flow to the symplectic setting. We discuss recent developments, with a primary focus on the complex dimension 2 setting. (Received January 22, 2018)

60 ► Probability theory and stochastic processes

1136-60-63 **Ahmed Idrees Merie*** (amerie2013@my.fit.edu), 220 E University Blvd, Apt 1701, Melbourne, FL 32901. *FLUCTUATION ANALYSIS IN QUEUES WITH SEVERAL OPERATIONAL MODES AND PRIORITY CUSTOMERS with N-policy.* Preliminary report.

We consider a class of queues with a single server who operates in four different modes, attends two queues, and dependent on circumstances, processes two different queues simultaneously. The server capacity is N>r ”, when serving primary customers. When the primary queue drops below < and unless it is empty. the server continues working in a slower mode and takes on a secondary queue simultaneously. There are different switching policies that specify when the server works on one or two queues. There are elements of a non-cooperative stochastic game when the server attends two queues. The main tools pertain to recent results in fluctuation theory, namely level-crossing techniques applied to piece-wise linear jump processes. One of the objectives in the paper is to model processes that occurs in software, computer, and electrical engineering, and argue that methods of fluctuation theory produce closed form functionals. Key Words: Single-server queueing systems, fluctuation theory, marked point processes, stochastic games, semi-regenerative processes. AMS Subject Classification: 60K10, 60K25, 60G51, 60G55, 60K05, 60G57. (Received December 26, 2017)

1136-60-91 **Leila setayeshgar***, 1 Cunningham Square, Providence, RI 02918, and **Mohammud Foondun**. *Large Deviations for a Class of Stochastic Semilinear Partial Differential Equations.*

Standard approaches to large deviations analysis for stochastic partial differential equations (SPDEs) are often based on approximations. These approximations are mostly technical and often onerous to carry out. In 2008, Budhiraja, Dupuis and Maroulas, employed the weak convergence approach and showed that these approximations can be avoided for many infinite dimensional models. Large deviations analysis for such systems instead relied on demonstrating existence, uniqueness and tightness properties of certain perturbations of the original process. In this talk, we use the weak convergence approach, and establish the large deviation principle for the law of the solutions to a class of semilinear SPDEs. Our family of semilinear SPDEs contains, as special cases, both the stochastic Burgers' equation, and the stochastic reaction-diffusion equation. (Received January 04, 2018)

1136-60-125 **Andrey Sarantsev*** (sarantsev@pstat.ucsb.edu), South Hall 5607A, Statistics and Applied Probability, University of California, Santa Barbara, CA 93106, and **Soumik Pal**. *Concentration of measure for reflected diffusions.* Preliminary report.

We find dimension-free Talagrand concentration inequalities for stochastic differential equations with normal reflection. We apply these results to systems of rank-based competing Brownian particles, used for financial modeling. (Received January 08, 2018)

1136-60-153 **Konstantinos Spiliopoulos*** (kspiliop@math.bu.edu), Boston University, Department of Mathematics and Statistics, Boston, MA 02215. *Large deviations and averaging for systems of slow–fast stochastic reaction–diffusion equations.* Preliminary report.

We study a large deviation principle for a system of stochastic reaction-diffusion equations (SRDEs) with a separation of fast and slow components and small noise in the slow component. The derivation of the large deviation principle is based on the weak convergence method in infinite dimensions, which results in studying averaging for controlled SRDEs. By appropriate choice of the parameters, the fast process and the associated control that arises from the weak convergence method decouple from each other. We characterize the limiting process via a "viable pair" that captures the limiting controlled dynamics and the effective invariant measure simultaneously. The characterization of the limit of the controlled slow-fast processes in terms of viable pair enables us to obtain a variational representation of the large deviation action functional. Due to the infinite–dimensional nature of our set–up, the proof of tightness as well as the analysis of the limit process and in particular the proof of the large deviations lower bound is considerably more delicate here than in the finite–dimensional situation. We emphasize that many issues that are present in the infinite dimensional case, are completely absent in finite dimensions. Joint work with Wenqing Hu and Michael Salins. (Received January 10, 2018)

1136-60-173 **Hoi H Nguyen*** (nguyen.1261@osu.edu). *A remark on long-range repulsion in spectrum of random matrices.*

In this talk we will address a "long-range" type repulsion among the singular values of random iid matrices, as well as among the eigenvalues of random Wigner matrices. We show evidence of repulsion under arbitrary perturbation even in matrices of discrete entry distributions. In many cases our method yields nearly optimal bounds. (Received January 12, 2018)

1136-60-218 **Vasileios Maroulas** and **Xiaoyang Pan*** (pan@math.utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 37996, and **Jie Xiong**. *Large deviations for the optimal filter of nonlinear dynamical systems driven by Lévy noise.*

In this talk, we focus on the asymptotic behavior of the optimal filter where both signal and observation processes are driven by Lévy noises. Indeed, we study large deviations for the case where the signal-to-noise ratio is small by considering weak convergence arguments. To that end, we first prove the uniqueness of the solution of the controlled Zakai and Kushner-Stratonovich equations. For this, we employ a method which transforms the associated equations into SDEs in an appropriate Hilbert space. Next, taking into account the controlled analogue of Zakai and Kushner-Stratonovich equations, respectively, the large deviation principle follows by employing the existence, uniqueness and tightness of the solutions. (Received January 16, 2018)

1136-60-230 **Parisa Fatheddin*** (parisa.fatheddin@afit.edu), 2950 Hobson Way, Wright-Patterson AFB, OH 45433, **P. Sundar** (psundar@lsu.edu), Louisiana State University, Baton Rouge, LA 70803, and **Jie Xiong** (jiexiong@umac.mo), Macau, Peoples Rep of China. *The Law of the Iterated Logarithm for a Class of SPDEs.* Preliminary report.

We introduce a class of SPDEs used to characterize two population models: super-Brownian motion and Fleming-Viot Process. First we derive the moderate deviation principle for the class and the models applying the weak convergence approach, then use the results to obtain the classical and Strassen's compact laws of the iterated logarithm. This is from joint work with P. Sundar and Jie Xiong. (Received January 16, 2018)

1136-60-254 **Kateryna Tatarko*** (tatarko@ualberta.ca), Dept. of Math. and Stat. Sciences, 632 Central Academic Building, University of Alberta, Edmonton, AB T6G 2G1, Canada. *An upper bound on the smallest singular value of a square random matrix.*

Let $A = (a_{ij})$ be a square $n \times n$ matrix with i.i.d. zero mean and unit variance entries. Rudelson and Vershynin showed that the upper bound for a smallest singular value $s_n(A)$ is of order $n^{-\frac{1}{2}}$ with probability close to one under additional assumption on entries of A that $\mathbb{E}a_{ij}^4 < \infty$. We remove the assumption on the fourth moment and show the upper bound assuming only $\mathbb{E}a_{ij}^2 = 1$. (Received January 17, 2018)

1136-60-277 **Mokshay Madiman*** (madiman@udel.edu). *Entropy power inequalities and the Stam region.*

We initiate the study of the Stam region, defined as the subset of the positive orthant in $\mathbb{R}^{2^n-1}$ that arises from considering entropy powers of subset sums of n independent random vectors in a Euclidean space of finite dimension. We show that the class of fractionally superadditive set functions provides an outer bound to the Stam region. We also develop some qualitative properties of the Stam region, showing for instance that its closure is a logarithmically convex cone. (Received January 18, 2018)

1136-60-313 **Padmanabhan Sundar***, Department of Mathematics, Lockett Hall, Louisiana State University, Baton Rouge, LA 70803. *Probabilistic Analysis for the Enskog Equation.*

The Boltzmann equation describes the time evolution of the density of gas particles for a given initial distribution. A non-localized form of it is the Enskog equation, and its solution is identified with the law of the solution of a McKean-Vlasov system driven by a Poisson random measure. An interacting system of N-particles with binary collisions is considered in order to establish the existence of weak solutions to the Enskog equation, in the limit as $N \to \infty$. The talk is based on joint works with S. Albeverio, M. Friesen, and B. Rüdiger. (Received January 19, 2018)

1136-60-343 **Wai-Tong Fan*** (louisfan@math.wisc.edu), 926 Eagle Heights C, Madison, WI 53705. *Genealogies for a biased voter model.*

I will present rigorous results about the genealogies of a biased voter model introduced by Hallatschek and Nelson (2007). To investigate the lineage dynamics, we derived a system of stochastic partial differential equations (SPDE) from the tracer dynamics in which the particles have different colors. Brunet et al. (2006) have conjectured that genealogies in models of this type are described by the Bolthausen-Sznitman coalescent. However, there are no simultaneous coalescences in our model, since the dual branching coalescing random walk converges to a branching Brownian motion in which particles coalesce after an exponentially distributed amount of intersection local time. A new duality equation is established to show uniqueness of the SPDE. By generalizing results of Mueller and Tribe (1995), we also identified different scalings for which our biased voter model converges to either the Wright-Fisher SPDE or the deterministic FKPP. Joint work with Rick Durrett. (Received January 19, 2018)

1136-60-367 **Vladislav Kargin*** (kargin@math.binghamton.edu), 4400 Vestal Pkwy East, Department of Mathematics, Binghamton, NY 13902. *Sampling Tilings and Convexity.* Preliminary report.

There have been much recent research on sampling tilings of plane regions. For example, it was shown that in many cases the Glauber Markov chain is rapidly converging to the uniform distribution on tilings.

I will briefly review this research and will talk about its relation to random distributions on convex polytopes. (Received January 20, 2018)

1136-60-377 **Tyrone E. Duncan***, duncan@ku.edu. *Some Stochastic Control Problems for Evolution Equations with State Dependent Gauss-Volterra Processes.*

A stochastic control problem for an evolution equation in an infinite dimensional Hilbert space and a stochastic term that is bilinear in the state and a noise process that is a scalar Gauss-Volterra process is formulated and solved. The Gauss-Volterra noise processes are obtained from the integral of a Brownian motion with a suitable kernel function. These noise processes include fractional Brownian motions with the Hurst parameter $H \in (\frac{1}{2}, 1)$, Liouville fractional Brownian motions with $H \in (\frac{1}{2}, 1)$, and some multifractional Brownian motions. The cost functional is quadratic in the state and the control and the time horizon can be finite or infinite. The family of admissible controls is a family of linear feedback controls. This restriction on the family of controls allows for a feasible implementation of the optimal controls. The optimal feedback controls are determined by the solution of a Riccati equation which differs from the well known Riccati equation for a linear-quadratic control problem. These equations can model stochastic partial differential equations of parabolic and hyperbolic types and some examples are given.

This is joint work with B. Maslowski and B. Pasik-Duncan. (Received January 20, 2018)

1136-60-379 **Florin Catrina** and **Aurel I Stan*** (stan.7@osu.edu). *A Holder-Young inequality for norms of Gamma Wick products.*

We define first the Wick product generated by a probability measure with finite moments of all orders. This definition depends on the monic orthogonal polynomials associated with that measure. We then apply this definition to the particular case of a Gamma distribution, and present an integral representation for the Gamma Wick products. Finally, we use the integral representation to prove an inequality for norms of Wick products generated by a Gamma probability measure with mean equal to the half of an integer. (Received January 20, 2018)

1136-60-457 **Grzegorz A Rempala*** (grempala@cph.osu.edu), Division of Biostatistics and, Mathematical Biosciences Institute, The Ohio State University, Columbus, OH 43210. *Quasi-steady state approximations for stochastic enzyme kinetics.*

In chemistry and biology, we often come across chemical reaction networks where one or more of the species exhibit a different intrinsic time scale and tend to reach an equilibrium state quicker than others. Quasi steady state approximation (QSSA) is a commonly used tool to simplify the description of the dynamics of such systems. In particular, QSSA has been widely applied to the important class of reaction networks known as the Michaelis-Menten models of enzyme kinetics. In this talk I will present a general approach to deriving various QSSAs using the multi- scaling approximation arguments. (Received January 21, 2018)

1136-60-465 **Le Chen*** (le.chen@unlv.edu), Department of Mathematical Sciences, University of Nevada, Las Vegas, Las Vegas, NV 89154-4020, and **Jingyu Huang** (jhuang@math.utah.edu). *Comparison principle for stochastic heat equation on $\mathbb{R}^d$.*

In this talk, I will present a recent joint-work with Jingyu Huang on the strong comparison principle and strict positivity of solutions to the following nonlinear stochastic heat equation on $\mathbb{R}^d$

$$\left(\frac{\partial}{\partial t} - \frac{1}{2}\Delta\right) u(t,x) = \rho(u(t,x))\, \dot{M}(t,x),$$

for measure-valued initial data, where $\dot{M}$ is a spatially homogeneous Gaussian noise that is white in time and ρ is Lipschitz continuous. These results are obtained under the condition that $\int_{\mathbb{R}^d}(1+|\xi|^2)^{\alpha-1}\hat{f}(\mathrm{d}\xi) < \infty$ for some $\alpha \in (0,1]$, where $\hat{f}$ is the spectral measure of the noise. The weak comparison principle and nonnegativity of solutions to the same equation are obtained under Dalang's condition, i.e., $\alpha = 0$. As some intermediate results, we obtain handy upper bounds for $L^p(\Omega)$-moments of $u(t,x)$ for all $p \geq 2$, and also prove that u is a.s. Hölder continuous with order $\alpha - \epsilon$ in space and $\alpha/2 - \epsilon$ in time for any small $\epsilon > 0$. (Received January 21, 2018)

1136-60-525 **Petros Valettas*** (valettasp@missouri.edu). *Concentration, anti-concentration, and Gaussian convexity.*

The concentration of measure phenomenon is already a fundamental tool in high-dimensional geometry and probability. In one of its simplest forms states that the deviation of a Lipschitz function about its mean is controlled by its metric oscillations, i.e. the Lipschitz constant.

In this talk we will emphasize a geometric, rather than metric, aspect of the Gaussian concentration. We will explain how one can obtain one-sided deviation estimates for convex functions (which are not necessarily Lipschitz). Moreover, the aforementioned concentration and anti-concentration inequalities are governed by the "probabilistic oscillations", i.e. the variance of the function. In the common context, where the function is assumed to be both Lipschitz and convex, the latter estimate quantifies the tightness of the Gaussian concentration in the classical setting.

These distributional inequalities can be viewed as a new type of concentration and anti-concentration, which lies in the convexity properties of the Gaussian measure. (Received January 22, 2018)

1136-60-535 **Andrey Sarantsev*** (sarantsev@pstat.ucsb.edu), South Hall 5607A, Statistics and Applied Probability, University of California, Santa Barbara, CA 93106. *INFINITE ATLAS MODEL.*

In the infinite Atlas model, the bottom-ranked Brownian particle moves with drift one, all other Brownian particles are driftless. We survey recent results on this model: stationary regimes, long-term convergence, scaling limits of the empirical measure. Joint work with Amir Dembo, Vladas Sidoravicius, Li-Cheng Tsai, Manuel Cabezas. (Received January 22, 2018)

1136-60-542 **Mohammud Foondun*** (mohammud.foondun@strath.ac.uk), Department of Mathematics and Statistics, University of Strathclyde, Glasgow, Scotland, United Kingdom. *Moment bounds on the solutions to some stochastic equations.*

n this talk, we will show how sharp bounds on the moments of the solutions to some stochastic heat equations can lead to various qualitative properties of the solutions. A major part of the method consists of approximating the solution by "independent quantities". These quantities together with the moments bounds give us sharp almost sure properties of the solution. (Received January 22, 2018)

1136-60-592 **Konstantin Tikhomirov***, Fine Hall, Washington road, Princeton, NJ 08544. *The condition number of random square matrices.*

The condition number of a square matrix is defined as the ratio of the largest and smallest singular values. In this talk we consider the problem of estimating the condition number for certain models of random matrices with independent rows/columns. (Received January 22, 2018)

1136-60-622 **Kavita Ramanan*** (kavita_ramanan@brown.edu), **Steven Soojin Kim** and **Nina Gantert**. *Large Deviations of Random Projections of High-dimensional Probability Measures.*

Properties of random projections of high-dimensional probability measures are of interest in a variety of fields, including asymptotic convex geometry, and high-dimensional statistics and data analysis. A particular question of interest is to identify what properties of the high-dimensional measure are captured by its lower-dimensional projections. While fluctuations of these projections have been well studied over the past decade, we describe more recent work on both annealed and quenched large deviations principles and associated conditional limit theorems for multidimensional projections. This talk is based on joint works with Nina Gantert and Steven Kim. (Received January 23, 2018)

1136-60-623 **Kavita Ramanan*** (kavita_ramanan@brown.edu) and **Pooja Agarwal** (pooja_agarwal@brown.edu). *Ergodicity of Stochastic Partial Differential Equations arising as Diffusion Approximations of Stochastic Networks.* Preliminary report.

We consider a class of stochastic partial differential equations (SPDEs) that arise as diffusion approximations of many-server stochastic networks. These SPDEs are defined on a domain and satisfy non-standard boundary conditions. We establish existence and uniqueness of the stationary distribution of such an SPDE. The proof of ergodicity entails the construction of a novel asymptotic (equivalent) coupling, which may be of independent interest. This is joint work with Pooja Agarwal. (Received January 23, 2018)

62 ► Statistics

1136-62-43 **Rida Benhaddou*** (benhaddo@ohio.edu), Department of Mathematics 321, Ohio University, 1 Ohio University, Athens, OH 45701. *Minimax adaptive wavelet estimator for the simultaneous blind deconvolution with fractional Gaussian noise.*

We consider the problem of estimating the response function in the simultaneous deconvolution model with noisy kernels where both noise sources are fractional Gaussians. A preliminary thresholding procedure is implemented to stabilize the inversion. The proposed wavelet-based estimator is adaptive and attains asymptotically optimal convergence rates in a wide range of Besov balls. It turns out that our convergence rates are expressed as the maxima between two terms, taking into account both noise sources, and they depend only on the parameters associated with the weakest long-range dependence, from amongst the channels at hand. In addition, the convergence rates deteriorate as these parameters get smaller and smaller. (Received December 09, 2017)

1136-62-110 **Lizhen Lin*** (lizhen.lin@nd.edu), Notre Dame, IN 46530, and **Drew Lazar** and **Bayan Saparbayeva**. *Robust inference of big manifold-valued data with applications to shapes.*

This talk focuses on robust inference of manifold-valued data based on Fréchet means. The theory and algorithms for the classical 'median of means' ideas are extended to the inference of big manifold-valued data. The resulting estimator is shown to be robust to outliers and contaminations of arbitrary nature and has stronger concentration around the population mean than the standard empirical Fréchet mean. We will demonstrate the estimation procedure and methods of computation for a large class of manifolds of interests including shape spaces. (Received January 06, 2018)

1136-62-139 **Justin Strait*** (strait.50@osu.edu), **Oksana Chkrebtii** and **Sebastian Kurtek**. *Automatic Detection and Uncertainty Quantification of Landmarks on Elastic Curves.*

A population quantity of interest in statistical shape analysis is the location of landmarks, which are points that aid in reconstructing and representing shapes of objects. We provide an automated, model-based approach to inferring landmarks given a sample of shape data. The model is formulated based on a linear reconstruction of the shape, passing through the specified points, and a Bayesian inferential approach is described for estimating unknown landmark locations. The question of how many landmarks to select is addressed in two different ways: (1) by defining a criterion-based approach, and (2) joint estimation of the number of landmarks along with their locations. Efficient methods for posterior sampling are also discussed. We motivate our approach using several simulated examples, as well as data obtained from applications in computer vision and biology; additionally, we explore placements and associated uncertainty in landmarks for various substructures extracted from magnetic resonance image slices. (Received January 09, 2018)

1136-62-344 **Sebastian Andrew Kurtek*** (kurtek.1@stat.osu.edu), **Karthik Bharath**, **Arvind Rao** and **Veerabhadran Baladandayuthapani**. *Radiologic Image-based Statistical Shape Analysis of Brain Tumors.*

We propose a curve-based Riemannian-geometric approach for general shape-based statistical analyses of tumors obtained from radiologic images. A key component of the framework is a suitable metric that (1) enables comparisons of tumor shapes, (2) provides tools for computing descriptive statistics and implementing principal component analysis on the space of tumor shapes, and (3) allows for a rich class of continuous deformations of a tumor shape. The utility of the framework is illustrated through specific statistical tasks on a dataset of radiologic images of patients diagnosed with glioblastoma multiforme, a malignant brain tumor with poor prognosis. In particular, our analysis discovers two patient clusters with very different survival, subtype and genomic characteristics. Furthermore, it is demonstrated that adding tumor shape information into survival models containing clinical and genomic variables results in a significant increase in predictive power. (Received January 19, 2018)

1136-62-389 **Leif Ellingson*** (leif.ellingson@ttu.edu), Texas Tech University, Department of Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409, and **Dhanamalee Bandara**. *Neighborhood Hypothesis Tests for Fréchet Mean Shapes.*

Classical hypothesis tests for mean shapes require covariance matrices to be invertible, but for modern shape analysis, this is typically not the case because the data have high (or infinite) dimensionality. Inspired by the neighborhood hypothesis tests of Munk et al (2008) for functional data, Ellingson et al (2013) developed an asymptotic inference procedure to test for the approximate equality of an extrinsic mean shape. By lifting the requirement of exact equality, this procedure uses the geometry of the shape space to bypass the need for an invertible covariance matrix. However, a limitation of the above methods is that it can be difficult to reasonably define the radius of a neighborhood for approximate equality in an interpretable meanner. Motivated by this, Bandara et al (2018) introduced a modified neighborhood hypothesis test for functional data that defines the size of the neighborhood with respect to the Fréchet total variance of the population. In this presentation, we adapt this modification to tests for Fréchet mean shapes (Received January 20, 2018)

1136-62-401 **Daniel F Linder*** (daniel.f.linder@gmail.com), 604 Harvey St, Milen, GA 30442. *Kinetic rates estimation for reaction networks.*

In this talk I will use data from a biological experiment in zebrafish to motivate the need for rigorous yet computationally efficient methods to perform parameter inference in reaction network models. I will discuss some of the popular methods from the literature, as well as methods I have developed with collaborators. (Received January 20, 2018)

1136-62-436 **James H. Degnan***, jamdeg@unm.edu, and **Huan Jiang**. *Trait evolution on two or more trees.*

In trait evolution models in phylogenetics, the mean value of a trait for a species evolves along the branches of a phylogeny. This process leads to correlated traits values at the tips of a phylogenetic tree, where tips that are more closely related tend to have more similar mean trait values. An implicit assumption in these models is that the mean trait value is evolving on a single tree. We consider a more general perspective in which trait values can be modeled as arising on a combination of trees. This is motivated by consideration of traits that are strongly influenced by a small number of genes, in which case it makes sense to think of the traits as evolving on the gene trees, which reflect the ancestry for gene orthologs sampled from different populations, as opposed to the species tree, which reflects the ancestral relationships for populations. The multiple genes contributing to a trait can be related to the species tree through the multispecies coalescent, for example, but we consider a model which allows arbitrary contributions from two or more gene trees to a trait value. In this model, the correlation structure for the observed traits is a linear combination of the correlation structures that arise on each of the contributing gene trees. (Received January 21, 2018)

1136-62-495 **Dena Marie Asta*** (dasta@stat.osu.edu). *Applications of Geometry to Network Inference.*

Graphs are often formed by sampling points from some manifold and connecting edges with some probability dependent on the manifold distances between points. There exists a plethora of research showing how the geometry of the manifold constrains properties of the sampled graphs. This talk surveys some such research and sketches its applications to network inference. (Received January 22, 2018)

1136-62-606 **Laura Kubatko*** (kubatko.2@osu.edu), **Julia Chifman**, **Paul Blischak** and **Andrea Wolfe**. *An Invariants-based Method for Efficient Identification of Hybrid Species From Genomic Data.*

Coalescent-based species tree inference has become widely used in the analysis of genome-scale multilocus and SNP datasets when the goal is inference of a species-level phylogeny. However, numerous evolutionary processes are known to violate the assumptions of a coalescence-only model and complicate inference of the species tree. One such process is hybrid speciation, in which a species shares its ancestry with two distinct species. We propose a method that can examine genome-scale data for a large number of taxa and detect those taxa that may have arisen via hybridization, as well as their potential “parental” taxa. The method is based on a model that considers both coalescence and hybridization together, and uses phylogenetic invariants to construct a test that scales well in terms of computational time for both the number of taxa and the amount of sequence data. We demonstrate the utility of the method using both simulated and empirical data. (Received January 22, 2018)

65 ► Numerical analysis

1136-65-5 **Lawrence A Harris*** (larry@ms.uky.edu), Mathematics Department, 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506. *Alternation points and bivariate Lagrange interpolation.*

We define numbers $h_0 > h_1 > \cdots > h_m$ to be alternation points for a finite sequence $p_0, p_1, \ldots, p_m$ of orthogonal polynomials if

$$p_{m-j}(h_n) = (-1)^n p_j(h_n) \quad \text{for all } j, n = 0, \ldots, m.$$

For example, the Chebyshev points $h_n = \cos(n\pi/m)$ are alternation points for the Chebyshev polynomials T_n. The main theorem is that the numbers of any decreasing finite sequence are alternation points for some finite sequence of orthogonal polynomials. We present an algorithm, analogous to the extended Euclidean algorithm, that computes explicit expressions for the orthogonal polynomials.

Application of this theorem allows us to extend bivariate interpolation and cubature theorems of [2] and [1] from the Chebyshev points to any decreasing finite sequence.

References

[1] B. Bojanov and G. Petrova, *On minimal cubature formulae for product weight functions*, J. Comput. Appl. Math. **85** (1997), 113–121.

[2] Yuan Xu, *Lagrange interpolation on Chebyshev points of two variables*, J. Approx. Theory **87** (1996), 220–238. (Received July 06, 2017)

1136-65-20 **Michael J Neilan*** (neilan@pitt.edu), 301 Thackeray Hall, 139 University Place, Pittsburgh, PA 15260, and **Johnny Guzman**. *Inf-sup stable finite elements on barycentric refinements producing divergence-free approximations in arbitrary dimensions.*

We construct several stable finite element pairs for the Stokes problem on barycentric refinements in arbitrary dimensions. A key feature of the spaces is that the divergence maps the discrete velocity space onto the the discrete pressure space; thus, when applied to models of incompressible flows, the pairs yield divergence-free velocity approximations. The key result is a local inf-sup stability that holds for any dimension and for any polynomial degree. With this result, we construct global divergence-free and stable pairs in arbitrary dimension and for any polynomial degree. (Received November 05, 2017)

1136-65-45 **Zheng Sun*** (zheng_sun@brown.edu). *A discontinuous Galerkin method for nonlinear partial differential equations with a gradient flow structure.*

We consider a class of time-dependent second-order partial differential equations with a gradient flow structure. The problem is governed by a decaying entropy. The solution usually corresponds to a density distribution, hence positivity (non-negativity) is expected. This class of equations covers important cases such as Fokker-Planck type equations and aggregation models, which have been studied intensively in the past decades. In this talk, we propose a high-order discontinuous Galerkin method for these equations. If the interaction potential is not involved, or the interaction is defined by a smooth kernel, our semi-discrete scheme admits an entropy inequality on the discrete level. Furthermore, by applying the positivity-preserving limiter, our fully discretized scheme produces non-negative solutions for all cases under a time step constraint. Numerical examples are given to confirm the high-order accuracy for smooth test cases and to demonstrate the effectiveness for preserving long time asymptotics. (Received December 12, 2017)

1136-65-166 **Ohannes Karakashian*** (okarakas@utk.edu), **Jerry L Bona**, **Hongqiu Chen** and **Michael 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 derivative. One approach preserves a certain important invariant of the system 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 January 11, 2018)

1136-65-168 **Vrushali Bokil** (bokilv@math.oregonstate.edu), Department of Mathematics, Oregon State University, Corvallis, OR 97331, **Yingda Cheng*** (ycheng@msu.edu), Department of Mathematics, Michigan State University, E. Lansing, MI 48824, **Yan Jiang** (jiangyan@math.msu.edu), Department of Mathematics, Michigan State University, E. Lansing, MI 48824, and **Fengyan Li** (lif@rpi.edu), Department of Mathematical Sciences, Rensselaer Polytechnic Institute, Troy, NY. *Energy Stable Discontinuous Galerkin Methods for Maxwell's Equations in Nonlinear Optical Media.*

The propagation of electromagnetic waves in general media is modeled by the time-dependent Maxwell's partial differential equations (PDEs), coupled with constitutive laws that describe the response of the media. In this work, we focus on nonlinear optical media whose response is modeled by a system of first order nonlinear ordinary differential equations (ODEs), which include a single resonance linear Lorentz dispersion, and the nonlinearity comes from the instantaneous electronic Kerr response and the residual Raman molecular vibrational response. We apply high order discontinuous Galerkin discretizations in space to the hybrid PDE-ODE Maxwell system with several choices of numerical fluxes, and the resulting semi-discrete methods are shown to be energy stable. Under some restrictions on the strength of the nonlinearity, error estimates are also established. We propose novel strategies to treat the nonlinearity in our model within the framework of the second-order leap-frog and implicit trapezoidal time integrators. The performance of the overall algorithms are demonstrated through numerical simulations of kink and antikink waves, and third-harmonic generation in soliton propagation. (Received January 11, 2018)

1136-65-175 **Xiaobing Feng*** (xfeng@math.utk.edu), Department of Mathematics, The University of Tennessee, Knoxville, TN 37996. *A discontinuous Ritz framework 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 the University of Oklahoma. (Received January 12, 2018)

1136-65-176 **Hengguang Li*** (li@wayne.edu), Department of Mathematics, Wayne State University, Detroit, MI 48202. *New Finite Element Methods for 3D Anisotropic Singular Solutions.*

We discuss a new construction of 3D anisotropic meshes to improve the finite element approximation of elliptic boundary value problems with singular solutions from the non-smoothness of the domain. These meshes can violate the maximum angle condition. We derive optimal error estimates for the proposed method. (Received January 12, 2018)

1136-65-187 **Slimane Adjerid*** (adjerids@vt.edu), McBryde Hall, Balcksburg, VA 24061, **Tao Lin** (tlin@vt.edu), MCBryde Hall, Balcksburg, VA 24061, **Ruchi Guo** (ruchi91@vt.edu), McBryde Hall, Blacksburg, VA 24061, and **Kihyo Moon** (hyoxt121@gmail.com), SAMSUNG, Seoul, South Korea. *High Order Immersed Methods for Interface Problems.*

We introduce the immersed finite element approach for solving interface problems modeled by partial differential equations with discontinuous coefficients. A brief historical review of immersed finite element methods will be presented. We will address few challenges faced in constructing higher-order immersed finite element spaces and weak Galerkin formulations for high accuracy computations. We will present computational results for several applications from acoustics, fluid dynamics and conclude with a list of open questions and future research projects. (Received January 14, 2018)

1136-65-195 **Tong Qin*** (qin.428@osu.edu), 231 W 18th Ave, Columbus, OH 43026, and **Chi-Wang Shu**. *Implicit positivity-preserving high-order discontinuous Galerkin methods for solving conservation laws.*

In this talk I will introduce our recent progress on designing implicit positivity-preserving discontinuous Galerkin methods for solving conservation laws. We consider the Euler backward and the Crank-Nicholson time discretization. For linear scalar equations, we derive CFL conditions for both methods to be positivity-preserving. For nonlinear equations and systems, numerical examples will be provided to illustrate the applicability of the proposed methods. (Received January 15, 2018)

1136-65-206 **Zhanjing Tao*** (tzjnchy555@math.msu.edu), **Wei Guo** and **Yingda Cheng**. *A Sparse Grid Discontinuous Galerkin Method for The Vlasov-Maxwell Equations.*

In this work, we develop a sparse discontinuous Galerkin (DG) scheme for the Vlasov-Maxwell equations in plasma simulations. Traditional DG scheme has too many degrees of freedom for high-dimensional simulations. To break the curse of dimensionality, the sparse grid method we developed is based on multiwavelets on tensorized nested grids and can significantly reduce the numbers of degrees of freedom. The accuracy and robustness of the scheme are validated by several numerical tests for Vlasov-Maxwell equations in up to four dimensions. (Received January 18, 2018)

1136-65-241 **Julienne Kabre*** (juliennekabre@gmail.com), 1320 Deagleway Drive Apt H, Fairborn, OH 45324, and **Jonah A Reeger** (jonah.reeger@afit.edu), Department of Mathematics and Statistics, Air Force Institute of Technology, 2950 Hobson Way, WPAFB, OH 45433. *Radial Basis Functions Generated Finite-Difference Method for the Korteweg-de Vries Equation.*

The Korteweg-de Vries equation (KDV) is a third order non-linear Partial Differential Equation(PDE) which solutions are traveling waves called solitons. A numerical method namely radial basis functions generated finite-difference (RBF-FD) integrating factor method was applied and the numerical solutions of the KDV equations were compared with the analytical solutions for 1, 2 and 3 solitons . Hyperviscosity was used for stability of the RBF-FD method in the case of irregular nodes. (Received January 17, 2018)

1136-65-278 **Zhongqiang Zhang*** (zzhang7@wpi.edu), Worcester, MA 01609. *Optimal error estimates of finite element methods for stochastic semilinear elliptic equations.*

We consider piecewise linear finite element methods for a class of semilinear elliptic equations with additive spatial white noise. We truncate the white noise using a spectral expansion of white noise. Taking a proper number of modes for the spectral approximation of the white noise, we prove optimal strong convergence order of the finite element approximation. We also discuss the weak convergence of the considered numerical methods. Numerical results confirm our prediction for one- and two-dimensional elliptic problems. This work is joint work with Boris Rozovskii and George Em Karniadakis. (Received January 18, 2018)

1136-65-293 **Anqi Chen*** (chenanq3@msu.edu), **Fengyan Li** and **Yingda Cheng**. *An ultra-weak discontinuous Galerkin method for Schrödinger equation in one dimension.*

In this paper, we develop an ultra-weak discontinuous Galerkin (DG) method to solve the one-dimensional nonlinear Schrödinger equation. Stability conditions and error estimates are derived for the scheme with a general class of numerical fluxes. The error estimates are based on detailed analysis of the projection operator associated with each individual flux choice. Depending on the parameters, we find out that in some cases, the projection can be defined element-wise, facilitating analysis. In most cases, the projection is global, and its analysis depends on the resulting 2×2 block-circulant matrix structures. For a large class of parameter choices, optimal *a priori* L^2 error estimates can be obtained. Numerical examples are provided verifying theoretical results. (Received January 18, 2018)

1136-65-350 **Susanne Brenner**, **Joscha Gedicke**, **Li-yeng Sung** and **Yi Zhang***, y_zhang7@uncg.edu. *An a posteriori analysis of C^0 interior penalty methods for a fourth order variational inequality.*

We consider the displacement obstacle problem of clamped Kirchhoff plates which is formulated as a fourth order variational inequality, and develop an a posteriori analysis of C^0 interior penalty methods. We discuss reliability and efficiency estimates for the residual based error estimator and introduce an adaptive algorithm. We will present numerical results to gauge the performance of the proposed methods. (Received January 19, 2018)

1136-65-396 **Fatih Celiker*** (celiker@wayne.edu), Department of Mathematics, Detroit, MI 48202, and **Huiqing Zhu** and **Zhimin Zhang**. *Superconvergent HDG methods for a distributed optimal control problem governed by convection-diffusion equations.*

We study the convergence of hybridizable discontinuous Galerkin methods (HDG) for a distributed optimal control problem governed by convection-diffusion equations. We prove optimal order of convergence $k+1$ for HDG approximations to fluxes when polynomials of degree no more than $k \geq 0$ are used. For $k \geq 1$ a super-closeness property of order $k+2$ for all three scalar variables are established. This extra gain in the order of convergence leads to an element-by-element post-processing that results in superconvergent approximations to the scalar unknowns with order $k+2$. (Received January 20, 2018)

1136-65-397 **Shuonan Wu***, 316 McAllister Building, University Pk, PA 16802. *Simplex-averaged Finite Element Methods for General Convection-diffusion Problems.*

In this talk, we construct and analyze a finite element approximation for the $H(D)$ convection-diffusion problem where D can be chosen as grad, curl or div in 3D case. An essential feature of this construction is to properly average the PDE coefficients on the sub-simplexes. The scheme is of the class of exponentially fitted method that results in a special upwinding scheme when the diffusion coefficient approaches to zero. The well-posedness is established for sufficiently small mesh size assuming that the convection-diffusion problem is uniquely solvable. Convergence of first order is derived under minimal smoothness of the solution. Some numerical examples are given to demonstrate its robustness and effectiveness for general convection-diffusion problems. (Received January 20, 2018)

1136-65-446 **Noel J. Walkington*** (noelw@andrew.cmu.edu). *Numerical Approximation Nematic Fluids.*

This talk focuses on the issues that arise when modeling and simulating fluids containing rod–like molecules (nematics). The (average) orientation of these fluids is typically modeled by a unit vector field which complicates both the analysis and numerical solution of these equations. In particular,

- The unit length constraint gives rise to topological singularities. While singularities are observed ubiquitously in liquid crystals, classical models assign infinite elastic energy to these configurations.
- The head–to–tail symmetry of the nematic molecules allows them to form non–orientable direction fields and degree half singularities, so director take values in real projective space.

The development of numerical schemes in this context will be discussed. (Received January 21, 2018)

1136-65-518 **wei wang*** (weiwang1@fiu.edu). *A Multiscale Discontinuous Galerkin Method for Stationary Schrodinger Equations.*

In this talk, we will introduce a multiscale discontinuous Galerkin method for one-dimensional stationary Schrodinger equations which have highly oscillating solutions. Because of the oscillatory behavior of the solutions, traditional numerical methods require extremely refined meshes to resolve the small scale structure of solutions, thus the computational cost is huge. The main ingredient of our method is to incorporate the small scales into finite element basis functions so that the method can capture the multiscale solution on coarse meshes. We prove that the DG approximation converges optimally with respect to the mesh size h in L2 norm without the constraint that h has to be smaller than the wave length. (Received January 22, 2018)

1136-65-536 **Vani Cheruvu*** (vani.cheruvu@utoledo.edu), Department of Mathematics and Statistics, The University of Toledo, Toledo, OH 43606. *Spectra of boundary integral operators defined on the unit sphere for the modified Laplace equation.*

We consider a modified Laplace equation on a unit sphere. Spherical harmonics are used for the expansion of the unknown function. We show that on the unit sphere, both modified Laplace single and double layer operators diagonalize in spherical harmonic basis. The analytic expressions for evaluating the operators away from the boundary are also derived. Currently, we are working on the numerical aspects. In this talk, we present both the analytical and numerical results of our work. (Received January 22, 2018)

1136-65-589 **Xiaochuan Tian***, 305 W 39th St, APT 105, Austin, TX 78751, and **Qiang Du**. *Asymptotically Compatible Schemes for Robust Discretization of Nonlocal Models.*

Nonlocal continuum models are in general integral-differential equations in place of the conventional partial differential equations. While nonlocal models show their effectiveness in modeling a number of anomalous and singular processes in physics and material sciences, they also come with increased difficulty in numerical analysis with nonlocality involved. In this talk, we study robust numerical approximations of linear nonlocal peridynamic models parametrized by the horizon parameter. In particular, we provide asymptotically compatible discretization for nonlocal parametrized models which give convergent schemes in both nonlocal settings and their local limits. (Received January 22, 2018)

68 ► Computer science

1136-68-296 **Henry D Pfister*** (henry.pfister@duke.edu). *Capacity via Symmetry.*

Recently, sequences of error-correcting codes with doubly-transitive permutation groups were shown to achieve capacity on erasure channels under symbol-wise maximum-a-posteriori decoding. From this, it follows that Reed-Muller and primitive narrow-sense BCH codes achieve capacity on erasure channels. This talk presents an extension of this result to codes whose permutation groups satisfy a condition weaker than double transitivity, including some cyclic and product codes. It concludes with a list of open questions in this area. The proof is based on the sharp-threshold property for symmetric monotone boolean functions and the area theorem for extrinsic-information transfer functions.

This talk is based on joint work with Santhosh Kumar and Robert Calderbank. (Received January 18, 2018)

1136-68-369 **Fiona Knoll*** (fknol309@gmail.com), fknol309@gmail.com, and **Alyson Fox**, **Gauri Joshi**, **Fatemah Kazemi** and **Emina Soljanin**. *Error-Correcting Codes Applied to Parallel Computation.*

To successfully complete large amounts of computation, companies have turned to distributed computing, the dividing up of computation task among available processors. However, the latency of computation can be greatly affected by stragglers, processors slow in the return of its assigned task. One such popular task is that of matrix-vector multiplication. Approaches used today such as block-striped decomposition and Fox's method do not address the straggler effect. In this presentation, we will show how error-correcting codes combined with reduced storage methods can be applied to distributed computing to navigate around the straggler effect. (Received January 22, 2018)

1136-68-469 **Anastasios Sidiropoulos*** (sidiropo@gmail.com), 851 S Morgan St., Room 1240 SEO, Chicago, IL 60607. *Approximation algorithms for graph planarization and related problems.*

Some central problems in topological graph theory concern the computation of parameters such as the crossing number, Euler genus, and planarization number of a given graph. When the value of this parameter, k, is a fixed constant, polynomial-time algorithms can be obtained using tools and ideas that originated in the graph minor theory of Robertson and Seymour. However, since computing any of these parameters is NP-hard, the resulting algorithms are efficient only for very small values of k. We present some recent results that bypass this obstacle by giving approximation algorithms for several of these problems.

Based mostly on joint works with Chandra Chekuri, and Ken-ichi Kawarabayashi. (Received January 21, 2018)

1136-68-611 **Ben Cousins*** (bcousins3@gatech.edu) and **Santosh Vempala**. *Gaussian Cooling and Volume Computation.*

The search for efficient algorithms for high-dimensional sampling and volume computation has led to a number of deep connections to convex geometry. Notably, the KLS conjecture, a purely geometric statement about isotropic convex bodies, was made by Kannan, Lovász, and Simonovits in 1995 alongside their search for a faster volume algorithm. In this talk, I will survey the current theoretical frontier of algorithms for high-dimensional sampling and volume computation. I will give an overview of the algorithmic approaches used for sampling, integration, and volume computation. Additionally, I will discuss recent progress on this line of work and show an $O^*(n^3)$ volume algorithm for well-rounded convex bodies. Achieving this complexity was previously though to rely on a positive resolution of the KLS conjecture, but we can circumvent the conjecture by utilizing properties of Gaussian distributions. Finally, I will give a brief demonstration of practical algorithms for high-dimensional sampling. (Received January 22, 2018)

74 ► Mechanics of deformable solids

1136-74-433 **Martin Bauer**, **Jakob Moeller-Andersen** and **Stephen C. Preston*** (stephen.preston@brooklyn.cuny.edu). *The furling of flags.*

We derive new equations for the idealized motion of a flag on a pole in 3-space, viewed as an unstretchable piece of fabric with no friction and ignoring self-collisions. Geometrically the flag represents a geodesic in the space of isometric immersions of a square into 3-space. We give a complete description of such immersions under a nondegeneracy condition, and use it to describe the manifold structure. The resulting equation is hyperbolic, nonlinear, and nonlocal; similar to the wave equation describing the motion of whips as inextensible curves. (Here we are describing literal flags that furl in space on a flagpole, which should not be confused with flags in the sense of linear algebra or homogeneous spaces.) (Received January 21, 2018)

76 ► Fluid mechanics

1136-76-169 **Shu-Ming Sun*** (sun@math.vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061. *Multi-hump surface waves on water with small surface tension.*

The talk discusses the exact theory of multi-hump surface waves with small oscillatory tails at infinity on a layer of water with finite depth. The fluid is assumed to be incompressible and inviscid with a constant density and the flow is irrotational. The wave on the free surface is traveling with a constant speed under gravity and surface tension forces, and the flow motion is governed by the exact fully nonlinear equations, called Euler equations. When the traveling speed is near a critical value and surface tension is small, it was proved that the Euler equations have solitary-wave solutions of elevation with small oscillations at infinity, known as generalized solitary waves. The talk tries to sketch a proof that under such conditions, the Euler equations will have two-hump solutions with small oscillations at infinity. The amplitude of the oscillations is algebraically small comparing with the inverse of the wave-length for the solitary-wave part. The basic idea to prove such existence is to glue two appropriate generalized solitary-wave solutions together using some free parameters. The idea can be extended to show the existence of other multi-hump solutions. (This is a joint work with S. Deng). (Received January 11, 2018)

1136-76-240 **Animikh Biswas*** (abiswas@umbc.edu), Department of Mathematics and Statistics, University of Maryland Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250, and **C Foias**, **C F Mondaini** and **E S Titi**. *Determining map for discrete data assimilation with observational error and applications.*

Based on a down-scaling data assimilation algorithm which employs a nudging term on the coarse scales, for observations discrete in time and possibly contaminated with a random error, we construct a *determining map* of coarse scale trajectories and investigate its properties. This map is then used to develop a down-scaling statistical data assimilation scheme for dissipative systems, where the coarse scale statistics of the systems are obtained from measurements. This is based on a joint work with C. Foias, C. Mondaini and E. S. Titi. (Received January 16, 2018)

1136-76-314 **Jerry L. Bona*** (jbona@uic.edu), Dept. Math., Statistics and Computer Sci., University of Illinois at Chicago, 851 S. Morgan Street MC 249, Chicago, IL 60607, **Angel Duran** (angel@mac.uva.es), Applied Mathematics Dept., University of Valladolid, Belen 15, 47011, Valladolid, Spain, and **Dimitrios Mitsotakis** (dimitrios.mitsotakis@vuw.ac.nz), School of Math., Statistics and O.R., Victoria University of Wellington, PO Box 600, Wellington, 6140, New Zealand. *Coupled Systems for Internal Wave Propagation.*

The discussion will feature coupled systems of evolution equations that serve as models for long-crested internal wave motion. Especial interest will be focused upon their solitary-wave solutions (Received January 19, 2018)

1136-76-354 **Vera Mikyoung Hur*** (verahur@math.uiuc.edu), 1409 W Green Street, Urbana, IL 61801, and **Sergey A Dyachenko** (sdyachen@illinois.edu), Urbana, IL 61801. *Stokes waves with constant vorticity: numerical computation.*

Stokes in his classical memoir made formal but far-reaching considerations about periodic traveling waves at the free surface of water, subject to the force of gravity, and conjectured that the wave of greatest height exhibits a 120 degree's corner at the crest. For zero vorticity, Amick, Fraenkel and Toland proved that such a limiting wave exists. But, for nonzero vorticity, the situation is much more complicated.

I will present a recent work, joint with Sergey Dyachenko, where the Stokes wave problem, permitting constant vorticity and finite depth, is formulated via a conformal mapping as a nonlinear pseudo-differential equation, involving a periodic Hilbert transform for a strip, and solved by the Newton-GMRES method and a fast Fourier transform. The result shows overhanging and touching waves for strong positive vorticity and the rigid body rotation of a fluid disk at the large vorticity limit. (Received January 19, 2018)

1136-76-466 **Michael Siegel***, Department of Mathematical Sciences, New Jersey Institute of Technology, Newark, NJ 07043. *Analysis and numerics for induced-charge electrokinetic flow with interfaces.* Preliminary report.

We consider two problems involving electrokinetic phenomena at drop and bubble interfaces. The starting point is the Nernst-Planck equations in the Stokes flow regime, with a simplified physiochemical interface model. First, the problem of a spherical drop suspended in an electrolyte solution and acted on by a uniform electric field is considered. A spectrally accurate numerical method is developed to compute the flow for arbitrary Debye layer thickness. Second, a multiscale method is introduced to describe the evolution of a deformable interface during the two-phase flow of ionic liquids. The method is based on an asymptotic reduction in the thin Debye layer limit, with a focus on arbitrary (large) deformation and time- dependent evolution. The connection between the two approaches will be discussed. This is joint work with Michael Booty, Rui Cao, Manman Ma, and Qiming Wang. (Received January 21, 2018)

1136-76-526 **Zineb Hassainia**, **Nader Masmoudi** and **Miles H. Wheeler*** (miles.wheeler@univie.ac.at). *Global bifurcation of rotating vortex patches.*

We consider the evolution of the boundary of a patch of constant vorticity in a two-dimensional fluid satisfying the Euler equations. Solutions which rotate at a constant angular velocity have previously been constructed as perturbations of the unit disk. In this talk we extend these local branches to global ones. At the end of each branch, the minimum value on the boundary of the patch of the angular fluid velocity becomes arbitrarily small in the rotating frame. This is consistent with the formation of sharp corners which is observed numerically. (Received January 22, 2018)

1136-76-594 **Benjamin F Akers*** (benjamin.akers@afit.edu). *Modulational Instabilities of Periodic Traveling Waves.*

Modulational instabilities of periodic traveling water waves are discussed. A near-resonant asymptotic is presented, in which the flat-state spectrum is expanded in both amplitude and Bloch parameter. The location and growth rates of instabilities are presented in the asymptotic context, for waves in both two and three dimensions. Numerical methods based on this asymptotic and implications regarding spectrum analyticity are suggested. (Received January 22, 2018)

81 ► Quantum theory

1136-81-233 **Bin Gui*** (bin.gui@vanderbilt.edu). *Energy bounds for intertwining operators of unitary vertex operator algebras.*

Intertwining operators of a vertex operator algebras (VOA) are "chiral halves" of the field operators in a 2d conformal field theory. Their geometric properties (braiding, fusion, etc.) are important for developing a tensor product theory for representations of VOAs, whereas their analytic ones are important for giving these theories a unitary structure. The energy bounds condition is such an analytic property. In this talk, I will give a general strategy to prove the energy bounds condition for intertwining operators of unitary VOAs. (Received January 16, 2018)

1136-81-292 **James Tener*** (jtener@math.ucsb.edu) and **Zhenghan Wang**. *Conformal field theories for modular tensor categories with small rank.*

The reconstruction problem for conformal field theories asks "What extra data is required to reconstruct a conformal field theory from a modular tensor category (MTC)?" Related conjectures of Gannon and Höhn address the existence and finiteness of conformal field theories corresponding to a given MTC. In this talk I will discuss new and old results regarding a class of conformal field theories for which we can prove existence, uniqueness, and finiteness results when the associated MTC has small rank. (Received January 18, 2018)

1136-81-430 **Colleen Delaney*** (cdelaney@math.ucsb.edu), **Parsa Bonderson**, **César Galindo**, **Eric C. Rowell**, **Alan Tran** and **Zhenghan Wang**. *A computational approach to link invariants of modular tensor categories.* Preliminary report.

For many years, modular tensor categories were believed to be distinguished by their so-called modular data, i.e., their S and T matrices. Recent work by Mignard and Schauenberg provides examples showing this is not the case. A natural question then is whether there are better invariants that can distinguish modular tensor categories. We discuss a link invariant that can be calculated with the help of computer algebra software and has the potential to outperform modular data in this respect. (Received January 21, 2018)

1136-81-515 **Andrew Schopieray** and **Yilong Wang*** (wang.3003@osu.edu). *Higher Gauss sum and higher central charges of premodular fusion categories.*

We will discuss recent progress in the study of higher central charges and higher Gauss sums of premodular categories. Examples and primitive results will be given. (Received January 22, 2018)

90 ► Operations research, mathematical programming

1136-90-494 **Nathan J. Russell*** (nathan.russell@eku.edu), Eastern Kentucky University, 521 Lancaster Avenue, Wallace Room 313, Richmond, KY 40475. *The Mathematical Mysteries and Fascinating Facts of Binary Self Dual Codes.* Preliminary report.

Binary self-dual codes are a theoretical and application rich area of mathematics. The existence, as well as nonexistence, of certain binary self-dual codes can have deep implications of other theory rich mathematical objects. This talk is aimed at providing an overview of some of these implications. Fascinating mathematical facts about specific codes and families of codes will be discussed. Several families of binary self-dual codes have been completely classified, however, there are codes known to exist that have yet to be constructed, as well as mathematically feasible codes whose existence are yet to be proven. A significant project is underway to compile much of the information about known binary self-dual codes into a centralized database that researchers can use to access the vast information collected on binary self-dual codes. During this talk a demonstration will be provided of how coding theorists can both research and access an API to download JSON formatted self-dual code data. (Received January 22, 2018)

91 ► Game theory, economics, social and behavioral sciences

1136-91-237 **Yaqin Feng** and **Min Wang*** (wangmin@rowan.edu), Department of Mathematics, Rowan University, Glassboro, NJ 08028. *Credit value adjustment (CVA) for Cliquet options under Heston models.*

In this talk, we consider the credit value adjustment (CVA) for Cliquet options under stochastic volatility models. A partial differential equation (PDE) is first derived to price Cliquet options under the Heston model. Numerical schemes are then provided to solve the PDE and calculate exposure and CVA. (Received January 16, 2018)

92 ► Biology and other natural sciences

1136-92-25 **William H Langhoff*** (langhoff@uwm.edu), 3200 N Cramer St, Milwaukee, WI 53211, and **Peter Hinow**, **J. Rudi Strickler** and **Jeannette Yen**. *Neuronal Network Modeling of Mate-Finding in a Copepod.*

Male copepods of the species *Temora longicornis* are able to follow a pheromone trail laid out by a female. Moreover, the male is able to change the direction of its movement if it initially follows the trail in the wrong direction. Previously we pro- posed that the female pheromone is a blend of multiple compounds with different chemical properties and that the male senses their ratio rather than an absolute concentration. This allows for a better method to decide in which direction to move. In this talk, we present a simple and efficient neuronal model for the olfactory apparatus that enables ratio detection. (Received November 21, 2017)

1136-92-34 **Victor James Barranca*** (vbarran1@swarthmore.edu). *The Role of Neuronal Network Structure in Encoding Natural and Non-Natural Scenes.*

The structure of receptive fields in the early visual system is hypothesized to be evolutionarily advantageous in image processing tasks. We address the potential functional benefits and shortcomings of the structural characteristics common in receptive fields in the context of an integrate-and-fire neuronal network model with visual stimulus inputs. Based on the sparsity of natural scenes, we utilize a compressive-sensing framework for reconstructing input images from measurements of the evoked neuronal firing rates, thereby giving a measure of how well the nonlinear network dynamics encode various classes of stimuli. Analyzing several receptive field models, we investigate how the accuracy of input encoding depends on the network architecture, and demonstrate that the center-surround structure common in receptive fields facilitates marked improvements in natural scene processing well beyond uniformly-random excitatory connectivity. However, we show that the spatial localization inherent in receptive fields combined with information loss introduced by nonlinear neuronal dynamics may underlie deficiencies in processing specific classes of non-natural stimuli, such as the Hermann grid, yielding a novel explanation for the manifestation of illusory effects. (Received December 04, 2017)

1136-92-68 **Veronica Ciocanel*** (ciocanel.1@mbi.osu.edu), 1735 Neil Avenue, Columbus, OH 43210, and **Anthony Brown** and **Peter Jung**. *Modeling Mechanisms of Neurofilament Transport in Axons.* Preliminary report.

Neurofilaments are the intermediate filaments of neurons, and their primary function is to structurally fill the axon and increase its cross-sectional area. This in turn makes them key in the propagation of nerve impulses across axons, and in ensuring proper speed of neuronal communication. In this work, we are interested in neurofilament transport along axons and across axon constrictions called nodes of Ranvier. Using computational modeling and experimental insights, we are studying how the kinetics of neurofilament transport regulates the density of neurofilaments along the axon and thus the axonal cross-sectional area. We are developing a stochastic model of the bidirectional transport of neurofilaments along a model axon informed by experimental data on transport velocities as well as on neurofilament length distributions. This approach allows us to better characterize neurofilament transport kinetics by parameterizing fluorescence microcopy data. (Received December 30, 2017)

1136-92-114 **Hermann Riecke*** (h-riecke@northwestern.edu), Applied Mathematics, 2145 Sheridan Rd, Evanston, IL 60208, and **John Hongyu Meng**, Applied Mathematics, 2145 Sheridan Rd, Evanston, IL 60208. *Synchronization of Brain Oscillations by Uncorrelated Noise.*

Rhythms representing the coherent activity of a large ensemble of neurons are ubiquitous in the brain. They are conjectured to enhance the communication between brain areas. How do multiple such rhythms interact with each other? We show that their synchronization properties can be very different from those of individual oscillators. In fact, certain types of rhythms become synchronized by noise. Importantly, in contrast to the case of stochastic synchronization, noise synchronizes these rhythms even if the noisy inputs to different oscillators are completely uncorrelated. Key for the synchrony *across* networks is the reduced synchrony *within* the networks: it substantially increases the frequency range across which the networks can be entrained by other networks or by periodic inputs. The underlying mechanism requires a minimal network size and emerges from the variability in the number of oscillators that participate in the collective oscillation. We condense this new synchronization mechanism into a simple iterated map, which captures the reverse period-doubling bifurcation that leads to the synchronization. The synchronization mechanism is robust: the networks can be comprised of type-1 or type-2 neurons and can vary in synaptic coupling and network connectivities. (Received January 06, 2018)

1136-92-116 **Mainak J Patel*** (mjpatel@wm.edu), College of William and Mary, Jones Hall, Office 121, 200 Ukrop Way, Williamsburg, VA 23188, and **Aaditya Rangan**. *Role of the locus coeruleus in the emergence of power law wake bouts in a model of the brainstem sleep-wake system through early infancy.*

Infant rats randomly cycle between the sleeping and waking states, which are tightly correlated with the activity of mutually inhibitory brainstem sleep and wake populations. Bouts of sleep and wakefulness are random; from P2–P10, sleep and wake bout lengths are exponentially distributed with increasing means, while during P10–P21, the sleep bout distribution remains exponential while the distribution of wake bouts gradually transforms to power law. The locus coeruleus (LC), via an undeciphered interaction with sleep and wake populations, has been shown experimentally to be responsible for the exponential to power law transition. Concurrently during P10–P21, the LC undergoes striking physiological changes – the LC exhibits strong global 0.3 Hz oscillations up to P10, but the oscillation frequency gradually rises and synchrony diminishes from P10–P21, with oscillations and synchrony vanishing at P21 and beyond. In this work, we construct a biologically plausible Wilson Cowan-style model consisting of the LC along with sleep and wake populations. We show that the changing physiology of the LC from P10–P21, coupled with reciprocal excitation between the LC and wake population, can explain the shift from exponential to power law of the wake bout distribution. (Received January 07, 2018)

1136-92-118 **Marissa Renardy*** (renardy.1@osu.edu), **Tau-Mu Yi**, **Dongbin Xiu** and **Ching-Shan Chou**. *Parameter uncertainty quantification using surrogate models applied to a spatial model of yeast mating polarization.*

A common challenge in systems biology is quantifying the effects of unknown parameters and estimating parameter values from data. For many systems, this task is computationally intractable due to expensive model evaluations and large numbers of parameters. In this work, we investigate a new method for performing sensitivity analysis and parameter estimation of complex biological models using techniques from uncertainty quantification. The primary advance is a dramatic improvement in computational efficiency from the replacement of model simulation by evaluation of a polynomial surrogate model. We demonstrate the method on two models of mating in budding yeast: a small ODE model of the heterotrimeric G-protein cycle, and a large spatial model of pheromone-induced cell polarization. (Received January 07, 2018)

1136-92-145 **Hector Banos*** (hdbanoscervantes@alaska.edu). *Identifying species network features from gene tree quartets under the coalescent model.*

A phylogenetic tree is not always enough to describe the relationship between species, in particular, when hybridization, horizontal gene transfer or gene flow occurs. Phylogenetic networks are the objects used to represent the relationship between species that admit such events.

We focus on phylogenetic networks whose cycles do not share edges, known as level-1 networks. Under the coalescent model on a level-1 network, the probabilities of gene tree quartets can be computed in terms of the probabilities arising on simplified networks. Using only the natural descending order in the real line of such probabilities for each 4-taxon set, we can generically identify all cycles of size greater than 3, and hybrid nodes in the cycles of size greater than 4, in the unrooted species network. We also show that we cannot identify the hybrid node of a 4-cycle by this approach. (Received January 09, 2018)

1136-92-165 **Sofia H Piltz*** (piltz@umich.edu), Department of Mathematics, 530 Church Street, 2074 East Hall, Ann Arbor, MI 48109. *A Discontinuous Map for a Human Sleep-Wake Network Model Predicts Recovery from Sleep Deprivation.*

Disrupted sleep schedules can cause desynchronization of the sleep-wake cycle and the 24-hour circadian rhythm. Such desynchronization has been suggested to contribute to several health issues including diabetes, cardiovascular disease, and cancer. In this work, we consider a physiologically-based model for human sleep, namely, a system of differential equations describing the firing rates of neuronal populations promoting sleep and wake states, the circadian rhythm, and the homeostatic sleep drive. To predict recovery from sleep deprivation, we apply a discontinuous map that has been computed from the model and relates the phase of sleep onset (relative to the circadian rhythm) on day n to sleep onset on day n+1. Our results show that small perturbations (e.g., 0-12 hours) in sleep onset timing result in shorter sleep episodes compared to large perturbations (e.g., 18-24 hours past the regular sleep onset time), as suggested by experimental observations. Moreover, the map allows us to predict the length of the sleep and wake episodes during recovery sleep as the sleep-wake cycle regains synchrony with the circadian rhythm. (Received January 11, 2018)

1136-92-184 **Hye-Won Kang*** (hwkang@umbc.edu), 1000 Hilltop Circle, Baltimore, MD 21250. *Multiscale stochastic reaction-diffusion algorithms for biochemical networks.*

A Markov chain model has become popular to present the discrete nature of the molecular copy numbers and inherent stochasticity in reaction-diffusion systems, but its computation can be expensive. A possible approach to reduce computational cost is to approximate a part of the model by some coarse-grained methods. In this talk, I will introduce two multiscale algorithms coupling the suitably discretized stochastic partial differential equations (SPDEs) and the Markov chain model, which provide good approximations to the solutions obtained by the Markov chain model applied in the entire spatial domain. Two coupling methods of the Markov chain model and the SPDEs across the interface will be discussed. This is joint work with Radek Erban at the University of Oxford. (Received January 14, 2018)

1136-92-194 **Bin Xu** (bxu2@nd.edu) and **Alexandra Jilkine*** (ajilkine@nd.edu). *Modeling the Dynamics of Cdc42 Oscillation in Fission Yeast.*

Regulation of polarised cell growth is essential for many cellular processes, including growth and division. We present a mathematical model of the mechanism responsible for the regulation of polarised growth dynamics by the small GTPase Cdc42. The model is based on the competition of growth zones of Cdc42 localised at the cell tips for a common substrate (inactive Cdc42) that diffuses in the cytosol. We consider several potential ways of implementing negative feedback between Cd42 and its GEF in this model that would be consistent with the observed oscillations of Cdc42 in fission yeast. We analyse the bifurcations in this model as the cell length increases, and total amount of Cdc42 and GEF increase. Symmetric antiphase oscillations at two tips emerge via saddle–homoclinic bifurcations or Hopf bifurcations. We find that a stable oscillation and a stable steady state can coexist, which is consistent with the experimental finding that only 50% of bipolar cells oscillate. Our model suggests that negative feedback is more likely to be acting through inhibition of GEF association rather than upregulation of GEF dissociation. (Received January 15, 2018)

1136-92-269 **Winfried Just**, **Joan Saldaña** and **Ying Xin*** (yx123812@ohio.edu). *Oscillations in epidemic models with spread of awareness.*

We study ODE models of epidemic spreading with a preventive behavioral response that is triggered by awareness of the infection. Previous studies of such models have mostly focused on the impact of the response on the initial growth of an outbreak and the existence and location of endemic equilibria. Here we study the question whether this type of response is sufficient to prevent future flare-ups from low endemic levels if awareness is assumed to decay over time. In the ODE context, such flare-ups would translate into sustained oscillations with significant amplitudes.

Our results show that such oscillations are ruled out in Susceptible-Aware-Infectious-Susceptible models with a single compartment of aware hosts, but can occur if we consider two distinct compartments of aware hosts who differ in their willingness to alert other susceptible hosts. (Received January 19, 2018)

1136-92-283 **Zoe M Himwich*** (zhimwich@stanford.edu) and **Noah A Rosenberg** (noahr@stanford.edu). *Roadblocked monotonic paths and the enumeration of coalescent histories for non-matching caterpillar gene trees and species trees.*

For a given gene tree topology and species tree topology, a coalescent history represents a mapping of the list of gene tree coalescences to branches of the species tree. Enumerative properties of coalescent histories have been of interest in the analysis of relationships between gene trees and species trees. One such enumerative result identifies a bijection between coalescent histories for a matching caterpillar gene tree and species tree with a class of monotonic paths on a lattice, producing a result that the number of coalescent histories for n-taxon matching caterpillar trees ($n \geq 2$) is the Catalan number C_{n-1}. We show a similar result for non-matching caterpillars, connecting coalescent histories for a non-matching caterpillar gene tree and species tree to "roadblocked" monotonic paths. The result enables a rapid proof of the result that given a caterpillar species tree, no non-matching caterpillar gene tree has more coalescent histories than the matching gene tree. We study the number of coalescent histories for non-matching caterpillar gene trees that differ by nearest-neighbor interchange, cyclic permutation of the taxa, and subtree-prune-and-regraft moves, characterizing the non-matching caterpillar with the largest number of coalescent histories. (Received January 18, 2018)

1136-92-319 **Alexandria Volkening***, volkening.2@mbi.osu.edu, and **Bjorn Sandstede**. *Modeling and analysis of agent-based dynamics in biological applications.*

Self-organization and collective behavior are present in many biological applications; for example, cells migrate and divide during wound healing, microtubule dynamics impact varicosity formation in axons and dendrites, and pigment cells organize to establish fish skin patterns. In this talk, we present agent-based models of such microscopic agents that interact through movement, competition, and division to produce macroscopic dynamics and patterns. While agent-based models can be developed closely to an underlying application, these models are difficult to analyze, especially when they combine stochastic and deterministic features. Using the framework of piecewise-deterministic Markov processes, we also study the stability of discrete models that include deterministic agent migration and stochastic fluctuations in population size. (Received January 19, 2018)

1136-92-325 **Matthew T Osborne*** (osborne.334@osu.edu), 100 Math Tower, 231 W. 18th Ave., Columbus, OH 43201, and **Joseph H Tien** and **Xueying Wang**. *Complex contagion leads to complex dynamics in models coupling behavior and disease.*

Models coupling behavior and disease as two contagions have existed since the mid 2000s. In these models behavior is typically treated as a simple contagion. However, the means of behavior spread may in fact be more complex. We will develop a family of disease-behavior coupled contagion compartmental models in order to examine the effect of behavior contagion type on disease-behavior dynamics. Both a simple and complex behavior contagion model will be investigated, revealing that behavior contagion type can have a significant impact on dynamics. (Received January 19, 2018)

1136-92-334 **Joshua Rubin Abrams**, **Anne Schwartz**, **Veronica Ciocanel** and **Alexandria Volkening***, volkening.2@mbi.osu.edu, and **Bjorn Sandstede**. *Exploring the impact of context on disease spread in social networks.*

Studying the spread of infections is an important tool in limiting future outbreaks. In this talk, we are interested in understanding the role of different social interactions in disease spread. Using an existing diary-based study tracking interactions at the University of Warwick, we present algorithms for extending this data to produce context-specific home, work, and social networks. This allows us to explore how disease transmission and dynamic responses to infection differ depending on interaction context. By simulating an influenza outbreak using an SIR (susceptible-infected-recovered) model on our network, we find that reducing encounters at work after infection is an effective way of decreasing flu season severity. (Received January 19, 2018)

1136-92-338 **Pamela B Pyzza*** (pbpyzza@owu.edu), 61 S. Sandusky Street, Delaware, OH 43015, and **Gregor Kovacic** and **David Cai**. *Idealized Models of Insect Olfaction.*

When a locust detects an odor, the stimulus triggers a specific sequence of network dynamics of the neurons in its antennal lobe. The odor response begins with a series of synchronous oscillations, followed by a short quiescent period, with a transition to slow patterning of the neuronal firing rates, before the system finally returns to a background level of activity. We begin modeling this behavior using an integrate-and-fire neuronal network, composed of excitatory and inhibitory neurons, each of which has fast-excitatory, and fast- and slow-inhibitory conductance responses. We further derive a firing-rate model for each (excitatory and inhibitory) neuronal population, which allows for more detailed analysis of and insight into the plausible olfaction mechanisms seen in experiments, prior models, and our numerical model. We conclude that the transition of the network dynamics through fast oscillations, a pause in network activity, and the slow modulation of firing rates can be described by a system which has a limit cycle of the fast variables, slowly passes through a saddle-node-on-a-circle bifurcation eliminating the oscillations, and, eventually, slowly passes again through the bifurcation point, producing a new limit cycle with a slower period. (Received January 19, 2018)

1136-92-349 **Lauren M Childs** and **Olivia F Prosper*** (olivia.prosper@uky.edu). *Simulating Within-Vector Generation of the Malaria Parasite Diversity.*

The malaria parasite Plasmodium falciparum undergoes an asexual stage within the human host, and a sexual stage within the vector host, Anopheles mosquitoes. Because mosquitoes may be superinfected with parasites of different genotypes, this sexual stage of the parasite life-cycle presents the opportunity to create genetically novel parasites. To investigate the role that mosquitoes' biology plays on the generation of parasite diversity, we first constructed a stochastic model of parasite development within-mosquito, generating a distribution of parasite densities at each parasite life-cycle stage, over the lifespan of a mosquito. We then coupled a model of sequence diversity generation via recombination between genotypes to the stochastic parasite population model. Our model framework shows that bottlenecks entering the oocyst stage decrease diversity from the initial gametocyte population in a mosquito's blood meal, but diversity increases with the possibility for recombination and proliferation in the formation of sporozoites. Furthermore, when we begin with only two distinct parasite genotypes in the initial gametocyte population, the probability of transmitting more than two unique genotypes from mosquito to human is over 50% for a wide range of initial gametocyte densities. (Received January 19, 2018)

1136-92-357 **Elizabeth S. Allman**, **Jonathan D. Mitchell** and **John A. Rhodes*** (j.rhodes@alaska.edu). *Gene Trees from Species Trees: Testing Multispecies Coalescent Model Fit.* Preliminary report.

The evolutionary histories of gene samples can differ from their species history for a variety of biological reasons, such as incomplete lineage sorting or lateral gene transfer. Given a collection of gene trees, how can we test whether ILS alone, as modeled by the multispecies coalescent on a tree, can explain them, or whether a more complex model, such as on a species network, is needed? One approach is through summarizing the gene trees by quartet concordance factors (frequencies of quartet topologies they display), and using log-likelihood ratio statistics in a standard hypothesis testing framework to judge model fit.

However, the coalescent predicts that concordance factors lie on a set with a singularity, and using a standard χ^2 distribution for measuring fit is problematic in its vicinity. Moreover, the data sets of the most interest, with significant amounts of incomplete lineage sorting, always lie near the singularity. To address this, we derive a new asymptotic approximation to the distribution of the log-likelihood ratio test statistic, and show its improved behavior throughout the model space. We briefly describe work underway to extend testing from 4-taxon trees to large ones. (Received January 19, 2018)

1136-92-387 **Christian G. Fink*** (tcfink@owu.edu), 61 S. Sandusky St., Delaware, OH 43015, and **Joseph Emerson**, **Momi Afelin** and **Viesulas Sliupas**. *Identifying "influential seizers" in a network model of epilepsy.* Preliminary report.

We present a network measure for identifying brain regions that most effectively spread epileptic seizures (i.e., "influential seizers"). Using a recently proposed dynamical model to simulate seizure spread on the macaque connectome, we first show that the model's results accord well with clinical data. We then present a centrality measure that uses network structure alone to accurately identify influential seizers, without running dynamical simulations. These results suggest that baseline brain connectivity predisposes particular regions to be more seizure-prone than others, even without pathological network reorganization. Our results also hint at improved, less invasive neurosurgical procedures to treat patients with focal epilepsy. (Received January 20, 2018)

1136-92-417 **Qingyi Lu*** (ql7917@hws.edu), 4414 Scandling Center, Geneva, NY 14456, and **Joseph Rusinko** and **Jennifer Vandenbussche**. *An Analysis of Statistical Binning.* Preliminary report.

Statistical binning is a technique for species tree reconstruction, which appears in a Science article, but the precise reason why this algorithm works remains unknown. For our research, first we tested the low and high levels of incomplete lineage sorting(ILS) and verified experimentally that this strategy can reduce gene tree estimation error. However, this method can not provide a good classification of which gene trees to bin together based on rules in the paper. To improve the strategy, we used the Booster, which is a new bootstrap computation along with topological constrains, instead of the traditional one. By using this bootstrap computation and the topological constraint we can improve the binning classification in both lower and higher level of ILS data sets. (Received January 21, 2018)

1136-92-434 **Jamie Prezioso*** (jep127@case.edu), Case Western Reserve University, 10900 Euclid Ave., Cleveland, OH 44106, and **Daniela Calvetti** and **Erkki Somersalo**. *Estimating Vascular Compliance in the Bayesian Framework.*

The increased cerebral metabolic rate following neuronal activity triggers a rapid increase in cerebral blood flow (CBF), a phenomenon that is at the base of several functional imaging modalities, e.g., optical diffusion tomography and BOLD- fMRI. While the connection between the brain activity and increased CBF has been demonstrated, the details of the neurovascular connection remain unclear. Mathematical models of cerebral hemodynamics assume a ballooning of the vessels to accommodate the additional blood, however many details of these models remain to be explained, and key parameters are unknown. To model mathematically the vascular systems response to neural activation by increasing vascular compliance an auxiliary function, a vasodilatory stimulus function, is introduced, however, there is no quantitative way to observe or measure this. Implicitly, estimating this function from blood flow data gives a way to infer on the compliance. We propose here an approach based on Bayesian hierarchical models, utilizing qualitative a priori knowledge. Computed examples illustrate the effectiveness of the proposed approaches and demonstrate the need for the Bayesian framework. (Received January 21, 2018)

1136-92-452 **Adriana T Dawes*** (dawes.33@osu.edu), Department of Mathematics, 231 West 18th Avenue, Columbus, OH 43210, and **Helen Chamberlin** and **Carly Williamson**. *Using asymptotics to explore long and short range signaling in cell patterning during development.*

Many biological systems rely on both long range and short range signals in order to produce proper cell patterns during development. These patterns, such as alternating cell fates, are defined by different gene and protein expression levels. However, the relative contribution of these two signaling modes in establishing proper patterns is not well understood. using vulval development of two nematode worm species, C. elegans and C. briggsae, as motivation, we derive an asymptotic PDE based on a simplified signaling network consisting of EGF, Notch and Wnt. We demonstrate that additional long range signals can prevent loss of patterning in response to network perturbations, and that short range signaling can amplify long range signals. These results suggest that long and short range signals have critical roles to play in proper cell patterning. (Received January 21, 2018)

1136-92-461 **Luay Nakhleh*** (nakhleh@rice.edu), Houston, TX 77005. *Statistical Inference of Reticulate Evolutionary Histories Using Data from Unlinked Loci.*

The multispecies coalescent (MSC) model has emerged as a major stochastic process that helps capture the intricate relationship between species trees and gene trees. Combined with models of sequence evolution, the MSC can be viewed as a generative model of genomic sequence data in the context of a (species) phylogenetic tree. A significant outcome of the use of genome-wide data has been the increasing evidence, or hypotheses, of reticulation (e.g., hybridization) during the evolution of various groups of eukaryotic species. Reticulate evolutionary histories are best represented as phylogenetic networks. I will describe the multispecies network coalescent (MSNC) model, which extends the MSC model so that it operates within the branches of a phylogenetic network. This extended model naturally allows for modeling vertical and horizontal evolutionary processes acting within and across species boundaries. In particular, it simultaneously accounts for gene tree incongruence across loci due to both hybridization and incomplete lineage sorting. I will then describe a likelihood function for this model, as well as a method for Bayesian sampling of phylogenetic networks and their parameters using reversible-jump Markov chain Monte Carlo (RJMCMC). (Received January 21, 2018)

1136-92-484 **Yanyu Xiao***, 2185 Commons Way, Cincinnati, OH 45221. *An SIR Model for infectious diseases with aged heterogeneity.*

We investigate an SIR epidemic model with discrete age groups to understand the transmission dynamics of an infectiousdisease in a host population with an age structure. Basic reproduction number R0 is derived and shown as a sharpthreshold parameter. The global stability of the endemic equilibrium whenR0>1 is established under a mild condition.This model is also used to analyze the measles outbreaks in India. (Received January 21, 2018)

1136-92-485 **Elizabeth Gross*** (elizabeth.gross@sjsu.edu), San Jose, CA 95192, and **Colby Long**, Columbus, OH. *Distinguishing phylogenetic networks.*

Phylogenetic networks are increasingly becoming popular in phylogenetics since they have the ability to describe a wider range of evolutionary events than their tree counterparts. In this talk, we discuss Markov models on phylogenetic networks, i.e. directed acyclic graphs, and their associated algebra, geometry, and combinatorics. In particular, assuming the Jukes-Cantor model of evolution and restricting to one reticulation vertex, using tools from computational algebraic geometry and combinatorics, we show that the semi-directed network topology of large-cycle networks is generically identifiable. (Received January 21, 2018)

1136-92-490 **Jacqueline Kane*** (jacqueline.kane@hws.edu), **Joseph Rusinko** and **Katherine Thompson**. *Phylogenetic Derivative: A Tool for Assessing Local Tree Reconstruction.*

Many population genetics problems are limited by the inaccuracy of inferred evolutionary histories of chromosomes sampled randomly from a population. This evolutionary history differs among genomic locations as an artifact of recombination events along a chromosome. Although work has been done to identify recombination points, even as a component of local phylogeny estimation, researchers lack an intuitive framework for thinking about changes in phylogenies across a chromosome. This challenges interpretations of phylogenetic trees across recombination points. Here, we introduce a phylogenetic derivative to describe the relatedness of neighboring trees along a chromosome. This phylogenetic derivative is a flexible metric that can be also be used assess the prevalence of recombination across a chromosome. These proposed methods are tested and perform well in analyzing both simulated data and real mouse data. (Received January 21, 2018)

1136-92-497 **Marisa C Eisenberg*** (marisae@umich.edu). *Identifiability and parameter reduction in mathematical biology.*

The interactions between parameters, model structure, and outputs can determine what inferences, predictions, and control strategies are possible for a given system. Parameter space reduction and identifiability analysis—and more generally, understanding the shape of the information contained in models with observational structure—are thus essential for many questions in mathematical modeling and uncertainty quantification. In this talk, we will introduce some of the ideas and methods from identifiability, and examine applications in cancer, neuroscience, and the spread of infectious diseases. We will also discuss the links between identifiability and other recent approaches to parameter reduction, such as active subspaces. (Received January 22, 2018)

1136-92-517 **Joseph M. Cicchese*** (cicchese@umich.edu), **Denise E. Kirschner** and **Jennifer J. Linderman**. *Multi-scale modeling of granuloma formation and surrogate-assisted optimization aid in optimizing antibiotic therapy of tuberculosis.*

Tuberculosis (TB) is one of the world's deadliest infectious diseases. Caused by infection with Mycobacterium tuberculosis, cellular lesions in lung tissue (granulomas) form as the immune system responds to fight the infection. The immune response that forms granulomas involves events that occur over multiple length and time scales. Although granuloma formation helps contain the infection, it also prevents antibiotic penetration during therapy. The length and complexity of antibiotic therapy – months of treatment with multiple antibiotics - and the emergence of drug-resistant TB indicate a need for enhanced antibiotic regimens. However, given an increasing number of potential antibiotics and dosing regimen combinations, the 'regimen design space' for TB therapy is too large to search exhaustively. We have developed a multi-scale, agent-based model that can simulate the formation of a granuloma and treatment with antibiotics. By combining our granuloma model with surrogate-assisted optimization, we can efficiently screen the regimen design space for optimal therapies. This method has been used to estimate optimal regimens for therapies of one or two antibiotics that compare reasonably to already established regimens. (Received January 22, 2018)

1136-92-523 **Kyle Dahlin*** (kdahlin@purdue.edu) and **Zhilan Feng**. *An Epizootiological Model of Avian Malaria.* Preliminary report.

Avian malaria is a parasitic disease of birds caused by protists of the genera Plasmodium, most notably Plasmodium relictum, which is transmitted via a mosquito vector. This disease has been identified as a primary cause of the drastic decline and extinctions of endemic birds in Pacific Island forests. In this work, we formulate an epizootiological model of the transmission of avian malaria between a generic bird species and the Southern House mosquito using a system of ODEs. We derive the basic reproduction number as well as criteria for the existence and stability of equilibria. We discuss strategies for minimizing the impact of avian malaria in two scenarios: disease-free populations which may be invaded by avian malaria and populations where this disease is enzootic but where bird species have not developed resistance. (Received January 22, 2018)

1136-92-527 **Katharine Gurski*** (kgurski@howard.edu), Howard University, Department of Mathematics, Washington, DC 20059, and **Kathleen Hoffman**. *Analysis of Staged HIV Transmission and Treatment in a Dynamic Model with Concurrency.*

HIV progression studies have asserted three stages: acute, chronic, and AIDS. We develop a model with three stages and include an infection class with Highly Active Anti-Retroviral Treatment leading to viral suppression. Capturing the incidence rate of HIV in minority U.S. women requires a model stratified by race/ethnicity and sexual behavior in addition to assumptions of assortative partner choice. We present a new autonomous deterministic model of the effect of concurrent sexual partnerships that allows for an analytical study of disease transmission. Time series analysis, as well as parameter sensitivity analysis, determine which strategy has the largest impact in the short and long term. Interventions focused on encouraging chronically infected into viral suppression, as well as interventions focused on maintaining viral suppression have the largest impact on the long term dynamics, and the latter having the largest impact on the heterosexual community due to current racial treatment disparity. While reducing concurrency likelihood and duration positively impacts the dynamics, left unchecked, an increase in concurrency will significantly raise the values of the endemic equilibrium. (Received January 22, 2018)

1136-92-540 **Joseph Rusinko*** (rusinko@hws.edu), **Yu Cai** and **Allison Doherty**. *Taxon Selection using Quartets.*

We examine quartet based phylogenetic tree species reconstruction under the coalescent model. We show that species tree reconstruction can be modestly improved by weighting quartets using a function that quantifies the confidence we might have that the quartet came from the true species tree. As an outgrowth of this analysis, we identify a data-driven process for evaluating which taxa are appropriate to consider in your phylogenetic analysis. (Received January 22, 2018)

1136-92-558 **Andrea K Barreiro*** (abarreiro@smu.edu), **Shree Hari Gautam**, **Woodrow L Shew** and **Cheng Ly**. *Constraining neural networks with spiking statistics.*

As experimental tools in neuroscience have advanced, measuring whole-brain dynamics with single-neuron resolution is becoming closer to reality. However, it remains technically challenging to measure the interactions within and across brain regions that govern system-wide dynamics. We propose a method to derive constraints on hard-to-measure neural network attributes — such as inter-region synaptic strengths — using easy-to-measure spiking statistics.

First, we propose a closure formula for multi-population firing rate models which allows fast evaluation of equilibrium statistics. Second, fast evaluation allows us to rapidly survey a high-dimensional parameter space describing admissible networks, to find which models are consistent with experimental data.

As a test case, we studied interactions in the olfactory system. We used microelectrode arrays to simultaneously record from olfactory bulb (OB) and olfactory cortex (PC) of rats exposed to several odors. We make several predictions about the network, notably that inhibition within OB and inhibition within PC were constrained to a narrow slice of possible values. These predictions were then validated in a more realistic spiking model of the OB-PC pathway. (Received January 22, 2018)

1136-92-590 **Sookkyung Lim*** (sookkyung.lim@uc.edu), 4199 French Hall West, Cincinnati, OH 45221. *Mechanisms of polymorphic transformation in flagellated bacterial swimming.*

Bacterial flagella go through polymorphic transformation and play an important role in the cell's movement. We present a mathematical model of a single flagellum described by Kirchhoff rod theory that is immersed in a fluid governed by Stokes equations. Two mechanisms that cause polymorphic transformation are presented. First, we consider a flagellar filament attached to a rotary motor in which transformations are triggered by a reversal of the direction of motor rotation. We then consider a filament that is fixed on one end and immersed in an external fluid flow. The detailed dynamics of the helical flagellum interacting with a viscous fluid is discussed and comparisons with experimental results are provided. This is a joint work with W. Ko, W. Lee, Y. Kim, H.C. Berg, and C.S. Peskin. (Received January 22, 2018)

1136-92-613 **Reginald McGee***, 1735 Neil Ave, Columbus, OH 43210, and **Jon del'Etoile** and **Adriana Dawes**. *Parameter informatics for high-dimensional nonlinear models.* Preliminary report.

In 2017, Dawes *et al.* created a nonlinear model for signal transduction in epithelial cell development in roundworms. Via a parameter space sampling procedure over 6000 parameter sets were found to satisfy a wild-type pattern defined by the expressions of a ligand and phosphotase in the signaling network. Moreover, in silico perturbations to the signaling pathway replicated species-specific responses of protein knockout experiments and separated the parameter sets into groups corresponding to the model organism *C. elegans* and the less studied roundworm *C. briggsae*. This talk presents preliminary insights into how both species-specific and dynamic-specific parameter sets differ using both principal component analysis and a nonlinear dimension reduction technique often used in the study of biomedical datasets. Finally we motivate a hypothesis on how criterion from model-based design of experiments can be used to create an objective clustering method for the parameter sets and allowing one to avoid bifurcation analysis. (Received January 22, 2018)

1136-92-615 **J Best*** (jbest@math.ohio-state.edu), **W Duncan**, **M Golubitsky**, **H F Nijhout**, **M Reed** and **I Stewart**. *Homeostasis in Neuronal Networks.*

Feed-forward inhibition plays an important conceptual role in neuroscience where it is used in many circuit diagrams. In this talk we explore feed-forward inhibition as a mechanism for homeostasis of firing rate, and we discuss other possible mechanisms such as feedback inhibition. We show that the method of Golubitsky and Stewart for finding homeostatic nodes in networks works for feedforward inhibition but not for feedback inhibition, and we consider a form of homeostasis that can persist despite instability of the homeostatic firing rate. (Received January 22, 2018)

1136-92-625 **Jessica Ausborn**, **Abigail Snyder**, **Natalia Shevtsova**, **Ilya Rybak** and **Jonathan E Rubin*** (jonrubin@pitt.edu). *State-dependent rhythmogenesis and frequency control in a half-center locomotor central pattern generator.*

In this work we use ODE models and dynamical systems analysis to address the issue of symmetry in the spinal central pattern generator (CPG) that drives limbed locomotion. This CPG generates activity with alternating flexion/extension phases. This pattern likely results from inhibition between distinct neural populations, or "half-centers", driving flexion and extension, respectively. It is unclear whether the CPG has a quasi-symmetric organization with both half-centers critically involved in rhythm generation; an asymmetric organization with flexor-driven rhythmogenesis; or comprises a pair of intrinsically rhythmic half-centers. There are experimental data that support each of these but appear inconsistent with each other. We analyze a CPG model that can operate in different regimes consistent with all 3 of the above depending on conditions. We show that control of frequency and phase durations depends on the phase transitions - escape or release - that shape activity in a given regime. Which transitions are possible depends in part on the half-centers' intrinsic rhythmic capabilities but in some cases is invariant to changes in intrinsic dynamics. (Received January 23, 2018)

1136-92-626 **Julia Chifman*** (chifman@american.edu) and **Laura Kubatko**. *Modeling the Evolutionary History of a Tumor Given Single-Cell Sequencing Data.* Preliminary report.

Advances in genomic technologies and specifically in single-cell sequencing have made cancer evolution a central topic among researchers, resulting in a great need for accurate computational models and methods that are able to produce realistic pictures of the diversity of cancer. The idea of tumor progression as an evolutionary process driven by somatic mutations and clonal expansions was established in the late 1970's, and thus insights into the complexity of cancer can be gained using classical evolutionary principles. We present a model that computes true site pattern genotype probabilities on the tumor tree by using a finite-sites continuous-time Markov model together with a model for single-cell sequencing errors and explore the mathematical properties of this model, such as rank conditions of flattenings of the 4-dimensional probability distribution. We evaluate the performance of the proposed method for the genotype model using simulation and empirical data. (Received January 23, 2018)

93 ► Systems theory; control

1136-93-32 **Michael Malisoff*** (malisoff@lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803-4918. *Stability and Control Design for Time-Varying Systems with Time-Varying Delays using a Trajectory-Based Approach.*

Time delays arise in many engineering applications where dynamical systems contain feedback controls, and where the controls must be computed from time-lagged (instead of current) values of the states of the systems. For instance, delays can arise from time-consuming information gathering from sensors. One approach to solving control problems under feedback delays involves solving the problems with the delays set to zero and then computing upper bounds on the delays that the systems can tolerate while still realizing the control objectives, and is well suited when the delays are short. An alternative method for systems with longer feedback delays is the reduction model approach, which can lead to implementation challenges, because of the distributed terms it produces in controls. A third approach involves sequential predictors, which can compensate for arbitrarily long delays using stacks of differential equations with no distributed terms. This talk summarizes the speaker's trajectory-based approach for proving asymptotic stability properties for linear time-varying systems with time-varying delays where the system dynamics may contain unknown parameters. It is based on the speaker's joint work https://doi.org/10.1137/15M1027838 with Frederic Mazenc and Silviu-Iulian Niculescu. (Received December 04, 2017)

1136-93-33 **Michael Malisoff*** (malisoff@lsu.edu), Department of Mathematics, 301 Lockett Hall, Louisiana State University, Baton Rouge, LA 70803-4918. *Tracking and Parameter Identification for Model Reference Adaptive Control.*

The adaptive tracking and parameter identification problem for control systems with unknown model parameters consists of (a) finding formulas for feedback controllers that ensure that all solutions of a given control system on its state space asymptotically track a desired reference trajectory and (b) constructing a dynamical extension whose state vector converges to the vector of unknown model parameters. This talk will present the speaker's adaptive tracking and parameter identification method for systems where the parameters to be identified are the entries of unknown weight and control effectiveness matrices. It is based on a new construction of barrier Lyapunov functions which also makes it possible to prove robustness and rate of convergence properties. This work is joint with Tansel Yucelen and Jonathan Muse. No prerequisite background in systems and control will be required to understand and appreciate this talk. (Received December 04, 2017)

1136-93-70 **Paul Varnell**, School of Electrical and Computer Engineering, 777 Atlantic Dr NW, Georgia Institute of Technology, Atlanta, GA 30332-0250, **Michael Malisoff***, Department of Mathematics, 301 Lockett Hall, Louisiana State University, Baton Rouge, LA , and **Fumin Zhang**, School of Electrical and Computer Engineering, 777 Atlantic Dr. NW, Georgia Institute of Technology, Atlanta, GA 30332-0250. *Stability and robustness analysis for human pointing motions with acceleration under feedback delays.*

Pointer acceleration is often used in computer mice and other interfaces to increase the range and speed of pointing motions without sacrificing precision during slow movements. However, the effects of pointer acceleration are not yet well understood. We use a system perspective and feedback control to analyze the effects of pointer acceleration. We use a new pointer acceleration model connected in feedback with the vector integration to endpoint model for pointing motions. When there are no feedback delays, we prove global asymptotic stability of the closed loop system for a general class of acceleration profiles. Our methods also allow us to prove robustness properties under delays and perturbations by building Lyapunov-Krasovskii functionals for delay systems, and to find state performance bounds using robust forward invariance with maximal perturbation sets. The results are relevant to designing pointing interfaces, and our simulations illustrate the good performance of our control under realistic operating conditions. (Received December 31, 2017)

94 ► Information and communication, circuits

1136-94-200 **N. Aydin***, aydinn@kenyon.edu, and **A. Halilovic**. *A Generalization of Quasi-twisted Codes: Multi-twisted codes.*

Cyclic codes and their various generalizations, such as quasi-twisted (QT) codes, have a special place in algebraic coding theory. Among other things, many of the best-known or optimal codes have been obtained from these classes. We recently introduced a new generalization of QT codes called multi-twisted (MT) codes and studied some of their basic properties. Presenting several methods of constructing codes in this class and obtaining bounds on the minimum distances, we show that there exist codes with good parameters in this class that cannot be obtained as QT or constacyclic codes. This suggests that considering this larger class in searches is promising for constructing codes with better parameters than currently best-known linear codes. Working with this new class of codes motivated us to consider a problem about binomials over finite fields and to discover a result that is interesting in its own right. (Received January 15, 2018)

1136-94-273 **Swanand Kadhe*** (`swanand.kadhe@berkeley.edu`) and **Robert Calderbank** (`robert.calderbank@duke.edu`). *Bounds and Constructions for Binary Locally Recoverable Codes with Availability.*

A locally recoverable code with availability has the property that every code symbol can be recovered from multiple, disjoint subsets of other symbols of small size. In particular, a code symbol is said to have (r, t)-availability if it can be recovered from t disjoint subsets, each of size at most r.

In this talk, we focus on binary, linear codes with availability. First, we establish a uniqueness result for binary 'rate-optimal' codes, showing that for certain classes of binary linear codes with $(r, 2)$ and $(2, 3)$-availability, any rate-optimal code must be a direct sum of shorter rate-optimal codes. Second, we present novel upper bounds on the rates of binary linear codes with $(2, t)$ and $(r, 3)$-availability. In particular, we devise a method for bounding the number of cosets of the dual of a code with availability, using its covering properties. Finally, we construct two families of binary codes with $(2, t)$-availability: one uses trace conditions to improve the rate and availability of simplex codes, and the other is based on cyclic codes. (Received January 18, 2018)

1136-94-315 **Jared E Antrobus*** (`jantrobus@uky.edu`). *Rank-Metric Codes in the Shapes of Ferrers Diagrams.* Preliminary report.

It is well known that maximum rank-distance codes exist, thanks to Gabidulin and Delsarte. It is now prudent to study rank-metric codes with the shapes of Ferrers diagrams, which are useful in constructing constant-dimension subspace codes. A simple upper bound for the maximum dimension of Ferrers diagram rank-metric codes is known, and is conjectured to be sharp. In this talk I will present some new and old findings, giving a brief overview of where the conjecture currently stands. (Received January 19, 2018)

1136-94-383 **Allison Beemer*** (allison.beemer@huskers.unl.edu), **Salman Habib**, **Christine A Kelley** and **Joerg Kliewer**. *Permutations and the design of SC-LDPC codes.*

Spatially-coupled low-density parity-check (SC-LDPC) codes are sparse graph codes that are currently of high interest due to their capacity-approaching performance on memoryless binary input channels. Absorbing sets are combinatorially-defined substructures in a code's graph representation whose presence affects iterative decoder performance. In this talk, we first unify existing SC-LDPC code construction methods under a generalized description of SC-LDPC codes based on algebraic lifts of graphs using certain permutations. Using this framework, we examine the effect of the spatial-coupling process on the presence of absorbing sets. Finally, we show how permutation assignments may be optimized during SC-LDPC code construction so as to reduce the number of dominant absorbing sets appearing in the resulting code. (Received January 20, 2018)

1136-94-406 **Lawrence Ong** and **Joerg Kliewer*** (jkliewer@njit.edu), University Heights, Newark, NJ 07102, and **Badri N Vellambi**. *On the Equivalence of Secure Network Coding and Secure Index Coding.*

A linear code equivalence between index coding and network coding was shown recently, which establishes that for any index-coding instance, there exists a network-coding instance for which any index code can be mapped to a suitable network code, and vice versa. Similarly, for any network-coding instance, there exists an index-coding instance for which a similar code equivalence can be constructed. In this talk, we extend the equivalence to secure index coding and secure network coding where we assume decodability under both zero and epsilon error and both perfect secrecy and non-zero secrecy leakage. (Received January 20, 2018)

1136-94-451 **Carolyn Mayer*** (cmayer@huskers.unl.edu) and **Christine A. Kelley**. *Partial Erasure Relay Channels.* Preliminary report.

We consider a simple erasure relay network consisting of source, receiver, and relay, where the connections source-relay, source-receiver, and relay-receiver are either erasure channels or partial erasure channels. In particular, we give bounds on the capacity of such networks for particular choices of partial erasure channel connections. (Received January 21, 2018)

1136-94-471 **Bahattin Yildiz*** (bahattin.yildiz@nau.edu), 628 W Cinnabar Trail, Flagstaff, AZ 86005, and **Abidin Kaya**. *Constructing self-dual $\mathbb{Z}_4$-codes from the ring $\mathbb{Z}_4[x]/(x^2-2x)$.* Preliminary report.

Unlike many other ring extensions of $\mathbb{Z}_4$, the ring $R=\mathbb{Z}[x]/(x^2-2x)$ possesses a distance and orthoganlity preserving linear Gray map. Thus codes over R can be used to construct self-dual codes over $\mathbb{Z}_4$. We explore several construction methods over the ring R to find self-dual codes over $\mathbb{Z}_4$ with good parameters. The first part of the talk is about some theoretical results concerning certain restrictions on length and the type of constructions that can be used. We prove that free self-dual codes over R exist only of lengths that are multiples of 8 and we also prove that the usual double circulant and four circulant constructions do not lead to self-dual codes. However, we find that by replacing the circulant with 3-circulant, we are able to find self-dual codes. In the second part of the talk, we will apply 3-double circulant, 3-fourcirculant and bordered double circuulant constrictions to the lnegths of 8 and 16, as a result of which we find many good self-dual $\mathbb{Z}_4$-codes of lengths 16 ans 32. For these codes, we will also explore if the binary images are linear. (Received January 21, 2018)

1136-94-588 **Jessalyn Bolkema*** (jessalyn.bolkema@huskers.unl.edu). *On belief propagation decoding of polar codes.*

While Arikan's polar codes have been celebrated for their capacity-achieving performance since first presented in 2008, the questions of optimal finite-length design and decoding remain open. One avenue of study is the performance of polar codes under graph-based belief propagation decoding. In this talk, we explore a graph-theoretic construction of *computation multitrees* applicable to decoding and present combinatoric and graph-theoretic results on decoding impediments, such as *deviations.* (Received January 22, 2018)

1136-94-599 **Iwan Duursma*** (duursma@illinois.edu). *Asymptotic properties of Reed-Muller codes.* Preliminary report.

Abbe et al. (2014) showed that Reed-Muller codes achieve capacity on the erasure channel at very low and very high rate. S. Kumar et al (2015) use the KKL Theorem for balanced boolean functions to extend this to all rates. We discuss the results and their implications for matroid polynomials associated to Reed-Muller codes. (Received January 22, 2018)

Abstracts of the 1137th Meeting.

00 ► General

1137-00-60 **Emiliano A Valdez*** (emiliano.valdez@uconn.edu), 341 Mansfield Road, Department of Mathematics, University of Connecticut, Storrs, CT 06269-1009, and **Banghee So** and **Guojun Gan**. *Data mining techniques for actuaries: an overview.*

Data mining involves the computational process of exploring and analyzing large amounts of data to uncover hidden and useful information. Such information is useful to process and efficiently reduce data into a more summarized, analytical representation. The ultimate goal of data mining is to be able to deliver predictive models applicable to new data. Predictive modeling is increasingly becoming an important function of an actuary in all areas of insurance: life, health, pensions, property and casualty. In this survey article, we explore and describe the data mining tasks associated with supervised and unsupervised learning. There are generally four primary data mining tasks: association rule learning, clustering, classification, and regression. With each data mining task, we illustrate, using real data whenever available, its potential applications in actuarial science and in different areas of insurance. We further demonstrate the usefulness of these data mining techniques for actuaries to perform predictive analytics. Additionally, we briefly describe the emerging development of a new class of machine learning algorithms called deep structured learning. This is joint work with Banghee So and Guojun Gan, both from the University of Connecticut. (Received January 23, 2018)

1137-00-241 **Katie Fankhauser*** (fankhaus@ohsu.edu), **Demetrios Gatziolis** and **Nikolay Strigul**. *Semi-autonomous forestry assessment using small UAVs and photogrammetry.*

Environmental resource monitoring and impact assessments are constrained by resource-intensive fieldwork while drone technology offers rapid, reliable, and replicable data collection and processing. This research leverages advancements in photogrammetry and market sensors and platforms. From images taken by a GoPro camera onboard a small commercial unmanned aerial vehicle (UAV) and processed by low-cost or open source software, for instance Agisoft Photoscan and Fusion, a sub-sample of national forest plots in central-southern Oregon are three-dimensionally reconstructed. Plot characteristics, such as number of trees, tree density, and height profiles, are extracted from these dense point clouds and compared to results obtained from light detection and ranging (LiDAR) flights and traditional field inventories. Preliminary work suggests UAVs will offer a complementary and supplementary tool to existing forestry monitoring and evaluation practices. This technology and work process has the potential to be customized for different contexts and applications, especially those where capacity and resources are limited. (Received February 05, 2018)

1137-00-299 **Yueyang Jiang***, 321 Richardson Hall, Corvallis, OR 97331, **John B Kim**, Pacific Northwest Research Station, USDA Forest Service, Corvallis, OR 97331, **Sonia Wharton**, Atmospheric, Earth and Energy Division, Lawrence Livermore National Laboratory, Livermore, CA, and **Bharat Rastogi**, **Frederick C Meinzer**, **Anna T Trugman**, **Youngil Kim**, **Steven Voelker** and **Christopher J Still**. *Linking tree physiological constraints with predictions of carbon, water, and energy fluxes at an old-growth coniferous forests.*

This study adapted and parameterized the Ecosystem Demography 2 (ED2) model for an old-growth coniferous forest in the Pacific Northwest, USA. We validated the model using an extensive suite of forest inventory, eddy covariance, and biophysical observations, and then used the model to explore the physiological responses of the forest to climate anomalies. The calibrated model well reproduced the observed forest composition and canopy structure, and successfully estimated carbon, water and energy fluxes. The modeled water-use efficiency (WUE) was almost doubled from 1998 to 2015, because the relative decrease in carbon uptake was smaller than that in water loss. By machine-learning techniques, we found that the relative importance of climate variables on WUE showed varied patterns across different time scale in that air temperature and VPD mainly determined WUE at seasonal scale, while VPD, radiation or atmospheric CO2 concentration can govern the daily or half-hourly WUE. Via the "top-flat" scheme of the current ED2 model, too much radiation transmitted through the canopy and led to over-heated leaves in the lower canopy. Higher leaf temperature with higher leaf VPD together caused substantial lower stomatal conductance through canopy, especially in the middle and lower canopy. (Received February 06, 2018)

03 ► Mathematical logic and foundations

1137-03-234 **Valentina Harizanov*** (harizanv@gwu.edu), Department of Mathematics, Washington, DC 21044. *Building models as products of structures.*

Various products of structures have been used to build models of theories with desired and often unusual properties. We use infinite sets that are indecomposable with respect to computably enumerable sets to build products of countably many computable structures where the structures are given by an algorithmic sequence. We call such products effective products, and show how definable properties transfer from structures to their effective product. If all structures are equal, a product is called a power. We are especially interested in the cases when indecomposable sets are the complements of computably enumerable sets. In these cases, for some familiar structures we study isomorphism types of effective powers, automorphism groups of effective powers, and how such results can be applied to famous open problems in computable algebra. Recent results are obtained jointly with Rumen Dimitrov. (Received February 05, 2018)

1137-03-282 **Trang T Ha*** (trangtha@gwu.edu), Phillips Hall, 801 22nd St NW, Room 724A, Washington, DC 20052. *Space of Orders on Computable Magmas.*

A magma is computable if it is finite, or if its domain can be identified with the set of natural numbers and the magma operation is computable. We study algebraic and topological properties of orderable magmas, and investigate the Turing complexity of orders on computable orderable magmas. We further discuss the spaces of orders on special self-distributive (and not necessarily associative) magmas that come from knot theory and are known as racks and quandles. (Received February 05, 2018)

05 ► Combinatorics

1137-05-8 **Michael A Laidacker*** (mlaidacker@lamar.edu). *An Efficient Algorithm for Finding a 3-Dim Maximum Independent Set.* Preliminary report.

The algorithm is of interest since it answers the associated NP-complete problem for any given Instance. The talk will describe the algorithm and some of its consequences. (It should be noted that the preliminary report has been read by several other faculty members with no report of errors .) (Received November 21, 2017)

1137-05-264 **João Gouveia**, **Antonio Macchia**, **Rekha R Thomas** and **Amy Wiebe*** (awiebe@uw.edu). *The slack ideal of a polytope.*

In this talk we discuss a new tool for studying the realization spaces of polytopes, namely the slack ideal associated to the polytope. We will look at the interplay between the algebraic properties of the ideal and the combinatorics of the polytope. In particular, we explain how the structure of this ideal encodes certain polytopal properties, gives us a new way to understand important concepts such as projective uniqueness, and suggests connections with the study of other algebraic and combinatorial objects (toric ideals and graphs, for example). (Received February 05, 2018)

1137-05-280 **Anthony Weaver*** (anthony.weaver@bcc.cuny.edu). *Counting Topological Types of Finite Group Actions on Surfaces.*

I'll report on recent progress in counting topological types of certain finite group actions on surfaces. I'll give explicit formulae for fully ramified actions of rank 2 elementary abelian p groups (p odd), and arbitrary rank elementary abelian 2 groups. The methods are combinatorial. Some of the work is joint with Mariela Carvacho, Universidad Tecnica Federico Santa Monica, Chile. (Received February 05, 2018)

11 ► Number theory

1137-11-5 **Ken Ono*** (ono@mathcs.emory.edu), Dept Math and Computer Science, Emory University, 400 Dowman Drive, Atlanta, GA 30317. *Recent Results on the Riemann Hypotheses.*

This lecture will survey recent work on two of the Riemann Hypotheses. Following the theme of the special session, the speaker will discuss period polynomials of classical modular forms, which are examples of quantum modular forms. Together with Jin, Ma, and Soundararajan, the speaker has proved the RH for the period polynomials of newforms. On the original Riemann Hypothesis for the Riemann zeta-function, the author has recent work with Griffin, Rolen, and Zagier which revisits the Jensen-Polya program designed to attack RH. This approach relies on establishing the hyperbolicity of Jensen polynomials for the derivatives of the Riemann Xi-function. Previous work established this hyperbolicity for degrees ¡4. Here we address the case of all degrees, and we prove that 100% of these polynomials for each degree are hyperbolic. Ruling out the possible exceptions would imply the full RH. (Received October 23, 2017)

1137-11-15 **George E Andrews*** (gea1@psu.edu), 306 McAllister Bldg., Math Dept, Pennsylvania State University, University Park, PA 16802-6403. *Ramanujan's Lost Notebook in Five Volumes—Reflections.*

Bruce Berndt and I have recently completed the fifth and final volume on Ramanujan's Lost Notebook. All of Ramanujan's assertions (with perhaps one of two exceptions) have been proved or, in very rare instances, refuted or corrected. Among these hundreds of formulas there are a number that stand out. For example, the recent explosion of results on mock theta functions and mock modular forms has it origin in the Lost Notebook. The "sums-of-tails" phenomenon also arose from the Lost Notebook. This talk will be a personal account of highlights from this project and questions, yet to be answered, that arose from this decades long effort. (Received December 21, 2017)

1137-11-19 **Jeremy Lovejoy*** (lovejoy@math.berkeley.edu), Deparment of Mathematics, University of California, Berkeley, 970 Evans Hall #3780, Berkeley, CA 94720-3780, and **Kazuhiro Hikami** (khikami@gmail.com). *The modularity of certain WRT invariants.*

In this talk I will discuss the modularity of the unified WRT invariant of some 3-manifolds constructed from surgery on torus knots. In all cases we have quantum modularity at roots of unity and for +2 surgery we obtain mock theta functions. The proofs depend on formulas for the colored Jones polynomials of torus knots and techniques from the theory of Bailey pairs. This is joint work with Kazuhiro Hikami (Kyushu). (Received January 02, 2018)

1137-11-77 **Nickolas Andersen*** (nandersen@math.ucla.edu) and **William Duke**. *Modular invariants for real quadratic fields and Kloosterman sums.*

We investigate the asymptotic distribution of integrals of the j-function that are associated to ideal classes in a real quadratic field. Twisted sums of these integrals appear as Fourier coefficients of mock modular forms of half-integral weight. To estimate the error term in our asymptotic formula, we prove a bound for sums of Kloosterman sums of half-integral weight that is uniform in every parameter. Along the way, we prove a new variant of Kuznetsov's formula where the spectral data is restricted to half-integral weight forms in the Kohnen plus space. (Received January 25, 2018)

1137-11-100 **Frank G. Garvan*** (fgarvan@ufl.edu), Mathematics Department, Unvesity of Florida, 358 Little Hall, PO BOX 118105, Gainesville, FL 32611-8105. *Higher Order Mock Theta Conjectures.* Preliminary report.

The Mock Theta Conjectures were identities stated by Ramanujan for his so called fifth order mock theta functions. Andrews and Garvan showed how two of these fifth order functions are related to rank differences mod 5. Hickerson was first to prove these identities and was also able to relate the three Ramanujan seventh order mock theta functions to rank differences mod 7. Based on work of Zwegers, Zagier observed that the two fifth order functions and the three seventh order functions are holomorphic parts of real analytic vector modular forms on $SL_2(Z)$. Zagier gave an indication how these functions could be generalized. We give details of these generalizations and show how Zagier's 11th order functions are related to rank differences mod 11. (Received January 29, 2018)

1137-11-123 **Paul Beirne** (paul.beirne@ucdconnect.ie), School of Mathematics and Statistics, University College Dublin, Belfield, Dublin, 4, Ireland, and **Robert Osburn*** (robert.osburn@ucd.ie), School of Mathematics and Statistics, University College Dublin, Belfield, Dublin, 4, Ireland. *Knots and modular forms.* Preliminary report.

In 2006, Dasbach and Lin observed stability in the coefficients of the Nth colored Jones polynomial for alternating knots. This observation and its consequences have sparked a flurry of activity in both number theory and quantum topology. For example, Garoufalidis, Le and Zagier conjectured identities which have a striking resemblance to those occurring in the classical setting of Rogers and Ramanujan. In this talk, we discuss these developments and the construction of a new infinite family of quantum knot invariants which are related to modular forms. This is partly joint work with Paul Beirne (UCD). (Received January 31, 2018)

1137-11-169 **Luca Candelori*** (candelori@math.hawaii.edu). *Fields of definition for mock modular forms with CM shadow.*

Given a harmonic Maass form of integral weight, the coefficients of its holomorphic part are in general transcendental, even when the shadow is a cuspidal eigenform defined over a number field. However, when the shadow has complex multiplication (CM) Bruinier, Ono and Rhoades have shown that the coefficients of the holomorphic part lie in a number field. Based on numerical evidence, they further conjectured that this number field coincides with the field of definition of the shadow. In this talk we present a proof of this conjecture, based on the geometric interpretation of harmonic Maass forms. Indeed, the proof relies on somewhat deep results concerning motives of CM modular forms. We also discuss the still open (and harder) 'converse' conjecture on whether the CM shadow case is the only such case when the coefficients of the holomorphic part are algebraic, relating it to well-known conjectures in algebraic geometry and transcendence theory. This is joint work with Pavel Guerzhoy (University of Hawaii). (Received February 02, 2018)

1137-11-171 **Scott Ahlgren*** (sahlgren@illinois.edu), Department of Mathematics, University of Illinois, 1409 W. Green St., Urbana, IL 61822. *Congruences for mock modular forms and the smallest parts function.*

The "smallest parts function" $\operatorname{spt}(n)$ is a function of combinatorial interest whose generating function is essentially a mock modular form of weight 3/2 for the full modular group. George Andrews proved the three congruences

$$\operatorname{spt}(5n+4) \equiv 0 \pmod{5}, \qquad \operatorname{spt}(7n+5) \equiv 0 \pmod{7}, \qquad \operatorname{spt}(13n+6) \equiv 0 \pmod{13}.$$

Among other things, I will discuss recent work with Byungchan Kim which shows that such congruences are rare in a certain precise sense. (Received February 02, 2018)

1137-11-271 **Olivia Beckwith*** (obeckwi@emory.edu), **Michael Mertens** (mmertens@math.uni-koeln.de) and **Christine Bessenrodt** (bessen@math.uni-hannover.de). *Recent results on partitions.*

In this talk I will present results from two projects on integer partitions. The first project is about the maximal values of a multiplicative extension of the k-regular partition function. With Christine Bessenrodt, we prove an explicit formula for these maximal values that is analogous to results shown by Bessenrodt and Ono for $p(n)$. The second project concerns the parts of partitions in residue classes. For large n, how many parts should one expect to be equivalent to $r \pmod{m}$? One might expect that the preference for smaller numbers to appear as parts limits the uniformity with which the parts over all partitions of n are distributed across residue classes. In joint work with Michael Mertens, we use the Circle Method to answer this question. (Received February 06, 2018)

1137-11-273 **Michael J Griffin*** (mjgriffin@math.byu.edu), 320 TMCB, Brigham Young University, Provo, UT 84602, and **Jonathan Hales**. *The modular parameterization of elliptic curves.*

In this talk I will discuss recent work with Jonathan Hales, an undergraduate at BYU. The modular parameterization of an elliptic curve $E/\mathbb{Q}$ gives two modular functions $X(z)$ and $Y(z)$ which satisfy the defining equation of the curve, and which parameterize the points of the curve over $\mathbb{C}$. The motivating idea of this project is to understand the pre-images of rational points on the curve. The theory of complex multiplication shows that traces of Heegner points give rational points on quadratic twists of the elliptic curve. If the rank of the twisted curve is 1, then Gross and Zagier show the point constructed in this manner has infinite order. We are particularly interested in understanding the pre-images of points which are not traces of Heegner points. (Received February 05, 2018)

1137-11-277 **Elena Mantovan*** (mantovan@caltech.edu), Pasadena, CA 91125. *Geometric realization of p-adic automorphic forms on unitary Shimura varieties.*

The notion of a p-adic modular form (a p-adic analogue of classical modular forms) was first introduced by Serre in 1973 via the q-expansion principle. Soon afterwards, Katz gave a new definition via the geometry of modular curves. The p-adic theory provides the appropriate framework for the study of congruences among classical forms, and p-adic interpolation (i.e. the construction of families of classical forms which converge p-adically) is a crucial tool behind many important arithmetic results on classical modular forms.

Automorphic forms are a vast generalization of modular forms. Yet, in recent years, many arithmetic properties of modular forms were extended to automorphic forms, with stunning consequences. In this talk we will introduce the notions of classical and p-adic automorphic forms over Shimura varieties. We will mostly focus on aspects of the p-adic theory related to Hida's Igusa tower, the q-expansion principle and their application to the construction of p-adic families of automorphic forms. (Received February 05, 2018)

1137-11-308 **Min-Joo Jang*** (min-joo.jang@uni-koeln.de), **Amanda Folsom** (afolsom@amherst.edu), **Susie Kimport** (skimport@stanford.edu) and **Holly Swisher** (swisherh@math.oregonstate.edu). *Quantum modular forms and singular combinatorial series.* Preliminary report.

Since Dyson defined the rank of a partition, a number of studies have been done on this statistic. For example, a celebrated result of Bringmann and Ono showed that the rank generating function is essentially a mock modular form. Andrews introduced k-marked Durfee symbols and more generally defined the rank for them. In particular, when k = 1 one recovers Dyson's rank. In this talk, we establish quantum modularity of this combinatorial series, the rank generating function for k-marked Durfee symbols. This is joint work with Amanda Folsom, Susie Kimport, and Holly Swisher. (Received February 06, 2018)

1137-11-339 **Robert Schneider*** (robert.schneider@emory.edu). *Jacobi's triple product, mock theta functions, unimodal sequences and the q-bracket.*

In Ramanujan's final letter to Hardy, he wrote of an enigmatic new class of infinite series he called "mock theta functions". It turns out the q-series listed in Ramanujan's letter are essentially specializations of a so-called universal mock theta function $g_3(z, q)$ of Gordon–McIntosh. Here we show that g_3 arises naturally from the reciprocal of the classical Jacobi triple product – and is intimately tied to rank generating functions for unimodal sequences, which are connected to mock modular and quantum modular forms – through the action of the q-bracket of Bloch–Okounkov. This operator from statistical physics has recently been studied by Zagier and other authors due to connections to quasimodular and p-adic modular phenomena, and plays a natural role in partition theory as well. (Received February 06, 2018)

1137-11-340 **Edray Herber Goins*** (egoins@purdue.edu), Purdue University, Mathematical Sciences Building, 150 North University Street, West Lafayette, IN 47907-2067, and **Rachel Davis**. *Metabelian Galois Representations.* Preliminary report.

We are used to working with Galois representations associated to elliptic curves by considering the action of the absolute Galois group on torsion points. However there is a slightly more exotic way to view this construction once we realize that the Tate module of an elliptic curve is just the abelianization of the étale fundamental group of the punctured torus.

In this talk, we discuss how to construct a class of Galois representations by considering covers of elliptic curves which are branched over one point. We discuss how this is related to the question of surjectivity of certain Galois representation, and how to construct representations with image isomorphic to the holomorph of the quaternions. We will not assume extensive knowledge of étale cohomology. This is joint work with Rachel Davis. (Received February 06, 2018)

13 ► Commutative rings and algebras

1137-13-6 **Songpon Sriwongsa*** (songpon@uwm.edu) and **Yi Ming Zou** (ymzou@uwm.edu). *Orthogonal classical Cartan subalgebra decomposition of $\mathfrak{sl}_n$ over a finite commutative ring.*

Orthogonal decomposition of the special linear Lie algebra over the complex numbers, which is a decomposition into a direct sum of Cartan subalgebras that are pairwise orthogonal with respect to the Killing form, was studied in the early 1980s and attracted further attentions in the past decade due to its application in quantum information theory. In this talk, we will present the orthogonal decomposition problem of the special linear Lie algebra over a finite commutative ring with identity. Under some sufficient conditions, we will give a construction of orthogonal decomposition of this Lie algebra. Moreover, some non-existence cases of this decomposition will be discussed. (Received November 08, 2017)

1137-13-94 **Satoshi Murai** (s-murai@ist.osaka-u.ac.jp), Department of Pure and Applied Mathematics, Osaka University, Suita, Osaka, Japan, **Isabella Novik*** (novik@math.washington.edu), Department of Mathematics, University of Washington, Seattle, WA , and **Ken-ichi Yoshida** (yoshida@math.chs.nihon-u.ac.jp), Department of Mathematics, Nihon University, Setagaya-ku, Tokyo, Japan. *A duality in Buchsbaum rings and triangulated manifolds.*

In this talk we will discuss extensions of several theorems by Hochster, Stanley, and Reisner on Stanley-Reisner rings and modules of triangulated spheres and balls to the generality of Stanley-Reisner rings and modules of triangulated manifolds with and without boundary. Our results build on works of Schenzel, Goto, Gräbe, and many others. (Received January 28, 2018)

1137-13-128 **Eloísa Grifo***, eloisa.grifo@virginia.edu. *Symbolic powers and the containment problem.* Preliminary report.

The Containment Problem for ordinary and symbolic powers of ideals asks when the containment $I^{(a)} \subseteq I^b$ holds. If I is a radical ideal in a regular ring, a famous result by Ein-Lazersfeld-Smith, Hochster-Huneke and Ma-Schwede partially answers this question. Harbourne proposed an improvement on this result, which unfortunately does not hold in full generality. In this talk, we will discuss versions of Harbourne's Conjecture that do hold. (Received January 31, 2018)

1137-13-152 **Giulio Caviglia** and **Alessio Sammartano*** (`asammartano@msri.org`). *Betti numbers of ideals containing a regular sequence.*

Let S be a polynomial ring over a field $\Bbbk$ and $I \subseteq S$ a homogeneous ideal containing a regular sequence $\mathbf{f} = f_1, \ldots, f_c$. In this talk we investigate the existence of sharp bounds on the Betti numbers of I in terms of the degree sequence of $\mathbf{f}$ and the Hilbert function or the Hilbert polynomial of I. (Received February 01, 2018)

1137-13-157 **Katharine Shultis*** (`shultis@gonzaga.edu`) and **Peder Thompson** (`peder.thompson@ttu.edu`). *Reducibility of parameter ideals in low powers of the maximal ideal.* Preliminary report.

It is well-known that a commutative, local, noetherian ring R is Gorenstein if and only if every parameter ideal of the ring is irreducible. A less well-known result due to Marley, Rogers, and Sakurai gives that there is an integer ℓ such that R is Gorenstein if and only if there exists an irreducible parameter ideal in the ℓ-th power of the maximal ideal. The proof of this result gives that ℓ is the smallest integer such that a certain map of Ext modules is surjective after taking socles. We investigate upper bounds on this integer ℓ. (Received February 01, 2018)

1137-13-163 **Madeline V Brandt*** (`brandtm@berkeley.edu`), 2529 College Avenue, Berkeley, CA 94704. *Realization spaces for matroids.*

Matroids are a well-studied combinatorial abstraction of linear independence in vector spaces. When studying a given matroid, one could ask whether or not the matroid is realizable by a collection of vectors in a vector space. Additionally, one could study algebraic varieties whose points are in correspondence with sets of vectors which produce the same matroid, called realization spaces of the matroid. In this talk, we discuss the algebraic, geometric, and combinatorial properties of a new realization space for matroids, obtained from the hyperplane incidence matrix of a matroid. This is based on joint work with Amy Wiebe. (Received February 02, 2018)

1137-13-190 **Hailong Dao** (`hdao@ku.edu`) and **Jonathan Montaño*** (`jmontano@ku.edu`), 66045. *Asymptotic vanishing behavior of local cohomology.* Preliminary report.

We study asymptotic vanishing of graded components of local cohomology of powers of ideals and modules. We are able to prove some Kodaira-like vanishing theorems, showing that under certain local conditions the smallest nonzero degree of these modules is bounded by a linear function. (Received February 03, 2018)

1137-13-199 **Christopher Eur*** (`chrisweur@gmail.com`) and **Sung Hyun Lim**. *Complete intersections with given Hilbert polynomials.*

The Hilbert polynomial of a homogeneous complete intersection is determined by the degrees of the generators of the defining ideal. The degrees of the generators are not, in general, determined by the Hilbert polynomial – but sometimes they are. When? We give some general criteria and completely answer the question up to codimension 6. (Received February 04, 2018)

1137-13-201 **Ben Richert*** (`brichert@calpoly.edu`), Math. Dept., Cal Poly, San Luis Obispo, CA 93407. *Two competing versions of the Lex-Plus-Powers Conjecture are equivalent.*

Roughly speaking, Lex-Plus-Powers (LPP) ideals are monomial ideals in $k[x_1, \ldots, x_n]$ which contain powers of the variables in prescribed degrees and are as lex as possible otherwise. These ideals play a central role in the Lex-Plus-Powers conjecture of Evans and Charalambous—they are conjectured to have largest graded Betti numbers among all ideals containing a regular sequence with the same degrees and attaining the same Hilbert function. There has been some debate, however, about the correct definition of LPP ideals. Some authors require LPP ideals to contain powers of the variables in prescribed degrees as minimal generators, while others forgo minimality. One the face of it, this gives rise to competing versions of the Lex-Pus-Powers conjecture. We show (via a proof of Evan's Convexity Conjecture about LPP ideals) that these competing versions of the Lex-Plus-Powers conjecture are equivalent. (Received February 04, 2018)

1137-13-257 **Connor Sawaske*** (sawaske@uw.edu). *Almost Buchsbaumness of some rings arising from complexes with isolated singularities.*

We study properties of the Stanley–Reisner rings of simplicial complexes with isolated singularities modulo two generic linear forms. Miller, Novik, and Swartz proved that if a complex has homologically isolated singularities, then its Stanley–Reisner ring modulo one generic linear form is Buchsbaum. Here we examine the case of non-homologically isolated singularities, providing many examples in which the Stanley–Reisner ring modulo two generic linear forms is a quasi-Buchsbaum but not Buchsbaum ring. (Received February 05, 2018)

1137-13-267 **Chris Peterson*** (peterson@math.colostate.edu) and **Zach Flores**. *Some aspects of the Weak Lefschetz property.* Preliminary report.

If B is a standard graded Artinian algebra, then B is said to have the Weak Lefschetz Property (WLP) if there exists a linear form, L, such that the multiplication map induced by L from B_i to B_{i+1} has maximal rank for every i. An influential paper by (Harima et al) illustrated how the Grauert-Mulich theorem could be used to help establish WLP in some important special cases. Brenner and Kaid extended these ideas to several further cases. In this talk, the goal is to describe some of these results (including a description of the Grauert-Mulich theorem) and outline how they can be further utilized in a more general setting. This is joint work with Zach Flores. (Received February 05, 2018)

1137-13-305 **Jake Levinson*** (jlev@uw.edu), **Jarod Alper** (jarod@uw.edu) and **Rowan Rowlands** (rowanr@uw.edu). *Equivariant syzygies and apolarity.* Preliminary report.

I'll describe some ongoing work with Jarod Alper and Rowan Rowlands concerning syzygies of the apolar ideals of the determinant and permanent polynomials. The homological properties of an apolar ideal are linked to measures of algebraic complexity, such as (in this case) the Waring rank of the underlying polynomial.

We have computed the syzygies of the apolar ideal of the determinant, using the fact that these syzygies carry an action of $GL_n \times GL_n$. Even in low degrees, the syzygies differ from those of the permanent. (Received February 06, 2018)

1137-13-311 **Jenny R Kenkel*** (kenkel@math.utah.edu), Salt Lake City, UT 84102. *Local Cohomology of Thickenings.* Preliminary report.

Abstract: Let k be a field, and consider an $m \times n$ matrix X, whose entries are independent indeterminates over k. Let $R = k[X]$, and set I_n to be the ideal generated by the size n minors of X, and consider the residue class rings, R/I_n, known as determinantal rings. I will discuss local cohomology of the thickenings R/I_n^t in both characteristic 0 and p, and how an interesting calculation of such a cohomology module reduces to a calculation over a hypersurface. (Received February 06, 2018)

1137-13-320 **Serkan Hosten*** (serkan@sfsu.edu), 1600 Holloway Avenue, San Francisco, CA 94132. *Cohen-Macaulayness of Initial Ideals of Normal Toric Ideals.* Preliminary report.

More than fifteen years ago Sturmfels asked whether a normal toric ideal has a Cohen-Macaulay monomial initial ideal. By a theorem of Hoechster, normal toric ideals themselves are known to be Cohen-Macaulay, but whether this property passes to some monomial initial ideal is not clear. We show that initial ideals associated to what we call normal liftings are Cohen-Macaulay, and we provide an effective test for the normal lifting property. We will also provide examples where normal toric ideals without such liftings can still have Cohen-Macaulay initial ideals. (Received February 06, 2018)

1137-13-322 **Louiza Fouli*** (lfouli@nmsu.edu), Department of Mathematical Sciences, Las Cruces, NM 88003, and **Tài Hà** and **Susan Morey**. *Depth bounds for monomial ideals.* Preliminary report.

We consider various lower bounds for the depths of monomial ideals. In the case of square-free monomial ideals, one can view them as edge ideals of hypergraphs and we use graph invariants to determine lower bounds for the depth of such ideals and in some instances for their powers as well. In general, even if we can find a lower bound for the depth of a monomial ideal, it is hard to find a precise regular sequence that realizes this bound. We propose a way to construct a sequence that is not necessarily a regular sequnce on R/I, but instead provides a lower bound on the length of a maximal regular sequence on R/I, where R is a polynomial ring and I is a monomial ideal. (Received February 06, 2018)

14 ► Algebraic geometry

1137-14-13 **Daniel Chan** (adam.nyman@wwu.edu), BELLINGHAM, WA 982258104, and **Adam Nyman*** (adam.nyman@wwu.edu), BELLINGHAM, WA 982258104. *A representation theoretic study of noncommutative symmetric algebras.*

We study Van den Bergh's noncommutative symmetric algebra $\mathbb{S}^{nc}(M)$ (over division rings) via Minamoto's theory of Fano algebras. In particular, we show $\mathbb{S}^{nc}(M)$ is coherent, and its proj category $\mathbb{P}^{nc}(M)$ is derived equivalent to the corresponding bimodule species. This generalizes a theorem of Minamoto, which in turn is a generalization of Beilinson's derived equivalence. As corollaries, we show that $\mathbb{P}^{nc}(M)$ is hereditary and there is a structure theorem for sheaves on $\mathbb{P}^{nc}(M)$ analogous to that for $\mathbb{P}^1$. (Received December 15, 2017)

1137-14-20 **Stefano Filipazzi*** (filipazz@math.utah.edu). *Generic vanishing fails for surfaces in positive characteristic.*

Generic Vanishing is a very powerful tool in the study of irregular varieties. Recently, Hacon and Kovács showed that this vanishing theorem does not extend to positive characteristc: They provide counterexamples in dimension three and higher. In this talk, we discuss how to produce a counterexample to Generic Vanishing in dimension two. Furthermore, we improve the result of Hacon and Kovács by producing counterexamples for which the Albanese map is finite. (Received January 05, 2018)

1137-14-21 **Yuchen Liu*** (yuchen.liu@yale.edu), 10 Hillhouse Ave, Department of Mathematics, Yale University, New Haven, CT 06511. *On the semi-continuity problem of normalized volumes of singularities.*

We show that in any $\mathbb{Q}$-Gorenstein flat family of klt singularities, normalized volumes are lower semi-continuous in the Zariski topology. A quick consequence is that smooth points have the largest normalized volume among all klt singularities. Using an alternative characterization of K-semistability developed by Li, Liu and Xu, we show that K-semistability is a very generic or empty condition in any $\mathbb{Q}$-Gorenstein flat family of log Fano pairs. This is a joint work with Harold Blum. (Received January 05, 2018)

1137-14-26 **Sean A Broughton*** (brought@rose-hulman.edu). *Topological and $\mathcal{H}_q$ Equivalence of Prime Cyclic p-gonal Actions on Riemann Surfaces.* Preliminary report.

Two Riemann surfaces S_1 and S_2 with conformal G-actions have topologically equivalent actions if there is a homeomorphism $h : S_1 \to S_2$ which intertwines the actions. A weaker equivalence may be defined by comparing the representations of G on the spaces of holomorphic q-differentials $\mathcal{H}^q(S_1)$ and $\mathcal{H}^q(S_2)$. We present the differences between topological equivalence and $\mathcal{H}^q$ equivalence of prime cyclic actions, where S_1/G and S_2/G have genus zero. (Received January 10, 2018)

1137-14-29 **Sándor J Kovács*** (skovacs@uw.edu). *Moduli theory and singularities.*

The ultimate goal of any discipline is to understand and classify the objects it is studying. When studying geometric objects, an initial classification is obtained by introducing discrete invariants: numerical ones such as dimension, degree, and genus, and other more complicated ones such as the fundamental group, homology, cohomology, and higher homotopy groups. After we run out of discrete invariants, the remaining classes form continuous families (or at least we hope they do). This phase of the classification theory is called, after Riemann, moduli theory. The algebraic theory of moduli of Riemann surfaces, or algebraic curves, has witnessed decades of intensive development. Recently the moduli theory of higher dimensional algebraic varieties has started a similar journey. An interesting facet of the theory is that even if one is primarily interested only in smooth objects, it is advantageous to understand the possibly singular degenerations of these smooth objects. In this talk, I will review recent advances in the moduli theory of higher dimensional algebraic varieties and the role singularities play in our understanding of this theory. (Received January 14, 2018)

1137-14-75 **Lucas Braune*** (lvhb@uw.edu), Department of Mathematics, University of Washington, Seattle, WA 98195. *Irrational Complete Intersections.*

I will explain the proof of the following new result: The complete intersection of r very general hypersurfaces in N-dimensional complex projective space is not ruled, and therefore not rational, provided that the sum of the degrees of the hypersurfaces is at least $\frac{2}{3}N + r + 1$. The proof is modeled on the one given by Kollár in the case of a single hypersurface on 1995. It has as key features a degeneration to positive characteristic and the use of characteristic-p versions of classical results from the singularity theory of maps between differentiable manifolds. (Received January 24, 2018)

1137-14-131 **Drew Johnson*** (drewj@uoregon.edu). *Universal Series for Hilbert Schemes and Strange Duality.*

Let S be a smooth, complex surface and F be a vector bundle. A result of Ellingsrud, Gottche, and Lehn says that any Chern number obtained using the tangent bundle of the Hilbert scheme of n points on S and the tautological sheaf associated to F can be expressed as a polynomial (independent of S) in Chern numbers of S and F. Even more structure is revealed when these numbers are assembled into certain generating series.

An example of such a number is the Euler characteristic of line bundles, which is of interest in strange duality. Strange duality relates the Euler characteristics of certain line bundles on moduli spaces. A strategy of Marian and Oprea relates these Euler characteristics to the cardinality of finite Quot schemes. In a recent paper, I have shown how viewing the expected length of the Quot scheme as a Chern number of a certain vector bundle suggests some surprising relationships between the generating series for these two sets of numbers. These conjectures have inspired some recent progress on computing top Segre classes of vector bundles on Hilbert schemes. (Received January 31, 2018)

1137-14-135 **Cristina Manolache*** (c.manolache@imperial.ac.uk). *Reduced Gromov–Witten invariants from cuspidal curves.*

In a series of papers Vakil-Zinger, Li-Zinger, and Zinger introduced reduced Gromov-Witten invariants and compared them to standard Gromov-Witten invariants. Reduced invariants are numbers which contain fewer degenerate contributions than Gromov-Witten invariants and they are also easier to compute. Together with Luca Battistella and Francesca Carocci, we use moduli spaces of stable maps from curves with cusps and we consider the corresponding invariants. We show that for the quintic three-fold these invariants are equal to reduced Gromov-Witten invariants. (Received February 05, 2018)

1137-14-147 **Tony Shaska*** (shaska@oakland.edu). *Riemann surfaces with extra automorphisms and endomorphism rings of their Jacobians.*

In this talk we will explore connections between the automorphism group of a Riemann surface $\mathcal{X}$ and the endomorphism ring of the Jacobian of $\mathcal{X}$. We will briefly describe work of Zarhin and others on the topic and explore some recent developments. (Received February 01, 2018)

1137-14-149 **Lubjana Beshaj***, 13 Autumn Leaf, 2-2, Highland Falls, NY 10928. *Minimal Models for Superellipic Riemann Surfaces with Extra Automorphism.*

A Riemann surface with affine equation of the form $y^n = f(x)$ is called a superelliptic Riemann surface. For such Riemann surfaces with extra automorphisms we will discuss how to find minimal integral equations when possible. We will briefly describe reduction theory through the work of G. Julia and some recent developments. (Received February 01, 2018)

1137-14-154 **Emily Clader*** (eclader@sfsu.edu). *Wall-crossing in Gromov-Witten and Landau-Ginzburg theory.*

The theory of quasi-maps, developed in recent work of Ciocan-Fontanine and Kim, is a generalization of Gromov-Witten theory that depends on an additional stability parameter varying over positive rational numbers. When that parameter tends to infinity, Gromov-Witten theory is recovered, while when it tends to zero, the resulting theory encodes information related to the "B-model." Ciocan-Fontanine and Kim proved a wall-crossing formula exhibiting how the theory changes with the stability parameter, and in this talk, we discuss an alternative proof of their result as well as a generalization to other gauged linear sigma models. This is joint work with Felix Janda and Yongbin Ruan. (Received February 01, 2018)

1137-14-155 **Brian Osserman*** (osserman@math.ucdavis.edu). *Moduli spaces of linear series and nodal curves.*

In the 1980's, work of Eisenbud, Harris, and Mumford illuminated the importance of the study of linear series on curves in understanding the geometry of moduli space of the curves themselves. It also demonstrated the importance of understanding the degeneration of linear series as the underlying curves degenerated, leading to the development by Eisenbud and Harris of the notion of limit linear series for curves of compact type. After reviewing these ideas, I will discuss several recent advances, partially joint with Murray and Lieblich, which have led to the solution of the long-standing problem of constructing a proper relative moduli space of (limit) linear series over the moduli space of curves of compact type. (Received February 01, 2018)

1137-14-158 **Roberto Fringuelli** (roberto.fringuelli@ed.ac.uk) and **Roberto Pirisi*** (roberto.pirisi86@gmail.com). *The Brauer group of the moduli stack of vector bundles on smooth curves (joint w/ R. Fringuelli).* Preliminary report.

The moduli stack of vector bundles over a fixed algebraic curves has been an important object of research in recent years. There are recent computations (Balaji et al.; Biswas, Holla) of the Brauer group of this stack and generalizations of it.

In a work in progress with R. Fringuelli we globalize these results to the moduli stacks $\mathcal{V}ec_{r,d} \to \mathcal{M}_g$ parametrizing couples (X, E) where X is a smooth curve of genus g and E is a vector bundle of rank r and degree d on X, and to its rigidification $\mathcal{V}_{r,d} \to \mathcal{M}_g$.

We show that for $g \geq 4$, in the case of $\mathcal{V}ec_{r,d}$ the cohomological Bruer group is trivial and in the case of $\mathcal{V}_{r,d}$ it is finite cyclic, with the class of $\mathcal{V}ec_{r,d} \to \mathcal{V}_{r,d}$, seen as a $\mathbb{G}_m$-gerbe, as a generator. (Received February 01, 2018)

1137-14-172 **Aaron D Wootton*** (wootton@up.edu), 5000 N Willamette Blvd, Portland, OR 97203, and **James W Anderson**. *The Lattice Structure of the Potential Signature Space.* Preliminary report.

The relationship between the number of distinct finite group actions on compact Riemann surfaces and the genus on which they act remains somewhat of a mystery – for example in genus 7, there are 148 and in genus 8, there are 108. Part of this mystery can be explained through the use of signatures that satisfy the Riemann Hurwitz formula though are not necessarily the signatures of actual group actions, so-called potential signatures. We shall show that the space of potential signatures has a lattice structure ordered by the divisibility of $g-1$ where g represents the genus of a surface. (Received February 02, 2018)

1137-14-177 **Cristian Martinez*** (martinez@math.ucsb.edu), Department of Mathematics, South Hall Room 6607, University of California, Santa Barbara, CA 93106, and **Benjamin Schmidt** (schmidt@math.utexas.edu), Department of Mathematics, The University of Texas at Austin, 2515 Speedway, Austin, TX 78712. *Stability conditions on blow-ups and counterexamples.*

Stability conditions have become an essential tool in the study of the birational geometry of moduli spaces of Gieseker semistable sheaves. However, the conjectural construction of stability conditions on threefolds depends on a generalization of the Bogomolov-Gieseker inequality, which fails in general. In this talk I will present a new class of counterexamples for the generalized Bogomolov-Gieseker inequality including blow-ups at points and some elliptic fibrations. I will also show how to modify the inequality in the case of blow-ups. (Received February 02, 2018)

1137-14-179 **Aaron Bertram*** (aaronbertram1984@gmail.com), 923 E 3rd Ave, Salt Lake City, UT 84103. *Strange Duality for Algebraic Surfaces.*

Strange Duality for sections of determinant line bundles associated to an algebraic curve is well-understood thanks to work of Alina Marian and Dragos Oprea. On an algebraic surface, the analogous Strange Duality is poorly understood, and possibly poorly formulated. In this talk, I will discuss work in the del Pezzo case with Thomas Goller and Drew Johnson, and also new conjectures for the case of other surfaces. (Received February 02, 2018)

1137-14-181 **Sarah Frei*** (sfrei@uoregon.edu). *Moduli spaces of sheaves on a K3 surface and Galois representations.*

There have been some interesting results in recent years about derived equivalences of varieties implying equality of their zeta functions. I will tell you about a new result extending this idea to moduli spaces of stable sheaves on a K3 surface. It turns out that regardless of derived equivalence, two such moduli spaces of the same dimension have equal zeta functions. We arrive at this result by studying the cohomology groups of the moduli spaces as Galois representations. (Received February 02, 2018)

1137-14-218 **Harold Blum*** (blum@umich.edu). *Thresholds, valuations, and K-stability.*

We study two invariants that measure the singularities of anticanonical divisors on Fano varieties. The first is the global log canonical threshold, which is also known as Tian's alpha invariant. The second is the stability threshold, an invariant recently introduced by Fujita and Odaka. Our approach to understanding these invariants involves valuations. Using results of Li and Fujita, we show that the K-(semi)stability of a Fano variety is detected by the stability threshold. This talk is based on joint work with Mattias Jonsson. (Received February 04, 2018)

1137-14-220 **Kenneth Ascher*** (kascher@mit.edu) and **Dori Bejleri**. *Compactifying the moduli space of degree one del Pezzo surfaces via elliptic fibrations.*

Stable pairs and KSBA moduli form the generalization of the Deligne-Mumford moduli space of stable curves in higher dimensions. In this talk I will describe a stable pairs compactification of the moduli space of degree one del Pezzo surfaces. We use the close relation between degree one del Pezzo surfaces and rational elliptic surfaces to construct this space as a limit of a space of weighted stable elliptic surfaces. We will also discuss the relationship to GIT compactifications of moduli of rational elliptic surfaces. This is joint work with Dori Bejleri. (Received February 04, 2018)

1137-14-230 **James S. Wolper*** (wolpjame@isu.edu), Idaho State University, 921 S. 8th Ave., MS 8085, Pocatello, ID 83209. *Periods of an Interesting Family of Curves with Automorphisms.* Preliminary report.

The Information-Theoretic Schottky Problem begins with the observation that the Jacobian of a complex algebraic curve has "too many" periods: the period matrix grows with the square of the genus, while the dimension of the moduli space grows linearly. This has expanded to include trying to derive properties of Abelian Varieties from the distribution of the periods. This talk will explore properties of the periods of an interesting family of three-sheeted covers of the Riemann Sphere. These curves have Jacobians that split and their period distribution is similar to that of hyperelliptic curves, which is not always the case with curves with automorphisms. (Received February 04, 2018)

1137-14-232 **Kristin DeVleming***, kdev@uw.edu. *Moduli of Hypersurfaces in $\mathbb{P}^3$.*

We will discuss a compactification of the moduli space of degree $d \geq 5$ hypersurfaces in $\mathbb{P}^3$, i.e. a parameter space whose interior points correspond to (equivalence classes of) smooth hypersurfaces in $\mathbb{P}^3$ and whose boundary points correspond to degenerations of such surfaces. Following a trail blazed by numerous others, instead of studying the surfaces D themselves, we study pairs $(\mathbb{P}^3, D)$ satisfying certain properties. Roughly, we require $(X, \alpha D)$ to be a stable pair for α slightly less than 1 and X to be a degeneration of $\mathbb{P}^3$. We will discuss classification of the singular pairs, boundedness, and why these pairs admit a good modular compactification. This work is inspired by ideas of Alexeev, Hacking, Kollár, and Shepherd-Barron. (Received February 05, 2018)

1137-14-238 **Oliver Leigh*** (oleigh@math.ubc.ca). *r-Spin Hurwitz and Stable Maps with Divisible Ramification.*

r-Spin Hurwitz numbers are a subclass of stationary Gromov-Witten invariants for $\mathbb{P}^1$ where all the psi-classes are raised to the power $r \in \mathbb{N}$. In this talk I will introduce a new geometric approach to r-spin Hurwitz numbers. I do this by constructing a moduli space which parameterises stable maps whose ramification is divisible by r, and showing it has a natural perfect obstruction theory. I will then discuss a proof of Zvonkine's r-ELSV formula using this concept. (Received February 05, 2018)

1137-14-256 **Amos Turchet*** (aturchet@uw.edu), Department of Mathematics, University of Washington, Seattle, WA 98195-4350, and **Kenny Ascher** and **Kristin DeVleming**. *Moduli spaces of stable pairs, uniformity of integral points and positivity of the log cotangent bundle.*

The number of integral points in a curve of log general type is finite and it is natural to ask how it varies in a (stable) family. The problem is related to the geometry of stable families of stable pairs and their fibered power. In this joint work (in progress) with Kenny Ascher and Kristin DeVleming we show that a conjecture of Vojta implies that the number is uniformly bounded and the bound depends only on the geometric invariants defining the curves involved. We also partially extend this to higher dimensions, using a suitable model of the moduli stack of stable pairs. If time permits I will discuss how very interesting problems arise already in dimension 2, and the role played by the log-cotangent bundle and its positivity. (Received February 05, 2018)

1137-14-313 **Jarod Alper***, jarod@uw.edu. *Quotients of algebraic varieties.*

In this talk, we will address the following question: given an algebraic group G acting on a variety X, when does the quotient X/G exist? We will provide an answer to this question in the case that G is reductive by giving necessary and sufficient conditions for the quotient to exist. We will discuss various applications to equivariant geometry, moduli problems and Bridgeland stability. (Received February 06, 2018)

1137-14-314 **Dustin James Ross***, rossd@sfsu.edu. *Higher-genus global mirror symmetry.*

Over ten years ago, Chiodo and Ruan proved a genus-zero global mirror theorem, relating the Gromov-Witten invariants of the quintic threefold to the corresponding Fan-Jarvis-Ruan-Witten invariants. Moreover, they suggested that the genus-zero relationship quantizes to an all-genus statement. In this talk, I'll describe recent work with Huailiang Chang, Shuai Guo, and Jun Li to compute higher-genus FJRW invariants and to verify the quantized global mirror theorem. (Received February 06, 2018)

1137-14-333 **Katrina Honigs*** (honigs@math.utah.edu). *Deforming derived equivalences.*

There are many results characterizing when derived categories of two complex surfaces are equivalent. The proofs of some of these theorems strongly use Torelli theorems and lattice-theoretic methods which are not available in positive characteristic. However, some analogous results may be proven over algebraically closed fields of positive characteristic by lifting derived equivalences from positive characteristic to characteristic 0. We will discuss these methods of lifting and their applications. This work is joint with M. Lieblich, L. Lombardi and S. Tirabassi. (Received February 06, 2018)

1137-14-335 **Vance T. Blankers*** (blankersv@gmail.com), 6703 Antigua Dr Unit 46, Fort Collins, CO 80525. *Rigidity and Extremality of Hyperelliptic Classes in Genus Two.*

A hyperelliptic class on a moduli space of marked curves is the Chow class of the closure of the locus of hyperelliptic curves with ℓ marked Weierstrass points, m marked conjugate pairs of points, and n marked free points. We show that in genus two such classes are rigid and extremal in the cone of effective codimension-$(\ell+m)$ classes on $\overline{\mathcal{M}}_{2,\ell+2m+n}$ using the rich recursive structure of the relevant moduli spaces. Our result establishes an infinite family of rigid and extremal classes in arbitrarily-high codimension. (Received February 06, 2018)

1137-14-338 **Emma Previato*** (ep@bu.edu), Department of Mathematics and Statistics, Boston University, Boston, MA 02215. *Automorphism groups and splittability.* Preliminary report.

A principally polarized abelian variety over $\mathbb{C}$ is said to be completely split if it isogenous to a product of elliptic curves. In a 1993 paper, T. Ekedahl and J.-P. Serre asked whether there exist curves of any genus whose Jacobian splits completely. They gave examples of modular curves with completely split Jacobian. A different approach, initiated by J. Paulhus in her 2017 Ph.D. thesis, constructs examples using the automorphism group of the curve. In recent work (arXiv:1603.00331), Paulhus and A. Rojas give new examples using both known lists of group actions and computational methods. These questions have not been investigated in positive characteristic. We use computational databases to list several possibly relevant features of modular curves reduced to positive characteristic, such as their automorphism groups, Weil polynomials, supersingularity. As the order of the field increases, we record different behaviors. The ultimate goal is to identify properties that characterize complete splittability. This is work in progress with Valentijn Karemaker, issuing from a project with Ekin Ozman originated at IHES in 2011. (Received February 06, 2018)

1137-14-359 **Elden Elmanto**, **Marc Hoyois*** (hoyois@usc.edu), **Adeel A. Khan**, **Vladimir Sosnilo** and **Maria Yakerson**. *Motivic infinite loop spaces.*

We prove a recognition principle for motivic infinite $\mathbb{P}^1$-loop spaces over an infinite perfect field k of characteristic not 2. This is achieved by developing a theory of *framed motivic spaces*, a motivic analogue of the theory of E_∞-spaces. As a consequence we obtain a description of infinite $\mathbb{P}^1$-loop spaces of $\mathbb{P}^1$-suspension spectra of smooth quasi-projective varieties in terms of Hilbert schemes of points in affine spaces. (Received February 07, 2018)

1137-14-360 **Eric M Friedlander*** (ericmf@usc.edu), Math Dept, USC, 3620 S. Vermont Ave, Los Angeles, CA 90089. *A search for an algebraic equivalence analogue of motivic theories.* Preliminary report.

The Lawson (co) homology and semi-topological K-theory for real and complex varieties utilize the analytic topology and are closely related to cycles modulo algebraic equivalence. Indeed, the relationship between rational equivalence and algebraic equivalence leads to a close relationship between motivic cohomology and algebraic K-theory and these less familiar theories. This talk will present challenges and thoughts for developing a theory for varieties over other fields which is associated to algebraic equivalence, a theory which should have a "good" relationship with existing motivic invariants. These ideas have grown out of lengthy discussions with Christian Haesemeyer and Mark Walker. (Received February 07, 2018)

15 ► Linear and multilinear algebra; matrix theory

1137-15-223 **Maxim Zinchenko*** (maxim@math.unm.edu). *A uniqueness problem for spectral shift functions.* Preliminary report.

In this talk I will present a uniqueness result for higher order spectral shift functions. The result asserts that under certain assumptions any higher order spectral shift function is identically zero if and only if the perturbation is zero. The talk is based on a joint work with A. Skripka. (Received February 04, 2018)

16 ► Associative rings and algebras

1137-16-14 **Chelsea Walton**, **Xingting Wang*** (xingting@temple.edu) and **Milen Yakimov**. *Irreducible representations of the 4-dimensional Sklyanin algebra at points of finite order.*

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. By exploring a compatible Poisson structure on the central affine variety of $A(E,\tau)$ obtained by formal deformation, we are able to describe the Azumaya locus and prove that it coincides with the smooth locus of $A(E,\tau)$. We also relate these irreducible representations to the fat point modules of intermediate multiplicity classified by Smith. This is a joint work of Chelsea Walton and Milen Yakimov. (Received February 02, 2018)

1137-16-16 **Elizabeth Wicks*** (lizwicks@uw.edu). *Frobenius-Perron Theory of Modified ADE 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 squared 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 with can be applied in general to calculate the Frobenius-Perron dimension of a radical squared zero bound quiver algebra. We use this result to introduce a family of abelian categories which produce arbitrarily large irrational Frobenius-Perron dimensions. (Received December 28, 2017)

1137-16-25 **G. Abrams**, **B. Greenfeld** and **Z. Mesyan***, Department of Mathematics, University of Colorado, Colorado Springs, CO 80918, and **K. M. Rangaswamy**. *Leavitt Path Algebras and the Kaplansky Property for Prime Spectra.*

In his 1974 monograph, Kaplansky identified a certain gap property enjoyed by the prime spectra of commutative rings. It is an open question whether all noncommutative rings have this gap property as well. Since, as recently shown, a very wide variety of partially ordered sets can be realized as prime spectra of Leavitt path algebras, it is natural to explore Kaplansky's property in these rings. We show that Kaplansky's gap property holds for the semiprime ideals in Leavitt path algebras, and also for the prime spectra of such algebras that are totally ordered by inclusion. This allows us to completely characterize the totally ordered sets that can be realized as the prime spectra of Leavitt path algebras. (Received January 09, 2018)

1137-16-37 **Kulumani M Rangaswamy*** (kmranga@gmail.com), Austin Bluffs Parkway, Colorado Springs, CO 80918. *Graded Primitive Leavitt Path Algebras Over Arbitrary Graphs.* Preliminary report.

Let L be a Z-graded Leavitt path algebras of a directed graph E over a field K. Characterizing graphical conditions on E are given under which L becomes graded prime and graded primitive. This is used to answer the graded version of a question of Kaplansky whether a graded prime Leavitt path algebra is graded primitive. (Received January 17, 2018)

1137-16-40 **Jason Gaddis*** (gaddisj@maimioh.edu). *Isomorphisms of graded path algebras.*

By a result of Bell and Zhang, if two connected ($\mathbb{N}$-)graded algebras are isomorphic as algebras, then they are isomorphic as graded algebras. We extend this result to the case of path algebras with homogeneous relations and discuss its applications to the study of graded Calabi-Yau algebras. (Received January 18, 2018)

1137-16-45 **Stephan Weispfenning*** (sweispfe@ucsd.edu). *Generalized Gorensteinness and Homological Determinants for Preprojective Algebras.* Preliminary report.

Studying invariant theory of commutative polynomial rings has motivated many developments in commutative algebra and algebraic geometry. The question under what conditions we can obtain a fixed ring with certain properties has been of particular interest. After generalizing the setting to certain noncommutative non-connected algebras, the main questions remain the same. This talk discusses a sufficient condition on the finite group acting to guarantee that the fixed ring has finite injective dimension and satisfies a generalized Gorenstein condition. Part of this result is the construction of a homological determinant of a non-connected algebra which turns out to be particularly nice for the examined preprojective algebras. (Received January 19, 2018)

1137-16-54 **Jonas T Hartwig*** (jth@iastate.edu). *Gelfand-Zeitlin modules over Galois orders.*

Galois orders form a class of noncommutative algebras introduced by Futorny and Ovsienko in 2010. Examples include enveloping algebras, truncated Yangians, finite W-algebras, and orthogonal Gelfand-Zeitlin algebras of type A. In this talk we present new techniques which allows us to prove that quantum analogs as well as parabolic generalizations of the mentioned examples are also Galois orders. In addition, the new approach provides a natural way to construct canonical simple Gelfand-Zeitlin modules over these algebras, generalizing recent results by several different authors. (Received January 22, 2018)

1137-16-71 **Richard G Chandler*** (richard.chandler@untdallas.edu), 7400 University Hills Blvd, Dallas, TX 75241, and **Michaela Vancliff**. *The Quantum Spaces of Certain Graded Algebras Related to $\mathfrak{sl}(2, \Bbbk)$.*

Inspired by the work of Le Bruyn and Smith, and the work of Shelton and Vancliff, we analyze certain graded algebras related to the Lie algebra $\mathfrak{sl}(2, \Bbbk)$ using geometric techniques in the spirit of Artin, Tate and Van den Bergh. In particular, we discuss the point schemes and line schemes of certain quadratic quantum $\mathbb{P}^3$s associated to the Lie superalgebra $\mathfrak{sl}(1|1)$, to a quantized enveloping algebra, $\mathcal{U}_q$, of $\mathfrak{sl}(2, \Bbbk)$, and to a color Lie algebra $\mathfrak{sl}_k(2, \Bbbk)$, respectively. The geometry we consider identifies the existence of a central element in the universal enveloping algebra of $\mathfrak{sl}(1|1)$ and in $\mathcal{U}_q$. (Received January 24, 2018)

1137-16-72 **Oswaldo Lezama*** (jolezamas@unal.edu.co), Universidad Nacional de Colombia, Bogotá, Colombia, and **Y.-H Wang** and **J.J Zhang**. *Zariski cancellation problem for rings.* Preliminary report.

The Zariski cancellation problem arises in commutative algebra and can be formulated in the following way: Let K be a field, $A := K[t_1, \ldots, t_n]$ be the algebra of usual polynomials and B be a commutative K-algebra,

$$A[t] \cong B[t] \Rightarrow A \cong B?$$

Recently the problem has been studied for noncommutative algebras that are domains (see for example, Bell, J., and Zhang, J. J., *Zariski cancellation problem for noncommutative algebras*, Selecta Math. (N.S.) **23** (2017), no. 3, 1709–1737). In this talk we discuss the Zariski cancellation problem for arbitrary rings based in a joint paper with Y.-H. Wang (Shanghai, China) and J.J. Zhang (Seattle, USA). (Received January 24, 2018)

1137-16-74 **Robert Laugwitz*** (robert.laugwitz@rutgers.edu) and **Vladimir Retakh**. *The Koszul property for algebras of quasi-Plücker coordinates.*

The commutative quadratic algebra of Plücker coordinates plays an important role in algebraic geometry. It describes the coordinate ring of the Grassmannian embedded into projective space. The Koszul property of this commutative ring is well-known. In this talk, a non-commutative analogue of the algebra of Plücker coordinates is discussed. This approach uses the theory of quasi-determinants of Gelfand and Retakh. The main result is that this algebra is a non-homogeneous quadratic Koszul algebra in the sense of Polishchuk and Positselski. (Received January 24, 2018)

1137-16-76 **Bach Nguyen*** (bnguy38@lsu.edu). *Quantum Group and Cluster Algebras.* Preliminary report.

As a noncommutative analog of cluster algebras, quantum cluster algebras were defined by Berenstein and Zelevinsky in 2005. Since then, such algebras have been an active research area with important applications in the study of canonical bases, combinatorics and representation theory. Recently, Goodearl and Yakimov gave a construction of quantum cluster structure for algebras which are CGL extensions. We apply their result to the setting of quantum foldings and extend it to more general situation. This is a work in progress. (Received February 06, 2018)

1137-16-102 **Jason Gaddis**, **Robert Won** and **Daniel Yee*** (dyee@fsmail.bradley.edu). *Center of Taft Algebra Smash Products.*

Given the n^2-dimensional Taft algebra H and an H-module algebra R, we determine the center of the smash product $R\#H$ under certain conditions. We apply this result to computing the discriminant, an automorphism invariant, of $A\#H$, where A is the skew polynomial algebra or the quantum Weyl algebra. (Received January 29, 2018)

1137-16-114 **Alexandru Chirvasitu*** (achirvas@buffalo.edu) and **Ryo Kanda**. *Flat families of non-commutative varieties.*

Non-commutative algebraic geometry revolves around the idea of studying connected graded algebras as homogeneous coordinate rings of "quantum projective varieties". One of the central techniques in the field is to attach to such an algebra ordinary projective varieties classifying, for each n, the cyclic graded modules with Hilbert series $1 + t + \cdots + t^n$ (the *n-truncated point modules* of the non-commutative scheme).

We consider families of graded algebras defined by allowing their spaces of relations to vary smoothly over a parameter space, and study the behavior of the corresponding schemes of truncated points. It turns out that these form flat families whenever they have "expected" (meaning minimal) dimension. As an application, we confirm a conjecture of C. Brazfield to the effect "most" non-commutative weighted projective 3-spaces with weights $(1, 1, 2, 3)$ have seventeen points.

(joint w/ Ryo Kanda) (Received January 30, 2018)

1137-16-211 **Ellen E. Kirkman*** (kirkman@wfu.edu), Department of Mathematics and Statistics, Wake Forest University, Winston-Salem, NC 27109, and **Jianmin Chen** and **James J. Zhang**. *Auslander's Theorem for group coactions on noetherian graded down-up algebras.*

Let $\Bbbk$ be a field of characteristic zero. M. Auslander proved that if G is a finite subgroup of $\mathrm{GL}_n(\Bbbk)$, containing no pseudo-reflections (e.g. subgroups of $\mathrm{SL}_n(\Bbbk)$), acting linearly on the commutative polynomial ring $A = \Bbbk[x_1, \ldots, x_n]$, with fixed subring A^G, then the natural map from the skew group algebra $A * G$ to $\mathrm{End}_{A^G}(A)$ is an isomorphism of graded algebras. We extend this result to Hopf actions on Artin-Schelter regular algebras by proving that if G is an inner-faithful, homogeneous, finite group coaction on a noetherian graded down-up algebra A, coacting on A with trivial homological codeterminant, then there is a natural graded algebra isomorphism $A\#H \cong \mathrm{End}_{A^H}(A)$, for $H = \Bbbk^G$; this result provides a relationship between certain modules over A^H and those over $A\#H$. (Received February 04, 2018)

1137-16-219 **Andrew B. Conner*** (abc12@stmarys-ca.edu), **Ellen Kirkman**, **W. Frank Moore** and **Chelsea Walton**. *Noncommutative Knörrer periodicity and quantum Kleinian singularities.*

Chan, Kirkman, Walton, and Zhang recently established a version of the McKay correspondence in characteristic 0 for the action of a semisimple Hopf algebra H acting inner-faithfully with trivial homological determinant on an Artin-Schelter (AS) regular algebra A of dimension 2. The invariant rings A^H for these actions are noncommutative hypersurfaces: they are isomorphic to $C/(\Omega)$ where C is a 3-dimensional AS-regular algebra and Ω is a normal element. The rings A^H were dubbed *quantum Kleinian singularities* and were shown to have finite Cohen-Macaulay (CM) type.

In this talk we use noncommutative matrix factorizations to describe the isomorphism classes of indecomposable maximal Cohen-Macaulay modules for the quantum Kleinian singularities. We then use a noncommutative analog of Knörrer periodicity to prove that $D/(\Omega + z_1^2 + z_2^2 + \cdots + z_d^2)$ has finite CM type where D belongs to a certain class of iterated Ore extensions of C. (Received February 04, 2018)

1137-16-287 **Johannes Flake*** (flake@math.rutgers.edu). *Dirac cohomology for generalized Hecke algebras.*

Dirac operators have played an important role in the representation theory of real reductive Lie groups and various types of Hecke algebras. In particular, their cohomology is often related to the central character of a representation. We explain recent work on how this can be shown in a generalized setting for a class of PBW deformations, using the theory of Hopf algebras, smash products, and superalgebras. Our results generalize known results for several special cases, but also apply to new cases, including infinitesimal Cherednik algebras. The classification of objects in the considered class of PBW deformations is an open problem, and we will present partial results on this question. (Received February 05, 2018)

1137-16-319 **Hans Erik Nordstrom*** (nordstro@up.edu), 5000 N Willamette BLVD, Portland, OR 97203, and **Jennifer A Firkins Nordstrom**. *Prime ideals of Leavitt path algebras over arbitrary rings.* Preliminary report.

Leavitt path algebras constructed over a base field have a rich history of research; most recently their ideal spectrum has come under study. Aranda Pino, Pardo, and Siles Molina initially characterized the prime spectrum in terms of graph-theoretic properties. Abrams, Bell and Rangaswamy showed this description coincided with a particular stratification, similar to that found by Goodearl and Letzter for many quantum groups, by proving that LPAs satisfy the *Dixmier-Moeglin equivalence.* We discuss how these results can be used to indicate prime ideals of LPAs build over arbitrary rings. (Received February 06, 2018)

1137-16-325 **Luigi Ferraro**, **Ellen Kirkman** and **W. Frank Moore*** (moorewf@wfu.edu), 1834 Wake Forest Road, 127 Manchester Hall, Winston-Salem, NC 27106, and **Robert Won**. *Hopf algebra actions on some AS-regular algebras of small 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 diffi- cult problem. In this preliminary report, we provide some new examples of Hopf actions of the algebras $\mathcal{A}_{4m}$ and $\mathcal{B}_{4m}$ of Masuoka, and the algebras H_{2n^2} of Pansera on some AS-regular algebras such that the ring of invariants is also AS-regular. (Received February 06, 2018)

1137-16-328 **Peter D. Goetz*** (peter.goetz@humboldt.edu). *The Koszul property for graded twisted tensor products.* Preliminary report.

An algebra C is called a twisted tensor product of algebras A and B if there are injections $A \to C$ and $B \to C$ such that the induced canonical map $A \otimes B$ to C is a vector space isomorphism. In joint work with A. Conner, we found necessary and sufficient conditions for when C is a quadratic algebra, given that A and B are quadratic. In that work we also constructed Koszul algebras A and B and a twisted tensor product C that is not Koszul. However, for these examples, C was not quadratic. Recently, A. Conner found examples in which A and B are Koszul, and C is quadratic, but not Koszul. In this talk I will introduce these examples, and discuss our attempts to understand them. Intriguingly, there may be some relationship to the characterization of Koszul algebras in terms of distributive lattices of vector spaces. (Received February 06, 2018)

1137-16-348 **Jesse S. F. Levitt***, University of Southern California, Los Angeles, CA 90005, and **Iris Buschelman**. *Co-nilpotent Connected Hopf Algebra Actions.* Preliminary report.

We present progress towards calculating Hopf algebra actions over several classes of quantum groups when the Hopf algebra is co-nilpotent and connected. This is part of a larger effort to develop software that will calculate and classify Hopf actions in low dimensional cases. We will demonstrate the software with several worked examples. (Received February 06, 2018)

17 ► Nonassociative rings and algebras

1137-17-7 **Garrett Johnson*** (gjohns62@nccu.edu). *Subprime solutions of the classical Yang-Baxter equation.*

We introduce a new family of r-matrices for the Lie algebra $\mathfrak{sl}_n$ that lies in the Zariski boundary of the Belavin-Drinfeld space $\mathcal{M}$ of quasi-triangular solutions to the classical Yang-Baxter equation. In this setting $\mathcal{M}$ is a finite disjoint union of components; exactly $\phi(n)$ of these components are SL_n-orbits of single points. These points are the generalized Cremmer-Gervais r-matrices $r_{i,n}$ which are naturally indexed by pairs of positive coprime integers, i and n, with $i < n$. A conjecture of Gerstenhaber and Giaquinto states that the boundaries of the Cremmer-Gervais components contain r-matrices having maximal parabolic subalgebras $\mathfrak{p}_{i,n} \subseteq \mathfrak{sl}_n$ as carriers. We prove this conjecture in the cases when $n \equiv \pm 1 \pmod{i}$. The subprime linear functionals $f \in \mathfrak{p}^*_{i,n}$ and the corresponding principal elements $H \in \mathfrak{p}_{i,n}$ play important roles in our proof. Since the subprime functionals are Frobenius in the cases when $n \equiv \pm 1 \pmod{i}$, this partly explains our need to require these conditions on i and n. We conclude with a proof of the GG boundary conjecture in an unrelated case, namely when $(i, n) = (5, 12)$. (Received November 10, 2017)

1137-17-188 **Zachary Cline*** (zcline@temple.edu). *Extending actions to the Drinfel'd double of various Hopf algebras "close" to Taft algebras.* Preliminary report.

Susan Montgomery and Hans-Jürgen Schneider classified all non-trivial n-dimensional module algebras A over the Taft algebras $T_n(q)$ of dimension n^2, $n > 2$. They further showed that each such module structure extends uniquely to make A a module algebra over the Drinfel'd double of $T_n(q)$. We examine if a similar phenomenon occurs for Hopf algebras "close" to the Taft algebras in various directions, and their module algebras. (Received February 03, 2018)

18 ► Category theory; homological algebra

1137-18-79 **Jonathan Beardsley** and **Liang Ze Wong*** (wonglz@uw.edu). *The enriched Grothendieck construction.* Preliminary report.

The Grothendieck construction and its inverse show that the category of fibrations over a base category $\mathcal{B}$ is equivalent to the category of pseudofunctors $\mathcal{B}^{op} \to \mathbf{Cat}$, also known as graded or indexed categories. In this talk, we develop the theory of fibrations for categories enriched over a semi-cartesian monoidal category $\mathcal{V}$, along with enriched versions of the Grothendieck construction and its inverse. We then mention some modifications required when enriching over $\mathbf{Vect}_k$, which is not semi-cartesian. (Received January 25, 2018)

1137-18-141 **Jonathan Beardsley*** (jbeards1@uw.edu) and **Marcy Robertson** (marcy.robertson@unimelb.edu.au). *Operads of Singular and Virtual Braids.*

There is an operad in the category of groupoids whose objects in arity n are orderings of the set $\{1, \ldots, n\}$, and whose morphisms are braids with strands labeled by that set. The algebras over this operad are braided monoidal categories, and its geometric realization is the little 2-disks operad of Boardman and Vogt. We describe similar operads in the category of categories whose morphisms are either singular braids (braids whose strands may intersect) or the virtual braids of L.H. Kauffman. We describe the algebras over these operads and give some specific examples. We also discuss our hopes for relating this structure to the Grothendieck-Teichmuller group and Vassiliev knot invariants. (Received January 31, 2018)

1137-18-142 **John M Zhang*** (jmzhang@math.ucla.edu). *Affine spaces over derivators.* Preliminary report.

Derivators can be thought of as an enhancement of triangulated categories with functorial cone construction. They also generalize concepts such as homotopy categories of model categories or derived categories of abelian categories. In this talk, we introduce a notion of $\mathbb{A}^1$ associated to a derivator and more generally, affine space $\mathbb{A}^n$ of a derivator. We will note some good properties about this $\mathbb{A}^1$ construction that have been persuasive in indicating that this plays a role akin to $\mathbb{A}^1$ in algebraic geometry. (Received January 31, 2018)

1137-18-167 **Alex Andrew Chandler*** (achandl@ncsu.edu), NC 27606. *A Categorification of the Vandermonde Determinant.* Preliminary report.

In the spirit of Bar Natan's construction of Khovanov homology, we give a categorification of (evaluations of) the Vandermonde determinant. As an input we take a knot diagram, and a family of special Frobenious algebras (one for each crossing) corresponding to the variables. We arrange these in a commutative diagram coming from the Bruhat order on the symmetric group, which plays the role of the cube of resolutions in Khovanov homology. From this commutative diagram we extract a homology theory. In case that the diagram is the alternating 2-strand braid diagram of the $(2, n)$ torus link, the Euler characteristic of this homology theory is the Vandermonde determinant. (Received February 02, 2018)

1137-18-168 **Victor William Summers*** (vwsummer@ncsu.edu), NC State Department of Mathematics, PO Box 8205, Raleigh, NC 27695, and **Radmila Sazdanovic** (rsazdanovic@math.ncsu.edu), NC State Department of Mathematics, PO Box 8205, Raleigh, 27695. *On Magnitude Homology.* Preliminary report.

Many mathematical constructions come equipped with a canonical measure of size; the cardinality of a set, Euler characteristic of a topological space, dimension of a vector space, to name just three. T. Leinster added magnitude of a metric space to this list of cardinality-like invariants. Graphs, when regarded as metric spaces, admit magnitude. R. Hepworth and S. Willerton went on to categorify the magnitude of graphs, realizing the invariant as the Euler characteristic of a bigraded homology theory; magnitude homology. In this talk we will introduce magnitude homology, describe structural results for some special types of graph, and discuss conjectures based on computational results. (Received February 02, 2018)

1137-18-247 **Kent Vashaw*** (kvasha1@lsu.edu). *Categorifications of Richardson Varieties via Serre Quotients by Prime Ideals.*

We describe a general theory of the prime, semiprime, completely prime, and primitive spectra of an abelian 2-category, providing a noncommutative version of Balmer's prime spectrum of a tensor triangulated category.

The prime ideals of an abelian 2-category can be described in terms of containment conditions of either thick or Serre ideals of the 2-category. The Serre prime spectrum of a 2-category is linked to the set of Serre primes of its Grothendieck ring, which is a $\mathbb{Z}_+$-ring. We construct a categorification of the quantized coordinate rings of open Richardson varieties for symmetric Kac-Moody groups, by constructing Serre completely prime ideals of monoidal categories of modules of the KLR algebras, and by taking Serre quotients with respect to them. This is a joint work with Milen Yakimov. (Received February 05, 2018)

19 ► K-theory

1137-19-342 **T Benedict Williams*** (tbjw@math.ubc.ca), 1984 Mathematics Road, Vancouver, BC V6T1Z2, Canada. *Suslin's Conjecture and the motivic homotopy of GLn.* Preliminary report.

The (Quillen) K theory of a field appears as the motivic homotopy groups of GL_n, whereas the Milnor K theory appears as a quotient of a stabilization map in the homology of GL_n. The two are therefore related by a Hurewicz map, first constructed by Suslin in 1983. He conjectured that the image of this Hurewicz map should be the subgroup generated by $(n-1)!$ in degree n. This conjecture was previously known to hold for $n \leq 3$. In this talk, I will give a view of this conjecture entirely within motivic homotopy theory, and exploiting stable calculations by Röndigs, Spitzweck and Østvær, along with some extraordinary isomorphisms, show the conjecture in the case $n = 5$. The cases $n = 4$ and $n \geq 6$ remain open.

This is joint work with Aravind Asok. (Received February 06, 2018)

20 ► Group theory and generalizations

1137-20-17 **Joel Zablow*** (dquandle@netscape.net), 290 9th Ave. Apt. 19H, New York, NY 10001. *Braid Relations and Deep Braiding.*

We look at braid relations $aba = bab$ in groups, focusing initially on such relations among cycles in symmetric groups S_n. We show k-cycles in S_n, which are braided, label vertices, faces, and edges of graphs and polyhedra, called platihedra. The platihedra exhibit many interactions between braiding and other algebraic properties, particularly conjugation, via their combinatorial structure. Braided n-cycles in S_n yield quandle structures on the graph components/skeletons of the platihedra. We give criteria under which braid relations in S_n can be lifted to "deep braids" (non-obvious braiding among products of generators) in braid groups, B_n, and also give examples of deep braiding in mapping class groups of surfaces, "lifting" braided elements in S_n. Time permitting, we discuss how deep braiding among cycles in S_n suggests deep braiding relations in B_n analogous to the Zamolodchikov tetrahedron equation and suggests existence of other analogous higher morphisms in higher categories. (Received December 29, 2017)

1137-20-124 **Rachel Davis*** (rachel.davis@wisc.edu). *Comparing the deck group and Veech group of an origami.* Preliminary report.

A natural question is which finite index subgroups of $\mathrm{SL}_2(\mathbb{Z})$ are Veech groups of origami. The distinction between congruence and noncongruence subgroups plays a role in many of the known results. A recent result of Chen and Deligne implies that if the deck group of an origami has derived length 2, then the Veech group of the origami is congruence. On the other hand, a conjecture of Chen implies that nonsolvable deck groups have an origami with a noncongruence Veech group. The expected motto is that for sufficiently nonabelian deck group, there is a noncongruence Veech group. (Received January 31, 2018)

1137-20-254 **Mariela Carvacho**, **Jennifer Paulhus*** (paulhus@math.grinnell.edu) and **Aaron Wootton**. *Potential Versus Actual Signature Space.*

Riemann's Existence Theorem tells us that necessary conditions for a group G containing elements of order $m_1, m_2, \dots m_r$ to act on a Riemann surface X with quotient genus h and signature $[h; m_1, \dots, m_r]$ is if (1) the Riemann Hurwitz formula is satisfied, and (2) if there are elements $g_1, \dots, g_r \in G$, with m_i being the order of the element g_i, so that $\{g_1, \dots, g_r\}$ generate the group and $g_1 g_2 \cdots g_r = 1_G$, the identity of G. We call numbers $h, m_1, \dots, m_r$ which satisfy (1) *potential signatures.*

Fix a group G and consider all potential signatures $[h; m_1, \dots, m_r]$. For which groups are all but a finite number of potential signatures in fact actual signatures? We present several new classification results towards answering this question. (Received February 05, 2018)

1137-20-298 **Larissa V. Sbitneva***, Av. Universidad 1001, Colonia Chamilpa, Morelos, 62210 Cuernavaca, Mexico. *On the development of smooth loops transformations theory.*
There are presented some attempts to construct the theory of transformations of smooth loops. Investigations related to Moufang loops transformations were initiated by E. Paal in the context of Moufang-Mal'tsev symmetry. Research on smooth Moufang-Mal'tsev symmetry involves the original approach of Sophus Lie to group transformations. The integrability conditions of the generalized Lie equations appear in the form of commutation relations. The study of Bol symmetries is motivated by the growing interest of physicists to Moufang transformations, due to presence of weak or hidden Moufang-Mal'tsev symmetries. For Bol loops, the representation can be treated as a Lie triple family of transformations in the sense of Yamaguti. This approach reveals that the notion of a left Bol loop and Bol-Bruck actions coincides with the (local) Nono family. We will focus on generalized Bol loops actions suggested by L. Sabinin in order to construct the infinitesimal theory. Another approach is based on the smooth right loops actions introduced by L. Sabinin. The differential equations of a strict action and the integrablity conditions give an analogue of the First y Second Lie Theorems. We emphasize the problem related to an analogue of the inverse Third Lie Theorem. (Received February 05, 2018)

1137-20-312 **Mariela Carvacho*** (`mariela.carvacho@usm.cl`), Avenida Espana 1680, 2390123 Valparaiso, Chile, and **Víctor González-Aguilera**. *Structure of* $\widetilde{\mathcal{M}_4}$. Preliminary report.
Given a group G acting on a compact Riemann surface X it induces an action on the space of holomorphic $1-$form of X. This action induces a representation group ρ called *analytic representation.*

It is known that the map to associate the pair $[X, G]$ to $[\rho]$ is injective for $g = 2$ and 3 but for genus 4 it is not injective Kimura.

The moduli space of genus 4, $\mathcal{M}_4$, has been studied in [1].

In this talk we show partial results about the structure of the moduli space of genus 4: 1-2 dimensional families, relation with the analytic representation and its boundary components using the results given in [2].

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(Received February 06, 2018)

1137-20-321 **S Joseph Lippert*** (`lippert19@up.edu`), 5000 N Willamette Blvd, Corrado Hall, Portland, OR 97203, and **Aaron Wootton**. *Bounding Skeletal Signature Spaces.* Preliminary report.
There are three infinite families of finite groups for which the space of signatures for group actions on compact Riemann surfaces coincides precisely with the space of skeletal signatures. For two of these families, we provide a detailed analysis of the space of skeletal signatures. A consequence of our work is explicit bounds on genus beyond which every possible skeletal signature is the signature of some action. (Received February 07, 2018)

28 ► *Measure and integration*

1137-28-61 **Zihui Zhao*** (`zhaozh@uw.edu`). *Elliptic measures and geometric properties of the domains.*
Elliptic measure is an analogue of the harmonic measure and it allows us to represent the solution to a Dirichlet problem by integrating the boundary function. The study of the relationship between the elliptic measure ω and the surface measure σ of the boundary, in particular under various geometric assumptions of the domain, goes back to 100 years ago. In this talk we focus on the converse question: Assume that $\sigma \ll \omega$, in a qualitative or quantitative sense, what conclusions can we draw about the geometric properties of the domain? (Received January 23, 2018)

1137-28-95 **A. Dali Nimer*** (`nimer@uchicago.edu`). *Uniform measures: a family of examples and characterizations.*
A measure in $\mathbb{R}^d$ is called n-uniform if the measure of a ball of radius r centered at a point x of its support is given by cr^n for some fixed constant $c > 0$. In this talk, I will present some results on their geometry including a description of their support and a family of new examples of uniform measures. (Received January 29, 2018)

1137-28-108 **Shiwen Zhang*** (zhangshiwen@math.msu.edu). *The exact Power Law for Buffon's needle landing near some Random Cantor Sets.*

In this talk, we study the Favard length of some random Cantor sets of Hausdorff dimension 1. We start with a unit disk in the plane and replace the unit disk by 4 disjoint subdisks (with equal distance to each other) of radius 1/4 inside and tangent to the unit disk. By repeating this operation in a self-similar manner and adding a random rotation in each step, we can generate a random Cantor set $\mathcal{D}(\omega)$. Let $\mathcal{D}_n$ be the n-th generation in the construction, which is comparable to the 4^{-n}-neighborhood of $\mathcal{D}$. We are interested in the decay rate of the Favard length of these sets $\mathcal{D}_n$ as $n \to \infty$, which is the likelihood (up to a constant) that "Buffon's needle" dropped randomly will fall into the 4^{-n}-neighborhood of $\mathcal{D}$. It is well known that the lower bound of the Favard length of $\mathcal{D}_n(\omega)$ is constant multiple of n^{-1}. We show that the upper bound of the Favard length of $\mathcal{D}_n(\omega)$ is Cn^{-1} for some $C > 0$ in the average sense. (Received January 30, 2018)

1137-28-185 **Laramie Paxton*** (realtimemath@gmail.com) and **Kevin R. Vixie** (vixie@speakeasy.net). *A C^1 Boundary Measure in Two Dimensions.*

The intersection of harmonic analysis and geometric measure theory (GMT) is an active area in mathematical research. Singular integrals are central to Fourier analysis, for example the Hilbert transform, while the generalized surfaces in GMT known as rectifiable sets behave measure-theoretically like C^1 submanifolds. In this talk, we present a singular integral that uses the distance function to compute the $(n-1)$-dimensional Hausdorff measure $\mathcal{H}^{n-1}$ of a compact C^1 hypersurface in $\mathbb{R}^n$ for the case of $n = 2$. We will also discuss the "barehanded" approach to the proof and briefly mention the case for arbitrary finite dimensions $n \in \mathbb{N}$. (Received February 03, 2018)

30 ► Functions of a complex variable

1137-30-49 **Dimitrios Ntalampekos*** (dimitrisnt@math.ucla.edu), UCLA Mathematics Department, Los Angeles, CA 90095-1555. *(Non)-Removability of the Sierpiński Gasket.*

Removability of sets for quasiconformal maps and Sobolev functions has applications in Complex Dynamics, in Conformal Welding, and in other problems that require"gluing" of functions to obtain a new function of the same class. We, therefore, seek geometric conditions on sets which guarantee their removability. In this talk, I will discuss some very recent results on the (non)-removability of the Sierpiński gasket.

A first result is that the Sierpiński gasket is removable for continuous functions of the class $W^{1,p}$ for $p > 2$. The method used applies to more general fractals that resemble the Sierpiński gasket, such as Apollonian gaskets and generalized Sierpiński gasket Julia sets.

Then, I will sketch a proof that the Sierpiński gasket is non-removable for quasiconformal maps and thus for $W^{1,p}$ functions, for $1 \le p \le 2$. The argument involves the construction of a non-Euclidean sphere, and then the use of the Bonk-Kleiner theorem to embed it quasisymmetrically to the plane. (Received January 20, 2018)

1137-30-63 **Antonio F. Costa** and **Milagros Izquierdo*** (milagros.izquierdo@liu.se), Department of Mathematics, Linköping University, 58183 Linköping, Sweden.
One-dimensional families of Riemann surfaces of genus g with 4g + 4 automorphisms.

In their classical, independent articles Accola and Maclachlan showed that the maximal number of automorphisms of a Riemann surface in all genera $g \geq 2$ is 8g+8. For genera $g \equiv 0, 1, 2 mod 4$ there is a unique surface with this many automorphisms: the Accola-Maclachlan surface. For genera $g \equiv 3 mod 4$ there is one more surface known as Kulkarni surface.

Here we show that the maximal number ag+b of automorphisms of equisymmetric and complex-uniparametric families of Riemann surfaces appearing in all genera is 4g + 4. For each integer $g \geq 2$ we find an equisymmetric complex-uniparametric family $\mathcal{A}_g$ of Riemann surfaces of genus g having automorphism group of order 4g + 4. For $g \equiv 3 mod 4$ we present another uniparametric family $\mathcal{K}_g$ with automorphism group of order 4g + 4. The family $\mathcal{A}_g$ contains the Accola–Maclachlan surface and the family $\mathcal{K}_g$ contains the Kulkarni surface. (Received January 24, 2018)

1137-30-182 **Oleg Ivrii***, 1200 E California Blvd, Pasadena, CA 91125. *Describing Blaschke products by their critical points.*

In this talk, I will discuss a question which originates in complex analysis but is really a problem in non-linear elliptic PDE. It is well known that up to post-composition with a Mobius transformation, a finite Blaschke product may be uniquely described by the set of its critical points. I will discuss an infinite-degree version of this problem posed by Dyakonov. Let J be the set of inner functions whose derivative lies in the Nevanlinna class. I will explain that an inner function in J is uniquely determined by the inner part of its derivative (its critical structure), and describe all possible critical structures of inner functions in J. I will also give a concrete description of the natural topology on J which respects the convergence of critical structures. Similar results hold for "nearly-maximal" solutions of the Gauss curvature equation and subspaces of kappa-Beurling-type of a weighted Bergman space. (Received February 02, 2018)

1137-30-192 **Sergei Kalmykov**, **Leonid V. Kovalev*** (lvkovale@syr.edu) and **Tapio Rajala**. *Metrically removable sets.*

A compact subset K of Euclidean space $\mathbb{R}^n$ is called metrically removable if any two points a, b of its complement can be joined by a curve that is disjoint from K and has length arbitrarily close to $|a-b|$. Every set of zero $(n-1)$-dimensional measure is metrically removable, but not conversely. Metrically removable sets can even have positive n-dimensional measure. I will describe some properties of metrically removable sets and outline a proof of the following fact: totally disconnected sets of finite $(n-1)$-dimensional measure are metrically removable. This answers a question raised by Hakobyan and Herron in 2008. (Received February 03, 2018)

1137-30-203 **M. Cheddadi** and **Paul M. Gauthier*** (gauthier@dms.umontreal.ca). *Mapping a given countable dense set to another given countable dense set.* Preliminary report.

Barth and Schneider have shown that, given any two countable dense subsets of the complex plane, there exists an entire function mapping one set onto the other. We discuss related results. (Received February 04, 2018)

1137-30-248 **Eric D Schippers*** (eric.schippers@umanitoba.ca), Department of Mathematics, 420 Machray Hall, 186 Dysart Rd, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada, and **Wolfgang Staubach** (wolfgang.staubach@math.uu.se), Department of Mathematics, Uppsala University, Box 480, 751 06, Uppsala, Sweden. *Plemelj-Sokhotski Jump on Quasicircles, Faber and Grunsky Operators.*

We outline extensions of the Plemelj-Sokhotski jump formula to quasicircles, and recent new characterizations of quasicircles in terms of Faber operators and approximation by Faber series. We then use this to shed light on the meaning of the Grunsky operator. (Received February 05, 2018)

1137-30-341 **Saroj Aryal*** (saroj.aryal@msubillings.edu), 1500 University Drive, Billings, MT 59101. *Stieltjes Continued Fractions Associated with Sparse Moment Problem.* Preliminary report.

One of the important variations of Stieltjes Moment Problem is the case of sparsity in a moment sequence. In this work, Stieltjes Continued Fractions are used to study properties of Sparse Moment Problem in $(0, \infty)$. Connections are made to determinacy of sparse moment problems. (Received February 06, 2018)

1137-30-347 **Catherine Beneteau**, **Myrto Manolaki*** (mmanolaki@usf.edu) and **Daniel Seco**. *Optimal polynomial approximants: limiting behaviour on the unit circle.* Preliminary report.

The notion of optimal polynomial approximants to reciprocals of functions in Dirichlet-type spaces $\mathcal{D}_\alpha$ was introduced to investigate the phenomenon of cyclicity. In particular, if p_n are the optimal polynomial approximants of order n to $1/f$ and the Dirichlet norm $\|p_n f - 1\|_\alpha$ tends to 0 as $n \to \infty$, we can conclude that f is cyclic in $\mathcal{D}_\alpha$. In this talk, focusing on the specific case of Hardy space, we will discuss some results and questions about the limiting behaviour of (p_n) on subsets of the unit circle. (Received February 06, 2018)

1137-30-350 **Kirill Lazebnik*** (lazebnik@caltech.edu). *Univalent Wandering Domains in the Eremenko-Lyubich class.*

We recall some basic notions in complex dynamics and discuss problems of existence and non-existence of wandering domains for various classes of transcendental entire functions. We present a result on the existence of univalent wandering domains in the space of transcendental functions with bounded singular set (known as the Eremenko-Lyubich class), based on a technique of Bishop. This is joint work with Núria Fagella and Xavier Jarque. (Received February 06, 2018)

31 ► Potential theory

1137-31-24 **Murat Akman*** (murat.akman@uconn.edu), 341 Mansfield Road, University of Connecticut, Storrs, CT 06269. *A Minkowski problem for nonlinear capacity.*

The classical Minkowski problem consists in finding a convex polyhedron from data consisting of normals to their faces and their surface areas. In the smooth case, the corresponding problem for convex bodies is to find the convex body given the Gauss curvature of its boundary, as a function of the unit normal. The proof consists of three parts: existence, uniqueness and regularity.

In this talk, we study a Minkowski problem for certain measure associated with a compact convex set E with nonempty interior and its $\mathcal{A}-$harmonic capacitary function in the complement of E. Here $\mathcal{A}-$harmonic PDE is a non-linear elliptic PDE whose structure is modeled on the p-Laplace equation. If μ_E denotes this measure, then the Minkowski problem we consider in this setting is that; for a given finite Borel measure μ on $\mathbb{S}^{n-1}$, find necessary and sufficient conditions for which there exists E as above with $\mu_E = \mu$. We will discuss the existence, uniqueness, and regularity of this problem in this setting. (Received January 09, 2018)

35 ► Partial differential equations

1137-35-23 **Matthew Badger*** (`matthew.badger@uconn.edu`). *Two-phase free boundary problem for harmonic measure with Hölder data.*

I will report on joint work with Max Engelstein and Tatiana Toro. We continue the study of non-variational two-phase free boundary problems for harmonic measure. Previously, in separate and joint works, we showed that under appropriate a priori topological conditions on a pair of complementary domains $\Omega^{\pm} \subset \mathbb{R}^n$, if the Radon-Nikodym derivative of harmonic measure of one domain with respect to the harmonic measure of the other domain has α-Hölder continuous logarithm, then the common boundary of the domains splits into a regular set and a singular set: the regular set is an $(n-1)$-dimensional $C^{1,\alpha}$ submanifold and the singular set is closed and has Hausdorff and Minkowski dimension at most $n-3$. In new work, we use a Weiss-type monotonicity formula and an epiperimetric inequality for homogeneous harmonic functions to obtain refined information about the singular set. In particular, we establish uniqueness of blowups and $C^{1,\beta}$ rectifiability of the singular set. (Received January 09, 2018)

1137-35-28 **Hong-Ming Yin*** (`hyin@wsu.edu`), Department of Mathematics and Statistics, Washington State University, Pullman, WA 99164. *On a Reaction-Diffusion System Modeling the Tumor Treatment.*

In this talk I will study a reaction-diffusion system which describes the interaction of a medical drug with normal, immune and tumor cells. We will design an optimal drug method which will be best to eliminate tumor cells. The major challenge for the optimal control problem is that the optimal solution must satisfy the certain constraints for normal cells. Existence and stability are established. (Received January 14, 2018)

1137-35-46 **Micah W. Warren***, Dept of Mathematics, 1222 University of Oregon, Eugene, OR. *Continuum Nash Bargaining Solutions.*

Nash‘s classical bargaining solution suggests that n players in a non-cooperative bargaining situation should find a solution that maximizes the product of each player's utility functions. We consider a special case: Suppose that the players are chosen from a continuum distribution μ and suppose they are to divide up a resource ν that is also on a continuum. The utility to each player is determined by the exponential of a distance type function. The maximization problem becomes an optimal transport type problem, where the target density is the minimizer to the functional which is the sum of an entropy term and a Wasserstein distance term, similar to the minimization problem solved in the Jordan-Kinderlehrer-Otto scheme. Thanks to optimal transport theory, the solution may be described by a potential that solves a fourth order nonlinear elliptic PDE, similar to Abreu's equation. Using the PDE, we prove solutions are smooth when the measures have smooth positive densities. (Received January 19, 2018)

1137-35-53 **Roberto Triggiani*** (`rtrggani@memphis.edu`), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152. *Analyticity, Spectral Analysis, and Uniform Stability of a Heat-viscoelastic Plate Interaction Models.* Preliminary report.

Analyticity, Spectral Analysis, and Uniform Stability of a Heat-viscoelastic Plate Interaction Model We consider a heat equation defined on an interior bounded domain coupled with a visco-elastic plate defined on a surrounding external domain. Coupling occurs at the interface between the two domains, through high order coupling conditions between the two dynamics. The complicated boundary conditions of the plate are physical. We establish that the coupled system generates a strongly continuous contraction semi-group on the natural space of finite energy, which moreover is analytic and uniformly stable. A sharp spectral analysis is also provided. In particular, the the resolvent operator of generator fails to be compact. (Received January 21, 2018)

1137-35-59 **Selim Sukhtaiev*** (sukhtaiev@rice.edu), Rice University, Department of Mathematics, Houston, TX 77005. *A bound for the eigenvalue counting function for higher-order Krein Laplacians on arbitrary open sets.*

In this talk I will discuss a bound for the eigenvalue counting function (for strictly positive eigenvalues) for higher-order Krein Laplacians. The latter are particular self-adjoint extensions of minimally defined, positive integer powers of the Laplacian on arbitrary open, bounded sets. The bound extends to open, finite volume domains of finite width, subject to a compact Sobolev embedding property, and shows the correct high-energy power law behavior familiar from Weyl asymptotics. This talk is based on joint work with M. Ashbaugh, F. Gesztesy, A. Laptev, and M. Mitrea. (Received January 22, 2018)

1137-35-62 **Ariel Barton*** (aeb019@uark.edu), **Steve Hofmann** and **Svitlana Mayboroda**. *The Neumann problem for symmetric higher order elliptic differential equations.*

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

The theory of higher order elliptic equations of the form $\nabla^m \cdot A\nabla^m u = 0$ is far less well understood. In this talk we will generalize well posedness of the L^2 Neumann problem in the half-space to the case of higher-order equations with real symmetric vertically constant coefficients. (Received January 23, 2018)

1137-35-64 **Koushik Ramachandran*** (koushik.math@gmail.com). *Convexity of level lines of Martin functions and some applications.*

Let Ω be an unbounded domain in $\mathbb{R} \times \mathbb{R}^d$. A positive harmonic function u on Ω that vanishes on the boundary of Ω is called a Martin function. In this talk, we will show that, when Ω is convex, the superlevel sets of a Martin function are also convex. As a consequence we obtain that if in addition Ω has certain symmetry with respect to the t-axis, and $\partial\Omega$ is sufficiently flat, then the maximum of any Martin function along a slice $\Omega \cap (\{t\} \times \mathbb{R}^d)$ is attained at $(t, 0)$. Based on joint work with J. Lebl and A.-K. Gallagher. (Received January 23, 2018)

1137-35-81 **Choah Shin*** (shinc@oregonstate.edu) and **Malgorzata Peszynska**. *Regularization of nonlinear conservation law with space-dependent flux function, and numerical approximation.*

We study a conservation law with space-dependent flux functional. The first challenge is that the conservation law contains a multivalued graph, and we use a change of variable to rewrite the conservation law. Another challenge is that the obtained flux function is not smooth and depends on two variables. We use regularization to obtain a smooth concave flux function and discuss the seemingly unphysical, and at first glance, unexpected "blow-up" behavior of this problem. We also discuss the convergence of the numerical solution to this problem using the Godunov's scheme with local phase behavior solver. This problem is motivated by the study of greenhouse gas methane transport and hydrate crystal formation in sediments under the ocean. (Received January 25, 2018)

1137-35-87 **Hui Yu*** (huiyu@math.columbia.edu). *On the multiple membranes problem: Regularity of solutions and classification of planar blow-up profiles.*

We study the equilibrium shape of multiple membranes under forcing. We show the optimal regularity of the solutions and classify possible blow-up profiles in the plane.

This is joint work with Ovidiu Savin (Columbia University). (Received January 27, 2018)

1137-35-117 **Olga Alekseevna Rumyantseva*** (olga.rumyantseva@wsu.edu), 14204 NE Salmon Creek Ave, Vancouver, WA 98686, and **Nick Strigul**. *Structural stability of the Perfect Plasticity Approximation (PPA) model.*

The Perfect Plasticity Approximation (PPA) is system of a macroscopic system of equations that predicts the large-scale dynamics of forest stands. The model is computationally efficient and is employed to scaling of vegetation dynamics and carbon and nutrient cycles using parameter values and functional forms of individual tree species. The model includes the system of McKendrick–von Foerster partial differential equations (one for every tree species) and an integral equation (the PPA equation). The McKendrick–von Foerster equation is a conservation law-based first-order hyperbolic partial-differential equation similar to the advection or transport equations that can be solved using the method of characteristics; however, the non-linear PPA integral equation presents a substantial challenge. In this presentation we will discuss structural stability of the PPA model, including the observed tendency of trees with particular shapes to produce unstable canopies. We will introduce

analytic conditions of canopy stability and analyze oscillations that PPA predicts for an arbitrary crown shapes. (Received January 30, 2018)

1137-35-118 **Ralph Showalter*** (show@math.oregonstate.edu), Department of Mathematics - Kidder 368, Oregon State University, Corvallis, OR 97331-4605, and **Alireza Hosseinkhan**. *Displacement Constraints in Biot Systems.* Preliminary report.

A fully-saturated poroelastic medium is deformed by internal pressure-driven fluid flow coupled on its boundary to the stress of the external fluid and the constraints of a bounding surface. The formulation leads to a well-posed unilateral initial-boundary-value problem for the Biot - fluid system and the unknown contact surface of the medium. (Received January 30, 2018)

1137-35-143 **Yekaterina Epshteyn*** (epshteyn@math.utah.edu), Department of Mathematics, The University of Utah, Salt Lake City, UT 84124. *Polycrystalline Materials and Evolution of Grain Boundaries Network.*

Cellular networks are ubiquitous in nature. Most technologically useful materials arise as polycrystalline microstructures, composed of a myriad of small crystallites or grains, separated by interfaces, or grain boundaries. The energetics and connectivity of the grain boundaries network plays a crucial role in determining the properties of a material across a wide range of scales. During the coarsening, or growth, process, an initially random grain boundary arrangement reaches a steady state that is strongly correlated to the interfacial energy density. In this talk, we will discuss recent progress on mathematical modeling and analysis of the grain boundaries network's evolution in polycrystalline materials. This is joint work with P. Bardsley, K. Barmak, E. Eggeling, M. Emelianenko, D. Kinderlehrer, C. Liu, M. Mizuno and S. Ta'asan. (Received January 31, 2018)

1137-35-144 **Benjamin Eichinger**, **Tom VandenBoom*** (tv4@rice.edu) and **Peter Yuditskii**. *The KdV hierarchy via Abelian coverings and operator identities.*

We establish precise spectral criteria for potential functions V of reflectionless Schrödinger operators $L_V = -\partial_x^2 + V$ to admit solutions to the Korteweg de-Vries (KdV) hierarchy with V as an initial value. More generally, our methods extend the classical study of algebro-geometric solutions for the KdV hierarchy to noncompact Riemann surfaces by defining generalized Abelian integrals and analogues of the Baker-Akhiezer function on infinitely connected domains with a uniformly thick boundary satisfying a fractional moment condition. (Received January 31, 2018)

1137-35-159 **Sam G. Krupa*** (skrupa@math.utexas.edu) and **Alexis F. Vasseur**. *Proving Uniqueness of Solutions for Burgers Equation Entropic for a Single Entropy, with Eye Towards Systems Case.*

For hyperbolic systems of conservation laws, uniqueness of solutions is still largely open. We aim to expand the theory of uniqueness for systems of conservation laws. One difficulty is that many systems have only one entropy. This contrasts with scalar conservation laws, where many entropies exist. It took until 1994 to show that one entropy is enough to ensure uniqueness of solutions for the scalar conservation laws (Panov). This single entropy result was proven again by De Lellis, Otto and Westdickenberg in 2004. These two proofs both rely on the special connection between Hamilton–Jacobi equations and scalar conservation laws in one space dimension. However, this special connection does not extend to systems. In our new work, we prove the single entropy result for scalar conservation laws without using Hamilton–Jacobi. Our proof lays out new techniques that are promising for showing uniqueness of solutions in the systems case. This is joint work with A. Vasseur. (Received February 01, 2018)

1137-35-162 **Ivan A Blank***, blanki@math.ksu.edu, and **Niles Armstrong**, **Ashok Aryal**, **Brian Benson**, **Zheng Hao** and **Jeremy LeCrone**. *Mean Value Theorems and the Geometry of Mean Value Sets for Divergence Form Elliptic PDEs.*

One basic property of harmonic functions is the fact that at any point the value of the function is exactly equal to the average value of the function over a ball (or a sphere) centered at that point. This theorem can be used to establish other basic properties of harmonic functions including the maximum principle, the Harnack inequality, and some important a priori estimates. Standard proofs of the mean value theorem rely on smoothness and symmetry properties of the Laplacian and therefore do not generalize nicely to non-Euclidean spaces or more general elliptic operators. However, in his Fermi lectures on the obstacle problem in 1998, Luis Caffarelli indicated how one could use solutions of specific obstacle problems to construct an elegant proof of the mean value theorem which does not depend on either the smoothness or symmetry properties of the Laplacian. In this talk, I will explain that proof and show how my collaborators and I have used it to generalize the mean value theorem to other settings. (Received February 01, 2018)

1137-35-178 **Jessica Lin*** (jessica.lin@mcgill.ca) and **Andrej Zlatos**. *Stochastic Homogenization for Reaction-Diffusion Equations.*

I will present several results concerning stochastic homogenization for reaction-diffusion equations. We consider heterogeneous reaction-diffusion equations with random nonlinear reaction terms. Under certain hypotheses on the environment, we show that the typical large-time, large-scale behavior of solutions is governed by a deterministic front propagation. The front propagation may be identified by a first-order nonlinear free boundary problem. This talk is based on joint work with Andrej Zlatos. (Received February 02, 2018)

1137-35-233 **Peter Hintz*** (phintz@berkeley.edu), 793 Evans Hall, Berkeley, CA 94720, and **András Vasy**. *Stability of Minkowski space and asymptotics of the metric.*

I will explain a new proof of the non-linear stability of the Minkowski spacetime as a solution of the Einstein vacuum equation. The proof relies on an iteration scheme at each step of which one solves a linear wave-type equation globally. The analysis takes place on a suitable compactification of $\mathbb{R}^4$ to a manifold with corners whose boundary hypersurfaces correspond to spacelike, null, and timelike infinity; I will describe how the asymptotic behavior of the metric can be deduced from the structure of simple model operators at these boundaries. (Received February 05, 2018)

1137-35-239 **Cornelia Mihaila***, cmihaila@math.utexas.edu. *Axial symmetry for fractional capillarity droplets.*

A classical result of Wente, motivated by the study of sessile capillarity droplets, shows the axial symmetry of every hypersurface which meets a hyperplane at a constant angle and has mean curvature depending only on the distance from that hyperplane. We will prove an analogous result for the fractional mean curvature operator. (Received February 05, 2018)

1137-35-246 **Dwight Holland*** (holladwi@oregonstate.edu), Corvallis, OR 97330, and **Ralph Showalter**. *Poro-Visco-Elastic Compaction.*

The porosity of a visco-elastic medium satisfies a nonlinear pseudo-parabolic partial differential equation of the form

$$u' + A(u)\left(\alpha(u) + \eta u'\right) = G(t,u)$$

in which u' denotes the time derivative, $A(v) = -\nabla\cdot\kappa(v)\nabla$ is a linear second order elliptic operator in divergence form with coefficient depending on a function $v(x)$, $G(t,u)$ is a linear first order operator in u, and $\eta > 0$. The third order nonlinear term $A(u)u'$ distinguishes this equation from the classical porous medium equation. The solvability of an elliptic boundary-value problem for $(I + \eta A(v))\,u = f$ for $\eta > 0$ and the continuous dependence of the solution u on the function v is used to establish existence of the solution of the initial-boundary-value problem for the pseudo-parabolic equation. We give conditions under which the solutions are physically valid, and discuss numerical approximations for this problem. (Received February 05, 2018)

1137-35-262 **Oliver Ruff*** (oruff@kent.edu) and **Gro Hovhannisyan**. *Young diagrams and solitons on a time scale.*

Hirota's "direct method" is a powerful technique for constructing multisoliton solutions to integrable nonlinear evolution equations. The resulting N-soliton solutions can be expressed as certain Wronskian (or Wronskian-type) determinants, and calculations involving them often have a nice interpretation in terms of Young diagrams. We consider Hirota's approach in the context of Hilger's time-scale calculus, where analogues of many classical equations are known, and examine the resulting combinatorics in the important case of the Kadomtsev-Petviashvili equation. (Received February 05, 2018)

1137-35-265 **Matti Lassas**, **Gunther Uhlmann** and **Yiran Wang*** (wangy257@math.washington.edu). *Determination of vacuum space-times from the Einstein-Maxwell equations.*

We study inverse problems for the Einstein-Maxwell equations in general relativity. We prove that it is possible to generate gravitational waves from the nonlinear interactions of electromagnetic waves. By sending electromagnetic waves from a neighborhood of a freely falling observer and taking measurements of the gravitational perturbations in the same neighborhood, one can determine the vacuum space-time structure up to diffeomorphisms in the largest region where these waves can travel to from the observer and return. (Received February 05, 2018)

1137-35-269 **Matthew Novack*** (mnovack@math.utexas.edu) and **Alexis Vasseur**. *Global Classical Solutions to the 3D Quasi-Geostrophic System.*

We show the existence of global in time classical solutions to the 3D quasi-geostrophic system with Ekman pumping for any smooth initial value (possibly large). This system couples an inviscid transport equation in $\mathbb{R}^3_+$ with an equation on the boundary satisfied by the trace. The proof combines the De Giorgi regularization effect on the boundary $z = 0$ –similar to the so called surface quasi-geostrophic equation– with Beale-Kato-Majda techniques to propagate regularity for $z > 0$. A bootstrapping argument combining potential theory and Littlewood-Paley techniques is used to strengthen the regularization effect on the trace up to the Besov space $\mathring{B}^1_{\infty,\infty}$. (Received February 05, 2018)

1137-35-270 **Dennis Kriventsov*** (dennisk@cims.nyu.edu), 251 Mercer St, New York, NY 10003. *Regularity for Shape Optimizers: The Degenerate Case.*

We consider minimizers of
$$F(\lambda_1(\Omega), \ldots, \lambda_N(\Omega)) + |\Omega|,$$
where F is a function nondecreasing in each parameter, and $\lambda_k(\Omega)$ is the k-th Dirichlet eigenvalue of Ω. This includes, in particular, functions F which depend on just some of the first N eigenvalues, such as the often studied $F = \lambda_N$. The existence of a minimizer, which is also a bounded set of finite perimeter, was shown recently. Here we show that the reduced boundary of the minimizers Ω is made up of smooth graphs, and examine the difficulties in classifying the singular points. Our approach is based on an approximation (”vanishing viscosity”) argument, which–counterintuitively–allows us to recover an Euler-Lagrange equation for the minimizers which is not otherwise available. (Received February 05, 2018)

1137-35-278 **Adam Layne*** (anlayne@uoregon.edu), Mathematics, 1222 University Of Oregon, Eugene,, OR 97403-1222, and **Beverly Berger** and **James Isenberg**. *Analytic results and numerical evidence for global behavior of the Einstein Field Equations in the T^2-symmetric setting.* Preliminary report.

Recent progress in understanding spatially closed, vacuum spacetimes with Killing fields has been characterized by instabilities. This is in contrast to the open case where, for example, Minkowski is known to be stable. With Profs. Berger and Isenberg, we prove several results related to the stability of such solutions, expanding on previous work of LeFloch and Smulevici. We also present recent numerical work exploring the space of T^2-symmetric spacetimes and the occurrence of these instabilities, as well as potential attractors far from most previously identified classes. (Received February 05, 2018)

1137-35-284 **S. Ries McCurdy***, Padelford Hall, Box 354350, Seattle, WA 98195. *A Tale of Two Approaches.* Preliminary report.

This talk will investigate the application of two different techniques, one developed by Naber and Valtorta and one developed by Edelen and Engelstein, to the investigation of the fine structure of solutions to a two-phase free boundary problem. Both approaches rely upon the exploitation of monotonicity formulae to build inductively-refined covers. This talk will focus on their relative strengths and differences.

The context of application will build upon work by Toro, Badger, and Engelstein, on two-sided free boundary problems with geometric conditions on the free boundary (two-sided NTA domains) and mild regularity on the Radon-Nikodym derivative of the harmonic measures from each side. Surprisingly, this context allows us to prove Minkowski dimension bounds on the strata of the critical set of such solutions across the free boundary. (Received February 05, 2018)

1137-35-309 **Thomas Backing**, **Donatella Danielli** and **Rohit Jain*** (rohit.jain@mcgill.ca), Mathematics and Statistics, McGill University, Burnside Hall, 805 Sherbrooke Street, Montreal, Quebec H3A 0B95, Canada. *Regularity results for a Two-Penalty Boundary Obstacle Problem.*

In this talk we present results concerning a two-penalty boundary obstacle problem of interest in thermics, fluid dynamics, and electricity. Specifically we prove existence, uniqueness, and optimal regularity of the solution. Moreover we present structural properties of the free boundary. (Received February 06, 2018)

1137-35-316 **Emanuel 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 $\Omega = (\{u \neq 0\} \cup \{\nabla u \neq 0\}) \cap \{x_n > 0\} \subset \mathbb{R}^n_+$ and $B_1' = \{x_n = 0\} \cap \overline{B_1^+}$, 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. Tangential touch for the Laplacian is well-understood and the more general case in two dimensions is joint work with Minne. This talk focuses on the problem in higher dimensions. (Received February 06, 2018)

1137-35-324 **Hector A. Chang-Lara*** (hector.chang@cimat.mx), De Jalisco 8A, Valenciana, 36240 Guanajuato, Guanajuato, Mexico, and **Nestor Guillen**. *From the free boundary condition for Hele-Shaw to the fractional parabolic equation.* Preliminary report.

We propose a method to determine the smoothness for the free boundary of sufficiently flat solutions of one phase Hele-Shaw problems. The novelty is the observation that under a flatness assumption the free boundary–represented by the hodograph transform of the solution–solves a nonlinear integro-differential equation. This nonlinear equation can be linearized to a (nonlocal) parabolic equation with bounded measurable coefficients, for which regularity estimates are available. (Received February 06, 2018)

1137-35-345 **Gregory Drugan***, 6300 SW Nicol Road, Portland, OR 97223. *An embedded $S^1 \times S^{n-1}$ self-shrinker in $\mathbb{R}^{n+1}$ via variational methods.*

In this talk, we give an alternative proof for the existence of an embedded $S^1 \times S^{n-1}$ self-shrinker in $\mathbb{R}^{n+1}$. The proof uses a modified curve shortening flow to find a closed geodesic for the conformal metric $r^{2(n-1)}e^{-(x^2+r^2)/2}(dx^2 + dr^2)$ on the half-plane $\{(x, r) \in \mathbb{R}^2 \mid r > 0\}$. A consequence of the proof is an upper bound for the weighted energy of the self-shrinker. This is a joint work with Xuan Hien Nguyen. (Received February 06, 2018)

37 ► Dynamical systems and ergodic theory

1137-37-109 **Svetlana Jitomirskaya** and **Wencai Liu*** (liuwencai1226@gmail.com), Rowland Hall 410P, IRVINE, CA 92697-3875, and **Darren Ong**. *Sharp spectral transition for eigenvalues embedded into essential spectrum of Laplacian on Riemannian manifold or Schrödinger operator.*

The first part of the talk (joint work with S.Jitomirskaya) is to study the eigenvalues of the Laplacian embedded in the essential spectrum on manifolds. Kumura proved that there are no eigenvalues embedded in the essential spectrum $\sigma_{ess}(-\Delta) = [\frac{1}{4}(n-1)^2, \infty)$ of Laplacians if the radial curvature $K_{\text{rad}} = -1 + o(r^{-1})$. Given any finite (countable) positive energies $\{\lambda_n\} \in [\frac{K_0}{4}(n-1)^2, \infty)$, we construct Riemannian manifolds with $K_{\text{rad}} + K_0 = O(r^{-1})$ with $K_0 \geq 0$ ($K_{\text{rad}} + K_0 = \frac{C(r)}{r}$, where $C(r) \to \infty$ arbitrarily slowly) such that the eigenvalues $\{\lambda_n\}$ are embedded in the essential spectrum.

The second part of the talk (joint work with D.Ong) is to study equation $Hu = -u'' + (V(x) + V_0(x))u = Eu$, where $V_0(x)$ is 1-periodic and $V(x)$ is a perturbation. Given any finite (countable) set of non-resonant points $\{E_j\}$ in any spectral band of H_0, we construct smooth functions $V(x) = \frac{O(1)}{1+|x|}$ ($|V(x)| \leq \frac{h(x)}{1+|x|}$, where $h(x) \to \infty$ arbitrarily slow)such that $H = H_0 + V$ has eigenvalues $\{E_j\}$. We also show that there is no eigenvalue of $H = H_0 + V$ embedded in the spectral bands if $V(x) = \frac{o(1)}{1+|x|}$. (Received January 30, 2018)

1137-37-184 **Zhenghe Zhang*** (zhenghe.zhang@ucr.edu), Department of Mathemtics, UC Riverside, Riverside, CA 92521. *Large deviation estimates in spectral analysis of ergodic Schrödinger operators.*

Lyapunov exponent plays a key role in the spectral analysis of 1D ergodic Schrödinger operators. In particular, some type of uniform large deviation estimates (LDT) for the Lyapunov exponent is one of the main ingredients in showing Anderson Localization and certain regularity property of the Lyapunov exponent and IDS. In this talk, I will try to describe some different mechnisms that lead to unform LDT for different type of base dynamics. (Received February 03, 2018)

1137-37-337 **Paul J Hurtado*** (phurtado@unr.edu), 1664 North Virginia Street, University of Nevada, Reno/0084, Reno, NV 89509, and **Adam Kirosingh**. *General Proofs and Extensions of the 'Linear Chain Trick' for Reducing Integro-differential Delay Equations to Ordinary Differential Equations.* Preliminary report.

This talk introduces new theory for more easily deriving mean-field ODEs (instead of equivalent integro-differential equations aka distributed delay equations) from continuous time stochastic state-transition models. The Linear Chain Trick (LCT; aka the Gamma Chain Trick) is for reducing integro-differential equations to equivalent ODEs when these are mean-field models of stochastic state transition models with Erlang (Gamma) distributed dwell-times. LCT shortcomings include (1) being limited to Erlang dwell-times, and (2) a lack of general theory to associate stochastic assumptions directly to ODE structure, thus requiring modelers to first derive system-specific integro-differential equations. Our results address both issues by allowing more straightforward applications of the LCT and various extensions to construct mean-field ODEs directly from stochastic model assumptions. Our Generalized Linear Chain Trick framework does this for a broad class of models with flexible dwell time distributions. These results (1) clarify the connections between underlying stochastic assumptions and mean-field ODE models, and (2) allow modelers to move beyond the simple LCT to construct ODE models that more accurately incorporate more realistic non-Erlang distributions. (Received February 06, 2018)

1137-37-356 **Mickaël D. Chekroun***, Department of Atmospheric and Oceanic Science, Maths Science Building, 520 Portola Plaza, Los Angeles, CA 90095. *Stochastic Dynamic Transitions for Stochastic Evolution Equations.* Preliminary report.

Stochastic partial differential equations (SPDEs) and stochastic delay differential equations (SDDEs), driven by a multiplicative noise, will be considered. For such equations, we will present new analytic formulas for Markovian as well as non-Markovian parameterizations of the scales lying beyond a cutoff wavenumber. Applications to the study of dynamic transitions arising in the presence of noise will be shown on a stochastic Cahn Hilliard equation and on an SDDE arising in the modeling of the El Niño-Southern Oscillation.

(Joint work with Honghu Liu (Virginia Tech.) and Shouhong Wang (Indiana University))

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(Received February 07, 2018)

41 ► *Approximations and expansions*

1137-41-35 **Somantika Datta*** (sdatta@uidaho.edu) and **Jesse Oldroyd** (oldroyd.j@wvwc.edu). *Construction of low coherence unit norm tight frames.*

Equiangular tight frames (ETFs) are characterized by the fact that the coherence between any two distinct vectors is equal to the Welch bound. This guarantees that the maximum coherence between pairs of vectors is minimized. Despite their usefulness and widespread applications, ETFs of a given size N are only guaranteed to exist in $\mathbb{R}^d$ or $\mathbb{C}^d$ if $N = d+1$. This leads to the problem of finding approximations of ETFs of N vectors in $\mathbb{R}^d$ or $\mathbb{C}^d$ where $N > d+1$. To be more precise, one wishes to construct a unit norm tight frame (UNTF) such that the maximum coherence between distinct vectors of this frame is as close to the Welch bound as possible. Here low coherence UNTFs in $\mathbb{R}^d$ are constructed by adding a strategically chosen set of vectors called an *optimal* set to an existing ETF of $d+1$ vectors. This is done by means of combinatorial objects called block designs. It is shown that for certain block designs, the constructed UNTF attains the smallest possible maximum coherence between pairs of vectors among all UNTFs containing the starting ETF of $d+1$ vectors. This is particularly desirable if there does not exist a set of the same size for which the Welch bound is attained. (Received January 16, 2018)

1137-41-73 **Bin Han*** (bhan@ualberta.ca), Dept. of Mathematical and Statistical Science, University of Alberta, Edmonton, Alberta T6G 2G1, Canada, and **Chenzhe Diao**. *Quasi-tight Framelets and Matrix Spectral Factorization.* Preliminary report.

Tight wavelet frames (i.e., tight framelets) have been extensively studied in the literature and employed in many applications such as image processing. However, not every refinable function can be used to construct tight framelets. In this talk we shall introduce the notion of quasi-tight framelets, which are dual framelets but behave almost identically as tight framelets. Then we show that the construction of quasi-tight framelets is closely linked to the matrix spectral factorization with constant signatures. As a consequence, we completely characterize compactly supported quasi-tight framelets with two framelet generators. We also show that from every compactly supported refinable function in $L_2(\mathbb{R})$, we can always construct a compactly supported quasi-tight framelet in $L_2(\mathbb{R})$ with the highest possible order of vanishing moments and with the minimum number of framelet generators. This is a joint work with Chenzhe Diao at the University of Alberta. (Received January 24, 2018)

1137-41-113 **John Haas*** (terraformthedreamscape@gmail.com), 105 Redwood, Columbia, MO 65203, and **Peter G. Casazza**, **Tin Tran** and **Joshua Stueck**. *Optimal packings of subspaces with mixed dimension.* Preliminary report.

We examine the min-max (chordal) packing problem for the case of fusion frames with projections of mixed rank. In order to endow "equal footing" to all elements, we use a classical embedding to send projections to points on a higher dimensional Euclidean sphere, where we formulate a notion of "optimally spread" mixed rank fusion in terms of *spherical codes .* We provide elementary examples which solve this reformulation of the problem, emphasizing that the examples agree with an intuitive notion of optimal spreading for the prescribed parameters. (Received January 30, 2018)

1137-41-132 **Jens G Christensen*** (jchristensen@colgate.edu). *Atomic decompositions of Bergman spaces on tube type domains.*

We derive atomic decompositions for Bergman spaces on tube type domains by taking Laplace extensions of atoms on Besov spaces on the cone. We then discuss how this extends classical results due to Coifman and Rochberg and relate it to a concurrent result by Bekolle, Gonessa, and Nana. (Received January 31, 2018)

1137-41-164 **Demetrio Labate*** (dlabate@math.uh.edu), Department of Mathematics, University of Houston, 651 Phillip G Hoffman, Houston, TX 77204-3008, and **Bernhard G Bodmann** and **Bart Goossens**. *Robust and stable region-of-interest tomography by sparsity inducing convex optimization.*

Region-of-interest (ROI) tomographic reconstruction is a challenging mathematical and computational problem, especially in the situation of noisy projection data. Under the assumption of a robust width prior that generalizes sparsity norms and measurement models used in compressed sensing, we derive performance guarantees for ROI tomographic reconstruction by establishing error bounds for stable recovery. The presence of noise motivates relaxing data fidelity and data consistency requirements of computed tomography. Based on these observations, we define an iterative reconstruction algorithm from ROI-focused projection data that is based on convex optimization and approximately minimizes a ridgelet-based sparsity norm within a finite number of steps. Under the robust width assumption, the result of the algorithm is guaranteed to satisfy predetermined fidelity and consistency tolerances while controlling the reconstruction error. We numerically verify the assumptions on the sparsity norm and the measurement geometry by estimating the robust width parameters. Extensive numerical tests using experimental data show that our algorithm performs very competitively with respect to state-of-the-art methods especially for small ROI radii. (Received February 02, 2018)

1137-41-189 **Mauro Maggioni*** (mauro.maggioni@jhu.edu), 3400 N Charles St, Baltimore, MD 21218, and **Wenjing Liao** and **Stefano Vigogna**. *Multiscale Methods for Dictionary Learning and Regression for data near low-dimensional sets.*

We discuss a family of ideas, algorithms, and results for analyzing various new and classical problems in the analysis of high-dimensional data sets. These methods we discuss perform well when data is (nearly) intrinsically low-dimensional. They rely on the idea of performing suitable multiscale geometric decompositions of the data, and exploiting such decompositions to perform a variety of tasks in signal processing and statistical learning. In particular, we discuss the problem of dictionary learning, where one is interested in constructing, given a training set of signals, a set of vectors (dictionary) such that the signals admit a sparse representation in terms of the dictionary vectors. We then discuss the problem of regressing a function on a low-dimensional unknown manifold. For both problems we introduce a multiscale estimator, fast algorithms for constructing it, and give finite sample guarantees for its performance, and discuss its optimality. These are joint works with W. Liao and S. Vigogna. (Received February 03, 2018)

42 ► Fourier analysis

1137-42-31 **Mark Magsino*** (mmagsino@math.umd.edu). *Constructing Tight Gabor Frames Using CAZAC Sequences.*

The construction of finite tight Gabor frames plays an important role in many applications which include signal and image processing. We explore when constant amplitude zero autocorrelation (CAZAC) sequences can be used to generate tight Gabor frames. The main theorem uses Janssen's representation and the zeros of the discrete periodic ambiguity function to give necessary and sufficient conditions for determining whether a Gabor frame is tight. The relevance of the theorem depends significantly on the construction of examples. These examples are necessarily intricate, and depend on CAZAC sequences. To conclude, we present an alternate method for determining when Gabor frames are tight. This alternate method uses the Gram matrix of the Gabor system instead. (Received January 16, 2018)

1137-42-33 **Matthew Fickus*** (matthew.fickus@afit.edu). *Equiangular tight frames from group divisible designs.*

Given positive integers $N \geq D$, an equiangular tight frame $\mathrm{ETF}(D,N)$ is a type of optimal packing of N lines in a real or complex Hilbert space of dimension D. In the complex setting, the existence of an $\mathrm{ETF}(D,N)$ remains unresolved for many choices of D and N. In this talk, we observe that the (D,N) parameters of many of the known constructions of ETFs are of one of two types. We further provide a new method for combining a given ETF of one of these two types with an appropriate group divisible design (GDD) in order to produce a larger ETF of the same type. By applying this method to known families of ETFs and GDDs, we obtain several new infinite families of ETFs. Our approach was inspired by a seminal paper of Davis and Jedwab which both unified and generalized McFarland and Spence difference sets. We provide combinatorial analogs of their algebraic results, unifying Steiner ETFs with hyperoval ETFs and Tremain ETFs. (Received January 16, 2018)

1137-42-68 **Chun-Kit Lai***, 1600 Holloway Ave, San Francisco, CA 94132, and **Azita Mayeli**. *Fuglede-Gabor problem over non-separable time-frequency lattices.*

Let $K \subset \mathbb{R}^d$ be a set with positive and finite Lebesgue measure. Let $\Lambda = M(\mathbb{Z}^{2d})$ be a lattice in $\mathbb{R}^{2d}$ with density $\mathrm{dens}(\Lambda) = 1$. We show that if M is any lower block triangular matrix with diagonal matrices A and B, we prove that if $\mathcal{G}(|K|^{-1/2}\chi_K, \Lambda)$ is an orthonormal basis, then K can be written as a finite union of fundamental domains of $A(\mathbb{Z}^d)$ and at the same time, as a finite union of fundamental domains of $B^{-t}(\mathbb{Z}^d)$. If A^tB is an integer matrix, then there is only one common fundamental domain, which means K tiles by a lattice and is spectral. However, surprisingly, we will also illustrate by an example that a union of more than one fundamental domains is also possible. Nonetheless, this set is still a tile and a spectral set. (Received January 24, 2018)

1137-42-104 **Dustin G. Mixon*** (mixon.23@osu.edu), 231 W. 18th Ave., MW 706, Columbus, OH 43210. *Towards a unified theory of equiangular tight frames.*

Several applications in signal processing require lines through the origin of a finite-dimensional Hilbert space with the property that the smallest interior angle is as large as possible. Line packings that achieve equality in the Welch bound are known as equiangular tight frames (ETFs). This talk will discuss a general theory of ETFs that draws on ideas from algebraic combinatorics and representation theory to simultaneously explain all real ETFs as well as all complex ETFs with sufficient symmetry. While the theory suggests a program to classify all ETFs with doubly transitive symmetries, it is currently insufficient to solve Zauner's conjecture on the existence of ETFs with Heisenberg symmetry. This is joint work with Joseph W. Iverson (Maryland) and John Jasper (South Dakota State). (Received January 29, 2018)

1137-42-161 **John E. Herr*** (jeherr@butler.edu), **Palle E.T. Jorgensen** (palle-jorgensen@uiowa.edu) and **Eric S. Weber** (esweber@iastate.edu). *Constructions and a Characterization of Positive Matrices in the Hardy Space with Prescribed Boundary Representations.*

Using the Kaczmarz algorithm, for any singular Borel probability measure μ on the unit circle, we use a Parseval frame in $L^2(\mu)$ "dextrodual" to the sequence $\{e^{2\pi inx}\}_{n=0}^{\infty}$ to construct positive matrices in $H^2(\mathbb{D})$ that have $L^2(\mu)$ boundary function representations and are reproducing kernels with respect to those representations. For a given positive matrix K in $H^2(\mathbb{D})$ of a common form and a Borel measure μ on the unit circle, we give a

characterization of when K has $L^2(\mu)$ boundary representations. This characterization is in terms of a matrix identity based on a new operator product called the Abel product. (Received February 01, 2018)

1137-42-226 **Gökalp Alpan***, alpan@rice.edu. *Szegő Condition on arbitrary subsets of* $\mathbb{C}$.

Let μ be a measure in the complex plane of the form $f ds_\gamma$ where γ is a union of finitely many disjoint C^{2+} Jordan arcs and curves and f is the Radon Nikodym derivative of μ with respect to the arc measure ds_γ on γ. If $\log f \in L^1(\mu_\gamma)$ (this is called the Szegő condition) then the orthogonal polynomials associated with μ obey certain asymptotic properties (Widom 1969). Here μ_γ is the potential theoretic equilibrium measure of γ.

We discuss how to extend the Szegő condition on arbitrary non-polar compact subsets of the plane. (Received February 04, 2018)

1137-42-231 **Azita Mayeli*** (amayeli@gc.cuny.edu), New York, NY 10016. *Convex and symmetric sets with smooth boundary do not have orthogonal Gabor bases.* Preliminary report.

Let K be a convex and symmetric bounded set in $\mathbb{R}^d$, $d \geq 2$, with smooth boundary. Using a combinatorial approach, we show that for $d \neq 1(mod4)$, the indicator function of K can not serve as an orthogonal Gabor window function for $L^2(\mathbb{R}^d)$. That means that there is no countable set $S \subset \mathbb{R}^{2d}$ such that the Gabor family $\mathcal{G}(1_K, S) = \{e^{2\pi i x \cdot b} 1_K(x-a) : (a,b) \in S\}$ is an orthogonal basis for $L^2(\mathbb{R}^d)$.

This is joint work with Alex Iosevich. (Received February 04, 2018)

1137-42-240 **Christopher M. Brislawn*** (cbrislawn@yahoo.com), 55 Paseo Encantado NE, Santa Fe, NM 87506. *A Diophantine approach to causal lifting factorization of discrete wavelet transforms.*

The theory of linear Diophantine equations over polynomial rings is applied to the problem of constructing causal lifting factorizations for two-channel FIR perfect reconstruction multirate filter banks and discrete wavelet transforms. The Diophantine approach leads to a fundamental result, the Linear Diophantine Degree-Reduction Theorem, that guarantees existence and uniqueness of causal lifting factorizations satisfying certain polynomial degree-reducing inequalities. This enables a new lifting factorization strategy called the Causal Complementation Algorithm that provides an alternative to the noncausal lifting scheme, based on the Extended Euclidean Algorithm, constructed by Daubechies and Sweldens. The new approach develops a generalization of polynomial division that ensures existence and uniqueness of quotients whose remainders satisfy user-specified divisibility constraints. The Causal Complementation Algorithm is shown to be more general than the Euclidean Algorithm approach by generating causal lifting factorizations not obtainable using the Euclidean Algorithm. Despite this greater generality, the uniqueness aspects of the underlying algebraic theory allow users to construct all possible degree-reducing causal lifting factorizations of a given filter bank. (Received February 05, 2018)

1137-42-255 **F. Bozkurt** and **K. Kornelson*** (kkornelson@ou.edu). *Dynamical sampling and connections to frames.* Preliminary report.

In a setting where a signal evolves in a known way over time, the signal may be reconstructed via samples taken both with respect time and space. In this talk, we examine some of the connections to problems in frame theory. (Received February 05, 2018)

1137-42-259 **Kasso A. Okoudjou** and **Shujie Kang***, 4176 Campus Drive - William E. Kirwan Hall, College Park, MD 20742. *Grassmannian Frames and Minimizers of the p-Frame Potentials.* Preliminary report.

The p-frame potential of a frame $\{v_i\}_{i=1}^N \subset \mathbb{R}^d$ is defined as $FP_{p,N,d} = (\sum\limits_{i<j} |\langle v_i, v_j \rangle|^p)^{1/p}$. Grassmannian frames are minimizers of the frame potential when $p = \infty$. More generally, one can ask if Grassmannian frames also minimize the p-frame potentials for $2 \leq p < \infty$. We report on recent progress made in solving this question in $\mathbb{R}^2$. There have been results showing this is true when p is even, and we conjecture that the statement also holds when p is odd. We shall motivate our approach by focusing on the case $p = 3$ and $N = 5$. Our preliminary results rely on certain techniques developed by Cohn and Kumar involving absolute continuous function and ultraspherical polynomials. (Received February 05, 2018)

43 ► Abstract harmonic analysis

1137-43-51 **Vignon Sourou Oussa*** (voussa@bridgew.edu), 131 Summer St, Bridgewater, MA 02325-0001. *Frames arising from solvable actions.*

In this presentation, we will provide a unified method which is exploited to construct reproducing systems arising from unitary irreducible representations of solvable Lie groups. In contrast to well-known techniques such as the coorbit theory and other discretization schemes, we do not assume the integrability or square-integrability of the representations of interest. Additionally, we will present various examples illustrating how our method handles a variety of groups relevant to wavelet theory and time-frequency analysis. (Received January 21, 2018)

1137-43-119 **Joseph W Iverson**, **John Jasper*** (john.jasper@sdstate.edu) and **Dustin G Mixon**. *Equiangular tight frames from association schemes.*

Several applications in signal processing require lines through the origin of a finite-dimensional Hilbert space with the property that the smallest interior angle is as large as possible. Packings that achieve equality in the Welch bound are known as equiangular tight frames (ETFs). In the real case, ETFs are in one-to-one correspondence with certain strongly regular graphs, which are well-studied objects in combinatorics. The complex case is harder, since the phases of inner products are no longer restricted to a discrete set. Still, there is a growing theory of complex ETFs arising from combinatorial objects known as association schemes. This talk will discuss a few recent developments along these lines. (Received January 30, 2018)

1137-43-166 **Gestur Olafsson*** (olafsson@lsu.edu), Louisiana State University, Department of Mathematics, Lockett Hall, Baton Rouge, LA 70803, and **Jens G. Christensen** and **Amer H. Darweesh**. *Projective representations, coorbits and Bergman spaces.*

Representation of topological groups are powerful tool to analyze Banach spaces of functions and distributions. Representation theory provides a unified framework for constructing function spaces and to study several generalizations of the wavelet transform. Recently representation theory has been used to provide atomic decompositions for a large collection of classical Banach spaces. But in some natural situations, including Bergman spaces on bounded domains, representations are too restrictive. The proper tools are projective representations. In this talks we discuss recent work with J. Christensen and A. Darweesh on coorbit spaces for projective representations. This leads naturally to twisted convolution, a well known idea from the Heisenberg group. We discuss some examples, the main one being atomic decompositions of Bergman spaces on the unit ball through the holomorphic discrete series for the group of isometries of the ball. (Received February 02, 2018)

46 ► Functional analysis

1137-46-86 **Jun Yan*** (junyan65@stanford.edu), 52 Dudley Ln, Apt 102B, Stanford, CA 94305. *An Algebra Model for the Higher Order Sum Rules.*

We introduce an algebra model to study higher order sum rules for orthogonal polynomials on the unit circle. We build the relation between the algebra model and sum rules, and prove an equivalent expression on the algebra side for the sum rules, involving a Hall-Littlewood type polynomial. By this expression, we recover an earlier result by Golinskii and Zlatõs, and prove a new case - half of the Lukic conjecture in the case of a single critical point with arbitrary order. (Received January 27, 2018)

1137-46-127 **Akram Aldroubi** (aldroubi@math.vanderbilt.edu), 2201 West End Ave, Nashville, TN TN 37235, **Longxiu Huang** (longxiu.huang@vanderbilt.edu), 2201 West End Ave, Nashville, TN 37235, and **Armenak Petrosyan*** (petrosyana@ornl.gov), 1 Bethel Valley Rd, Oak Ridge, TN 37280. *Frames from continuous actions of an operator.*

The dynamical sampling problem is to recover an unknown signal from the space-time samples of an evolving process for which the signal is the initial state. In our recent study, we assume the samples are taken in continuous time at fixed locations. This problem can be reformulated as finding conditions on $A \in B(\mathcal{H})$, $G \subset \mathcal{H}$ and $0 < L < \infty$ that make the iterated system $\{A^t g : g \in G, t \in [0, L]\}$ complete, Bessel or a frame in the Hilbert space $\mathcal{H}$. Additionally, we will discuss the connection between a semi-continuous frame $\{A^t g : g \in G, t \in [0, L]\}$ and its time-discretization $\{A^{t_i} g\}_{g\in G, i\in I}$ with $|I| < \infty$. (Received January 31, 2018)

1137-46-165 **Dorin Ervin Dutkay*** (ddutkay@gmail.com), Orlando, FL 32816, and **Gabriel Picioroaga**. *A unified construction of some classical and some new orthonormal bases.*

We show how representations of Cuntz algebras can be used to construct Fourier bases, Walsh bases, wavelet bases , Fourier bases on fractal measures and generalized Walsh bases. (Received February 02, 2018)

1137-46-186 **Judith A Packer*** (packer@colorado.edu), Department of Mathematics, Campus Box 395, Univeristy of Colorado, Boulder, Boulder, CO 80309-0395. *Wavelets for higher-rank graph C^*-algebras.* Preliminary report.

This talk will concern recent developments in the study of wavelets for higher-rank graph C^*-algebras. In our setting, the Hilbert space is L^2 of the infinite path space associated to the finite k-graph being studied, with respect to a specified probability measure determined by that graph, and isometries and partial isometries associated to the k-graph play the role of dilation and translation operators. The talk involves ongoing joint works with Carla Farsi, Elizabeth Gillaspy, Palle Jorgensen, Antoine Julien and Sooran Kang. (Received February 03, 2018)

1137-46-225 **Alejandro Chavez-Dominguez**, **Daniel Freeman*** (daniel.freeman@slu.edu) and **Keri Kornelson**. *Finite unit norm tight frames and the frame potential in Banach spaces.*

We define a frame potential for frames in a finite dimensional Banach space. As is the case for frames in Hilbert spaces, we prove that the frame potential can be used to characterize finite unit norm tight frames (FUNTFs) for finite dimensional Banach spaces. That is, a frame of k vectors in an n-dimensional Banach space is a FUNTF if and only if its frame potential is k^2/n.

We prove the existence of FUNTFs for a variety of spaces, and in particular that every n-dimensional complex Banach space with a 1-unconditional basis has a FUNTF of k vectors for every $k \geq n$. However, many interesting results on FUNTFs and sums of rank one projections for Hilbert spaces remain unknown for Banach spaces and we pose multiple open questions. (Received February 04, 2018)

1137-46-242 **Dimitri Shlyakhtenko*** (shlyakht@math.ucla.edu), Department of Mathematics, UCLA, Los Angeles, CA 90095. *A (co)homology theory for subfactors and planar algebras.*

The so-called standard invariant (or planar algebra) of a subfactor is a rich mathematical object, introduced by Jones, which captures a kind of "quantum symmetry" of the underlying subfactor inclusion. In our joint work with S. Popa and S. Vaes, we introduce a (co)homology theory for these objects. This in particular leads to the theory of L^2-Betti numbers in this context. The theory connects well with approximation properties of the underlying objects, such as an analog of property T, the Haagerup property, and amenability. Our work provides a common framework for cohomology theories for groups, equivalence relations as well as quantum groups. We also present some computations. (Received February 05, 2018)

1137-46-296 **Mihai Stoiciu*** (mstoiciu@williams.edu), Williams College - Mathematics and Statistics, Bascom House, 33 Stetson Ct, Williamstown, MA 01267. *Numerical Investigations of the Eigenvalue Distribution of Random Hermitian and Unitary Operators.* Preliminary report.

We will present several numerical investigations of the distribution of the eigenvalues of various classes of random self-adjoint and unitary operators. In particular we will investigate the microscopic eigenvalue statistics and the microscopic level spacings, as well as the global eigenvalue distribution and the global eigenvalue spacing distribution. We will present cases which exhibit Poisson and picket fence eigenvalue distribution, as well as cases with weak eigenvalue repulsion. (Received February 05, 2018)

1137-46-318 **Jon D Vanderwerff***, Department of Mathematics, La Sierra University, 4500 Riverwalk Drive, Riverside, CA 92515. *On the generic nature of various classes of convex functions.* Preliminary report.

This talk will examine whether certain classes of convex functions such as uniformly convex, or those attaining certain types of strong minimums are residual in the space of proper lower semicontinuous functions on a Banach space. The results are motivated by a recent paper of C. Planiden and X. Wang. (Received February 06, 2018)

47 ► Operator theory

1137-47-57 **Boo Rim Choe**, **Hyungwoon Koo** and **Wayne Smith*** (wayne@math.hawaii.edu), Department of Mathematics, University of Hawaii, Honolulu, HI 96822. *Sarason's composition operator over the half-plane.*

Let $\mathbf{H} = \{z \in \mathbf{C} : \operatorname{Im} z > 0\}$ be the upper half plane, and denote by $L^p(\mathbf{R})$, $1 \leq p < \infty$, the usual Lebesgue space of functions on the real line $\mathbf{R}$. We define two "composition operators" acting on $L^p(\mathbf{R})$ induced by a Borel function $\varphi : \mathbf{R} \to \overline{\mathbf{H}}$, by first taking either the Poisson or Borel extension of $f \in L^p(\mathbf{R})$ to a function on $\overline{\mathbf{H}}$, then composing with φ and taking vertical limits. Classical composition operators, induced by holomorphic functions and acting on the Hardy spaces $H^p(\mathbf{H})$ of holomorphic functions, correspond to a special case. Our main results provide characterizations of when the operators we introduce are bounded or compact on $L^p(\mathbf{R})$,

$1 \leq p < \infty$. The characterization for the case $1 < p < \infty$ is independent of p and the same for the Poisson and the Borel extensions. The case $p = 1$ is quite different. (Received January 22, 2018)

1137-47-103 **Jean Bourgain**, **Svetlana Jitomirskaya** and **Ilya Kachkovskiy*** (ikachkov@math.msu.edu). *Localization and delocalization for two interacting 1D quasiperiodic particles.* Preliminary report.

The talk is about several tentative results, joint with J. Bourgain and S. Jitomirskaya. We consider a model of two 1D almost Mathieu particles with a finite range interaction. The presence of interaction makes it difficult to separate the variables, and hence the only known approach is to treat it as a 2D model, restricted to a range of parameters (both frequencies and phases of the particles need to be equal). In the usual 2D approach, a positive measure set of frequency vectors is usually removed, and extra care needs to be taken in order to keep the diagonal frequencies (which is a zero measure set) from being removed. We show that the localization holds at large disorder for energies separated from zero and from certain values associated to the interaction.

We also study the model in the regime of strong interaction, in which case an additional band of spectrum ("droplet band") is created. We show that this droplet band is localized in the regime of large interaction and fixed difference between phases (in particular, it covers the "physical" regime of equal phases). However, there is another regime where the difference between phases is close to pi/2, in which case the droplet band has some ac spectrum. (Received January 29, 2018)

1137-47-116 **Joel H Shapiro*** (joels314@gmail.com), Fariborz Maseeh Department of, Mathematics and Statistics, Portland State University, Portland, OR 97201. *Remarks on algebras associated with composition operators.* Preliminary report.

Each bounded linear operator T on a Hilbert space gives rise to the unital algebra $A(T)$ that it generates, and to three naturally related algebras that are closed in the weak operator topology:

(a) The weak-operator closure $W(T)$ of $A(T)$,

(b) The commutant $\{T\}'$ of T, and

(c) The "double commutant" $\{T\}''$.

It's easy to see that $W(T) \subset \{T\}'' \subset \{T\}'$, so it's of interest to ask, for a given operator T, if either of these set containments is an equality.

This talk will survey some recent work done by various authors on this question for T a linear-fractionally induced composition operator on the Hardy space of the unit disc, and it will explore the relationship between these results and Victor Lomonosov's notion of *strong compactness*.

These results follow a well-known pattern: Linear-fractionally induced composition operators exhibit surprisingly diverse behavior; even the simplest such maps can give rise to surprisingly vexing questions. (Received January 30, 2018)

1137-47-173 **Rajinder Mavi*** (mavi.maths@gmail.com), 619 Red Cedar Road, Wells Hall, MI 48824, and **Jeffrey Schenker**. *Anderson localization for a disordered polaron.*

We will consider an operator modeling a tracer particle on Z^d subject to an Anderson field, we associate a one dimensional oscillator to each site of the lattice. This forms a polaron model where the oscillators communicate only through the hopping of the tracer particle. This introduces, a priori, infinite degeneracies of bare energies at large distances. We nevertheless show Dynamical Localization of the tracer particle for compact subsets of the spectrum. This is joint work with Jeff Schenker. (Received February 02, 2018)

1137-47-175 **Simon Becker** and **Rui Han*** (rhan@ias.edu), 027 Simonyi Hall, School of Math, IAS, Princeton, NJ 08540, 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 February 02, 2018)

1137-47-180 **Brian Simanek*** (brian_simanek@baylor.edu), Baylor Math Department, One Bear Place #97328, Waco, TX 76798. *Hyponormal Toeplitz Operators Acting on the Bergman Space.*

An operator is called hyponormal if its commutator with its adjoint is positive definite. Such operators are of interest because of Putnam's inequality, which provides spectral estimates on such operators in terms of the norm of this commutator. We will consider operators that act on the Bergman space of the unit disk by multiplication by a bounded function (called the symbol) followed by a projection. Our focus will be on the case when the symbol is a certain non-harmonic algebraic function and we will determine when the operator is hyponormal. (Received February 02, 2018)

1137-47-202 **Jake Fillman** and **Darren C Ong*** (darrenong@xmu.edu.my), Mathematics Department, Xiamen University Malaysia, Jalan Sunsuria, Bandar Sunsuria, 43900 Sepang, Selangor, Malaysia. *Purely singular continuous spectrum for limit-periodic CMV operators with applications to quantum walks.*

We show that a generic element of a space of limit-periodic CMV operators has zero-measure Cantor spectrum. We also prove a Craig–Simon type theorem for the density of states measure associated with a stochastic family of CMV matrices and use our construction from the first part to prove that the Craig–Simon result is optimal in general. We discuss applications of these results to a quantum walk model where the coins are arranged according to a limit-periodic sequence. (Received February 04, 2018)

1137-47-258 **Tsz Chiu Kwok*** (tckwok0@gmail.com), **Lap Chi Lau**, **Yin Tat Lee** and **Akshay Ramachandran**. *The Paulsen Problem, Continuous Operator Scaling, and Smoothed Analysis.*

The Paulsen problem is a basic open problem in operator theory: Given vectors $u_1, \dots, u_n \in \mathbb{R}^d$ that are ϵ-nearly satisfying the Parseval's condition and the equal norm condition, is it close to a set of vectors $v_1, \dots, v_n \in \mathbb{R}^d$ that exactly satisfy the Parseval's condition and the equal norm condition? We consider the squared distance $\inf_v \sum_{i=1}^n \|u_i - v_i\|_2^2$ where the infimum is over the set of exact solutions. Previous results show that the squared distance of any ϵ-nearly solution is at most $O(\text{poly}(d, n, \epsilon))$ and there are ϵ-nearly solutions with squared distance at least $\Omega(d\epsilon)$. The fundamental open question is whether the squared distance can be independent of the number of vectors n.

We answer this question affirmatively by proving that the squared distance of any ϵ-nearly solution is $O(d^{13/2}\epsilon)$. Our approach is based on a continuous version of the operator scaling algorithm. We first define a dynamical system based on operator scaling to give a looser bound, and then we show that the dynamical system will converge faster by slightly perturbing the input vectors. (Received February 05, 2018)

1137-47-263 **Waleed K. Al-Rawashdeh***, 1300 West Park Street, Butte, MT 59701. *Generalized composition operators on Weighted Hilbert Spaces of Analytic Functions.*

Let φ be an analytic self-map of the open unit disk $\mathbb{D}$ and g be an analytic function on $\mathbb{D}$. The generalized composition operator induced by the maps g and φ is defined by the integral operator

$$I_{(g,\varphi)}f(z) = \int_0^z f'(\varphi(\zeta))g(\zeta)d\zeta.$$

Given an admissible weight ω, the weighted Hilbert space $\mathcal{H}_\omega$ consists of all analytic functions f such that $\|f\|^2_{\mathcal{H}_\omega} = |f(0)|^2 + \int_{\mathbb{D}} |f'(z)|^2 w(z)dA(z)$ is finite. In this talk, we characterize the boundedness and compactness of the generalized composition operators on the space $\mathcal{H}_\omega$ using the ω-Carleson measures. Moreover, we give a lower bound for the essential norm of these operators. (Received February 05, 2018)

1137-47-310 **Heinz H. Bauschke**, **Minh N. Bui*** (nhutminh.bui@alumni.ubc.ca) and **Xianfu Wang**. *On the sum of projectors onto convex sets.*

The projectors onto the Minkowski sum of closed convex sets is generally not equal to the sum of individual projectors. In this talk, we provide a complete answer to the question of characterizing the instances where such an equality holds. Our results unify and extend the case of linear subspaces and Zarantonello's results for projectors onto cones. We establish the partial sum property for projectors onto convex cones, and we also present various examples as well as a detailed analysis in the univariate case. This talk is based on a joint work with Heinz Bauschke and Xianfu Wang. (Received February 06, 2018)

49 ► Calculus of variations and optimal control; optimization

1137-49-4 **Tim Hoheisel*** (tim.hoheisel@mcgill.ca), 805 Sherbrooke St West, Room 1114, Montreal, Canada H3A 0B9, Canada, and **James V. Burke**. *Applications of the generalized matrix-fractional function.*

The generalized matrix-fractional function (GMF) is (shown to be) a support function of the graph of the function mapping a matrix to the product with its transpose intersected with an affine manifold. It establishes connections between optimal value functions for quadratic optimization problems, covariance estimation, and the nuclear norm. We present a detailed study of the convex-analytical properties of the GMF, in particular, we give a full description of its subdifferential and characterize the points of differentiability. We will show that many powerful results on Ky-Fan norms and variational Gram functions arise from infimal projections of the sum of the GMF and a closed, proper, convex function. (Received October 17, 2017)

1137-49-11 **Scott Boivin Lindstrom*** (scott.lindstrom@uon.edu.au), V123 Mathematics Building, University Drive, Callaghan, NSW 2308, Australia. *Proximal Averages for Minimization of Entropy Functionals.*

We provide a basic overview of the convex analysis of the Lambert W function and go on to explore its role in duality theory where it appears quite naturally in the closed forms of the convex conjugates for important functions. We exploit these forms to solve minimization problems for entropy functionals. We then explore the analogous relevance of the Lambert W function for computing proximal averages, solving another set of entropy functionals and revealing several advantages of the homotopy afforded therein.

This presentation includes work from collaborations with Jonathan M. Borwein and Heinz H. Bauschke. (Received December 04, 2017)

1137-49-18 **Peter Hinow*** (hinow@uwm.edu), Department of Mathematical Sciences, Milwaukee, WI 53201. *A nonsmooth program for jamming hard spheres.*

We study packings of n hard spheres of equal radius in the d-dimensional unit cube. We present a nonsmooth function whose local extrema are the radii of jammed packings (where no subset of spheres can be moved keeping all others fixed) and show that for a fixed number of spheres there are only finitely many radii of such jammed configurations. We propose an algorithm for the maximization of this maximal radius function and present examples for 5 - 8 disks in the unit square and 4 - 6 spheres in the unit cube. The method allows straightforward generalization to packings of spheres in other compact containers. The origin of this research is a problem in pharmaceutical science on predicting the release kinetics of matrix tablets. This work has been partially supported by the US National Science Foundation through grant DMS 1016214. (Received December 29, 2017)

1137-49-22 **Max D Engelstein*** (maxe@mit.edu). *Regularity at Isolated Singularities for Almost-Minimizing Currents.*

We prove a uniqueness of blowup result at isolated (multiplicity-one) singularities of (almost-)area minimizing currents. When the blowup has extra structure (i.e. integrability) we get a power rate of convergence. For minimizers, this reproves a result of Leon Simon (Annals, '83). However, our methods are purely variational, which allows us to study almost-minimizers (but prevents us from addressing stationary currents). This is joint work with Luca Spolaor (MIT/Princeton) and Bozhidar Velichkov (Universite Grenoble Alpes). (Received January 09, 2018)

1137-49-34 **Ilya Shvartsman*** (ius13@psu.edu), Middletown, PA 17057. *Second-Order Optimality Conditions for Singular Extremals in Optimal Control Problems with Equality Endpoint Constraints.*

We use the method of finite-dimensional approximations to derive second-order necessary optimality conditions for singular Pontryagin local minimizers in optimal control problems with equality endpoint constraints. The talk is based on the joint work with A. Arutyunov and Z. Zhukovskaya. (Received January 16, 2018)

1137-49-50 **Yunfeng Hu**, **Matthew Hudelson**, **Bala Krishnamoorthy**, **Altansuren Tumurbaatar** and **Kevin R. Vixie*** (vixie@speakeasy.net), 610 SE Spring Street, Pullman, WA 99163. *Median Shapes: existence, regularity and computation.*

I will give a brief account of results obtained by representing shapes as currents and medians of those shapes through the use of the multiscale flat norm as a distance on those shapes. (Received January 21, 2018)

1137-49-52 **Robin Neumayer*** (neumayer@math.northwestern.edu). *The Cheeger constant of a Jordan domain without necks.*

In 1970, Cheeger established lower bounds on the first eigenvalue of the Laplacian on compact Riemannian manifolds in terms of a certain isoperimetric problem. The analogous problem on domains of Euclidean space has generated much interest in recent years, due in part to its connections to capillarity theory, image processing, and landslide modeling. In this talk, based on joint work with Leonardi and Saracco, we give an explicit characterization of minimizers in this isoperimetric problem for a very general class of planar domains. (Received January 21, 2018)

1137-49-88 **Xianfu Wang*** (shawn.wang@ubc.ca), **Honglin Luo** (071025013@fudan.edu.cn) and **Lukens Brett**. *Variational analysis on the signed distance functions.*

The signed distance function (or oriented distance function) of a set in a metric space determines the distance of a given point from the boundary of the set, with the sign determined by whether the point is in the set or in its complement. The knowledge of signed distance functions is a very valuable information in various fields of applied mathematics such as collision detection, binary classification, shape analysis, fuzzy numbers ranking and level set methods. One distinguished feature of the signed distance function is that it reflects the geometric structure of the set much better than the distance function does. We explore many interesting analytical properties of signed distance functions, and use the signed distance function to construct convex functions with nonconvex subdifferential domains. (Received January 28, 2018)

1137-49-125 **Warren L Hare*** (warren.hare@ubc.ca), Kelowna, BC V1V 1V7, Canada, and **Gabriel Jarry-Bolduc**. *Calculus of the Simplex Gradient.*

Derivative-free optimization (DFO) is the mathematical study of the optimization algorithms that do not use derivatives. The Simplex Gradient, essentially the gradient of a linear interpolation approximation, is a common tool in DFO. Recent work by Regis extended the definition of the Simplex gradient to include a unified framework for under-determined and over-determined interpolation sets. Regis also introduced a sum-rule and product-rule for the simplex gradient of two functions. Unfortunately, the product-rule only works under a restrictive set of assumptions. In this talk, we review Regis' framework, and product rule. We then provide an alternate product rule, which requires no unreasonable assumptions for application. We introduce a chain rule, and include several corollaries (such as a quotient rule). (Received January 31, 2018)

1137-49-187 **Mau Nam Nguyen**, **Sam Reynolds** and **Tuyen Tran*** (tuyen2@pdx.edu). *Constrained clustering and multifacility location via distance function penalty methods and DC programming.*

Cluster analysis tackles an emerging class of optimization problems that have numerous applications in data science, machine learning, and multifacility location problems, to name a few. In this talk we introduce a constrained model of multifacility location and use the distance function penalty method, Nesterov's smoothing techniques and the DCA to provide an effective optimization scheme for solving the problem. In our problem, the centers to be found must lie in the intersection of some given set constraints. Different numerical examples with artificial and real data sets are provided to test our method.

(This talk is based on the joint work with Mau Nam Nguyen and Sam Reynolds.) (Received February 03, 2018)

1137-49-193 **Boris Mordukhovich*** (boris@math.wayne.edu). *DISCRETE APPROXIMATIONS AND OPTIMAL CONTROL OF PROX-REGULAR SWEEPING PROCESSES.*

This talk concerns optimal control problems for several versions of the controlled sweeping process governed by dissipative differential inclusions while the main attention is paid to brand new results concerning a nonconvex prox-regular version of the sweeping process and its applications. Such dynamic optimization problems constitute a new and challenging class in optimal control of discontinuous systems with intrinsic state constraints of inequality and equality types. We develop the method of discrete approximations for this class of optimal control problems and establish its strong convergence properties. Using advanced tools of variational analysis and generalized differentiation allows us to derive necessary optimality conditions for discrete-time problems and then pass to the limit with respect to the vanishing discretization step. In this way we derive nondegenerate necessary optimality conditions for the original sweeping control problems expressed in terms of given local minimizers and problem data. Some efficient applications of the obtained results to the planar crowd motion model are also discussed in the talk. (Received February 03, 2018)

1137-49-215 **Julia Eaton*** (jreaton@uw.edu), 1900 Commerce Street, Box 358436, Tacoma, WA 98402, and **Mert Gurbuzbalaban**, **Sara Grundel** and **Michael Overton**. *Optimizing the polynomial radius and abscissa subject to affine constraints.*

Polynomial root optimization problems arise in the control of continuous and discrete time dynamical systems. The polynomial abscissa (the largest real part of an root of a polynomial) and the polynomial radius (the largest root in modulus) are examples of functions of polynomial root functions connected to such problems. A polynomial is Schur stable if its roots lie in the unit disk and it is Hurwitz stable if its roots lie in the left-half plane. We consider optimizing the polynomial radius and abscissa subject to affine constraints on the coefficients. For the radius, we recover a 2012 result of root activity when there is only one constraint, and extend this result when there are multiple constraints. For the polynomial abscissa, we derive similar results when the optimal solution is attained. We derive information about the variational structure of set of Hurwitz stable polynomials in order to understand the case where the optimal value is not attained. (Received February 04, 2018)

1137-49-217 **Milagros Loreto*** (mloreto@uw.edu), 18115 Campus Way NE, Bothell, WA 90011, and **Yiting Xu** (xyt@uw.edu) and **David Kotval** (dhk2e@mtmail.mtsu.edu). *Spectral Subgradient Method for Unconstrained Optimization.*

The spectral subgradient method combines the classical subgradient approach with the spectral step length, which does not require any previous knowledge of the optimal value, to solve nonsmooth unconstrained minimization problems. We focus on the interesting case where the objective function is convex and continuously differentiable almost everywhere, but often non-differentiable at minimizers. We present numerical results on different sets of nonsmooth functions to compare our proposed method with other traditional subgradient methods, showing that using the spectral step length can improve the quality of the solution found (Received February 04, 2018)

1137-49-249 **Eric Baer*** (ebaer@math.wisc.edu) and **Alessio Figalli**. *Characterization of isoperimetric sets inside almost-convex cones.*

We discuss a recent result showing that a characterization of isoperimetric sets (that is, sets minimizing a relative perimeter functional with respect to a fixed volume constraint) inside convex cones as sections of balls centered at the origin (originally due to P.L. Lions and F. Pacella) remains valid for a class of "almost-convex" cones. Key tools include compactness arguments and the use of classically known sharp characterizations of lower bounds for the first nonzero Neumann eigenvalue associated to (geodesically) convex domains in the hemisphere. (Received February 05, 2018)

1137-49-253 **Kuang Bai*** (kuangbai@uvic.ca), Victoria, Canada. *On directional pseudo/quasi-normality and directional enhanced KKT conditions.*

In this paper we mainly study the metric subregularity of a set-valued map which is the sum of a single-valued Lipschitz continuous mapping and a closed subset. First we derive a sufficient condition for metric subregularity called quasi-first order sufficient condition for metric subregularity (FOSCMS) that is weaker than the FOSCMS recently introduced by Gfrerer. Then we introduce a directional version of the pseudo-normality and quasi-normality which is weaker than the classical pseudo-normality and quasi-normality respectively. The directional quasi-normality are stronger than the quasi-FOSCMS but easier to verify. An example is used to illustrate that the directional pseduo-normality can be weaker than both the FOSCMS and the quasi-normality. For the class of set-valued maps where the Lipschitz mapping is linear and the closed set is the union of finitely many convex polyhedral sets, we show that the directional pseudo-normality holds automatically at each point of the graph. Finally we apply our results to non-smooth optimization problems. Under directional pseudo/quasi-normality, we show that any local minimizer must satisfy the directional enhanced KKT condition which is a stronger optimality condition than the classical enhanced KKT condition. (Received February 05, 2018)

1137-49-261 **Damek Davis** (dsd95@cornell.edu), **Dmitriy Drusvyatskiy*** (ddrusv@uw.edu), **Kellie J MacPhee** (kmacphee@uw.edu) and **Courtney Paquette** (yumiko88@math.washington.edu). *Subgradient methods without convexity: error bounds, linear convergence, and statistical guarantees.* Preliminary report.

Subgradient methods converge linearly on a convex function that grows sharply away from its solution set. In this talk, I will explain that the same is true for sharp functions that are only weakly convex, provided that the subgradient methods are initialized within a fixed tube around the solution set. A variety of statistical and signal processing tasks come equipped with good initialization, and provably lead to formulations that are both weakly convex and sharp. Therefore, in such settings, subgradient methods can serve as cheap local search procedures. I will illustrate the techniques on phase retrieval and covariance estimation problems. (Received February 05, 2018)

1137-49-266 **Huanqun Jiang*** (jiangh@oregonstate.edu), Department of Mathematics, Kidder Hall, Oregon State university, Corvallis, OR 97331. *Optimal barrier strategies for heavy-tailed surplus and interest rates.*

This talk will focus on the optimal barrier strategy in the classical dividend distribution problem in insurance mathematics. The capital process is modelled as the spectrally negative Lévy process as usual. In particular, it will discuss the proof of the conditions for the optimality of barrier strategy, when the discounting factor is an exponential Lévy process. It suggests when the constant barrier strategy is the best one if both the capital process and the interest rate are allowed to evolve with Lévy jumps. (Received February 05, 2018)

1137-49-286 **Mau Nam Nguyen***, Department of Mathematics and Statistics, Portland, OR 97201. *On Mordukhovich's Criteria for Lipschitz Properties of Nonsmooth Functions and Set-Valued Mappings.*

In this talk we revisit Mordukhovich's subdifferential criterion for Lipschitz continuity of nonsmooth functions and coderivative criterion for the Aubin/Lipschitz-like property of set-valued mappings. The criteria are useful and beautiful results in modern variational analysis showing the state of the art of the field. We also present some applications of the criteria to obtain necessary and sufficient conditions for Lipschitz properties of a number of important class of nonsmooth functions and set-valued mappings. (Received February 05, 2018)

1137-49-304 **Giovanni Colombo**, **Boris S. Mordukhovich** and **Dao Nguyen*** (gc9683@wayne.edu), Detroit, MI 48202. *Optimal control of a perturbed sweeping process.*

This talk deals with an optimal control problem for a perturbed sweeping (Moreau) process, where control function is in additive perturbations on the right-hand side of the dissipative differential inclusion without changing the moving set and merely measurable without any Lipschitzian. It should be emphasized that the velocity mapping in the differential inclusions under consideration is highly non-Lipschitz, unbounded and the control is just measurable, which cannot be treated by means of known results in optimal control for differential inclusions. To overcome such principal issues, we develop the method of discrete approximations married with catching-up algorithm and combine it with appropriate generalized differential tools of modern variational analysis, which allows us to adequately replace the original optimal control problem by a sequence of well-posed finite-dimensional optimization problems whose optimal solutions strongly converge to that of the original controlled perturbed sweeping process. Then we use this direct method to obtain nondegenerate necessary optimality conditions for the so-called intermediate relaxed local minimum of the controlled sweeping process. Furthermore, the established necessary optimality conditions are illustrated by several examples. (Received February 06, 2018)

1137-49-315 **Yves Lucet*** (yves.lucet@ubc.ca), ASC 350, UBC Okanagan, 3187 University Way, Kelowna, BC V1V1V7, Canada, **Heinz H Bauschke** (heinz.bauschke@ubc.ca), Kelowna, BC , Canada, and **Hung M Phan** (hung_phan@uml.edu), Lowell, MA. *A linear-time algorithm to check the convexity of piecewise linear-quadratic functions.*

Functions that are piecewise defined are a common sight in mathematics while convexity is a property especially desired in optimization. Suppose now a piecewise-defined function is convex on each of its defining components - when can we conclude that the entire function is convex? Our main result provides sufficient conditions for a piecewise-defined function f to be convex. We also provide a sufficient condition for checking the convexity of a piecewise linear-quadratic function, which play an important role in computer-aided convex analysis. Finally, we propose a finite algorithm running in linear worst-case time complexity to determine whether a bivariate piecewise linear-quadratic function is convex. (Received February 06, 2018)

1137-49-317 **Javier A Morales Delgado***, javierm1@cscamm.umd.edu. *Least action principles with applications to gradient flows and kinetic equations.*

In this talk, we introduce a variational formulation for a family of kinetic reaction-diffusion and their connection to Lagrangian dynamical systems. Such a formulation uses a new class of transportation costs between positive measures, and it generalizes the notion of gradient flows. We use this class to build solutions to reaction-diffusion equations with drift subject to boundary conditions via an extension of De Giorgi's interpolation method for the entropy functional. Additionally, we use this variational formulation to obtain results for the dynamics of the Kuramoto Sakaguchi equation. (Received February 06, 2018)

1137-49-327 **Yunfeng Hu*** (yunfeng.hu@wsu.edu), 1630 NE Valley Rd, M106, Pullman, WA, and **Enrique Alvarado**, **Kevin Vixie**, **Yufeng Cao**, **Yuan Wang**, **Michael Newsham** and **Laramie Paxton**. *Bayesian Analysis and Nonlocal Means Method on Tumor Detection.*

Our goal it to classify tumor, vessel and healthy cells from a set of time snaps of patient liver scans. We first use the training data to get the reference signals for each of the cells, use Bayesian analysis on the test scans, classify those which we are confident on, and then use Non-Local Means technique to classify those cells which we are less confident on. (Received February 06, 2018)

1137-49-329 **Enrique G Alvarado*** (ealvarado9611@gmail.com), 435 NE Howard Street, #B, Pullman, WA 99163, and **Kevin R Vixie**. *A Lower Bound for the Reach of a Flat-Norm Minimizer.*

Given a closed curve in the plane that is given to us by the boundary of a set with finite perimeter, there is a smoothed out version of the curve that is given to us by applying the multi-scale flat norm to the curve; the

scale being λ. We show how we can get a lower bound (dependingon λ) on the reach of such a smoothed out object. (Received February 06, 2018)

1137-49-343 **Ebrahim Sarabi*** (sarabim@miamioh.edu), 410A E. Chestnut St., Oxford, OH 45056. *A Semismooth Inverse Mapping Theorem for $\mathcal{C}^{1+}$ Functions under Tilt Stability.*

Taking into account an unconstrained optimization problem with a $\mathcal{C}^{1+}$ objective function, we present a semismooth inverse mapping theorem for its tilt-stable local minimizers. Then we introduce a Newton method via the notion of the graphical derivative and will discuss its superlinear convergence for tilt-stable local minimizers of this problem. The talk is based on a joint work with Boris Mordukhovich. (Received February 06, 2018)

51 ► Geometry

1137-51-38 **Sebastián Reyes-Carocca*** (sebastian.reyes@ufrontera.cl), Avenida Francisco Salazar 01145, Temuco, Chile. *On the one-dimensional family of Riemann surfaces of genus q with $4q$ automorphisms.*

Bujalance, Costa and Izquierdo have recently proved that all those compact Riemann surfaces of genus $g \geq 2$ different from $3, 6, 12, 15$ and 30, with exactly $4g$ automorphisms form an equisymmetric one-dimensional family, denoted by $\mathcal{F}_g$.

In this talk, for every prime number $q \geq 5$, we shall explore further properties of each Riemann surface S in $\mathcal{F}_q$ as well as of its Jacobian variety JS.

(Received January 17, 2018)

1137-51-281 **Jerzy Kocik*** (jkocik@siu.edu), Department of Mathematics, SIU, Carbondale, IL 62901. *Apollonian coronas, spinor structures, tessellations and Epstein-like Zeta functions.*

The Descartes configuration of circles has a hidden sl(2) spinor structure. We shall present the "square root of Descartes formula" and show how it relates to certain plane tessellations. Also, with its help, the areas of Apollonian coronas will be evaluated in terms of certain series that resemble the Epstein Zeta functions. (Received February 05, 2018)

53 ► Differential geometry

1137-53-47 **Nicola Garofalo**, **Arshak Petrosyan** and **Mariana Smit Vega Garcia*** (marianag@uw.edu). *The singular free boundary in the thin obstacle problem.*

In this talk I will overview the thin obstacle problem for a divergence form elliptic operator, and I will describe a few methods used to tackle two fundamental questions: what is the optimal regularity of the solution, and what can be said about the singular free boundary in the case of zero thin obstacle, a problem that is related to the study of nodal sets of solutions to various equations. The proofs are based on Weiss and Monneau type monotonicity formulas. This is joint work with Nicola Garofalo and Arshak Petrosyan. (Received January 19, 2018)

1137-53-65 **Curtis Pro*** (cpro@csustan.edu) and **Fred Wilhelm**. *Extending a diffeomorphism finiteness theorem to dimension 4.*

In the early 90s, Grove, Petersen, and Wu, and independently Perelman, showed in dimensions different than 4, the conclusion of Cheeger's Finiteness Theorem still holds without the assumption of an upper curvature bound. Namely, given numbers $k \in \mathbb{R}, v, D > 0$, if $n \neq 4$, there are at most finitely many differentiable structures on the class of n-manifolds M that support metrics with $\sec M \geq k, \operatorname{vol} M \geq v$, and $\operatorname{diam} M \leq D$. In this talk, I'll present joint work with Fred Wilhelm that shows, with a new approach, the same is also true in dimension 4. (Received January 23, 2018)

1137-53-69 **Ailana Fraser***, University of British Columbia, and **Richard Schoen**, U.C. Irvine. *Shape optimization for an eigenvalue problem on manifolds with boundary.*

In this talk we will give an overview of progress that has been made on an extremal eigenvalue problem for surfaces with boundary, and contrast the two-dimensional case with some recent results in higher dimensions. (Received January 24, 2018)

1137-53-90 **Boris Botvinnik*** (botvinn@uoregon.edu), Department of Math., University of Oregon, Eugene, OR 97402. *Topology of spaces of metrics of positive scalar/Ricci curvature.*

Firs, I will review the Hitchin's index-difference map from the space $\mathcal{R}^{psc}(W^d)$ of psc-metrics to the real K-theory. In particular, we discuss the result by myself, J. Ebert and O. Randal-Williams that the index-difference map induces nontrivial homomorphism in homotopy groups $\pi_k\mathcal{R}^{psc}(W^d) \to KO_{k+d+1}$ are not trivial.

Next, I plan to discuss related recent results on the space of positive Ricci curvature. In particular, that some rational homotopy groups of the space $\mathrm{R}^{pRc}(W^d)$ of metrics with positive Ricci curvature, where $W^d = (S^n \times S^n)^{k\#}$ for some n and k. This work is joint with J. Ebert and D. Wraith. (Received January 28, 2018)

1137-53-97 **Pam Sargent*** (psargent@math.ubc.ca). *Index bounds for free boundary minimal surfaces of convex bodies.*

In this talk, we give a relationship between the eigenvalues of the Hodge Laplacian and the eigenvalues of the Jacobi operator for a free boundary minimal hypersurface of a Euclidean convex body. We then use this relationship to obtain new index bounds for such minimal hypersurfaces in terms of their topology. In particular, we show that the index of a free boundary minimal surface in a convex domain in $\mathbb{R}^3$ tends to infinity as its genus or the number of boundary components tends to infinity. (Received January 29, 2018)

1137-53-106 **Bradley Lewis Burdick*** (bburdick@uoregon.edu), Department of Mathematics, Fenton Hall, University of Oregon, Eugene, OR 97403. *Connected sums of Riemannian manifolds with positive Ricci curvature.*

Given two Riemannian manifolds with positive Ricci curvature, is it possible to find a metric on the connected sum that also has positive Ricci curvature? The general approach to questions of this type, following the Gromov-Lawson construction, is to find a local deformation of the metric so that the resulting metric is standard near a point and still has the desired curvature conditions. The Gromov-Lawson construction applied directly can be seen to leave positive Ricci curvature, and the source of this failure is that the choice of "standard" necessarily forces negative curvature.

In this talk, we will revisit a paper of Perelman, in which he constructs metrics with positive Ricci curvature on the connected sum of arbitrarily many complex projective planes. I will explain my recent work that generalizes this construction to metrics with positive Ricci curvature on arbitrary connected sums of complex, quaternionic, and octonionic projective spaces in every dimension. I will also explain Perelman's candidate for what "standard metric" we ought to use when considering a Gromov-Lawson approach to this problem. He showed that a local deformation exists in very special circumstance, to which I will add some further examples. (Received January 29, 2018)

1137-53-145 **Tracy Payne*** (payntrac@isu.edu), **Sara Ebrahimpour** and **Beau Hansen**. *Filiform Lie groups and their soliton metrics.* Preliminary report.

Nonabelian nilpotent Lie groups do not admit left-invariant Einstein metrics. However, they often admit soliton metrics, and by a result of J. Lauret, such nilpotent Lie groups always have solvable extensions that admit Einstein metrics. In this talk, we will survey the background and summarize main results in the area before we focus on the class of filiform nilpotent Lie groups. Filiform Lie groups are nilpotent Lie groups whose lower central series is as long as possible; i.e. having $n-2$ nontrivial groups if the group's dimension is n. We determine which filiform Lie groups in low dimensions and certain infinite classes admit soliton metrics. However, since filiform Lie groups are not classified, we also need to address the classification problem, and we classify rank one filiform Lie algebras in low dimensions and some other special classes. As a corollary, we can classify which solvable Lie groups in certain classes admit Einstein metrics. (Received February 01, 2018)

1137-53-151 **Po-Ning Chen***, poningc@ucr.edu. *Quasi-local energy in general relativity.*

In this talk, we will introduce a newly defined quasi-local energy for spacetimes with a non-zero cosmological constant using the Hamilton-Jacobi approach with the de-Sitter or the anti de-Sitter space as the reference space. We will describe the properties of the new quasi-local energy and compare them with earlier results on quasi-local energy without a cosmological constant.

The talk is based on joint work with Mu-Tao Wang and Shing-Tung Yau. (Received February 01, 2018)

1137-53-156 **Stephen Krughoff*** (krughofs@math.oregonstate.edu), Department of Mathematics, Kidder Hall 368, Oregon State University, Corvallis, OR 97331. *The topology of moduli spaces of planar pentagons with singularities.* Preliminary report.

We consider the topology of the space of polygons with fixed edge-lengths in the Euclidean plane, modulo orientation preserving isometries. The topology of such spaces does depend on the combinatorics of the fixed edge-lengths, but these spaces are generically manifolds. Kapovich and Millson studied these manifold topologies in 1995, and much of the subsequent research has focused on the manifold case. For certain edge-lengths, however, singularities can arise. In this talk I'll adapt Kapovich and Millson's techniques to study the possible singular topologies of moduli spaces of planar pentagons. (Received February 01, 2018)

1137-53-196 **McFeely Jackson Goodman*** (mcfeelyg@math.upenn.edu), Department of Mathematics, David Rittenhouse Lab., 209 South 33rd Street, Philadelphia, PA 19104. *On the Moduli Spaces of Metrics with Nonnegative Sectional Curvature.*

The Kreck-Stolz s invariant is used to distinguish connected components of the moduli space of positive scalar curvature metrics. We use a formula of Kreck and Stolz to calculate the s invariant for metrics on S^n bundles with nonnegative sectional curvature. We then apply it to show that the moduli spaces of metrics with non-negative sectional curvature on certain 7-manifolds have infinitely many path components. These include the first non-homogeneous examples of this type and certain positively curved Eschenburg and Aloff-Wallach spaces. (Received February 03, 2018)

1137-53-200 **Yu Yuan*** (yuan@math.washington.edu), University of Washington, Department of Mathematics Box 354350, Seattle, WA 98195. *Exterior Bernstein and Bernstein problems for Hessian equations.*

We survey some new and old rigidity results for Hessian equations such as special Lagrangian equations, Monge-Ampere equations, and symmetric Hessian equations. In particular, a unified approach to quadratic asymptote of solutions over exterior domains will be presented. Special Lagrangian and Monge-Ampere equations are the potential equations for minimal and maximal "gradient" graphs in Euclid and pseudo-Euclid spaces respectively. (Received February 04, 2018)

1137-53-227 **Ren Guo*** (guoren@oregonstate.edu). *Discrete conformal geometry of polyhedral surfaces.*

A polyhedral surface is a topological surface with constant curvature metric everywhere except at finite many points. On such a surface, discrete conformal geometry studies the relationship between some discrete metrics and curvatures, including metrics of inversive distance circle packing, combinatorial Yamabe flow and virtual radius circle packing. The background geometry on a polyhedral surface can be Euclidean, hyperbolic or spherical. All cases can be unified under one framework using variational principles. They also closely connect to the volume of hyperbolic polyhedra and the theory of Teichmüller space. (Received February 04, 2018)

1137-53-285 **Eric Bahuaud*** (bahuaude@seattleu.edu), **Christine Guenther** and **James Isenberg**. *Convergence stability for the Ricci flow.* Preliminary report.

Suppose that the solution to a geometric flow with initial metric g exists for all time and converges to a fixed-point geometry that is stable in an appropriate sense. We say the geometric flow is convergence stable if there is a neighborhood of the initial metric g (in an appropriate topology) such that the flow emanating from any metric in this neighborhood exists for all time and converges to a fixed-point geometry. In this talk we use semigroup methods to give a proof of continuous dependence of the Ricci flow in a certain topology, and then show that a Ricci flow converging to a flat metric on the 3-torus is convergence stable. We then explain our prospects for extending this result to noncompact manifolds. (Received February 06, 2018)

54 ► General topology

1137-54-84 **Robert M Owczarek*** (rowczare@unm.edu), 59 Coryphodon Ln, Jemez Springs, NM 87025. *In between dimensions: graphs and knots.* Preliminary report.

Some reflections on the relationships between graphs and knots, and so between geometric topology of 2D and 3D objects will be presented. (Received January 27, 2018)

1137-54-197 **Charles Camacho*** (camachoc@math.oregonstate.edu), 1605 East Olive Street, Apartment 208, Seattle, WA 98122. *Dessins d'Enfants, Topological Cyclic Actions on Surfaces, and Counting Quasiplatonic Surfaces.* Preliminary report.

A *quasiplatonic* group is a finite group G which acts topologically on a surface X whose orbit space X/G is homeomorphic to a sphere. Using results of R. Benim and A. Wootton, we present current work on formulas enumerating the distinct quasiplatonic topological actions of the cyclic group of order n on compact Riemann surfaces of genus at least two. We demonstrate the connections between counting group actions, distinguishing quasiplatonic surfaces, and enumerating regular dessins d'enfants (equivalently, hypermaps or bipartite maps) embedded on these surfaces. (Received February 03, 2018)

55 ► Algebraic topology

1137-55-83 **David Pengelley*** (davidp@nmsu.edu), Mathematics, Oregon State University, Corvallis, OR 97331. *How efficiently can one untangle a double-twist? Waving is believing!*

Physicists and mathematicians have long known it is possible to unravel a double-twist in three space, embodied in motions like the Dirac belt trick, Feynman plate trick, or Philippine candle dance. Quaternions can reveal how efficiently and beautifully this can be done, providing both theoretical constraints on the minimal required complexity, and insights into the geometry and level of simplicity possible. You will emerge knowing how to perform the quaternionic unraveling with your hand. (Received January 26, 2018)

1137-55-111 **Agnes Beaudry*** (agnes.beaudry@colorado.edu), Campus Box 395, Boulder, CO 80309-0001. *The Linearization Conjecture.* Preliminary report.

In this talk, I will discuss the Linearization Conjecture. This conjecture predicts the equivariant homotopy type of the functional dual of Morava E-theory, an object that plays a central role in chromatic homotopy theory. I will motivate the conjecture via an example from real Lie group theory.

The material in this talk is joint work with Paul Goerss, Mike Hopkins and Vesna Stojanoska (Received January 30, 2018)

1137-55-126 **David Ayala*** (david.ayala@montana.edu), **Aaron Mazel-Gee** and **Nick Rozenblyum**. *Geometry of cyclotomic trace.*

This talk will give an albro-geometric construction of the cyclotomic trace map from algebraic K-theory to topological cyclic homology. This construction is afforded through an articulation of stratified algebraic stacks via recollements.

This is a report on joint work with Aaron Mazel-Gee and Nick Rozenblyum. (Received January 31, 2018)

1137-55-130 **John A. Lind*** (lind@reed.edu). *Transfer maps in topological Hochschild homology.* Preliminary report.

A transfer map is a stable wrong-way map which exists under appropriate finiteness hypotheses and contains information related to Euler characteristics and indices. The transfer map in topological Hochschild homology (THH) is constructed using Morita theory, and is important because it is closely related to the transfer map in algebraic K-theory. An important example of the THH transfer is the transfer map of free loop spaces $LB_+ \to LE_+$ associated to a fibration $E \to B$ with finite CW complex fibers.

In previous work with C. Malkiewich, we gave a new construction of the transfer map in THH using K. Ponto's theory of traces for bicategories. In this talk, I will report on applications of our work to fixed point theory and string topology. (Received January 31, 2018)

1137-55-139 **Natsumi Oyamaguchi***, 1-1 Daigaku-cho, Yachiyo, Chiba 276-0003, Japan. *Trace Diagram and Biquandle Brackets.*

In this talk we introduce a method of computing biquandle brackets of oriented knots and links using a type of decorated trivalent spatial graphs we call trace diagrams. We identify algebraic conditions on the biquandle bracket coefficients for moving strands over and under traces and identify a new stop condition for the recursive expansion. In the case of monochromatic crossings we show that biquandle brackets satisfy a Homflypt-style skein relation and we identify algebraic conditions on the biquandle bracket coefficients to allow pass-through trace moves. This is a joint work with Sam Nelson. (Received January 31, 2018)

1137-55-210 **Viktor Kleen*** (kleen@usc.edu), 3620 S Vermont Avenue, USC Department of Mathematics, KAP104, Los Angeles, CA 90089. *Hopf Invariants in Motivic Homotopy Theory.* Preliminary report.

I will give an introduction to Hopf invariants in unstable motivic homotopy theory. Their use was first introduced in the work of Asok, Wickelgren and Williams on the EHP sequence in $\mathbb{A}^1$-homotopy theory. Classically, Hopf invariants were used by James and Toda to prove primary exponent theorems for homotopy groups of spheres. In the motivic world, it is known that an exact analogue of these theorems cannot hold. A natural question would be to what extent similar statements about motivic spheres can be made and where the classical methods break down. I will give an overview of classical primary exponent theorems and outline possible generalizations to the motivic setting. (Received February 04, 2018)

1137-55-289 **Jeremiah Heller** and **Marc Stephan*** (mstephan@math.ubc.ca). *Interactions between $(\mathbb{Z}/p)^n$-actions and commutative algebra.*

Carlsson conjectured that if a finite CW complex admits a free action by an elementary abelian p-group of rank n, then the sum of its mod-p Betti numbers is at least 2^n. For the prime $p = 2$, he reformulated the conjecture as a problem about DG modules over the polynomial ring and established it for small n.

In this talk, I will discuss the connections to commutative alebra, then I will review recent counterexamples to an algebraic version of the conjecture at odd primes due to Iyengar and Walker. To conclude, I will explain how to extend Carlsson's reformulation to all primes. (Received February 05, 2018)

1137-55-291 **Qingying Deng*** (814251161@qq.com), 1111 south laflin street, AP 1610, chicago, IL 60607, and **Xian'an Jin** and **Louis H Kauffman**. *Graphical virtual links and a polynomial of signed cyclic graphs.*

For a signed cyclic graph G, we can construct a unique virtual link L by taking the medial construction and convert 4-valent vertices of the medial graph to crossings according to the signs. If a virtual link can occur in this way then we say that the virtual link is *graphical*. In the article we shall prove that a virtual link L is graphical if and only if it is checkerboard colorable. On the other hand, we introduce a polynomial $F[G]$ for signed cyclic graphs, which is defined via a deletion-marking recursion. We shall establish the relationship between $F[G]$ of a signed cyclic graph G and the bracket polynomial of one of the virtual link diagrams associated with G. Finally we give a spanning subgraph expansion for $F[G]$. (Received February 05, 2018)

1137-55-292 **Leanne Elizabeth Merrill*** (merrill@wou.edu). *Periodic Margolis Self Maps at $p = 2$.* Preliminary report.

The Periodicity theorem tells us that any finite spectrum supports a v_n-map for some n. We are interested in finding finite 2-local spectra that both support a v_2-map with a low power of v_2 and have few cells. Following the process outlined by Palmieri and Sadofsky, we study a related class of self-maps, known as u_2-maps, between stably finite spectra. We construct examples of spectra that might be expected to support u_2^1-maps, and then we use Margolis homology and homological algebra computations to show that they do not support u_2^1-maps. We also show that one example does not support a u_2^2-map. The nonexistence of u_2-maps on these spectra eliminates certain examples from consideration by this technique. (Received February 05, 2018)

1137-55-294 **Krishanu Roy Sankar*** (sankark1991@gmail.com), 3550 W 1st Avenue, Vancouver, BC V6R 1G8, Canada. *Steinberg summands and symmetric powers of the equivariant sphere spectrum.*

The mod p Steenrod algebra is the (Hopf) algebra of stable operations on mod p cohomology. This algebra can be computed in several possible ways: one way is to filter the Eilenberg-Maclane spectrum $H\mathbb{F}_p$ using the finite symmetric powers of the sphere spectrum. The cofibers of this filtration are Steinberg summands (from the representation theory of $\mathrm{GL}_k(\mathbb{Z}/p)$) of the classifying spaces $B(\mathbb{Z}/p)^k$.

Our main result is to lift this to G-equivariant stable homotopy theory, where G is any finite abelian p-group (the main case of interest being a cyclic p-power group). We can thus compute the G-equivariant Steenrod algebra by decomposing the G-equivariant classifying space of $\mathbb{Z}/p$ - we'll describe this computation for $G = C_p$. When $p = 2$ and $G = C_2$, the equivariant dual Steenrod algebra is known due to Hu-Kriz and others, but at odd primes this is new. If there is time, we will then discuss a conjectured construction of the equivariant analogues of the Milnor operations (the indecomposables in the dual Steenrod algebra), as well as some current applications in homotopy theory. (Received February 05, 2018)

1137-55-301 **Courtney M Thatcher*** (cthatcher@pugetsound.edu) and **Jim Fowler** (fowler@math.osu.edu). *Free $\mathbb{Z}/p \times \mathbb{Z}/p$ actions on $S^n \times S^n$.* Preliminary report.

The topological spherical space form problem asks what groups can act freely on the sphere, and how can the finite group actions be classified? Smith (1944) and Milnor (1957) discovered necessary conditions for a group to act freely, and Madsen, Thomas, and Wall (1978) showed these conditions to be sufficient. A natural extension asks what groups can act on products of spheres, and how do they act? For $S^n \times S^n$ specifically, it has been shown that a group acting freely can have rank at most 2, but A_4 cannot act. The question of what the correct conditions are remains open.

This talk considers the case of $\mathbb{Z}/p \times \mathbb{Z}/p$ actions on $S^n \times S^n$. We will discuss how the group can act, and what that tells us about conditions for larger groups that contain $\mathbb{Z}/p \times \mathbb{Z}/p$ as a subgroup to act freely. (Received February 06, 2018)

1137-55-330 **Elden Elmanto*** (eldenelmanto@gmail.com), 2033 Sheridan Road, Evanston, IL 60208, and **Jay Shah**. *Some Remarks on Real Topoi and Real Motives.* Preliminary report.

There are strong analogies between C_2-equivariant homotopy theory and motivic homotopy theory over the reals. In the former theory, one can describe the ∞-category of genuine C_2-spectra in terms of Borel equivariant spectra and classical spectra using the language of "recollement." We examine these analogies in the setting of algebraic geometry, thinking of the the former as "etale" and the latter as "real-etale." Pursuing this line of thought, two pictures seem to emerge.

In the unstable situation, taking the homotopy C_2-fixed points of the ∞-topos of etale sheaves on a $X_{\mathbb{C}}$ where X is an $\mathbb{R}$-variety gives the real-etale ∞-topos of X. This enhances results of Scheiderer to a homotopy coherent setting. In the stable case, we give a description of the derived category of Voevodsky motives in terms of etale motives, real etale motives and "b-motives" using Suslin's rigidity and Bachmann's theorem on real etale motivic homotopy. Time permitting, we also speculate on further generalizations of these results.

This is joint work in progress with Jay Shah. (Received February 06, 2018)

1137-55-344 **Brittany Terese Fasy*** (brittany@cs.montana.edu), 363 Barnard Hall, Bozeman, MT 59717. *Functional Summaries of Persistence Diagrams.*

The main object of study in applied algebraic topology is the persistence diagram However, persistence diagrams do not lend themselves naturally to statistics, as common algebraic operations–such as addition, division, and multiplication–are challenging (e.g., the mean might not be unique). Thus, we extend our investigation to consider functional summaries of persistence diagrams such as Landscapes and Silhouettes. Functional summaries map a persistence diagram into a function. Then, the problem of analyzing a set of diagrams becomes the problem of analyzing a set of functions, which is a topic that has been studied for decades in statistics. We establish. a generalized collection of functional summaries, and to analyze their statistical aspects.

This is joint work with Eric Berry, Jessi Ciseweski, and Yen-Chi Chen. (Received February 06, 2018)

1137-55-361 **Bjorn I. Dundas**, **Michael A. Hill*** (mikehill@math.ucla.edu), **Kyle M. Ormsby** and **Paul Arne Østvaer**. *Motivic Hochschild homology of Eilenberg-Mac Lane spectra.* Preliminary report.

I will discuss some recent computations of the topological Hochschild homology of certain motivic Eilenberg-Mac Lane spectra as functors of the underlying field. (Received February 07, 2018)

57 ▶ Manifolds and cell complexes

1137-57-56 **Louis H Kauffman*** (kauffman@uic.edu), Louis H Kauffman, Apartment 7C, 5530 South Shore Drive, Chicago, IL 60637-1946. *Khovanov Homology for Knotoids.* Preliminary report.

This talk will discuss the structure of Khovanov homology for knotoids. Knotoids are knot or link diagrams with ends so that the ends can be in different regions of the diagram. The diagrams are taken up to Reidemeister moves that do not pass arcs across the ends of the diagram. (Received January 22, 2018)

1137-57-91 **Alexandra Kjuchukova*** (kjuchukova@wisc.edu), 480 Lincoln Dr, Madison, WI 53706, and **Sebastian Baader**. *Symmetric quotients of knot groups and the Gordian graph.*

The classical Fox p-colorings of knot diagrams capture the existence of homomorphisms from knot groups to the dihedral group D_p. I will discuss colorings of knot diagrams which capture homomorphisms to the symmetric group S_n. Specifically, I will focus on $\binom{n}{2}$-colorings, which encode homomorphims mapping meridians of the knot to transpositions in the symmetric group. I will use these colorings to prove the existence of a 1-dense metric filtration of the Gordian graph. $\binom{n}{2}$-coloring are also a powerful tool for obtaining strong lower bounds on the meridional rank (and bridge number) of knots.

This is joint work with Sebastian Baader.

(Reference: https://arxiv.org/abs/1711.08144) (Received January 28, 2018)

1137-57-110 **Oliver Dasbach**, **Adam Lowrance** and **Heather M. Russell*** (hrussell@richmond.edu). *Region crossing change for links on surfaces.* Preliminary report.

A region crossing change (RCC) reverses all crossings incident to a region of a link diagram. For diagrams in the plane, Shimizu showed that RCC is an unknotting operation, and Cheng-Gao analyzed which link diagrams in the plane can be unlinked via RCC. In recent work with Dasbach, we investigate checkerboard colorable diagrams on closed, orientable surfaces providing a formula for the number of equivalence classes of such diagrams under

RCC. This result requires us to compute the kernel of a certain map on homology. Together with Lowrance and Dasbach, our current aim is to extract the meaning of this result on the level of diagrams and eventually find direct diagrammatic methods for answering RCC-related questions. (Received January 30, 2018)

1137-57-120 **Jozef H. Przytycki** and **Xiao Wang*** (wangxiao@gwmail.gwu.edu). *Computing Khovanov homology via Hochschild homology.*

The relationship between Khovanov homology and Hochschild homology was pointed out by Przytycki in May of 2005. We generalize this idea and compute Khovanov homology for more links by using Hochschild. (Received January 30, 2018)

1137-57-121 **Sujoy Mukherjee*** (sujoymukherjee@gwu.edu) and **Jozef H. Przytycki** (przytyck@gwu.edu). *The graphic axiom and self-distributivity.* Preliminary report.

Shelves, racks, spindles, and quandles are algebraic structures with axioms inspired by the Reidemeister moves in knot theory. The graphic axiom, $a * b = (a * b) * a$ was introduced by F. W. Lawvere in 1987 while studying graphic monoids.

Certain quandles satisfying the graphic axiom have interesting properties. In this talk, we will study these quandles from the point of rack and quandle homology. (Received January 30, 2018)

1137-57-133 **Rhea Palak Bakshi*** (rhea_palak@gwu.edu), **Józef H. Przytycki** (pryzytyck@gwu.edu), **Marithania Silvero** (marithania@us.es) and **Xiao Wang** (wangxiao@gwu.edu). *Multiplying links in the thickened sphere with four holes.* Preliminary report.

In 1987, Józef H. Przytycki introduced Skein Modules as a way to extend the knot polynomials of the 1980's to knots and links in arbitrary 3-manifolds. Since their introduction, Skein Modules have become central in the theory of 3-manifolds.

In 1997, Frohman and Gelca gave a nice product-to-sum formula for the Kauffman Bracket Skein Algebra (KBSA) of $T^2 \times [0,1]$. We try to discover a similar formula for the multiplication of links in the KBSA of $F_{0,4} \times [0,1]$, the thickened sphere with four holes. We will present partial results for this case. (Received January 31, 2018)

1137-57-140 **Thomas W. Tucker*** (ttucker@colgate.edu), 406 Williston, PO Box 163, Sagamore Beach, MA 02562. *Unfaithful Maps.* Preliminary report.

A map M on a closed surface is *unfaithful on vertices (respectively, edges or faces)* if $Aut(M)$ has a non-identity element that fixes every vertex (respectively, edge or face). For example, an n-cycle in the sphere is unfaithful on both vertices and faces. in fact, it is *simultaneously* unfaithful on vertices and edges, since there is a non-identity automorphism that fixes every vertex and every edge. When n is odd, the Petrie dual of this map has only one face, so it is simultaneously unfaithful on vertices, edges, and faces. We classify maps that are unfaithful on vertices, maps that are unfaithful on edges, maps that are simultaneously unfaithful on both vertices and faces. All these maps involve multiple edges or loops in the primal or dual map. (Received January 31, 2018)

1137-57-235 **Jozef H. Przytycki*** (przytyck@gwu.edu), Phillips Hall 801 22nd St. NW Washington, Washington, DC 20052. *Kauffman Bracket Skein Algebras: Old and New.*

I will outline the history of the Kauffman Bracket Skein Algebras from Summer 1985 and Kauffman discovery of his bracket, via my definition of Kauffman bracket skein module in April 1987, my work with Jim Hoste, Doug Bullock, and Adam Sikora till the recent work with Mathathoners (Marithania, Rhea, Sujoy, and Xiao) on product to sum formulas. (Received February 05, 2018)

1137-57-236 **Carmen Caprau***, Department of Mathematics, California State University, Fresno, 5245 N. Backer Avenue M/S PB 108, Fresno, CA 93740. *From trivalent tangles to handlebody-tangles and their invariants.* Preliminary report.

We use trivalent tangles and classical knot theory to provide a recipe for constructing invariants of knotted trivalent graphs and handlebody-tangles. (Received February 05, 2018)

1137-57-237 **Giang Le*** (giangl@oregonstate.edu). *Action dimensions of some simple complexes of groups.*

The action dimension of a discrete, torsion-free group G is the smallest dimension of a model for its classifying space BG by a manifold. In other words, action dimension of G is the minimum dimension of the thickening of a CW model for BG to a manifold, possibly with boundary. We compute the action dimension of some simple complexes of groups, in particular, of the fundamental groups of aspherical complements of arrangements of affine hyperplanes. This is a joint work with M. Davis and K. Schreve. (Received February 05, 2018)

1137-57-243 **Daniel S Silver** and **Susan G Williams*** (swilliam@southalabama.edu). *Tangles and links: a view with trees.*

In 1999, D. Krebes used the Kauffman bracket and skein theory to show that if a tangle T embeds in a link ℓ, then the determinant of ℓ is divisible by the gcd of the determinants of the numerator and denominator closures of T. D. Ruberman later gave a proof using homology of branched cyclic covers. We give a short proof using an elementary result about spanning forests for graphs. We also recover an analogous result about 6-tangles that first appeared in the authors' 2005 paper with J. Przytycki. (Received February 05, 2018)

1137-57-244 **Daniel S Silver*** (silver@southalabama.edu), Department of Mathematics and Statistics, University of South Alabama, Mobile, AL 36688, and **Susan G Williams** (swilliam@southalabama.edu), Department of Mathematics and Statistics, University of South Alabama, Mobile, AL 36688. *Three Flavors of Knot Group Presentations.* Preliminary report.

The fundamental group G of the exterior of a knot — the knot group — is usually described by a Wirtinger presentation of a plane diagram. Here generators of G correspond to arcs of the diagram while relations are read from the crossings. Less common but also well known is the Dehn presentation of G with generators (resp. relators) corresponding to regions (resp. crossings). We introduce a third type of knot group presentation inspired by the 1926/27 paper of J.W. Alexander and G.B. Briggs. The Alexander-Briggs presentation of G has generators corresponding to crossings and relations corresponding to regions of the diagram. (Received February 05, 2018)

1137-57-245 **Uwe Kaiser*** (ukaiser@boisestate.edu), Department of Mathematics, Boise State University, 1910 University Drive, Boise, ID 83725. *Spaces of Immersions of Circles in 3-manifolds and Skein Theory.* Preliminary report.

We study the spaces of immersions of unions of circles in oriented 3-manifolds. Using transversality we define a 2-groupoid *deforming* the fundamental 2-groupoid, and study presentations of it. We also define graded and bordism versions of the groupoid. A general algebraic framework for linearization and *representation* of 2-groupoids is related to completions of Conway-type skein modules of oriented and singular links. We also describe how Jones-type skein modules can be described using local systems on the mapping spaces. Finally we define certain lifts and extensions of Chas-Sullivan's string topology operations and corresponding relations for presentations of the completed skein modules. If time permits we speculate on higher categorical structures derived from the mapping spaces using transversality. (Received February 05, 2018)

1137-57-251 **Mustafa Hajij***, University of South Florida, Tampa, FL, and **Khaled Bataineh**, **Mohamed Elhamdadi** and **Sam Nelson**. *Singular Knots and Quandles.*

We give a generating set of the generalized Reidemeister moves for oriented singular links. We use it to introduce an algebraic structure arising from the study of oriented singular knots: Quandles on singular knots. We also give the version for this structure when the knots are unoriented. We give non-trivial examples of such structures and we illustrate their utilization in singular knot classification. (Received February 05, 2018)

1137-57-272 **Jozef H. Przytycki*** (przytyck@gwu.edu), Department of Mathematics CCAS, Washington, DC 20052. *How to define homology for non-associative structures.*

I will discuss several examples of constructions of homology theories with motivation by link invariants and structure extensions (abelian or affine). Homology of entropic magma $(a*b)*(c*d) = (a*c)*(b*d)$ is a nice example illustrating our approach. (Received February 05, 2018)

1137-57-290 **Mauricio Gomez Lopez*** (megomezl@uoregon.edu), 1 Deady Hall, University of Oregon, Eugene, OR 97403. *The homotopy type of the topological cobordism category.* Preliminary report.

The goal of this talk is to report on the progress of a joint project with A. Kupers in which we aim to prove a topological version of the groundbreaking result of Galatius, Madsen, Tillman, and Weiss which describes the homotopy type of the smooth cobordism category. More specifically, in this talk, I will introduce a cobordism category of topological manifolds and explain how one can prove that its classifying space is weak homotopy equivalent to the infinite loop space associated to a particular Thom spectrum. This talk will also include a brief overview of some of the standard tools from the theory of topological manifolds, such as smoothing theory and microbundles. (Received February 05, 2018)

1137-57-295 **Kanako Oshiro*** (oshirok@sophia.ac.jp) and **Atsushi Ishii**. *Link invariants obtained from augmented Alexander matrices.*

An augmented Alexander matrix can be obtained from a link diagram equipped with a quandle coloring. It is an generalization of the Alexander matrix. By taking some information from an augmented Alexander matrix, we can construct several link invariants such as Alexander polynomials. In this talk, we will show some calculation examples of our invariants for some knots. (Received February 05, 2018)

1137-57-297 **Patricia Cahn*** (pcahn@smith.edu) and **Alexandra Kjuchukova**. *Ribbon Obstructions and Colored Tri-Plane Diagrams.*

Consider a four-manifold Y which is presented as a p-fold dihedral branched cover of S^4, with one singularity on the branching set, modeled on the cone on a knot K. Kjuchukova showed that the signature of Y is an invariant of K. We show that this signature is a ribbon obstruction, and give an algorithm for computing this signature from a p-colored knot diagram of K. We use colored tri-plane diagrams to identify the diffeomorphism type of the cover for given families of singularities. In particular, we construct infinitely many singular dihedral covers of S^4 by CP^2. We conclude by giving a classification of singular dihedral branched covering maps from CP^2 to S^4, and explain the implications of this classification for finding potential counterexamples to the Slice-Ribbon Conjecture (Received February 05, 2018)

1137-57-351 **Krzysztof K. Putyra** and **Alexander N. Shumakovitch*** (shurik@gwu.edu), 801 22nd St. NW, Phillips Hall, Suite 739, Department of Mathematics, The George Washington University, Washington, DC 20052. *On computations of Khovanov homology over the group ring $\mathbb{Z}\mathbb{Z}_2$.* 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 $\mathbb{Z}\mathbb{Z}_2$. The goal of this talk is to show how to find these modules and to compare unified Khovanov homology for different knots and links. We start with a convenient pullback presentation of these modules to show that they are always separated. Consequently, there exist an explicit algorithmic procedure for representing them as a direct product of indecomposables. The algorithm relies on the classification of indecomposable $\mathbb{Z}\mathbb{Z}_2$-modules due to Lawrence S. Levy. Finally, we present numeric evidence that the unified Khovanov homology is a stronger knot invariant than the even and odd Khovanov homology combined. (Received February 06, 2018)

58 ► Global analysis, analysis on manifolds

1137-58-191 **Teresa Arias-Marco**, **Emily Dryden**, **Carolyn Gordon**, **Asma Hassannezhad**, **Allie Ray** and **Elizabeth Stanhope*** (stanhope@lclark.edu). *Upper bounds on the Steklov eigenvalues of an orbifold.* Preliminary report.

The Steklov spectrum of a Riemannian orbifold with boundary is the eigenvalue spectrum of the Dirichlet-to-Neumann operator associated to the orbifold. This operator has applications in electrical impedance tomography, for example. We discuss two approaches to obtaining upper bounds on Steklov eigenvalues in terms of the geometry and topology of the orbifold. The first generalizes work of B. Colbois, A. El Soufi, A. Girouard and A. Hassannezhad to the orbifold setting, and the second examines extensions of Weinstock's inequality to orbifolds. (Received February 03, 2018)

1137-58-194 **Teresa Arias-Marco**, **Emily Dryden**, **Carolyn Gordon**, **Asma Hassannezhad**, **Allie Ray** and **Elizabeth Stanhope*** (stanhope@lclark.edu). *Can we detect the geometry and topology of an orbisurface from its Steklov spectrum?*

Motivated by work of Girouard, Parnovski, Polterovich and Sher, we use the asymptotics of the Steklov spectrum of a 2-orbifold to study the geometry and topology of the orbifold. We show that the Steklov spectrum determines the topology of the boundary of the orbifold, as well as the geometry of the boundary up to an equivalence relation. We also construct examples of Steklov isospectral orbifolds that provide, for example, a 2-orbifold counterexample to a problem closely related to the inverse tomography problem. (Received February 03, 2018)

1137-58-358 **Rafe Mazzeo*** (rmazzeo@stanford.edu), Department of Mathematics, Stanford University, Stanford, CA 94305. *Perspectives on localized gluing.* Preliminary report.

The technique of localized gluing, introduced by Corvino and extended by Corvino-Schoen, Chrusciel-Delay, Carlotto-Schoen and others, has had significant impact in relativity. This talk will explain some perspectives that have actually been around for many years which may elucidate the analysis needed to carry out localized gluing and help extend it to new settings. (Received February 07, 2018)

60 ► Probability theory and stochastic processes

1137-60-96 **Runhuan Feng***, 1409 W Green St., Urbana, IL 61822, and **Alexey Kuznetsov** (kuznetsov@mathstat.yorku.ca) and **Fenghao Yang**. *Exponential functionals of Lévy processes and variable annuity guaranteed benefits.*

Exponential functionals of Brownian motion have been extensively studied in financial and insurance mathematics due to their broad applications, for example, in the pricing of Asian options. The Black-Scholes model is appealing because of mathematical tractability, yet empirical evidence shows that geometric Brownian motion does not adequately capture features of market equity returns. One popular alternative for modeling equity returns consists in replacing the geometric Brownian motion by an exponential of a Lévy process. In this paper we use this latter model to study variable annuity guaranteed benefit s and to compute explicitly the distribution of certain exponential functionals. (Received January 29, 2018)

1137-60-98 **Xueying Wang***, Department of Mathematics and Statistics, Washington State University, Pullman, 99164, and **Pauline van den Driessche**. *Stochastic Models of Bovine Babesiosis With Juvenile Cattle.*

Bovine Babesiosis is a tick borne parasitic disease, which renders more than 1.3 billion bovines at potential risk of being infected worldwide. This work is devoted to stochastic models of Bovine Babesiosis, with a focus on the disease extinction and outbreak and probability distribution of the infectious adult bovine and that of infectious ticks. The stochastic models are a system of continuous time Markov chains derived based on the dynamics of deterministic ordinary differential equation models, i.e., Model J in Saad-Roy et al. (BMB, 2015) and Model Aranda et al. (Math Methods Appl Sci, 2012) (which is a special case of Model J). The multitype branching process approximation is used to estimate the probability of disease extinction/outbreak. Unlike the deterministic dynamics that indicate the basic reproduction number R_0 serves a sharp disease threshold (i.e., if R_0 is less than or equal to the unity, the disease dies out; if R_0 is above the unity, the disease is uniformly persist and becomes established, in Saad-Roy et al. (BMB, 2015)), our stochastic models indicate, more realistically, that there is always a positive probability that disease extinction within both cattle and tick populations. This is joint work with Pauline van den Driessche. (Received January 29, 2018)

1137-60-204 **Sooie-Hoe Loke*** (lokes@cwu.edu), Department of Mathematics, 400 East University Way, Ellensburg, WA 98926, and **Florin Avram**. *On central branch/reinsurance risk networks: exact results and heuristics.*

Modeling the interactions between a reinsurer and several insurers, or between a central management branch (CB) and several subsidiary business branches, or between a coalition and its members, are fascinating problems, which suggest many interesting questions. Beyond two dimensions, one cannot expect exact answers. However, reductions to one dimension or heuristic simplifications allow occasionally getting explicit approximations, which may be useful for getting qualitative insights. Here, we consider a ruin problem for a two-dimensional CB network, under a new mathematical model which combines a bail-out model with an older model involving proportional reinsurance. The motivation is to investigate how a CB should combine distress bail-outs with continuous risk-sharing of the type used in reinsurance, and in particular with the simplest proportional reinsurance, which leads sometimes to exact solutions. (Received February 04, 2018)

1137-60-250 **Sean D Lawley*** (lawley@math.utah.edu), **James P Keener**, **Alla Borisyuk** and **Gregory Handy**. *The curiously strong impact of recharging enzymes, receptors, and predators.*

In phosphorylation reactions, enzymes are inactive for a transitory "recharge" time following each substrate modification. A similar scenario occurs in neuroscience, in which synaptic receptors cannot bind neurotransmitters continuously, but rather must "recharge" after each binding. In ecology, this recharge time is called handling time, and it is the time a predator takes to process captured prey before it hunts additional prey.

In this talk, we formulate and analyze mathematical models of these systems. For enzymatic reactions, we use probabilistic methods to incorporate the spatio-temporal effects of recharge into simple ordinary differential equation models. In contrast, previous work has resorted to computationally expensive agent-based spatial simulations. We use this analysis to predict how reactions on cell membranes compare to reactions in cytoplasm. Moving to recharging receptors, we prove that the number of molecules that bind to receptors grows only logarithmically in the number of released molecules for any nonzero recharge time, whereas the growth is linear in the absence of recharge. We discuss implications of this result in neuroscience and ecology, including a system in which recharge reduces neurotransmitter bindings by several orders of magnitude. (Received February 05, 2018)

62 ► Statistics

1137-62-93 **Amelia Taylor*** (ajt@ameliajtaylor.com). *Transitioning from Commutative Algebra to Data Science, Robots and Biology.*

In summer 2016 I was selected to be an Insight Data Science Fellow and through that started working as a data scientist at Zymergen after nearly 20 years in academic mathematics with a research focus in commutative algebra. I will talk about that decision, how my most recent mathematical research fits in, and my mathematical life at Zymergen where we integrate robotics, software and biology to provide predictability and reliability to the process of rapidly improving microbial strains through genetic engineering, and I solve a surprising number of mathematics problems. (Received January 28, 2018)

1137-62-323 **Humberto C Godinez*** (hgodinez@lanl.gov), Los Alamos National Laboratory, Applied Mathematics and Plasma Physics, MS B284, Los Alamos, NM 87545. *Application of Koopman Operators for Data Assimilation.*

Data assimilation are methods that combine information from a model and observations to produce a accurate forecast or prediction of the phenomena of interest. There are various assimilation methods ranging from variational to ensemble and Monte Carlo approaches. Common among them is the high computational cost due to model simulation. In order to reduce the computational burden of assimilating data into large-scale systems, spectral decomposition methods are used to to define a subspace that reduces the dimension of the problem. In this talk we use a recent decomposition technique based on the Koopman operator and present how it applied to data assimilation methods. We use the eigenmodes defined by the Koopman operator that represent the non-linear behavior of a dynamical system for the assimilation of data into a shallow water model, and compare its performance with other subspace projections methods. (Received February 06, 2018)

65 ► Numerical analysis

1137-65-27 **Malgorzata Peszynska*** (mpesz@math.oregonstate.edu), Mathematics, Oregon State University, Corvallis, OR 97331. *Phase field model for mixtures: convexity and regularity.* Preliminary report.

In this talk we discuss a phase-field model for two-component mixture of methane and water which under low temperature and high pressure conditions can exist either in liquid or crystal (hydrate) phase. The model, originally proposed by [Tegze et al, 2010] is a gradient flow of an energy functional, with degenerate mobilities. We discuss appropriate convexity conditions, and the degenerate and singular advection-diffusion-reaction equation which governs the migration of methane across the phase interface. If time allows, we present numerical simulations. (Received January 13, 2018)

1137-65-30 **Maxim Olshanskii*** (molshan@math.uh.edu). *A finite element method for the Stokes problem posed on a surface.*

We consider a Stokes problem posed on a 2D surface embedded in a 3D domain. The equations describe an equilibrium area-preserving tangential flow of a viscous surface fluid and serve as a model problem in the dynamics of material interfaces. We develop and analyze a Trace finite element method (TraceFEM) for such a surface Stokes problem. TraceFEM relies on finite element spaces defined on a fixed, surface-independent background mesh which consists of shape-regular tetrahedra. Thus, there is no need for surface parametrization or fitting surface with the mesh. The TraceFEM discussed in the talk is based on P1 bulk finite elements for both the velocity and the pressure. (Received January 14, 2018)

1137-65-58 **Azhar Saeed Alhammali*** (alhammaz@oregonstate.edu), 2000 SW Campus way, Corvallis, OR 97331, and **Malgorzata Peszynska** (mpesz@math.oregonstate.edu), 2000 SW Campus way, Corvallis, OR 97331. *Analysis and numerical analysis of a coupled system for biofilm growth.*

We consider a coupled system of nonlinear parabolic partial differential equations solved for unknowns B and N. The first unknown B is subject to constraints; thus, the first equation is a parabolic variational inequality. The second equation is not constrained. The equations are coupled by the right-hand side growth and consumptions terms, which are Lipschitz in both variables. In the talk, we first present the well-posedness of the weak formulation of the problem. Next, we discuss the finite element discretization in space and backward Euler discretization in time of the problem. Furthermore, we discuss the solver. (Received January 22, 2018)

1137-65-129 **Brittany A Erickson*** (berickson@pdx.edu) and **Leif Karlstrom**. *A Linearized Stability Analysis of Acoustic-gravity Waves in a Volcanic Conduit with a Spatially Variable Background State.*

Explosive volcanic eruptions involve the ascent of multiphase magma through crustal conduits towards Earth's surface at sufficiently high rates that the mixture fragments from a suspension of bubbles and crystals in a melt to a mixture of liquid and solid fragments in a gas. Eruptions are largely driven by the growth and expansion of bubbles during ascent which may accelerate the flow to high speeds, up to or perhaps even exceeding the fluid sound speed. Here we consider short-time, unsteady behavior during explosive volcanic eruptions by considering perturbations to a steady state, fragmenting flow of bubbles and liquid through an axisymmetric conduit. We study flow stability in the presence of small amplitude mechanical disturbances. The linearized governing equations form a set of hyperbolic partial differential equations that describe wave motion in an accelerating flow with strongly variable material properties, within a conduit of non-constant cross sectional area. The equations are solved numerically by applying a finite difference discretization with weak enforcement of boundary conditions (that leads to a provably stable method) and an eigenmode analysis determines the stability of perturbations to various background states. (Received January 31, 2018)

1137-65-174 **Jeffrey S Ovall***, Portland State University, PO Box 751, and **Akash Anand**, **Steffen Weisser** and **Samuel Reynolds**. *A Trefftz-Nyström method for finite elements on (curvilinear) polygonal meshes.*

In the past several years there has been a surge in the development of finite element methods on meshes whose cells are allowed to be general polytopes. In this talk we consider families of finite elements on (curvilinear) polygonal meshes, that are defined implicitly on each mesh cell as solutions of local Poisson problems. We will discuss some of the relevant theoretical and computational features of working with such function spaces, and describe a practical approach for finite element computations in these spaces. Numerical examples will be provided that illustrate many of the features we have highlighted. (Received February 02, 2018)

1137-65-176 **Timothy Meagher*** (meagher@pdx.edu) and **Bin Jiang** (bjiang@pdx.edu). *A New Finite Difference Time Domain Method to Solve Maxwell's Equations.*

We have constructed a new Finite Difference Time Domain (FDTD) method in this project. Our new algorithm focuses on the most important and most challenging transverse electric (TE) case. Our new algorithm is built based upon the integral version of the Maxwell's equations as well as the above continuity conditions. The theoretical analysis shows that the new algorithm can reach second-order convergence $\mathcal{O}(\Delta x^2)$ with mesh size Δx. The subsequent numerical results demonstrate this algorithm is very stable and its convergence order can reach very close to second order, considering accumulation of some unexpected numerical approximation and truncation errors. In fact, our algorithm has clearly demonstrated significant improvement over all related FDTD methods using effective permittivities reported in the literature. Therefore, our new algorithm turns out to be the most effective and stable FDTD method to solve Maxwell's equations involving multiple media. (Received February 02, 2018)

1137-65-183 **Reza Mollapourasl*** (mollapor@oregonstate.edu), **Majid Haghi** and **Ruihua Liu** (rliu01@udayton.edu). *Localized meshfree method for pricing financial options under regime switching jump diffusion model.*

In this work, we consider European and American option pricing problems under regime switching jump diffusion models which are formulated as a system of partial integro-differential equations (PIDEs) with fixed and free boundaries. For free boundary problem arisen in pricing American option, we use operator splitting method to deal with early exercise feature of American option. For developing a numerical technique we employ localized radial basis function generated finite difference (RBF-FD) approximation to overcome the ill-conditioning and high density issues of discretized matrices. The proposed method leads to linear systems with tridiagonal and diagonal dominant matrices. Also, stability of the proposed method is discussed and the second order in time and space convergence rate are derived. Numerical examples are presented to illustrate the robustness and practical performance of the proposed algorithm for pricing European and American options. (Received February 03, 2018)

1137-65-214 **Robert L. Higdon*** (higdon@math.oregonstate.edu), Department of Mathematics, Kidder Hall 368, Oregon State University, Corvallis, OR 97331-4605. *Automatic Well-Balancing in a Formulation of Pressure Forcing for Discontinuous Galerkin Modeling of Oceanic Flows.*

During the development of a Galerkin numerical method, a beginning step is to multiply by a test function and integrate by parts. The goal of the present talk is to show that this process can be used to overcome a standard difficulty that is encountered with the shallow water equations, a system of partial differential equations that arises in various circumstances in geophysical fluid dynamics. In the case of variable bottom topography, the usual formulation of this system includes a static forcing term that must be implemented carefully in order to avoid spurious forcing. Such forcing could, for example, cause the fluid to start moving in circumstances when it should remain at rest, and in that event the forcing is not "well-balanced". With an alternative that is developed here for Discontinuous Galerkin (DG) methods, the plan is to re-visit the derivation of the shallow water equations from physical principles. At a certain step in that derivation, proceed directly to a weak Galerkin form by multiplying by a test function and integrating over the water column that lies on a given horizontal grid element. The resulting formulation is automatically well-balanced. (Received February 04, 2018)

1137-65-228 **Yekaterina Epshteyn**, **Gunilla Kreiss**, **Gustav Ludvigsson**, **Kyle R. Steffen*** (steffen@math.utah.edu), **Simon Sticko**, **Siyang Wang** and **Qing Xia**. *The Difference Potentials Method for interface problems and models with moving geometry.*

The numerical approximation of partial differential equations (PDE) posed in domains with complicated geometry (e.g., moving domains, or domains with interfaces between two or more subdomains) is crucial in the analysis and study of mathematical models from fluid dynamics, phase transitions (melting and freezing), and materials science (models for an annealing metal), among many other areas.

In this talk, first we will give an introduction to the Difference Potentials Method (DPM), which is a framework for designing high-order accurate and efficient methods for the numerical approximation of PDE posed in arbitrary domains. (The DPM can be viewed as a discrete analog to the method of Calderón potentials and Calderón boundary equations with projections from the theory of PDE.) Then, we will discuss our recent work in designing the DPM to consider parabolic PDE posed in domains with implicitly-defined interfaces, and elliptic PDE in moving geometries. Moreover, we will consider benchmark problems for parabolic interface problems, and present numerical results and comparisons with other methods.

This talk is based on joint work with Y. Epshteyn, G. Kreiss, G. Ludvigsson, S. Sticko, S. Wang, and Q. Xia. (Received February 04, 2018)

1137-65-268 **Tanya V Kostova-Vassilevska*** (tan.v.kos@gmail.com). *Computational model reduction by proper orthogonal decomposition.*

Complex mathematical models are usually hard to analyze analytically and are usually studied by numerical approximations and multiple simulations. Models based on partial differential equations can present time and resource consuming computational problems. One way to deal with computational complexity is to substitute the problem with a simpler one, exploiting the dynamical properties of the model. Model order reduction using Proper Orthogonal decomposition is a popular method in engineering but is not well known to biomathematicians. I will discuss the method - the approach, its advantages, shortcomings and mathematical challenges and will present numerical simulations with the FitzHugh-Nagumo model. (Received February 05, 2018)

1137-65-279 **Kirill Voronin***, kirill.v.voronin@gmail.com. *Multigrid with local Schwarz-type smoothers for space-time CFOSLS.*

We present a modified smoother in a geometric multigrid method which is used as a preconditioner for solving various classical PDEs in constrained space-time first-order system least squares (CFOSLS) framework. Space-time (in 3D/4D) CFOSLS formulations of transport, heat and wave equations lead after finite element discretization to saddle-point sparse linear systems where the divergence constraint represents the original equation.

One of the approaches to solve such systems is to find a particular solution which satisfies the divergence constraint, and then look for a divergence-free correction using a conjugate gradient method. To make this approach feasible an efficient preconditioner is required which acts in the divergence-free subspace.

Geometric multigrid can be used as a preconditioner provided that it works in the appropriate subspace. The main idea of the presented work is to combine a local Schwarz-type smoother with a standard Gauss-Seidel smoother. This allows an efficient CFOSLS functional minimization and significantly reduces iteration count in 4D. A numerical study of the proposed multigrid method in terms of convergence and scalability is presented. (Received February 05, 2018)

1137-65-306 **Vrushali A Bokil*** (bokilv@math.oregonstate.edu), **Yingda Cheng**, **Yan Jiang**, **Fengyan Li** and **Puttha Sakkaplangkul**. *High Spatial Order Energy Stable FDTD Methods for Maxwell's Equations in Nonlinear Optical Media.*

We consider electromagnetic (EM) wave propagation in nonlinear optical media in one spatial dimension, modeled by the time-dependent Maxwell's equations coupled with a system of nonlinear ordinary differential equations (ODEs) for the response of the medium to the EM waves. The nonlinearity in the ODEs describes the instantaneous electronic Kerr response and the residual Raman molecular vibrational response. The ODEs also include the single resonance linear Lorentz dispersion. For this model, we will design and analyze fully discrete finite difference time domain (FDTD) methods that have arbitrary (even) order in space and second order in time. We present novel modifications of second-order leap-frog and trapezoidal temporal schemes within the framework of FDTD methods. We present fully discrete modified leap-frog FDTD methods which are proved to be stable under appropriate CFL conditions. These method can be viewed as an extension of the Yee-FDTD scheme to this nonlinear Maxwell model. We also design fully discrete trapezoidal FDTD methods which are proved to be unconditionally stable. The performance of the fully discrete FDTD methods are demonstrated through numerical experiments involving kink, antikink waves and third harmonic generation in soliton propagation.
(Received February 06, 2018)

1137-65-349 **Nathan L Gibson*** (gibsonn@math.oregonstate.edu). *Analysis of Methods for Dispersive Electromagnetics with Distributions of Parameters.*

Electromagnetic wave propagation in complex dispersive media is governed by the time dependent Maxwell's equations coupled to auxiliary differential equations that describe the evolution of the induced macroscopic polarization. We consider polydispersive materials represented by distributions of dielectric parameters in a polarization model. Polynomial Chaos Expansions are used to approximate the resulting random polarization ODEs with systems of deterministic ODEs, providing a computational framework amenable to standard time and spatial discretization methods. We show how stability and dispersion analyses are affected by the presence of variability. (Received February 06, 2018)

70 ► Mechanics of particles and systems

1137-70-336 **Alexander Panchenko*** (panchenko@math.wsu.edu). *An averaged continuum model of active particle systems.*

Starting from a fine-scale dissipative particle dynamics (DPD) model of self-motile point particles, we derive meso-scale continuum equations by spatial averaging. The resulting stochastic continuum equations are similar to the phenomenological model of Toner and Tu. However, unlike that model, our theory contains explicit constitutive equations in terms of the parameters of the DPD model, including a constitutive equation for the probability distribution of the averaged stochastic force. Although the self-propulsion forces in the DPD model contain no explicit mechanism for aligning the velocities of neighboring particles, the continuum equations include the commonly encountered cubically nonlinear (internal) body force density which is known to promote flocking.
(Received February 06, 2018)

74 ► Mechanics of deformable solids

1137-74-288 **Samuel Britton*** (sbrit004@ucr.edu), Riverside, CA 92507, and **Oleg Kim**, **Zhiliang Xu**, **Rustem Litvinov**, **John Weisel** and **Mark Alber**. *Model of Stress Propagation in Fibrin Network.* Preliminary report.

The fibrin network is one of the primary components of a blood clot. Its mechanical properties determine the structural behavior and stability of clots. Novel mechanism of dynamical deformation of fibrin networks under compression is shown to be based on bending and linking of individual fibrin fibers using discrete worm-like chain model. The model, calibrated using atomic force microscopy data, is used to study how microscopic fiber mechanisms lead to changes of fiber density, elasticity, and bending stiffness, which impact macroscopic dynamics, i.e. Young's Modulus, network strain and densification. Structures of the networks used in model simulations are constructed to fit different types of experimental confocal microscopy data. Simulated results demonstrate good agreement with the data from rheometer experiments and they confirm hypothesized mechanism of stress propagation through the network and characterize how rearrangement and linkage of fibrin fibers effects network stiffening. Quantification of fiber mechanisms has applications in clot construction and lysis. (Received February 05, 2018)

76 ► Fluid mechanics

1137-76-12 **Aleksey S Telyakovskiy*** (alekseyt@unr.edu), Department of Mathematics and Statistics, University of Nevada, Reno, NV 89557, and **Jeffrey Olsen** and **Jeff Mortensen**. *Similarity Solutions to the Forchheimer Equation.* Preliminary report.

The nonlinear Forchheimer equation models turbulent flows in groundwater aquifers. For certain types of initial and boundary conditions with similarity transformation initial-boundary value problem for partial differential equation can be reduced to a free boundary value problem for a nonlinear ordinary differential equation. Polynomial approximate solutions to that nonlinear ordinary differential equation were constructed and they were compared with a highly accurate numerical solution obtained through a rescaling algorithm. (Received December 05, 2017)

1137-76-99 **Joe Umhoefer*** (umhoefej@oregonstate.edu), **Malgorzata Peszynska** and **Timothy Costa**. *Influence of Changing Geometries on Pore Scale Flow and Transport Models.*

We consider a coupled system of PDEs for modeling viscous flow and transport in complex geometries. We use the Stokes equation to describe the flow and we model transport with an advection-diffusion equation. The geometry of the domain in which we solve this problem is the void (pore) space between the rock grains, also known as the pore scale. After we solve an IBVP at the pore scale [μm-mm], we use (numerical) homogenization to inform macro scale [m-km] models through upscaling.

Pore scale simulations can help to predict many important properties of flow and transport at higher scales, and have become ubiquitous in applications to geosciences, from fundamental geologic processes to energy resource storage and production. When pore scale geometry changes, crucial macro scale parameters such as porosity and permeability change as well. A pore scale flow model should be flexible in accounting for geometry changes, and in modeling the coupling to the (transport or phase change) processes changing the pore geometry. In this presentation we show the impact of changes in the pore scale geometry on upscaled results. For flow solutions at the pore scale we use HybGe-Flow3D, a library designed for the solution of fluid flow problems in complex, uncertain and evolving geometries. (Received February 05, 2018)

80 ► Classical thermodynamics, heat transfer

1137-80-334 **James R Langenbrunner*** (jrl@lanl.gov), MS F644, Los Alamos National Laboratory, Los Alamos, NM 87545. *Chain Rule Approach for Calculating the Time-derivative of Flux.* Preliminary report.

The reaction history (gamma-flux observable) is mathematically studied by using the chain rule for taking the total-time derivatives. That is, the total time-derivative of flux is written as the product of the ion temperature derivative with respect to time and the derivative of the flux with respect to ion temperature. Some equations are derived using the further simplification that the fusion reactivity is a parametrized function of ion temperature. Deuterium-tritium (D-T) fusion is used as the application with reactivity calculations from three established reactivity parametrizations. (Received February 06, 2018)

1137-80-355 **James R Langenbrunner*** (jrl@lanl.gov), MS F644, XCP-8, Los Alamos National Laboratory, Los Alamos, NM 87545, and **Jane M Booker** and **Hanna E Makaruk** (hanna_m@lanl.gov), MS T080, P-21, Los Alamos National Laboratory, Los Alamos, NM 87545. *Inferring fusion temperature and ion velocity distributions using gamma flux, recent progress.* Preliminary report.

Deuterium-tritium (D-T) and deuterium-deuterium (D-D) fusion reaction rates are observable using gamma flux. A direct measurement of g-rays with equipment that exhibits fast temporal response could be used to infer temperature, if the detector signal is amenable for taking the logarithmic time-derivative, alpha. We consider the temperature dependence for fusion cross section reactivity and the role of assumptions commonly used for the ion velocity distribution. (Received February 07, 2018)

81 ► Quantum theory

1137-81-44 **Chris Marx*** (cmarx@oberlin.edu), Oberlin College, Department of Mathematics, 10 N Professor Street, Oberlin, OH 44074, and **Peter D Hislop** (peter.hislop@uky.edu), University of Kentucky, Department of Mathematics, 753 Patterson Office Tower, Lexington, KY 40506-0027. *Dependence of the density of states on the probability distribution for discrete random Schrödinger operators.*

We prove the Hölder-continuity of the density of states measure (DOSm) and the integrated density of states (IDS) with respect to the probability distribution for discrete random Schrödinger operators with a finite-range potential. In particular, our result implies that the DOSm and the IDS for smooth approximations of the Bernoulli distribution converge to the corresponding quantities for the Bernoulli-Anderson model. Other applications of the techniques are given to the dependency of the DOSm and IDS on the disorder, and the continuity of the Lyapunov exponent in the weak-disorder regime for dimension one.

The talk is based on joint work with Peter Hislop (Univ. of Kentucky) (Received January 19, 2018)

1137-81-326 **Peter D. Hislop***, Mathematics Department, 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506-0027. *Dependence of the density of states on the probability distribution for discrete random Schrödinger operators, Part 2.*

We prove the Hölder-continuity of the density of states measure (DOSm) and the integrated density of states (IDS) with respect to the probability distribution for discrete random Schrödinger operators with a finite-range potential. In particular, our result implies that the DOSm and the IDS for smooth approximations of the Bernoulli distribution converge to the corresponding quantities for the Bernoulli-Anderson model. Other applications of the techniques are given to the dependency of the DOSm and IDS on the disorder, and the continuity of the Lyapunov exponent in the weak-disorder regime for dimension one.

The talk is based on joint work with Chris Marx (Oberlin College) (Received February 06, 2018)

82 ► Statistical mechanics, structure of matter

1137-82-357 **Bruno Nachtergaele**, **Robert Sims** and **Amanda Young*** (amyoung@math.arizona.edu). *On the stability of frustration-free lattice fermion systems with topologically ordered ground states.* Preliminary report.

In recent years, there have been several results on the spectral gap stability for frustration-free quantum spin models with topologically ordered ground states. We will consider frustration-free lattice fermion systems with a non-vanishing spectral gap above one or more (infinite-volume) ground states and discuss recent progress on extending the stability results in the quantum spin setting to these fermion models. (Received February 07, 2018)

83 ► Relativity and gravitational theory

1137-83-55 **Louis H Kauffman*** (kauffman@uic.edu), Louis H Kauffman, 5530 South Shore Drive, Apartment 7C, Chicago, IL 60637-1946. *General Relativity, Constraints Theory and Non-Commutative Worlds.* Preliminary report.

This talk is joint work with Anthony Deakin. We study the constraints imposed by representing differentiation by commutators in non-commutative worlds so that basic identities in advanced calculus remain true. The most elementary constraints demand a quadratic Hamiltonian and so, in this way, relate classical and quantum formulations. The next constraint, via an observation of Clive Kilmister, leads to a second order version of Einstein's equations for General Relativity. We explain this connection and discuss some of the consequences and questions that arise. (Received January 22, 2018)

1137-83-209 **David Maxwell*** (damaxwell@alaska.edu). *On the conformal method in the far-from CMC setting.*

The conformal method of generating solutions of the Einstein constraint equations in general relativity has been a cornerstone of initial data construction, both for theoretical purposes, and in numerical settings. The method has nearly ideal properties for the construction of constant-mean curvature (CMC) solutions of the constraint equations, and these carry over well to the non-CMC setting. Although there was reason, at one point, to hope that these good properties extend more generally, over the last several years we have gained some understanding of the shortcomings of the conformal method when applied to constructing far-from-CMC solutions. This talk gives an overview of the current state of affairs. (Received February 04, 2018)

1137-83-224 **Noah Samuel Benjamin*** (noahbenjamin@lclark.edu) and **Iva Stavrov**. *The effects of self-interaction on constructing relativistic point particles.*

We introduce a framework for studying the effects of self-interaction on the construction of point particle initial data in General Relativity. Within this framework we rigorously prove the claim of Arnowitt, Deser and Misner that electrically neutral point source modeled by a Dirac delta distribution must have zero ADM mass. We further identify a geometric structure and a scaling parameter that allow one to determine, by controlling the effects of self-interaction, when a sequence of "collapsing" matter distributions yields non-zero mass in the limit. (Received February 04, 2018)

1137-83-274 **Henri P Roesch*** (hroesch@uci.edu), 3700 Parkview Lane, Apt. 8A, Irvine, CA 92612. *Null Geometry and the Penrose Conjecture.* Preliminary report.

Beginning in 1973, Roger Penrose considered the relation between the mass of a spacetime and the contributions of its black holes. Penrose's physical arguments lead to a fascinating geometric Conjecture identifying the size of a black hole outer boundary or "horizon" to its mass contribution. In recent work by the author using a new quasi-local mass functional, a "doubly convex" condition for conical null hypersurfaces in spacetime was identified that would lead to a proof of the Null Penrose Conjecture. In this talk we will explore the validity of this doubly convex condition from the perspective of a stable horizon. (Received February 05, 2018)

1137-83-276 **Maxime Van de Moortel***, mcrv2@cam.ac.uk. *Stability and instability of charged scalar fields on black holes in spherical symmetry.*

The question of black holes stability is one of the central problems of Mathematical General Relativity. It impacts the interior structure of black holes, which is deeply linked to Penrose's Strong Cosmic Censorship Conjecture, stating that General Relativity is a deterministic theory.

This has been rather well understood for the Einstein–Maxwell-**Uncharged**-Scalar-Field model in spherical symmetry. That model however only admits two-ended black holes, unlike its **charged** analogue which allows for the more physically relevant one-ended black holes.

In this talk I will present my recent work about spherically symmetric charged scalar fields on black holes, featuring both stability and instability results, related to the asymptotic behavior of charged scalar fields on black hole space-times. (Received February 05, 2018)

1137-83-283 **David Wiygul*** (dwiygul@uci.edu). *Mass estimates for static vacuum extensions of nearly Euclidean spheres.*

An interesting boundary value problem posed on the exterior of the unit ball in Euclidean space asks for an asymptotically flat static vacuum metric which induces on the boundary sphere a prescribed metric and mean curvature. I will present recent and ongoing work to estimate the ADM mass of certain such metrics with boundary data close to that of the standard unit Euclidean sphere, as well as implications for the Bartnik mass of such data. (Received February 05, 2018)

86 ► Geophysics

1137-86-353 **Demetrios Gatziolis*** (dgatziolis@fs.fed.us), 620 SW Main Street, Suite 400, Portland, OR 97205, and **Robert J McGaughey** (bmcgaughey@fs.fed.us), University of Washington PO Box 352100, Seattle, WA 98195. *Point cloud-derived LiDAR platform trajectory over forested landscapes.*

The precise location and directional vectors of Light Detection and Ranging (LiDAR) instruments onboard airborne platforms are recorded in high frequency and are a prerequisite for generating spatially consistent point clouds. Unfortunately instrument trajectory data are often excluded from acquisition deliverables. The omission precludes certain types of LiDAR data analyses, including the estimation of forest canopy cover and normalization of LiDAR intensity. We developed a novel approach that estimates the trajectory of the LiDAR instrument exclusively from the point cloud. We calculate the closest point of approach in 3D space of multi-return LiDAR pulses and then fit a cubic spline through those points. Method evaluation in several biomes and physiographic conditions against recorded trajectories show good fit over forests with 3D RMSE lower than 1m.

Over sparse and short vegetation the fit is substantially worse (RMSE > 10m). The magnitude of error over forests is practically negligible for LiDAR data analyses dependent on instrument trajectory data. (Received February 06, 2018)

90 ► Operations research, mathematical programming

1137-90-70 **Jane J. Ye*** (janeye@uvic.ca), Department of Mathematics and Statistics, University of Victoria, PO BOX 3060 STN CSC, Victoria, BC V8W 2Y2, Canada. *Variational analysis perspective on linear convergence of some first order methods for nonsmooth optimization problems.*

In this work we try to understand linear convergence of some first-order methods such as the proximal gradient method and its variants for minimizing the sum of a smooth function and a nonsmooth function from a variational analysis perspective. We introduce a new analytic framework based on some theories on variational analysis such as the error bound/calmness/metric subregularity. This variational analysis perspective enables us to provide some concrete sufficient conditions for checking linear convergence. By using the new framework we are able to improve some existing results and obtain novel results unknown in the literature. (Received January 24, 2018)

1137-90-170 **Nghia T. A. Tran** (nttran@oakland.edu), **Ming Yan** (myan@msu.edu) and **Trinh Tran*** (thitutrinhtran@oakland.edu), 12880 De Cook Dr, Sterling Heights, MI 48313-3324. *Linear convergence of iterative soft thresholding and solution uniqueness to general Lasso in Hilbert spaces.*

Iterative soft thresholding is a popular and effective method for solving Lasso problem. Local linear convergence of this method was obtained in many works with nontrivial assumptions on initial data. In this talk, we attempt to improve the result. Indeed, we prove the global linear convergence of this method without supposing any expensive condition on the problem. This is a costly result since it helps undermine the conditions in the previous works. The approach also allows us to obtain new characterizations to the uniqueness of optimal solution to Lasso. (Received February 02, 2018)

1137-90-208 **James V Burke*** (jvburke@uw.edu), **Aleksandr Aravkin**, **Dmitriy Drusvyatskiy**, **Michael P Friedlender** and **Kellie MacPhee**. *Foundations of gauge and perspective duality.*

Common numerical methods for constrained convex optimization are predicated on efficiently computing nearest points to the feasible region. The presence of a design matrix in the constraints yields feasible regions with more complex geometries. When the functional components are gauges, there is an equivalent optimization problem—the gauge dual—where the matrix appears only in the objective function and the corresponding feasible region is easy to project onto. We discuss the foundations of gauge duality and show that the paradigm arises from an elementary perturbation perspective. This puts gauge and Fenchel-Rockafellar duality on an equal footing, explain gauge dual variables as sensitivity measures, and show how to recover primal solutions from those of the gauge dual. (Received February 04, 2018)

91 ► Game theory, economics, social and behavioral sciences

1137-91-80 **Simina Branzei*** (simina.branzei@gmail.com), 1205 Lawson Building, 305 N University St West, West Lafayette, IN 47907, and **Ruta Mehta** and **Noam Nisan**. *Universal Growth in Production Economies.* Preliminary report.

We study a basic model of an economy that develops over time, in which players invest their money in different goods and use the bundles obtained for production.

We show that a simple decentralized dynamic, where players update their bids proportionally to how useful the investments were, leads to growth of the economy in the long term (whenever growth is possible) but also creates unbounded inequality, i.e. very rich and very poor players emerge. We analyze several other phenomena, such as how the relation of a player with others influences its development and the Gini index of the system.

Joint work with Ruta Mehta and Noam Nisan. (Received January 25, 2018)

92 ► Biology and other natural sciences

1137-92-39 **Leonid Hanin*** (hanin@isu.edu), Department of Mathematics and Statistics, Idaho State University, 921 S. 8th Avenue, Stop 8085, Pocatello, ID. *A Mathematical Model of the Metastatic Cascade with Application to Breast Cancer Recurrence.*

We seek to uncover clinically important aspects of post-surgery metastatic relapse of breast cancer and quantify effects of surgery on metastatic progression. We classified metastases into three categories: (1) solitary cancer cells formed before or during surgery; (2) dormant avascular metastases; and (3) vascular secondary tumors. We developed a general mathematical model of post-surgery dynamics of these metastatic states and its parametric versions assuming exponentially or Erlang distributed state sojourn times. Model parameters were estimated from metastatic relapse or censoring times for 673 breast cancer patients treated with surgery. We estimated the expected number of metastases and mean sojourn times for the three states and found that they decrease with state number. We also computed the probability that metastatic relapse resulted from a metastasis in a given state at surgery.

CONCLUSIONS. (1) Metastasis may occur before surgery; (2) Metastatic dormancy is significant; (3) Surgery may stimulate escape from dormancy, promote angiogenesis and accelerate metastatic growth in some breast cancer patients. These findings call into question the widely held belief that primary tumor resection is universally beneficial to patients with invasive breast cancer. (Received January 17, 2018)

1137-92-78 **Michael Isaiah Ham*** (mikeh@lanl.gov), 2538 35th St Unit A, Los Alamos, NM 87544. *Not so fast: Exploration of masking in human psychophysics performance.* Preliminary report.

The time scale of accurate object recognition, in simple pop-out vision tasks, provides key insight into the biological mechanisms required for humans to process images. Previous reports have suggested that humans and primates can recognize objects presented for as little as 14ms in masked, speed-of-sight psychophysics experiments. However, many others report time scales in the 40-80ms range. Here, masking efficacy and object recognition time scales are explored using a backward masking, 2 alternative forced choice paradigm with multiple stimulus onset asynchrony delays. Target and mask images were paired in such a way as to make the object recognition task span the range from trivial to difficult. We demonstrate, for well-masked targets, that the time required for accurate object recognition ranges from 80-160ms depending on the images. Our results provide data that can be used to constrain biologically inspired models of the visual system and for developing non-trivial psychophysics experiments. (Received January 25, 2018)

1137-92-89 **Jim M Cushing***, Department of Mathematics, 617 N Santa Rita, University of Arizona, Tucson, AZ 85721. *Periodic matrix models for seasonal dynamics of structured populations with application to a seabird population faced with climate change.*

For structured populations with an annual breeding season, life-stage interactions & behavioral tactics may occur on a faster time scale than that of population dynamics. Motivated by recent field studies of the effect of rising sea surface temperature (SST) on within-breeding-season behaviors in colonial seabirds, we formulate and analyze a general class of discrete-time matrix models designed to account for changes in behavioral tactics within the breeding season and their dynamic consequences at the population level across breeding seasons. As a specific example, we focus on egg cannibalism and the daily reproductive synchrony observed in seabirds. Using the model, we investigate circumstances under which these life history tactics can be beneficial or non-beneficial at the population level in light of the expected continued rise in SST. Using bifurcation theoretic techniques, we study the nature of non-extinction, seasonal cycles as a function of environmental resource availability as they are created upon destabilization of the extinction state. Of particular interest are backward bifurcations in that they typically create strong Allee effects in population models which, in turn, lead to the benefit of possible (initial condition dependent) survival in adverse environments. (Received January 28, 2018)

1137-92-105 **Mikahl Banwarth-Kuhn**, **Ali Nematbakhsh**, **Weitao Chen**, **Stephen Snipes**, **Andrew Whitaker**, **Venugopala Gonehal** and **Mark Alber*** (malber@ucr.edu), Department of Mathematics, University of California, Riverside, Surge 246, Riverside, CA 92521. *Coupled experimental and computational study of the interplay of mechanical properties and chemical signaling in patterns of stem cell division and differentiation in plants.*

One of the central problems in developmental biology is how chemical and mechanical signals interact in a tissue to produce the final form, size and function of an organ. Cell wall extensibility and distribution of stress contribute to determining rates of cell expansion and orientation of cell division. How cell wall mechanical properties influence cell behavior and how chemical gradients regulating cell mechanical properties are maintained is largely unknown. First, the biological background of the shoot apical meristems (SAMs) of Arabidopsis will be presented. Second, a novel, multi-scale, computational model of the mechanical properties of the SAM will be described along with model calibration using experimental data. Third, a novel signaling model will be demonstrated. Model predictive simulations reveal relative impacts of cell wall extensibility, distribution of stress, and chemical signals on growth rate and division plane orientation in the SAM and illuminate the relationship between individual cell processes and global tissue patterns in stem cell maintenance and differentiation. Multiscale modeling platform provides novel biological insights about stem cells that can be used for studying development of cancerous cells including epithelial cells in the colon. (Received January 29, 2018)

1137-92-107 **Chiu-Yen Kao*** (ckao@cmc.edu). *Study of a Mixed Dispersal Population Dynamics Model.*
In this talk, we discuss a mixed dispersal model with periodic and Dirichlet boundary conditions and its corresponding linear eigenvalue problem. This model describes the time evolution of a population which disperses both locally and nonlocally. We investigate how long time dynamics depend on the parameter values. Furthermore, we study the minimization of the principal eigenvalue under the constraints that the resource function is bounded from above and below, and with a fixed total integral. Biologically, this minimization problem is motivated by the question of determining the optimal spatial arrangement of favorable and unfavorable regions for the species to die out more slowly or survive more easily. Our numerical simulations indicate that the optimal favorable region tends to be a simply connected domain. Numerous results are shown to demonstrate various scenarios of optimal favorable regions for periodic and Dirichlet boundary conditions. This is a joint work with Marina Chugunova, Baasansuren Jadamba, Christine Klymko, Evelyn Thomas and Bingyu Zhao. (Received January 30, 2018)

1137-92-112 **Diana Schepens*** (diana.schepens@montana.edu), Bozeman, MT 59717, and **Ross Carlson**, **Jeff Heys**, **Ashley Beck** and **Tomas Gedeon**. *Emergence of Cooperativity in Microbial Consortia.*
Metabolic cross-feeding between microbes is observed in many microbial communities. It has been experimentally observed that cross-feeding synthetic communities have an increased level of fitness and cell growth as compared to wild type cells. There are also numerous examples of cross-feeding communities in nature. We developed a model to analyze the conditions under which cross-feeding emerges in a microbial community. Specifically, we analyze the different behaviors resulting from varying levels of transport efficiency in models which use passive transport of metabolites compared to models that incorporate active transport. We also consider the effect of a non-cooperative cheater strain on emerging cooperative behavior. (Received January 30, 2018)

1137-92-115 **Nikolay S. Strigul*** (nick.strigul@wsu.edu), 14204 NE Salmon Creek Ave, Vancouver, WA 98686. *Scaling of forest dynamics and self-organization using discrete and continuous conservation law models.*
One of the ecological challenges is to understand why plant species coexist, and which forces drive forest community structure and dynamics. I consider the forest as a complex adaptive system. The modeling includes: 1) the use of individual-based models, as a promising tool for simulating complex-adaptive systems and interactions on multiple scales, 2) the development of scaling methods that approximate individual-based processes, and 3) the investigation of inverse problems to connect models with empirical data. The first component involves mostly simulations of analytically intractable stochastic processes. Scaling methods allow models to be reduced to analytically tractable objects–such as different stochastic and deterministic dynamical systems–which are both more valuable for experimental scientists and computationally simpler. The same scaling method can be presented in several alternative mathematical forms. I will discuss scaling methods that are non-linear partial differential or integral equations in case of continuous models, and non-linear difference equations and Markov chains in case of discrete models. The mathematical problems are quite challenging including analysis of the transient dynamics and stationary states for non-linear discrete or continuous models. (Received January 30, 2018)

1137-92-122 **Weitao Chen*** (weitaoc@ucr.edu). *Data-driven multiscale mathematical models of signaling in the maintenance of transcription factor distribution in stem cell homeostasis.*
The regulation of transcription factor levels is critical in spatiotemporal regulation of gene expression in development biology. WUSCHEL, a stem cell-promoting homeodomain transcription factor was found to activate and repress transcription at lower and higher levels respectively. The differential accumulation of WUSCHEL is critical for spatial regulation on the level of CLAVATA3, a negative regulator of WUSCHEL transcription, to establish the overall gradient. Experiments show that subcellular partitioning and protein destabilization control the WUSCHEL protein level. Meanwhile the destabilization of WUSCHEL also depends on the protein

concentration. However, the utilization of transcriptional regulatory domains for sensing hormones in regulating protein concentration forms a feedback which is difficult to understand in experiments alone. We develop a 3D cell-based mathematical model which integrates sub-cellular partition with cellular concentration across the spatial domain to analyze the regulation of WUS and stem cell homeostasis. By using this model, we investigate the machinery of the maintenance of WUS gradient within the tissue. We also incorporate cell division to study the shoot apical meristem growth under chemical signaling network. (Received January 31, 2018)

1137-92-134 **Hannah R Biegel*** (hbiegel@math.arizona.edu), 617 N. Santa Rita Ave, Tucson, AZ 85721, and **Joceline Lega**. *Incorporating data assimilation methods in a simple model for influenza.* Preliminary report.

When trying to fit mathematical models to data at the onset of an epidemic, parameters are often not known and the available data is often noisy. While complex models are useful once their parameters are known, simple models that rely on fewer parameters can be useful to predict an outbreak early in its course. Here we describe a simple model for seasonal influenza. We use variational data assimilation (VDA) to systematically address the issue of imperfect data and fit model parameters and initial conditions.

We present two synthetic data experiments with VDA applied to our model predicting the incidence of influenza in the United States. First, we fix model parameters to their true values and use VDA to fit initial conditions. Then, we use VDA to fit model parameters in addition to initial conditions. We also demonstrate how these techniques can be applied to CDC data from a recent influenza season. We find that incorporation of VDA improves the prediction capabilities of the model, supporting the use of data assimilation as a tool to predict an epidemic when the outbreak is starting and little data is available. We expect that these preliminary results could be improved with further development of the VDA minimization technique. (Received January 31, 2018)

1137-92-138 **Alfonso Landeros**, **Alexander Alekseyenko**, **Kevin Keys**, **Kenneth Lange** and **Mary E. Sehl*** (msehl@mednet.ucla.edu), 100 UCLA Medical Plaza, Suite 550, Departments of Medicine and Biomathematics, Los Angeles, CA 90095. *Biosimulator: a user-friendly Julia package for stochastic simulation in systems biology.*

Stochastic reaction kinetics allows simulation of complex biological systems with inherent stochasticity, including systems with small population sizes, rare events, and multiple overlapping feedback and feedforward loops. We will discuss a simple and flexible stochastic simulation software package, Biosimulator, designed to implement fast and accurate stochastic simulation algorithms with broad applicability in systems biology. Featured output includes the ability to diagram Petri Nets describing the connectivity of each reaction, and to plot mean trajectories as well as frequency distributions of each reactant species over time. We will illustrate the application of this software to important problems in cancer research, including a model of the breast cancer stem cell niche and investigation of therapeutic strategies aimed at cancer stem cell eradication. We will discuss future directions, including the expansion of our stochastic simulation methods to study spatial effects in cancer modeling. (Received January 31, 2018)

1137-92-146 **Laramie Paxton*** (realtimemath@gmail.com) and **Yufeng Cao** (ycao1@hotmail.com). *A New Model for Liver Segmentation Using Min-cut/Max-flow Algorithms.*

While advancements have been made in liver segmentation from 3D imaging, leading to improvements in diagnosis, planning, and assessment, it is still a challenging task due to complex image backgrounds, fuzzy boundaries, and variation among livers. In this talk, we propose a new model that starts with scalar pixels and then associates a vector with each pixel through various convolutions. We will discuss the ways in which we compute the intensities and label means for our three-label problem and the result of solutions obtained using min-cut/max-flow algorithms. (Received February 01, 2018)

1137-92-150 **Ivana Bozic*** (ibozic@uw.edu). *Evolutionary dynamics of cancer.*

Cancer is the result of a stochastic evolutionary process characterized by the accumulation of mutations that are responsible for tumor growth, immune escape, and drug resistance, as well as mutations with no effect on the phenotype. Stochastic modeling can be used to describe the dynamics of tumor cell populations and to obtain insights into the hidden evolutionary processes leading to cancer. I will present recent approaches that use branching process models of cancer evolution to quantify intra-tumor heterogeneity and the development of drug resistance, and their implications for interpretation of cancer sequencing data and the design of optimal treatment strategies. (Received February 01, 2018)

1137-92-153 **Tilmann Glimm*** (glimmt@wwu.edu). *Modeling pattern formation mechanisms in the vertebrate limb: What can we learn from tetrapod evolution?*

The limbs or fins of vertebrates contain an endoskeleton made up of nodules, bars or plates of bone or cartilage. The generation of these elements occurs by processes involving production and diffusion of morphogens, adhesion, and receptor dynamics. Several potential self-organizing mechanisms have been described and modeled.

One such mechanism in the chick acts through the adhesive activity of galectin-1 together with galectin-8. Galectin-1 has homologs in all jawed vertebrates. Using a mathematical model of this network based on a system of nonlocal reaction-advection-diffusion equations (Glimm, Bhat, Newman, 2014), we present evidence that in the tetrapods, a putative galectin-8 control module was acquired that enabled proximodistal increase in the number of pre-cartilage elements.

We also address other self-organizing networks that convert pre-cartilage protocondensations into skeletal tissues. These are the basis for other models, e.g. the BSW model by Raspopovic et al. (2014). We present ideas about a unified interpretation of the functioning of these networks and how their progressive appearance may refine the identities of the resulting arrays of elements.

This talk is based on joint work with S. A. Newman (NY Medical College) and R. Bhat (IIS, Bangalore). (Received February 01, 2018)

1137-92-160 **Alexander G Dimitrov*** (alex.dimitrov@wsu.edu), 14204 NW Salmon Creek Ave, Vancouver, WA 98686. *Modeling of perceptual invariances in biological sensory processing.* Preliminary report.

A problem faced by all perceptual systems is natural variability in sensory stimuli associated with the same object. This is a common problem in sensory perception: Interpreting varied optical signals as originating from the same object requires a large degree of tolerance. Understanding speech requires identifying phonemes, such as the consonant /g/, that constitute spoken words. A major goal of an object recognition problem then is the ability to identify individual objects while being invariant to changes stemming from multiple stimulus transformations.

In an ongoing project, we are testing the hypothesis that broad perceptual invariance is achieved through specific combinations of what we term locally invariant elements. The main questions we would like to address are: 1. What are the characteristics of locally-invariant units in sensory pathways? 2. How are biological locally-invariant units combined to achieve broadly invariant percepts? 3. What are the appropriate mathematical structures with which to address and model these sensory processes? The mathematical aspects of the research involve an interesting combination of probability theory (a must in the study of biological sensory systems) and group theory, needed to characterize invariants and symmetries. (Received February 01, 2018)

1137-92-198 **Lae Un Kim**, **Maria D'Orsogna** and **Tom Chou*** (tomchou@ucla.edu), Dept. of Biomathematics, UCLA, LSB 5209, Los Angeles, CA 90095-1766. *Onset, timing, and exposure therapy of stress disorders: mechanistic insight from a mathematical model of oscillating neuroendocrine dynamics.*

The hypothalamic-pituitary-adrenal (HPA) axis is a neuroendocrine system that regulates stress response. Disruptions in the activity of the HPA axis are correlated with stress-related diseases such as post-traumatic stress disorder (PTSD) and major depressive disorder. In this talk, we characterize "normal" and "diseased" states of the HPA axis as basins of attraction of a dynamical system describing the inhibition of peptide hormones such as corticotropin-releasing hormone (CRH) and adrenocorticotropic hormone (ACTH) by circulating glucocorticoids such as cortisol (CORT). Our model distinguishes the relatively slow process of cortisol-mediated CRH biosynthesis from rapid trans-synaptic effects that regulate the CRH secretion process. We show that the slow component of the negative feedback allows external stress-induced reversible transitions between "normal" and "diseased" states in novel intensity-, duration-, and timing-dependent ways. Our two-step negative feedback model suggests a mechanism whereby exposure therapy of stress disorders such as PTSD may act to normalize downstream dysregulation of the HPA axis. (Received February 04, 2018)

1137-92-205 **Eric J Kostelich*** (kostelich@asu.edu), School of Mathematical & Statistical Sciences, Box 871804, Arizona State University, Tempe, AZ 85287. *Prediction, Data Assimilation, and Uncertainty Quantification in Cancer Dynamics.*

Contemporary weather forecast systems are a triumph of modern science. Accurate predictions of complex atmospheric dynamics (e.g., Hurricanes Sandy and Harvey) have saved many lives. Can similar mathematical approaches be developed for prediction of complex biological dynamics, such as the evolution of cancerous tumors, in specific patient cases? My talk will outline some of the necessary ingredients in addition to the development of the mathematical models themselves, including observation operators, data assimilation methods, and quantifications of prediction accuracy. (Received February 04, 2018)

1137-92-206 **Zachary J. Robbins*** (zachar4@pdx.edu), **Robert M. Scheller**, **Bradley S. Case** and **Nikolay Strigul**. *The Parameterization of PPA Formulas Using a SORTIE-ND Model For Harvard Forest.*

Spatially-implicit forest growth models, such as the perfect plasticity approximation (PPA), allow for the computationally efficient scaling of forest dynamics to the landscape scale, by using simplified mechanisms of individual tree competition. The parameterization and calibration of PPA using empirical data is challenging, limiting its applications in biogeochemistry and forest modeling. In contrast, the statistical methodology for parameterization of spatially explicit individual-based forest models, such as SORTIE, is well developed. In this work we parameterize the spatially-implicit PPA model by calibrating the spatially-explicit SORTIE-ND model using Harvard forest as a test site. Despite the two models using different tree competition mechanisms, both predicted similar biomass dynamics. Community composition diverged in the two models: between an Eastern hemlock dominated system in SORTIE-ND and a red maple dominated in PPA. This illustrates that the different competition mechanisms employed in spatially-explicit and -implicit models can lead to different predictions of forest successions, and provides a method for an initial parametrization of PPA using SORTIE-ND which is sufficient for scaling of biomass dynamics, but requires further calibration for species dynamics. (Received February 04, 2018)

1137-92-213 **Abba Gumel*** (agumel@asu.edu), School of Mathematical and Statistical Scienc, Tempe, AZ 85287, and **Steffen Eikenberry** and **Kamaldeen Okuneye**. *Mathematics of Climate Change and Malaria Dynamics.*

Climate change is known to significantly affect the dynamics of vector-borne diseases, such as malaria. In particular, the species involved in the transmission dynamics of malaria are affected by various abiotic conditions, such as temperature, precipitation, humidity and vapor pressure . A number of models, typically statistical (using data and statistical approaches to correlate some climate variables with malaria incidence) or mechanistic (accounting for the detailed dynamic nonlinear processes involved in disease transmission), have been employed to assess the likely impact of anthropogenic climate change on malaria transmission dynamics and control. These models have (generally) reached divergent conclusions, with some predicting a large expansion in the continental land area suitable for transmission and in the number of people at risk of malaria, while others predict only modest poleward (and altitudinal) shifts in the burden of disease, with little net effect , and the issue remains unresolved thus far. I will discuss some of our recent results on modeling the effect of some climate variables (e.g., temperature and precipitation) on the dynamics of malaria vector and the disease. This is a joint work with Steffen Eikenberry and Kamaldeen Okuneye. (Received February 04, 2018)

1137-92-216 **Ami Radunskaya*** (aer04747@pomona.edu). *What's next in biomathematics? Describing the dynamics of a disease using networks.*

How can we use mathematics to understand disease progression? Traditional ODE models can be validated using time-series data from experiments. However, in trying to understand the evolution of a disease at the cellular level, we often lack this time-series data. Instead, we are presented with data from two states: 'healthy' and 'diseased', and we'd like to know what has changed. How can we reconstruct the dynamics of the disease from a small number of time points, typically with small sample sizes of high-dimensional data? In this talk, I will describe an approach to this problem that uses network complexity metrics and transcription data. I will describe how information from several sources can be used to identify key players in the development of the disease, as well as the beginnings of a theoretical framework that will give us confidence in the results that we obtain from this method.

Progress in biomathematics requires collaboration across disciplinary boundaries. Many challenges remain in using high-dimensional data to inform the dynamical progression of a disease; I look forward to a productive discussion.

This is joint work with Jo Hardin (Pomona College) and Christina Duron (Claremont Graduate University). (Received February 04, 2018)

1137-92-260 **Robert Dillon*** (dillon@math.wsu.edu) and **Lisa Fauci** (fauci@tulane.edu). *Effects of dynein activation and viscosity on the emergent waveform of an elastic, internally-actuated, model flagellum.*

We describe a fluid-mechanical model of an individual sperm which incorporates discrete representations of the dynein arms, the passive elastic structure of the axoneme including the microtubules and nexin links. This model couples the internal force generation of the molecular motors through the passive elastic structure with the external fluid mechanics governed by the Navier-Stokes equations. The explicit representation of the dynein motors gives us the flexibility to incorporate various dynein activation theories. Here we use a simple activation mechanism based on local curvature with a time delay. The flagellar beat is not preset and is an emergent property of the interacting components of the coupled fluid-axoneme system. (Received February 05, 2018)

1137-92-275 **Travis Axe*** (traxe@uw.edu), Seattle, WA 98117, and **L. Monika Moskal** (lmmoskal@uw.edu), Seattle, WA 98507. *Estimating Effective Leaf Area Index in Heterogeneous Riparian Forest-Buffers: Airborne Lidar vs. Airborne Structure-from-Motion.* Preliminary report.

We demonstrate and compare the estimation of effective leaf area index (LAIE) using two remote-sensing techniques: airborne laser scanning (ALS) and airborne Structure-from-Motion (SfM). The study examines riparian forest-buffers in the Mashel watershed, Washington, for both its hydrologically complex landscape and range of riparian forest types.

Field-estimates were first compared to ALS analysis. These results showed that the penetration rate of first returns was strongly related to LAIE (R2 = 0.66). We used models that tested light attenuation variations of the Beer-Lambert law and saw similar results. However, these were more limited because the complexity of leaf angle distribution, canopy structure, and terrain within the project area, which is not completely captured within field-estimates or accounted in model variations.

The SfM approach utilized the point cloud of a digital surface model (DSM) which was rendered from airborne photography. Although this mimics ALS input data, many of the alluded models perform poorly because of the relative lack of appropriate ground-points. However, linear regression variations revealed an association between the coefficient of variation of point elevations within the upper-canopy and field-estimates of LAIE (R2 = 0.56). (Received February 05, 2018)

1137-92-300 **Elizabeth Gross*** (elizabeth.gross@sjsu.edu), San Jose, CA 95192, and **Colby Long**. *Distinguishing phylogenetic networks.*

Phylogenetic networks are increasingly becoming popular in phylogenetics since they have the ability to describe a wider range of evolutionary events than their tree counterparts. In this talk, we discuss Markov models on phylogenetic networks, i.e. directed acyclic graphs, and their associated algebra and geometry. In particular, assuming the Jukes-Cantor model of evolution and restricting to one reticulation vertex, using tools from commutative algebra, we show that the semi-directed network topology of large-cycle networks is generically identifiable. (Received February 06, 2018)

1137-92-302 **Adam Erickson*** (adam.erickson@wsu.edu), Department of Mathematics and Statistics, 14204 NE Salmon Creek Ave, Vancouver, WA 98686, **Robert Scheller** (rschell@ncsu.edu), Dept. of Forestry and Environmental Resources, 2820 Faucette Dr., Campus Box 8001, Raleigh, NC 27695, **Nikolay Strigul** (nick.strigul@wsu.edu), Department of Mathematics and Statistics, 14204 NE Salmon Creek Ave, Vancouver, WA 98686, and **Melissa Lucash** (lucash@pdx.edu), Department of Geography, 1721 SW Broadway, Portland, OR 97201. *Toward the efficient approximation of energetic and biogeochemical processes in terrestrial biosphere models: next-generation forest models.* Preliminary report.

Over the past 80 years, forest models have progressed from empirical linear models to physiological process models to hybrids of both. Early empirical models simulated the growth and yield of pure even-aged forest stands. Four decades later, individual-based multi-species physiological gap models emerged with JABOWA and FORET. Despite reasonable fidelity to Moore's Law, efforts to upscale gap models remain limited by algorithmic and parametric complexity, with existing solutions relying on sampling strategies. Following model reduction techniques demonstrated in LANDSIM, a new class of model emerged blending empirical and physiological components. Such hybrid models include the two popular cohort models, LANDIS-II and Sortie-PPA. While the former is based on species life history strategies and the CENTURY model, the latter is based on phototropism and crown plasticity combined with recent biogeochemistry models. Here, we discuss approximations used in LANDIS-II and Sortie-PPA, as well as Bayesian methods for estimating parameters and prediction uncertainties. We also discuss combining the PPA cohort model with a big-leaf biogeochemistry model in the latest version of Sortie-PPA, known as Sortie-PPA-BGC, intended to inform future terrestrial biosphere models. (Received February 06, 2018)

1137-92-303 **John B Kim*** (jbkim@fs.fed.us), 3200 SW Jefferson Way, Corvallis, OR 97331.
Simulating Climate Change Impacts on Vegetation Dynamics, Carbon Storage and Wildfire Activity in the Conterminous USA Using Localized Constructed Analogs Downscaled Climate Data. Preliminary report.

We present simulations of impacts of climate change on forests and other vegtation types in the conterminous USA using the MC2 dynamic global vegetation model. MC2 simulates changes in future terrestrial ecosystem vegetative cover, including shifts in vegetation types over time, and burned area across the contiguous U.S. in the 21st century. We ran MC2 with 1/16 degree LOCA downscaled climate projections for RCP4.5 and RCP8.5 scenarios. MC2 results project generally increasing carbon uptake by forests under warming temperatures, partly offset by increased fire activities. In some places, MC2 simulates vegetation type conversion leading to reduced fire frequencies. Carbon flux projections in the contiguous U.S. fluctuate and are highly variable by GCM, with the magnitude and even directionality of impacts varying over time. Through the end of the century, national terrestrial ecosystem carbon storage is projected to increase by 3.0 billion metric tons under RCP8.5 and 0.36 billion metric tons under RCP4.5. Under RCP8.5, wildfire acres burned in the contiguous U.S. are projected to remain consistent with rates observed over the past several decades, but moderately decrease under RCP4.5, with changes under both scenarios driven by shifts in vegetation over time. (Received February 06, 2018)

93 ► Systems theory; control

1137-93-92 **Irena Lasiecka*** (lasiecka@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152-3370. *Boundary Feedback Control with Applications to High Intensity Focused Ultrasound (HIFU).*

This talk will discuss boundary feedback control associated with PDE models arising in HIFU modles -which are PDE's of third order i time. This leads to a notion of a non-standard Riccati equations which provide suitable gain operators for the feedback control. Singularity of the control action compromises the usual regularity of the associated Riccati operators-making the analysis challenging particularly in the case of boundary controls. In this latter case, the loss of regularity is "double" - due to singularity caused by the appearance if time derivatives in control function and also due to the intrinsic loss associated with unbounded and un-closeable trace operators. In order to construct viable theory one needs to develop suitable regularity theory within teh framework of non-smooth optimization. It will be shown how the propagation of hidden trace regularity in hyperbolic dynamics allows to build suitable concepts. (Received January 28, 2018)

94 ► Information and communication, circuits

1137-94-148 **Joseph D Lakey*** (jlakey@nmsu.edu). *An analogue of Slepian vectors for Boolean hypercubes.* Preliminary report.

Slepian vectors are a finite-dimensional analogue of prolate spheroidal wave functions that are optimally concentrated in time among all bandlimited functions. N-dimensional Boolean cubes can be regarded as N-regular graphs, on one hand, and as N-fold products of the group of integers mod two. The structure enables one to develop aspects of time–frequency analysis analogous to the Euclidean setting. Here we address basic questions about which vertex functions on Boolean cubes are most concentrated among all bandlimited functions, and methods to compute these functions. This represents joint work with Jeff Hogan. (Received February 01, 2018)

97 ► Mathematics education

1137-97-48 **Elise Lockwood***, 064 Kidder Hall, Corvallis, OR 97331. *Leveraging Computing to Teach Mathematical Content: The Case of Programming and Productive Combinatorial Thinking.* Preliminary report.

For decades there have been reports that computational activities such as designing algorithms or engaging in programming might help students learn mathematics more effectively (e.g., Fenton & Dubinsky, 1996; Tedre & Denning, 2016). With the increasing ubiquity of computing and the importance of computing in future STEM jobs, though, the need is greater than ever to better understand the relationship between computational activity and students' learning of particular mathematical topics. In this talk, I describe efforts to demonstrate ways in which students might benefit from engaging in particular computational activity (writing and implement simple Python programs) in order to reinforce productive aspects of combinatorial thinking (the relationship between counting process and sets of outcomes (Lockwood, 2013)). I elaborate theoretical reasons for why this case makes sense and provide initial findings from a study with undergraduate students. I conclude with some modest implications and offer suggestions for avenues for future research. (Received January 20, 2018)

1137-97-66 **Zbigniew Oziewicz*** (oziewicz.zbigniew@gmail.com), UNAM Facultad de Estudios Superiores, Estado de Mexico, 54715 Cuautitlan Izcalli, Mexico. *Metric tensor is groupoid.*

A category in which every morphism is isomorphism is said to be the groupoid category. Groupoid category (with many objects) generalize the one-object group category. The concept of a groupoid (that is not a group) was invented by H. Brandt in 1927. I am going to present several examples of very important groupoids, that include every metric tensor is a groupoid. Another example is a groupoid category of velocities-isomorphism with associative composition, contrasted with the Einstein non-associative composition of reciprocal velocities considered by Larissa Sbitneva since 2001 within the loop theory together with Lev Sabinin. Recently Jerzy Kocik presented this loop non-associative composition in beautiful geometric framework. Instead I will contrast non-associative quasi-groups and loops with associative groupoids. (Received January 23, 2018)

1137-97-82 **David Pengelley*** (davidp@nmsu.edu), Mathematics, Oregon State University, Corvallis, OR 97331. *From lecture to active learning: Rewards for all, and is it really so difficult?*

What is active learning? What is the scientific evidence about it in the classroom? What is the lecture-textbook trap? What are the alternatives, and how difficult are they? What about issues such as 'first contact', and linkages between before-, during-, and after-class. Is there a motto about student reading? What are the rewards of active learning for both teachers and students? How much inertia is there? I will address these questions based on pedagogy developed in 17 distinct university courses at all levels over 20 years. And there will still be plenty of time left for discussion. (Received January 26, 2018)

1137-97-85 **Natalie L.F. Hobson*** (natalie.hobson@sonoma.edu), 1801 E. Cotati Ave., Darwin Hall, Rohnert Park, CA 94924. *Students' ways of thinking about graphs.*

Numerous researchers and educators have reported and observed persistent difficulties students encounter with graphs. Given these reports and the prevalence of graphical representations in the study of mathematics, students' ways of thinking for graphs is an important focus. In this talk, I draw from clinical interviews to illustrate certain ways of thinking (or habits) undergraduate students maintain for assimilating graphs. In particular, I characterize students' ways of thinking about graphs that were incompatible with a covariational relationship they came to conceptualize constituted a given situation. These findings signal curriculum and instructional features that may potentially constrain students' opportunities to understand graphs as representing covariational relationships between quantities. (Received January 27, 2018)

1137-97-101 **Eva Thanheiser*** (evat@pdx.edu), Portland, OR, and **Brittney Ellis** (bme3@pdx.edu) and **Jennie Osa** (jennie.osa@pdx.edu), Portland, OR. *Number talks to promote active learning, flexibility, access, and equity.*

We share our experience with using number talks in mathematics courses to promote active learning, flexibility, access, and equity. Number talks are brief (5 to 15 minute) classroom conversation around purposefully crafted problems that are solved mentally (Parrish, 2010). Number talks could serve as a gateway practice for teachers who are trying to change their teaching practice. We share examples from one of our classes. In this class we worked on number talks in more than half of the class sessions. In their reflections on the class 65% of the students mentioned number talks as an essential element of the class. The following themes emerged in their reflections: (1) Number talks allowed the students to recognize that there are multiple pathways to solve a problem and that alternate ways (to your own way) may be valid too. (2) Number talks trained the student to be open to new ideas in mathematics. (3) Number talks allowed students to practice solving problems more than one way. (4) Number talks pushed students to work on communicating/justifying their ideas/explain their thinking. (5) Number talks made students more proficient at mental math. (6) Number talks created a comfortable environment for student to share their answers and thus made math more approachable. (Received February 02, 2018)

1137-97-195 **Alison G. Lynch*** (alynch@csumb.edu), 100 Campus Center, Seaside, CA 93955, and **Alexandria Cervantes**. *Impact of Undergraduate Remedial Math Enrollment on Student Attitudes Toward Mathematics and Persistence in STEM.* Preliminary report.

Each year, 33% of students enrolling at 4-year institutions are placed into remedial non-credit bearing (NCBR) mathematics courses. National data has shown these students are significantly less likely to persist in STEM majors and significantly less likely to complete a college degree. In response to promising data from other states, the California State University system is eliminating all NCBR mathematics courses beginning in Fall 2018 and placing students directly into supported credit-bearing courses. In this study, we investigate the impacts of both models on student attitudes toward mathematics and student persistence in STEM. We follow two cohorts of STEM-intending students through their freshman year, with one cohort consisting of students placed into NCBR mathematics courses and the other cohort consisting of students placed into supported credit-bearing courses. In this talk, we present preliminary findings from interviews with our first cohort, including students' perceptions of their placement and the value of their NCBR course, as well as the impact of the course on students' beliefs about their own mathematics ability. (Received February 03, 2018)

1137-97-207 **Mark Matthew Maxwell*** (maxwell@math.utexas.edu), 123 Lower Wood Lane, Bastrop, TX 78602. *Advances in Actuarial Mathematics Education.*

The two major North American actuarial accrediting organizations, the Casualty Actuarial Society (CAS) and the Society of Actuaries (SOA) have recently modified their preliminary examination requirements with growing importance of mathematical statistics and predictive analytics.

In addition to specialized content knowledge and problem solving skills, employers would like students to have an understanding of business, computer acumen, and the ability to communicate their work to diverse audiences.

This presentation will focus on how the University of Texas at Austin actuarial classes have changed over the past 10 years. Some advances are technical allowing students to interactively practice their content knowledge and problem solving ability. Most of the changes involve methods of content delivery and student expectations. (Received February 04, 2018)

1137-97-212 **Anna Marie Bergman*** (a.bergman@pdx.edu) and **Timothy French**. *Using the Emergent Models Heuristic to Describe and Support a Preliminary Local Instructional Theory for the Guided Reinvention of the Classification of Chemically Important Point Groups.* Preliminary report.

Abstract algebra is an essential part of undergraduate mathematical learning and yet this subject is also known for its high level of difficulty at the collegiate level. A comprehensive understanding of molecular symmetry and group theory is also an important part of undergraduate chemistry curriculum. In this presentation, I will describe a preliminary local instructional theory which aims to engage students in learning abstract algebra, specifically group theory, within the context of undergraduate chemistry by supporting students in their guided reinvention of the classification of chemically important point groups. Using the emergent models heuristic from the instructional design theory of realistic mathematics education and data from a recent pilot study with a pair of students, I will illustrate how the students engaged with the context of molecular shapes to move through various levels of mathematical activity; from a very situated activity, considering specific molecules, to a more general level of activity, considering any molecule. (Received February 04, 2018)

1137-97-221 **Robert Ely*** (ely@uidaho.edu), University of Idaho. *Student reasoning with definite integrals using infinitesimals-based notation registers.*

Recent research (e.g., Jones 2016) has shown that students in calculus classes rarely develop ways to interpret definite integral notation that help them with modeling and interpreting. Drawing on Jones' framework and Duval's (2006) semiotic theory of registers, this study describes two notational registers for definite integral notation used and studied in several experimental calculus classes: the adding up pieces (AUP) and multiplicatively-based summation (MBS) registers. These registers are situated in a broader "informal infinitesimals" approach to calculus, in which differentials like dx directly represent infinitesimal quantities instead of serving as notational finesses or vestiges of a limiting process. Student reasoning data suggests that the AUP register supports modeling and interpreting with integral notation and the MBS register supports sense-making of the relationship between accumulation and rate-of-change functions. This indicates some potential benefits of teaching calculus with informal infinitesimals rather than limits. (Received February 04, 2018)

1137-97-222 **Emily S Cilli-Turner*** (emilyct@uw.edu), 1900 Commerce Street, Box 358436, Tacoma, WA 98402. *Fostering Creativity in Proof-Based Courses: The Creativity-in-Progress Rubric (CPR) on Proving.*

While most mathematicians will agree that creativity is an important part of their work, research on how best to foster and value creativity in undergraduate classrooms is sparse. One such attempt is the development of the Creativity-in-Progress Rubric (CPR) on Proving, which is a formative assessment for use in undergraduate proof-based courses. This talk will discuss the development and implementation of the rubric in various proof-based courses as well as highlight future work including task development in conjunction with the rubric and teacher actions that can contribute to more creative student work. (Received February 04, 2018)

1137-97-252 **Zackery K. Reed*** (reedzac@oregonstate.edu). *Student Generalizations in Real Analysis.*

Real analysis is a core field of study which all mathematics students encounter. At the undergraduate level, students often struggle to learn advanced calculus concepts while also learning to engage in proof and to think formally. Further, learning graduate-level real analysis may involve substantial cognitive abstractions depending on the content that undergraduate analysis courses cover. In an effort to study how students learn core ideas in real analysis from their understandings of advanced calculus, I conducted a paired teaching experiment in which students reinvented the definition of a general metric. Starting with exposure only to the absolute value metric, the students generalized notions of distance and convergence into more abstract spaces such as vector, sequence and function spaces. In these spaces, the students engaged in a variety of generalizing activities as understandings of general distance were built up from the structure of the absolute value metric on $\mathbb{R}$, as well as the Euclidean metric on $\mathbb{R}^2$. I will discuss the students' generalizing activity in various spaces, as well as the nuances of characterizing generalization from understandings that are formal in nature. (Received February 05, 2018)

1137-97-331 **Valerie J Peterson*** (petersov@up.edu), 5000 N Willamette Blvd, Portland, OR 97203. *The REFLECT Project: Spreading Evidence-Based Teaching in STEM.* Preliminary report.

We all want our teaching to matter. This talk focuses on an attempt to make teaching matter a little more at one university. Redesigning Education For Learning through Evidence and Collaborative Teaching (REFLECT), an NSF-funded project underway at the University of Portland, is aimed at spreading the use of evidence-based pedagogical practices in STEM classes on campus. Participating instructors will first (be paid to) attend a week-long summer institute focused on active learning techniques and their potential benefits, and will then collaborate in year-long reflective teaching cohorts while engaging in peer observation. This preliminary report summarizes what our grant team has learned so far about motivating and supporting teacher change, reshaping institutional culture, leveraging internal resources (administrators), and utilizing external partners (AAC&U, ASCN), and also analyzes a snapshot of current teaching practices on campus. We hope to share a model for effecting widespread adoption of evidence-based instructional practices and changing campus culture that could be used at similar regional comprehensive universities. (Received February 06, 2018)

1137-97-352 **John S Caughman*** (caughman@pdx.edu), Portland, OR. *One Mean Problem on Intermediate Values.*

In this talk, I will share one of my favorite problems for engaging students at all levels. When used in an appropriate group setting, this problem can provide opportunities for students to practice justification and the ensuing discussions can lead to rich conjecturing and exploration. (Received February 06, 2018)

1137-97-354 **Torrey Kulow*** (kulow@pdx.edu), Portland, OR 97201. *Preservice Teachers' Reasoning about Multiplication, Division, and Proportions in terms of Quantities.*

Multiplication, division, ratios, and proportional relationships are critical topics in mathematics, yet research in mathematics education reports that teachers persist in having difficulty understanding and teaching these topics in K-12 education. Scholars in the Mathematics Teacher Education advocate that teacher preparation programs help preservice teachers develop a coherent, solid, and flexible understanding of the mathematics content they teach. This session shares research from a multi-year, NSF-funded project based at the University of Georgia investigating how undergraduate preservice middle grades and secondary teachers develop a coherent, solid, and flexible understanding of multiplicative structures, ratios, and proportional reasoning while enrolled in mathematics content courses. In this session, I will discuss the instructional approach that our project team developed and refined to teach preservice teachers these topics and have participants analyze examples of preservice teachers' work on assignments and assessments given in the mathematics content courses. (Received February 07, 2018)

Abstracts of the 1138th Meeting.

00 ► General

1138-00-44 **Seung-Yeop Lee** and **Meng Yang*** (mengyang@mail.usf.edu). *Discontinuity in the asymptotic behavior of planar orthogonal polynomials under a perturbation of the Gaussian weight.*

We consider the orthogonal polynomials, $\{P_n(z)\}_{n=0,1,\cdots}$, with respect to the measure

$$|z-a|^{2c}e^{-N|z|^2}dA(z)$$

supported over the whole complex plane, where $a>0$, $N>0$ and $c>-1$. We look at the scaling limit where n and N tend to infinity while keeping their ratio, n/N, fixed. The support of the limiting zero distribution is given in terms of certain "limiting potential-theoretic skeleton" of the unit disk. We show that, as we vary c, both the skeleton and the asymptotic distribution of the zeros behave discontinuously at $c=0$. The smooth interpolation of the discontinuity is obtained by the further scaling of $c=e^{-\eta N}$ in terms of the parameter $\eta\in[0,\infty)$. (Received January 23, 2018)

1138-00-199 **Rachel Bass Lanning*** (rebass@clemson.edu). *Vertex Degrees and Chemical Indices.*

Graph invariants are functions defined on the graph structures that stay the same under taking graph isomorphisms. Many such graph invariants, including some commonly used graph indices in Chemical Graph Theory, are defined on vertex degrees and distances between vertices. We explore generalizations of such graph indices and the corresponding extremal problems in trees. We will also briefly mention the applications of our results. (Received February 09, 2018)

05 ► Combinatorics

1138-05-11 **XiaoDong Zhang*** (xiaodong@sjtu.edu.cn), 800 Dongchuan Road, Shanghai, Shanghai 200240, Peoples Rep of China. *Chemical Indices of Graphs with Given Degree Sequences.*

The chemical indices, such as the Wiener index, ABC index, Harry index, Zagreb Index etc, of a graph have received a lot of attention. In this talk, we introduce some progress and new results on these chemical indices of graphs with given degree sequences. In addition, some problems are concluded. (Received December 06, 2017)

1138-05-18 **Joseph E. Bonin*** (jbonin@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *Minor-Closed Classes of Polymatroids.* Preliminary report.

A polymatroid is a function $\rho: 2^E\to\mathbb{Z}$ with all of the properties of a matroid rank function except that $\rho(X)$ may exceed $|X|$. Some polymatroids can be obtained by adding matroid rank functions, that is, for some matroids $M_1, M_2, \ldots, M_k$ on E,

$$\rho(X)=r_{M_1}(X)+r_{M_2}(X)+\cdots+r_{M_k}(X)$$

for all $X\subseteq E$. Murty and Simon (1978) showed that not all polymatroids are of this type. D. Chun (2009) characterized those that arise when $k=2$ and $M_1=M\backslash e$ and $M_2=M/e$ for some matroid M. We consider several minor-closed classes of polymatroids that result by imposing various conditions on $M_1, M_2, \ldots, M_k$; some have attractive excluded-minor characterizations; for others we provide evidence that excluded-minor characterizations would be very difficult to obtain. (Received January 05, 2018)

1138-05-22 **N. Bradley Fox*** (foxb@apsu.edu) and **John Asplund**. *Minimum Coprime Labelings of Graphs.*

A *prime labeling* of a graph of order n is a way to label the vertices with the integers $\{1,2,\ldots,n\}$ such that the labels of any adjacent vertices are relatively prime. These labelings have been studied for over thirty years with a vast array of graphs having been shown to be prime (i.e. they have a prime labeling), but many graphs have also been found to not be prime. This talk will focus on the latter set of graphs where we expand the set of labels to be from a set $\{1,2,\ldots,m\}$ for some $m>n$ and attempt to label the graph so that we satisfy the relatively prime adjacency condition while minimizing the value m, which we call a *minimum coprime labeling.*

Graphs that we will consider include the complete graph, wheels, and the results of applying the union, square, or join operations to paths and cycles. (Received January 09, 2018)

1138-05-26 **Boštjan Brešar**, **Sandi Klavžar**, **Douglas F Rall*** (doug.rall@furman.edu) and **Kirsti Wash**. *Packing Colorings of Graphs.*

If $S = (s_1, s_2, \ldots, s_r)$ is a non-decreasing sequence of positive integers, then an S-packing coloring of a graph G is a partition $(V_1, V_2, \ldots, V_r)$ of the vertex set of G such that the distance in G between each pair of distinct vertices from V_i is at least $s_i + 1$. The smallest k such that G has a $(1, 2, \ldots, k)$-packing coloring is the packing chromatic number of G. The packing chromatic number was introduced by Goddard et al. in [W. Goddard, S.M. Hedetniemi, S.T. Hedetniemi, J. Harris and D.F. Rall, *Broadcast chromatic numbers of graphs*, Ars Combin. **86** (2008) 33-49.] under the name broadcast chromatic number. Since that time a number of papers on the packing chromatic number have been published - in particular, concerning its value on trees, subcubic graphs, various lattices and other infinite graphs.

In this talk we survey some of what has been done on the packing chromatic number and report on some recent work regarding the packing chromatic number of the subdivision of subcubic graphs as well as relationships between the packing chromatic number, the chromatic number and the clique number of a graph. (Received January 11, 2018)

1138-05-31 **Bjarne Toft*** (btoft@imada.sdu.dk), Mathematics and Computer Science, University of Southern Denmark, DK-5230 Odense M, Denmark. *Edge-coloring of graphs - A brief survey.*

In 1977 Stanley Fiorini and Robin Wilson published a book Edge-colorings of graphs (Pitman Research Notes in Mathematics 16) containing the first comprehensive exposition of edge-coloring theory. The book is stimulating and useful, including a complete bibliography of more than 200 works related to edge-coloring up to 1977. In 2012 a second book devoted to edge-coloring appeared (Stiebitz et al., Graph Edge Coloring, Wiley 2012), where Tashkinov trees are treated in detail. There is also a more recent interesting survey by Jessica McDonald in (Topics in Chromatic Graph Theory, ed. L.W. Beineke and R.J. Wilson, Cambridge Univ. Press 2015).

Starting from the Fiorini-Wilson book the further development, leading to the Stiebitz et al. book, will be highlighted, in particular the (somewhat neglected) work of Ram Prakash Gupta and the very important results and conjectures of Paul Seymour. The conjecture of Mark Goldberg (also called the Goldberg-Seymour Conjecture) (1970s) is still the most important unsolved problem in the area. Other famous problems are the Berge-Fulkerson Conjecture (late 1970s) and the List-Chromatic- Index Conjecture (1980s). (Received January 18, 2018)

1138-05-43 **Nicholas A. Loehr***, 460 McBryde Hall, 225 Stanger Street, Blacksburg, VA 24061-0123, and **Kyungyong Lee** and **Li Li**. *Chain decompositions for q,t-Catalan numbers.*

The *q,t-Catalan numbers* $C_n(q,t)$ are polynomials in q and t that reduce to the ordinary Catalan numbers when $q = t = 1$. These polynomials have important connections to representation theory, algebraic geometry, and symmetric functions. Haglund and Haiman discovered combinatorial formulas for $C_n(q,t)$ as weighted sums of Dyck paths (or equivalently, integer partitions contained in a staircase shape). This talk investigates the joint symmetry property $C_n(q,t) = C_n(t,q)$. We conjecture some structural decompositions of Dyck objects into "mutually opposite" subcollections leading to a bijective explanation of joint symmetry in certain cases. A key new idea is the construction of infinite chains of partitions that are independent of n but induce the joint symmetry for all n simultaneously. Using these methods, we can prove combinatorially that for $0 \leq k \leq 9$ and all n, the terms in $C_n(q,t)$ of total degree $\binom{n}{2} - k$ have the required symmetry property. (Received January 23, 2018)

1138-05-55 **Eva Czabarka**, **Peter Dankelmann** and **Laszlo A. Szekely*** (szekely@math.sc.edu). *Maximum Wiener index of planar triangulations and quadrangulations.* Preliminary report.

The Wiener index of a connected graph is the sum of distances for all unordered pairs of vertices. This is perhaps the most frequently used graph index in sciences, since Harold Wiener in 1947 observed that the Wiener index is closely correlated with the boiling points of alkane molecules. We determine (asymptotically) the maximum Wiener index of planar triangulations and quadrangulations on n vertices. (Received January 26, 2018)

1138-05-56 **Shuliang Bai***, 519 saluda ave, apt 3. *Analogies between the crossing number and the tangle crossing number.*

Tanglegrams are special graphs that consist of a pair of rooted binary trees with the same number of leaves, and a perfect matching between the two leaf-sets. These objects are of use in phylogenetics and are represented with straightline drawings where the leaves of the two plane binary trees are on two parallel lines and only the matching edges can cross. The tangle crossing number of a tanglegram is the minimum crossing number over all such drawings and is related to biologically relevant quantities, such as the number of times a parasite switched hosts. In this talk we present results for tanglegrams, which have parallels for the crossing number of graphs. We show that removing any matching edge from a tanglegram with n leaves results in a drop of the tangle crossing number by at most $n-3$, and this is sharp. We also show that the maximum tangle crossing number of a tanglegram with n leaves is asymptotically $n(n-1)/4$. Finally we present an algorithm for computing non-trivial lower bounds on the tangle crossing number in $O(n^4)$ time. Joint work with R. Anderson, F. Barrera-Cruz, É. Czabarka, G. da Lozzo, N.L.F. Hobson, J.C.-H. Lin, A. Mohr, H.C. Smith, L.A. Székely, H. Whitlatch. (Received January 26, 2018)

1138-05-61 **Heather Smith*** (heather.smith@math.gatech.edu), **Laszlo Szekely**, **Hua Wang** and **Shuai Yuan**. *Extremal Properties of Vertex Attributes in Trees.*

For tree T and vertex v, define the eccentricity $ecc(v) := \max_{u\in V(T)} d(u,v)$, the distance $d(v) := \sum_{u\in V(T)} d(u,v)$ and the number of subtrees $F(v)$ containing vertex v. Each defines a "middle" of the tree consisting of the vertices with the maximum (or minimum) value.

First, we explore the interactions of $ecc(v)$ and the total eccentricity $Ecc(T) := \sum_{v\in V(T)} ecc(v)$ by examining extremal values and structures for the ratios $\frac{ecc(v)}{ecc(u)}$ and $\frac{Ecc(T)}{ecc(v)}$. Analogous studies have been done for distance [Barefoot, Entringer, Székely, Discrete Appl. Math. **80** (1997), 37-56] and number of subtrees [Székely, Wang, Electron. J. Combin. **20** (2013) 1-20]. We also compare the three different middles, determining how far apart they can appear in a single tree and characterizing many of the extremal structures. (Received January 26, 2018)

1138-05-67 **Eric O. D. Andriantiana*** (e.andriantiana@ru.ac.za), Deaprtment of Mathematics (Pure & Applied), Rhodes University, PO Box 94, Grahamstown, 6140, South Africa, and **Valisoa R. Misanantenaina** and **Stephan G. Wagner**. *Extremal trees with fixed degree sequence.*

The so called greedy tree $G(D)$ and alternating greedy tree $\mathcal{M}(D)$ are known to be extremal graphs among elements of the set $\mathbb{T}_D$ of trees with degree sequences D, with respect to various graph invariants. This talk will discuss generalized proof that cover a larger family of invariants for which $G(D)$ or $\mathcal{M}(D)$ is an extremal graph in $\mathbb{T}_D$. In addition to the known results on the Wiener index, the number of subtrees, the number of independent subsets, the Hosoya index, the terminal Wiener index, and the energy of graphs, new results on the number of rooted spanning forests, the incidence energy and the solvability of a graph also follow. By comparing greedy trees, and alternating greedy trees, with different degree sequences, the results in $\mathbb{T}_D$ are extended to the set of trees whose degree sequences are majorized by D. (Received January 29, 2018)

1138-05-69 **Ada Nicole Morse*** (ada.morse@uvm.edu), Burlington, VT 05401. *Interlacement and Activities in Delta-Matroids.*

We generalize theories of graph, matroid, and ribbon-graph activities to delta-matroids. As a result, we obtain an activities based feasible-set expansion for a transition polynomial of delta-matroids defined by Brijder and Hoogeboom. This result yields feasible-set expansions for the two-variable Bollobás-Riordan and interlace polynomials of a delta-matroid. In the former case, the expansion obtained directly generalizes the activities expansions of the Tutte polynomial of graphs and matroids. (Received January 29, 2018)

1138-05-70 **Jesse L Taylor*** (jesse.taylor@angelo.edu), 2601 W AVE N, Department of Mathematics, San Angelo, TX 76909. *Graphic matroids that guarantee their duals as minors.*

A natural question for matroids follows: Which matroids N guarantee that, when present as minors in a larger matroid M, their duals are also present as minors? The main result of this talk addresses this question with the additional constraints that N and M are 3-connected and graphic. (Received January 29, 2018)

1138-05-71 **Anton Bernshteyn**, **Alexandr Kostochka*** (kostochk@math.uiuc.edu) and **Xuding Zhu**. *DP-coloring of graphs versus list coloring: similarities and differences.*

DP-coloring of graphs was introduced by Dvořák and Postle to answer a question of Borodin on list-coloring of planar graphs. Formally, a DP-k-coloring of a graph G is an independent set in an auxiliary graph $H(G,k)$. However, DP-coloring has many properties of ordinary and list colorings. In some respects, DP-coloring resembles list coloring, but not in all.

In this talk we discuss properties of DP-coloring of graphs and compare them with those of list coloring. We also discuss some open questions on this parameter. (Received January 29, 2018)

1138-05-74 **Y Zhao*** (yzhao@mail.ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *upper bounds for $\Delta(\Sigma)$ where $-53 \leq \chi(\Sigma) \leq -8$.*

Vizing's Planar Graph Conjecture states that every planar graph of maximum degree at least 6 is class one. If for a surface Σ, we define $\Delta(\Sigma) = \max\{\Delta(G) |\ G$ is a connected class two graph of maximum degree Δ that is embedded in $\Sigma\}$, then one can claim that for a surface Σ, any connected graph of maximum degree Δ that is embedded in Σ is class one if $\Delta > \Delta(\Sigma)$. Further, Vizing's Planar Graph Conjecture also can be restated as $\Delta(S) = 5$ if S is a sphere. In this talk, we will focus on $\Delta(\Sigma)$ and upper bounds for $\Delta(\Sigma)$ for surfaces Σ of characteristic $-53 \leq \chi(\Sigma) \leq -8$. (Received January 29, 2018)

1138-05-75 **Jim Haglund*** (jhaglund@math.upenn.edu), **Brendon Rhoades** and **Mark Shimozono**. *Macdonald Delta Operators when t=0.*

The Delta Conjecture of the speaker, Remmel and Wilson gives a combinatorial description (involving two parameters q,t) of a symmetric function originally defined analytically using the Delta operator from Macdonald polynomial theory. This operator was introduced by Haiman in his study of the Hilbert scheme and the diagonal coinvariant ring. In a recent preprint Garsia, the speaker, Remmel and Yoo prove the special case of the Delta Conjecture when t=0. In this talk we show how their methods can be used to prove to prove a more general result, involving other symmetric functions defined using the Delta operator at t=0. We also give a new proof of their result. (Received January 30, 2018)

1138-05-81 **Hays Wimsatt Whitlatch*** (hww@math.sc.edu) and **Joshua Cooper** (cooper@math.sc.edu). *Pressing Sequences for Mitochondrial Genome Graphs.*

In the 1930's, two biologists, Dobzhansky and Sturtevant, introduced the idea that the degree of disorder between the genes in two genomes is an indicator of the evolutionary distance between two organisms. This has inspired extensive work in the fields of computational biology, bio-informatics and phylogenetics. In particular, researchers have pursued the question of how a common ancestral genome may have been transformed by evolutionary events into distinct, yet homologous, genomes. In mathematics, we often represent genomes as signed permutations, and evolutionary events are encoded as operations on signed permutations. Hannenhalli and Pevzner famously showed that sorting such sequences can be done in polynomial time and that they are essentially equivalent to a certain sequences of operations - "vertex pressing" - on bicolored graphs. In this talk we examine the combinatorial matrix algebra over GF(2) that arises from the theory of such sequences, providing a collection of equivalent conditions for their existence and showing how linear algebra, poset theory, and group theory can be used to study them. We also discuss enumeration, characterization, and recognition of uniquely pressable graphs (those with exactly one pressing sequence). Joint work with Joshua Cooper. (Received January 30, 2018)

1138-05-83 **Theodore Molla** and **Michael Santana*** (santanmi@gvsu.edu). *Extending a result of Corrádi and Hajnal.* Preliminary report.

In 1963, Corrádi and Hajnal verified a conjecture of Erdős by showing that every n-vertex graph G, where $n \geq 3k$ and $\delta(G) \geq 2k$, contains k vertex-disjoint cycles. This result is best possible in multiple senses and has been the inspiration for a wide variety of research in the area of cycle structure. One particular extension by Balogh, Molla, and Sharifzadeh, shows that in the case where G is dense (i.e., $n = 3k$ and is sufficiently large), the bound on the minimum degree can be significantly improved, provided that the independence number of the graph is small. In this talk, we will present a similar result for the 'sparse' case. This is joint work with Theodore Molla. (Received January 31, 2018)

1138-05-106 **Elizabeth J Hartung*** (e.hartung@mcla.edu), 375 Church St, MCLA, North Adams, MA 01247-4124, and **Jack E Graver**, **Jennifer Edmond** and **Joshua Fenton**. *The Fullerene Project.* Preliminary report.

A *fullerene* models a pure carbon molecule and is a 3-regular plane graph with only hexagonal and pentagonal faces. A *Kekulé structure* is a perfect matching of the edges, and corresponds to a double bond structure of the molecule. The *Clar number* of a fullerene is the maximum number of independent resonant hexagons over all Kekulé structures (the maximum size of an independent set of hexagons with 3 of their bounding edges in the perfect matching). A higher Clar number is correlated with higher molecular stability. We have begun a "Fullerene Project" with the goal of finding the Clar number for all highly symmetric fullerenes. Results will be discussed, as will opportunities for research, including at the undergraduate level. (Received February 04, 2018)

1138-05-107 **Arthur S. Finbow**, **Bert L. Hartnell** and **Michael D. Plummer*** (michael.d.plummer@vanderbilt.edu), Vanderbilt University, Nashville, TN 37240. *On the structure of 4-regular planar well-covered graphs.*

A graph is well-covered if every maximal independent set of vertices has the same cardinality. From a computational point of view, it was shown by Chva'tal and Slater and by Sankaranarayana and Stewart that the recognition of non-well-covered graphs is NP-complete, or equivalently, recognizing well-covered graphs is co-NP-complete. However, for certain graph subclasses (e.g., cubic graphs, claw-free graphs, planar triangulations), polynomial recognition algorithms are known. In this talk, we discuss structural properties of a previously unstudied class of well-covered graphs, i.e., those which are 4-regular and planar. (Received February 04, 2018)

1138-05-110 **Tair Akhmejanov***, Cornell University, Ithaca, NY 14850. *Growth Diagrams from Polygons in the Affine Grassmannian.*

We introduce a new type of growth diagram, arising from the geometry of the affine Grassmannian for GL_m. These affine growth diagrams are in bijection with the $c_{\vec{\lambda}}$ many components of the polygon space Poly($\vec{\lambda}$) for $\vec{\lambda}$ a sequence of minuscule weights and $c_{\vec{\lambda}}$ the Littlewood–Richardson coefficient. Unlike Fomin growth diagrams, they are infinite periodic on a staircase shape, and each vertex is labeled by a dominant weight of GL_m. Letting m go to infinity, a dominant weight can be viewed as a pair of partitions, and we recover the RSK correspondence and Fomin growth diagrams within affine growth diagrams. The main combinatorial tool used in the proofs is the n-hive of Knutson–Tao–Woodward. The local growth rule satisfied by the diagrams previously appeared in van Leeuwen's work on Littelmann paths, so our results can be viewed as a geometric interpretation of this combinatorial rule. (Received February 05, 2018)

1138-05-118 **Sandi Klavzar*** (sandi.klavzar@fmf.uni-lj.si), Jadranska 19, 1000 Ljubljana, Slovenia, and **M.J. Nadjafi-Arani**. *Partition distance in graphs.*

If G is a graph and $\mathcal{P}$ is a partition of $V(G)$, then the partition distance of G is the sum of the distance between all pairs of vertices that lie in the same part of $\mathcal{P}$. This concept generalizes several metric concepts (such as the (terminal) Wiener index). It will be demonstrated that the partition distance of a graph can be obtained from the Wiener index of weighted quotient graphs induced by the transitive closure of the Djoković-Winkler relation as well as by any partition coarser than it. Many earlier results follow from the obtained theorems. Applying the main results, upper bounds on the partition distance of trees with prescribed order and radius will also be shown and corresponding extremal trees presented. (Received February 06, 2018)

1138-05-120 **Edward Allen**, **Josh Hallam** and **Sarah Mason***, masonsk@wfu.edu. *Dual immaculate quasisymmetric functions expand positively into quasisymmetric Schur functions.*

We discuss the connection between two recently introduced bases for quasisymmetric functions, both of which are natural quasisymmetric analogs of Schur functions due to the combinatorial properties they exhibit. The quasisymmetric Schur functions are obtained through specializations of Macdonald polynomials. The dual immaculate basis is dual to a basis for non-commutative symmetric functions constructed through non-commutative Berenstein creation operators. Both bases can be defined using tableaux-like objects. We describe a Remmel-Whitney-style algorithm for writing a dual immaculate quasisymmetric function as a positive sum of quasisymmetric Schur functions. We also explore properties of the insertion algorithm used to prove this decomposition.
(Received February 06, 2018)

1138-05-122 **Zi-Xia Song*** (zixia.song@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Recent Results on Gallai-Ramsey Numbers of Cycles.*

We study Ramsey-type problems in Gallai-colorings. Given a graph G and an integer $k \geq 1$, the Gallai-Ramsey number $gr_k(K_3, G)$ is the least positive integer n such that every k-coloring of the edges of the complete graph on n vertices contains either a rainbow triangle (that is, a triangle with all its edges colored differently) or a monochromatic copy of G. It turns out that $gr_k(K_3, G)$ behaves more nicely than the classical Ramsey number $r_k(G)$. However, finding exact values of $gr_k(K_3, G)$ is far from trivial. In this talk, we survey recent results on Gallai-Ramsey numbers of cycles. (Received February 06, 2018)

1138-05-124 **Abdelmalek Abdesselam*** (malek@virginia.edu), Department of Mathematics, University of Virginia, P.O. Box 400137, Charlottesville, VA 22904. *On the SL_2 analogue of the Foulkes-Howe Conjecture.*

For V a vector space, there is a natural $GL(V)$-equivariant map between plethysms of symmetric powers $S^p(S^{qr}(V)) \to S^q(S^{pr}(V))$. This map was studied by Brion in 1993, and it generalizes the one featuring in the Foulkes-Howe Conjecture (now known to be false). I will focus on the two-dimensional or SL_2 case, with $r > 1$, where the analogue of the FH conjecture turns out to be quite interesting an challenging. I will review

partial results about it and connections to recent conjectures by Bergeron. The main question can be formulated as a lower bound on the minimal degree of generators of the ideal of the variety of binary forms that are r-th powers of forms of degree q. I will also review a description of this ideal, due to Dunkl, in terms of Jack polynomials. (Received February 06, 2018)

1138-05-134 **Carolyn Chun** and **James Oxley*** (oxley@math.lsu.edu). *Bipartite minors of binary matroids.* Preliminary report.

A binary matroid M is affine if all of its circuits have even cardinality. Thus the cycle matroid of a graph G is affine if and only if G is bipartite. Recently, Chudnovsky, Kalai, Nevo, Novik, and Seymour introduced the notion of bipartite minors for graphs and proved that a bipartite graph is planar if and only if it does not have $K_{3,3}$ as a bipartite minor. This talk will extend the definition of bipartite minor to binary matroids. For a binary affine matroid, we characterize, in terms of excluded bipartite minors, when M is graphic and when M is cographic. In addition, we extend Seymour's decomposition theorem for regular matroids to binary affine matroids that are regular. (Received February 11, 2018)

1138-05-142 **C A Rodger*** (rodgec1@auburn.edu). *Embedding Graph Decompositions.*

In this talk, the focus is on embeddings, both edge-colorings of graphs into Hamilton decompositions and reflecting back on similar problems for partial idempotent latin squares. Recently, progress in this area has required understanding the structure of a closely related graph, and in particular on certain components arising that can determine whether or not the embedding is possible. (Received February 07, 2018)

1138-05-148 **Tara Fife*** (tfife2@lsu.edu), Louisiana St Univ, Baton Rouge Department of Mathematics, Field House Dr, Baton Rouge, LA 70803-4918, and **Dillon Mayhew**, **James Oxley** and **Charles Semple**. *Unbreakable Biased Matroids.* Preliminary report.

A Matroid M is unbreakable if M/F is connected for all flats F of M, or equivalently, if the dual of M has no two skew circuits. Pfeil showed that the only simple graphic matroids that are unbreakable are the cycle matroids of complete graphs and cycles. This talk extends this result to the matroids of biased graphs. (Received February 07, 2018)

1138-05-153 **Xi Chen*** (xc2g@mtmail.mtsu.edu), **Dong Ye** (dong.ye@mtsu.edu) and **Xiaoya Zha** (xiaoya.zha@mtsu.edu). *Resonance Polynomials of Cata-Condensed Hexagonal Systems.*

A hexagonal system is a finite 2-connected plane bipartite graph in which every interior face is bounded by a regular hexagon. A hexagonal system is called cata-condensed if it is outer planar. A set of disjoint hexagons H of a hexagonal system G is a forcing resonant set if a subgraph consisting of deleting all vertices of H from G has a unique perfect matching. The forcing resonance polynomial of G is defined as $f(x) = \sum_{i=0}^{cl(G)} a_i x^i$ where a_i is the number of distinct forcing resonant set of size i and $cl(G)$ is the Clar number of G. The polynomial can be used to enumerate the forcing resonant sets of hexagonal systems. In this paper, we compute the forcing resonance polynomial of cata-condensed hexagonal system G. Our computation results demonstrate that an isomer with larger coefficient vectors of forcing resonance polynomial has larger HOMO-LUMO gap. In other words, an isomer with larger coefficient vector is more stable. (Received February 08, 2018)

1138-05-164 **Neil Epstein***, George Mason University, Fairfax, VA 22030. *Partial matroids.* Preliminary report.

As a development from previous joint work with Joseph Brennan on "generic matroids", a new combinatorial structure is here introduced that is somewhat more restrictive than the traditional matroid structure, called the *partial matroid.* Many restrictions of a partial matroid are actual matroids (and indeed some of these restrictions will be part of the axiomatization), but the axioms for the overall structure are weaker. Examples include ordinary matroids, graded Noether normalizations of a finitely generated algebra over a field, and minimal reductions of an ideal in a local Noetherian ring. Axiom systems in terms of e.g. independent sets, bases, closure, and flats, as well as cryptomorphisms between them, will be exhibited. (Received February 08, 2018)

1138-05-167 **Emily Sergel*** (esergel@math.upenn.edu). *On C-expansions for monomial symmetric functions.*

In 2005, Haglund, Haiman, Loehr, Remmel and Ulyanov first stated the Shuffle Conjecture, which gives a combinatorial interpretation for the Frobenius character of the module of Diagonal Harmonics in terms of parking functions. A key ingredient in Carlsson and Mellit's recent proof (2015) was the Compositional Shuffle Conjecture of Haglund, Morse, and Zabrocki (2012). This refinement revealed that certain plethystic operators, referred to here as C-operators, together with the ∇ operator of Bergeron and Garsia (1999), act as building blocks for parking functions.

More precisely, if a symmetric function f has a positive expansion in terms of these C-operators applied to 1, then we automatically get a positive combinatorial interpretation for ∇f in terms of parking functions, which in turn give LLT polynomials. Unfortunately, this expansion is not unique. Here we give a positive, combinatorial expansion for any hook monomial symmetric function. Our expansion is closely related to Kulikauskas and Remmel's (2006) expansion for monomials into homogeneous symmetric functions, and we conjecture that similar expansions exist for non-hook shapes. (Received February 08, 2018)

1138-05-174 **Peter Johnson*** (johnspd@auburn.edu), Department of Math. & Stat., Auburn University, AL 36849. *(n,k,t) Problem.* Preliminary report.

Let P be a graph property, and let n, k, and t be positive integers, in non-increasing order. A P-(n,k,t) graph is a simple graph on n vertices such that every induced subgraph of order k has a subgraph of order t which has property P. (In a variant, it may be required that each induced subgraph of order k has an induced subgraph of order t with property P.) For choices of P and values of n, k, and t such that P-(n,k,t) graphs exist, the P-(n,k,t) problems are to determine which such graphs have the least or greatest number of edges. When P is the property of being complete, the "maximum edges" problem is trivial and the minimum edges problem is unsolved. It is conjectured that every such graph with the minimum number of edges has complete components. This holds in many cases. When P is the property of being connected, the maximum edges problem is again trivial, while the minimum edges problem appears very hard, but intriguing. It is early days. (Received February 08, 2018)

1138-05-188 **Kevin M. Grace*** (kgrace3@lsu.edu) and **Stefan H. M. van Zwam**. *Applications of Matroid Templates.*

The classes of even-cycle matroids and even-cut matroids each have hundreds of excluded minors. We show that, subject to announced results of Geelen, Gerards, and Whittle, the number of excluded minors for these classes can be drastically reduced if we consider only the highly connected matroids of sufficient size.

Three closely related classes of GF(4)-representable matroids are the golden-mean matroids, the matroids representable over all fields of size at least 4, and the matroids representable over GF(4) as well as fields of all characteristics. Subject to these same announced results, we have characterized the highly connected matroids in each of these classes. As a direct consequence of this characterization, we give the extremal functions for these classes of matroids, including the golden-mean matroids. The extremal function indicates the maximum number of elements of a simple matroid of rank r. This implies that a conjecture made by Archer in 2005 holds for matroids of sufficiently large rank. (Received February 09, 2018)

1138-05-194 **Colton Magnant*** (cmagnant@georgiasouthern.edu), Georgia Southern University, Statesboro, GA 30460. *Gallai-Ramsey Numbers - General Bounds and Sharp Cases.*

Given a positive integer k and a graph G, the Gallai-Ramsey number is defined to be the minimum integer n such that every k-coloring of the edges of a complete graph on n vertices contains either a rainbow colored triangle or a monochromatic copy of G. In this talk, we discuss several new precise values of Gallai-Ramsey numbers as well as some general bounds and strategies. (Received February 09, 2018)

1138-05-197 **Jim Haglund** and **Andy Wilson*** (atwilson0328@gmail.com). *Macdonald polynomials and chromatic quasisymmetric functions.* Preliminary report.

In recent work, Haglund and Wilson discovered connections between Macdonald polynomial theory and chromatic quasisymmetric functions, as defined and explored by Shareshian and Wachs. We discuss these connections and their possible implications. (Received February 09, 2018)

1138-05-198 **Jessica McDonald*** (mcdonald@auburn.edu) and **Gregory J. Puleo**. *t-Cores for $(\Delta + t)$-edge-colouring.*

Numerous authors have found sufficient conditions for Δ-edge-coloring a simple graph by studying its *core*, that is, the subgraph induced by the its vertices of maximum degree. In this talk we discuss extending the notion of core to *t-core* – subgraph induced by the vertices v with $d(v) + \mu(v) > \Delta + t$ – and find a sufficient condition for $(\Delta + t)$-edge-coloring. In particular, we show that for any $t \geq 0$, if the t-core of G has multiplicity at most $t + 1$, with its edges of multiplicity $t + 1$ inducing a multiforest, then $\chi'(G) \leq \Delta + t$. This extends previous work of Ore, Fournier, and Berge and Fournier. A stronger version of our result (which replaces the multiforest condition with a vertex-ordering condition) generalizes a theorem of Hoffman and Rodger about cores of Δ-edge-colourable simple graphs. (Received February 09, 2018)

1138-05-200 **Guantao Chen**, **Ronald J. Gould** and **Xiaofeng Gu***, Department of Mathematics, University of West Georgia, 1601 Maple St, Carrollton, GA 30118, and **Akira Saito**. *Chorded cycles in dense graphs.*

A cycle of length k is called a k-cycle. A non-induced cycle is called a chorded cycle. Let n be an integer with $n \geq 4$. A graph G of order n is chorded pancyclic if G contains a chorded k-cycle for every integer k with $4 \leq k \leq n$. Cream, Gould and Hirohata have proved that a graph of order n satisfying $\deg_G u + \deg_G v \geq n$ for every pair of nonadjacent vertices u, v in G is chorded pancyclic, with some exceptional graphs. They have also conjectured that if G is hamiltonian, we can replace the degree sum condition with the weaker density condition $|E(G)| \geq \frac{1}{4}n^2$ and still guarantee the same conclusion. We prove this conjecture by showing that if a graph G of order n with $|E(G)| \geq \frac{1}{4}n^2$ contains a k-cycle,then G contains a chorded k-cycle, with some exceptional graphs. We further relax the density condition for sufficient large k. (Received February 09, 2018)

1138-05-204 **Mark N. Ellingham**, **J. Zachary Gaslowitz**, **Kelly O'Connell*** (`kelly.m.oconnell@vanderbilt.edu`) and **Gordon Royle**. *Hamiltonicity of 3-connected, planar, $K_{1,1,5}$-minor-free graphs.*

The Hamiltonicity of various classes of graphs has long been a topic of interest. Tutte proved in 1956 that all 4-connected planar graphs are Hamiltonian. Weakening the connectivity condition to 3-connectivity is not sufficient for Hamiltonicity, however; there exist infinite families of graphs that are 3-connected and planar, but not Hamiltonian.

We look at the restricted class of 3-connected planar graphs obtained by forbidding $K_{1,1,5}$ as a minor. Using certain properties of induced fans, we are able to prove that with exactly one exception, all 3-connected, planar, $K_{1,1,5}$-minor-free graphs are Hamiltonian. The one non-Hamiltonian graph in our class is the well-known Herschel graph, a bipartite graph on 11 vertices. (Received February 09, 2018)

1138-05-205 **Beth Bjorkman**, **Garner Cochran*** (`gcochran@math.sc.edu`), **Wei Gao**, **Lauren Keough**, **Rachel Kirsch**, **Mitch Phillipson**, **Danny Rorabaugh**, **Heather Smith** and **Jennifer Wise**. *k-foldability of words.*

We extend results regarding a combinatorial model which generalizes the folding of the RNA molecule in biology, first introduced by Black, Drellich, and Tymoczko (2017+). RNA is represented by a word from the alphabet of nucleotides A, U, C, and G in which Watson-Crick bonds form between nucleotides A and U and between C and G. The resulting two-dimensional structure is generally modeled as a planar tree with edges representing bonds. (Received February 09, 2018)

1138-05-207 **Zachary Gershkoff*** (`zgersh2@math.lsu.edu`), zgersh2@math.lsu.edu, and **James Oxley**. *A splitter theorem for connected 2-polymatroids.* Preliminary report.

Brylawski and Seymour independently proved that if N is a connected minor of a connected matroid M, and e is an element of M but not of N, then the deletion or contraction of e from M is connected and has N as a minor. This talk discusses an analogy of this theorem for connected 2-polymatroids. (Received February 14, 2018)

1138-05-210 **Joao Paulo Costalonga**, **Talmage James Reid*** (`mmreid@olemiss.edu`) and **Haidong Wu**. *On Vertex-Disjoint Cycles and a Fixed Edge in a 3-connected Graph.* Preliminary report.

Dirac classified the 3-connected graphs with no pair of vertex-disjoint cycles. We provide analogous theorems that relate to a fixed edge in a graph. For example, we determine when a 3-connected graph contains an edge that possesses the property that there exists no pair of vertex-disjoint cycles whose union contains the edge. (Received February 09, 2018)

1138-05-217 **Guoli Ding*** (`ding@math.lsu.edu`) and **Shilin Wang**. *Rooted graphs without a heavy path.* Preliminary report.

A *rooted graph* consists of a graph G and a subset R of $V(G)$. For any path P of G, we call $|R \cap V(P)|$ the *weight* of P. We characterize rooted graphs that do not contain a heavy path. We also present a couple of related results. (Received February 09, 2018)

1138-05-219 **Eva Czabarka*** (`czabarka@math.sc.edu`), **Laszlo A. Szekely** and **Stephan Wagner**. *A tanglegram Kuratowski theorem.*

A tanglegram of size n is a pair of binary trees on n leaves with a matching between the leaves. It is used in phylogenetics (e.g. the evolutionary trees of parasites and hosts, the matching giving which parasite exploits which host). A tanglegram layout is a straight line drawing where only edges in the matching can cross.

The tanglegram crossing number is the minimum crossing number among all of the layouts. It is related the biologically relevant quantities (e.g. number of times parasites switch hosts) We give an analog of the Kuratowski theorem; i.e. we show that a tanglegram has tangle-crossing number 0 unless it contains one of two size 4 tanglegrams as an induced subtanglegram. (Received February 09, 2018)

1138-05-222 **He Guo*** (he.guo@gatech.edu), Room 117, Skiles Building, 686 Cherry Street, Atlanta, GA 30332, and **Lutz Warnke**. *Packing nearly optimal Ramsey $R(3,t)$ graphs.*

In 1995 Kim famously proved the Ramsey bound $R(3,t) \geq ct^2/\log t$ by constructing an n-vertex graph that is triangle-free and has independence number at most $C\sqrt{n\log n}$. We extend this celebrated result, which is best possible up to the value of the constants, by approximately decomposing the complete graph K_n into a packing of such nearly optimal Ramsey $R(3,t)$ graphs.

More precisely, for any $\epsilon > 0$ we find an edge-disjoint collection $(G_i)_i$ of n-vertex graphs $G_i \subseteq K_n$ such that (a) each G_i is triangle-free and has independence number at most $C_\epsilon\sqrt{n\log n}$, and (b) the union of all the G_i contains at least $(1-\epsilon)\binom{n}{2}$ edges. Our algorithmic proof proceeds by sequentially choosing the graphs G_i via a semi-random (i.e., Rödl nibble type) variation of the triangle-free process.

As an application, we prove a conjecture in Ramsey theory by Fox, Grinshpun, Liebenau, Person, and Szabó (concerning a Ramsey-type parameter introduced by Burr, Erdős, Lovász in 1976). Namely, denoting by $s_r(H)$ the smallest minimum degree of r-Ramsey minimal graphs for H, we close the existing logarithmic gap for $H = K_3$ and establish that $s_r(K_3) = \Theta(r^2\log r)$. (Received February 09, 2018)

1138-05-225 **Chun-Hung Liu*** (chliu@math.princeton.edu). *Packing topological minors half-integrally.*

Thomas conjectured that for every graph H, there exists a function f such that for every graph G, either G contains k H-minors such that every vertex of G is contained in at most two of them, or there exists a set of at most $f(k)$ vertices of G intersecting all H-minors in G. This conjecture was confirmed by Norin. The main result of this talk is a strengthening of this conjecture. We prove that for every graph H, there exists a function f such that for every graph G, either G contains k H-topological minors such that every vertex of G is contained in at most two of them, or there exists a set of at most $f(k)$ vertices of G intersecting all H-topological minors in G. (Received February 09, 2018)

1138-05-228 **Daniel Gray*** (dagray@georgiasouthern.edu), **Ryan Fortenberry** (rfortenberry@georgiasouthern.edu) and **Hua Wang** (hwang@georgiasouthern.edu). *Hexagonal Arrangements in the Plane.*

In Chemistry, Polycyclic Aromatic Hydrocarbons (PAHs) are modeled by connected graphs formed by adjoining identical hexagons, where each hexagon must share an edge with at least one other hexagon. We will focus on PAHs whose graphs live strictly in the plane. An exact formula for the number of such PAHs whose graphs are composed of n hexagons is extremely unlikely, but we prove that this number has exponential growth as well as provide lower and upper bounds. Moreover, we look at which PAHs have graphs maximizing/minimizing the Wiener index, a topological index which has been well-studied for many types of graphs and which has been shown in the case of alkanes to be highly correlated to properties such as boiling point, surface tension, and density. (Received February 10, 2018)

1138-05-229 **Jie Han** (jhan@ime.usp.br) 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 answers a question of Krivelevich, Kwan and Sudakov. (Received February 10, 2018)

1138-05-232 **Bing Wei*** (bwei@olemiss.edu), Department of Mathematics, University of Mississippi, University, MS 38677. *On domination and independent domination in graphs.*

For a graph $G = (V,E)$, a subset D of V is called a dominating set if every vertex not in D is adjacent to at least one vertex in D. If a dominating set D is an independent set, that is, no edge between any two vertices in D, then D is called an independent dominating set. Let $\gamma(G)$ and $i(G)$ denote the number of vertices in a smallest dominating set and in a smallest independent dominating set of G, respectively. In this talk, some lower and upper bounds on both $\gamma(G)$ and $i(G)$ will be presented, several results on our recent outcomes about the relationships between $\gamma(G)$ and $i(G)$ will be introduced and related research problems will be proposed. (Received February 10, 2018)

1138-05-235 **Samantha N Petti*** (spetti@gatech.edu) and **Santosh S Vempala**. *Approximating Sparse Graphs: The Random Overlapping Communities Model.*

How can we approximate sparse graphs and sequences of sparse graphs (with average degree unbounded and $o(n)$)? We consider convergence in the first k moments of the graph spectrum (equivalent to the numbers of closed k-walks) appropriately normalized. We introduce a simple random graph model that captures the limiting spectra of many sequences of interest, including the sequence of hypercube graphs. The Random Overlapping Communities (ROC) model is specified by a distribution on pairs (s, q), $s \in \mathbb{Z}_+, q \in (0, 1]$. A graph on n vertices with average degree d is generated by repeatedly picking pairs (s, q) from the distribution, adding an Erdős-Rényi random graph of edge density q on a subset of vertices chosen by including each vertex with probability s/n, and repeating this process so that the expected degree is d. Our proof of convergence to a ROC random graph is based on the Stieltjes moment condition. The model is an effective approximation for individual graphs. For almost all possible triangle-to-edge and four-cycle-to-edge ratios, there exists a pair (s, q) such that the ROC model with this single community type produces graphs with both desired ratios, a property that cannot be achieved by block models of bounded size. (Received February 10, 2018)

1138-05-239 **Jie Zhang*** (zhangjie.sjtu@163.com). *Wiener index, degrees, and segments in trees.*

Wiener index is probably one of the most well known chemical indices. The extremal problems with respect to Wiener index has been extensively studied for various structures including trees with a given degree sequence or segment sequence. We will consider analogous questions on maximizing or minimizing the Wiener index among trees with a given degree sequence and a segment sequence. The question and its (partial) solution is sometimes very similar to existing work, and sometimes very different. (Received February 10, 2018)

1138-05-240 **Ahmad Abdi*** (a3abdi@uwaterloo.ca), 200 University Ave W, Waterloo, ON N2L 3G1, Canada, and **Bertrand Guenin** (bguenin@uwaterloo.ca), 200 University Ave W, Waterloo, ON N2L 3G1, Canada. *The f-flowing conjecture.*

Take a signed binary matroid. When do the odd circuits form an ideal clutter? Seymour's 1977 f-flowing conjecture predicts that there are only three excluded minors for this minor-closed property, namely the odd-K_5, the odd-F_7 as well as a specially signed R_{10}. We prove that these are the only excluded minors with an odd circuit or signature of size 3. Using this result, we show that in every blocking pair of excluded minors and through every element, one of them has a signed F_7 minor with six odd elements. (Received February 10, 2018)

1138-05-242 **Cédric Lecouvey**, Faculté des Sciences et Techniques, Université François Rabelais, Parc de Grandmont, 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. *Combinatorics of Lusztig's t-analogue of weight multiplicity.*

Lusztig defined the Kostka-Foulkes polynomial $K_{\lambda\mu}(t)$ as a t-analogue of the multiplicity of a weight μ in the irreducible representation of highest weight λ of a semisimple Lie algebra. This polynomial has remarkable properties, such as being an affine Kazhdan-Lusztig polynomial. Finding combinatorial formulas for $K_{\lambda\mu}(t)$ beyond type A_n has been a long-standing problem. We give the first such formula, for $K_{\lambda,0}(t)$ in type C_n; the special case $\mu = 0$ is, in fact, the most complex one. We use combinatorics of Kashiwara's crystal graphs, as well as a recent non-stable branching rule for the symplectic group due to J.-H. Kwon. Related aspects and applications will also be discussed. (Received February 10, 2018)

1138-05-248 **Linyuan Lu*** (lu@math.sc.edu), Irmo, SC 29208, and **Zhiyu Wang** (zhiyuw@math.sc.edu), Columbia, SC 29208. *Color disjoint rainbow spanning trees of edge-colored graphs.*

For any $t \geq 1$ and an edge-colored multigraph G, we show that G has t color-disjoint rainbow spanning trees if and only if for any partition P of $V(G)$, there are at least $t(|P|-1)$ distinct colors occurring in the crossing edges of P. Our theorem generalizes two previous results: Nash-Williams-Tutte theorem and Schrijver's theorem. As an application, we resolve a conjecture of Jahanbekam and West: $r(n,t) = \binom{n-2}{2} + t$ whenever $n \geq 2t + 2 \geq 6$. Here $r(n,t)$ is the maximum number of colors in an edge-coloring of K_n not having t edge-disjoint rainbow spanning trees. (Received February 11, 2018)

1138-05-250 **Ricky Ini Liu*** (riliu@ncsu.edu), **Karola Mészáros** and **Alejandro H. Morales**.
Flow polytopes and the space of diagonal harmonics.

A result of Haglund implies that the (q,t)-bigraded Hilbert series of the space of diagonal harmonics is a (q,t)-Ehrhart function of the flow polytope of the complete graph with netflow vector $(-n,1,\ldots,1)$. We study the (q,t)-Ehrhart functions of flow polytopes of threshold graphs with arbitrary netflow vectors. Our results generalize previously known specializations of the mentioned bigraded Hilbert series at $t=1$, 0, and q^{-1}. (Received February 11, 2018)

1138-05-251 **Huseyin Acan*** (huseyin.acan@rutgers.edu) and **Boris Pittel** (bgp@math.ohio-state.edu). *On the largest component of the intersection graph of a random chord diagram.*

A chord diagram of size n is a pairing of $2n$ points. When the points are placed on a circle, this gives n chords. For a chord diagram D, its intersection graph is formed by taking the chords of D as the vertices of the graph and creating an edge between two vertices whenever the corresponding chords cross each other. We study the largest component of $H_{n,m}$, where $H_{n,m}$ denotes the intersection graph of a uniformly random chord diagram with n chords and m crossings. We show that, with high probability, (i) the largest component contains almost all the edges and a positive fraction of all the vertices of $H_{n,m}$ when $m/(n\log n)$ tends to a limit in $(0,2/\pi^2)$ and (ii) the size of the largest component is $O(\log n)$ when $m\le n/14$. Hence, if there is a threshold for the appearance of a giant (linear size) component, it must be of order $\Omega(n)$ and $O(n\log n)$. (Received February 11, 2018)

1138-05-255 **Peter Dankelmann*** (pdankelmann@uj.ac.za), Department of Pure and Applied Mathematics, University of Johannesburg, Johannesburg, 2006, South Africa. *Steiner k-Wiener index and minimum degree.*

The Wiener index of a connected graph G is defined as the sum of the distances between all unordered pairs of vertices of G. The Steiner distance of a set S of vertices of a connected graph G is the minimum size of a connected subgraph of G containing the vertices of S. The Steiner distance generalises the notion of distance in graphs to more than two vertices.

The Steiner k-Wiener index combines these two notions. For $k\in\mathbb{N}$, the Steiner k-Wiener index of a graph G is defined as the sum of the Steiner distances of all k-subsets of the vertex set of G. The Steiner 2-Wiener index is the Wiener index.

It is known that for $n,k\in\mathbb{N}$ with $2\le k\le n$, the Steiner k-Wiener index of a connected graph of order n cannot exceed $\frac{(k-1)(n+1)}{k+1}\binom{n}{k}$, with equality holding for paths. In our talk we show that for graphs of minimum degree δ this bound can be improved by a factor of approximately $\frac{3}{\delta+1}$, and this is best possible. (Received February 11, 2018)

1138-05-259 **Yan Cao**, Department of Mathematics and Statistics, Georgia State University, Atlatna, GA 30303, and **Guantao Chen*** (gchen@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlatna, GA 30303. *Vizing's Average Degree Conjecture on Edge Chromatic Critical Graphs.* Preliminary report.

Let G be a simple graph. Denote by $\Delta(G)$, $\delta(G)$, and $\chi'(G)$ the maximum degree, minimum degree and the chromatic index of G. A graph G is *edge-Δ-critical* if $\chi'(G)=\Delta+1$ and $\chi'(H)\le\Delta$ for any proper subgraph of H of G. Let $\overline{d}(G)$ denote the average degree of G, Vizing in 1968 conjectured that the $\overline{d}(G)\ge\Delta-1+\frac{3}{n}$ if G is an edge-Δ-critical graph of order n. We show that if G is an edge-Δ-critical graph with $\Delta\ge16$, then $\overline{d}(G)\ge\frac{3}{4}\Delta-8$. Moreover, we show that there exist two functions D and d such that for any positive real number $\epsilon\in(0,1)$, if G is an edge-Δ-critical graph with $\Delta\ge Delta(\epsilon)$ and $\delta(G)\ge d(\epsilon)$, then $\overline{d}(G)\ge(1-\epsilon)\Delta$. We will give two specific functions satisfies the statement above. By using this theorem, we also show that an edge-Δ-critical graph G has $\overline{d}(G)\ge\Delta-o(\Delta)$ if $\delta(G)\ge(\log\Delta)^{\frac{3}{4}}$. (Received February 11, 2018)

1138-05-261 **Brendan Pawlowski** and **Brendon Rhoades*** (bprhoades@math.ucsd.edu). *Delta Schubert calculus.*

We describe a variety $X_{n,k}$ which depends on two positive integers $k\le n$. When $k=n$ our variety $X_{n,k}$ is homotopy equivalent to the space $\mathcal{F}\ell(n)$ of complete flags in $\mathbb{C}^n$. Our variety $X_{n,k}$ is related to the Delta Conjecture in the same way that the flag variety is related to the Shuffle Theorem. We will describe the extension (and non-extension) of various results in Schubert calculus to $X_{n,k}$. (Received February 11, 2018)

1138-05-264 **Hamed Amini*** (amini@math.miami.edu), Coral Gables, FL 33146. *Bootstrap Percolation in Inhomogeneous Random Graphs.*

A bootstrap percolation process on a graph G is an "infection" process which evolves in rounds. Initially, there is a subset of infected nodes and in each subsequent round every uninfected node which has at least θ infected neighbours becomes infected and remains so forever. We consider this process in the case where the underlying graph is an inhomogeneous random graph whose kernel is of rank 1. Assuming that initially every vertex is infected independently with probability p, we provide a law of large numbers for the number of vertices that will have been infected by the end of the process. We also focus on a special case of such random graphs which exhibit a power-law degree distribution with exponent in (2,3). We show the existence of a critical function $a_c(n)$ such that $a_c(n) = o(n)$ with the following property. Let n be the number of vertices and let $a(n)$ be the number of the vertices that are initially infected. If $a(n) << a_c(n)$, then the process does not evolve at all, with high probability as n grows, whereas if $a(n) >> a_c(n)$, then with high probability the final set of infected vertices is linear. This is based on joint work with Nikolaos Fountoulakis and Konstantinos Panagiotou. (Received February 11, 2018)

1138-05-275 **Philippe R Di Francesco*** (philippe@illinois.edu). *Macdonald operators, from Cluster Algebra to Elliptic Hall algebra.*

We investigate generalized Macdonald difference operators that interpolate between quantum cluster algebras associated to Q-systems and the so-called Elliptic Hall, or Ding-Iohara-Miki algebra which play a central role in the so-called AGT conjecture. We will show how some of these operators for type A arise naturally from Double-Affine Hecke Algebra representations, and obey relations in the Elliptic Hall algebra as a consequence. Relations to Cluster Algebra in the limit $t \to \infty$ will be obtained by use of Shuffle Algebra techniques. Generalizations to B, C, D types will also be presented.

(Joint work with Rinat Kedem.). (Received February 12, 2018)

1138-05-280 **Runrun Liu**, **Sarah Loeb**, **Yuxue Yin** and **Gexin Yu*** (gyu@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA. *DP-coloring of planar graphs with three colors.* Preliminary report.

DP-coloring is a generalization of list coloring introduced recently by Dvořák and Postle (2017). In this talk, we will show how to extend some list coloring results on planar graphs with three colors to DP-coloring. This is joint work with Runrun Liu, Sarah Loeb, and Yuxue Yin. (Received February 12, 2018)

1138-05-286 **Sooyeon Lee*** (slee27@olemiss.edu) and **Haidong Wu**. *The beta invariant and chromatic uniqueness of wheels.*

Using the beta invariant and the characteristic polynomial of a matroid M, we prove that if M is a 3-connected matroid such that the chromatic polynomial of M is equal to the chromatic polynomial of a wheel, then M is isomorphic to the wheel. And we show a splitting formula of the beta invariant of a general parallel connection across a 3-point line and 3-sum of two matroids and how this result is related to the connectivity condition of the chromatic polynomial result. (Received February 12, 2018)

1138-05-289 **Marthe Bonamy**, **Frantisek Kardos**, **Tom Kelly** and **Peter Nelson***, apnelson@uwaterloo.ca, and **Luke Postle**. *Induced binary submatroids.*

A restriction N of a simple binary matroid M is *induced* if its ground set is a flat of M. I will discuss a theorem characterising the binary matroids containing neither the Fano matroid nor a three-element free matroid as an induced restriction; the theorem implies that a natural analogue of the Gyárfás-Sumner conjecture is false. (Received February 12, 2018)

1138-05-292 **Karen Gunderson*** (karen.gunderson@umanitoba.ca), University of Manitoba, Department of Mathematics, 186 Dysart Road, Winnipeg, MB R3T 2N2. *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 February 12, 2018)

1138-05-294 **Nathan Kahl***, nathan.kahl@shu.edu. *Vulnerability Parameters and Graph Compression.*
Given a simple graph G and vertices $u, v \in V(G)$, let X denote the set of vertices adjacent to u but not adjacent to v. The compression of G from u to v produces a new graph $G_{u \to v}$ by, for each $x \in X$, removing edges from G of the form ux and replacing them with corresponding edges of the form vx. Kelmans, and independently Satyanarayana, Schoppmann, and Suffel, showed that for any graph G and any $u, v \in V(G)$, compression from u to v could not increase, and typically decreased, both the number of spanning trees of G and the all-terminal reliability of G. Both of these are vulnerability parameters, i.e., measures of the strength of a network. We show that a number of other prominent vulnerability parameters—including vertex connectivity, edge connectivity, toughness, scattering number, and binding number—are affected by compression in exactly the same way as number of spanning trees and all-terminal reliability. As a corollary all of the vulnerability parameters considered are, like number of spanning trees and all-terminal reliability, minimized by threshold graphs. (Received February 12, 2018)

1138-05-303 **Erik Carlsson*** (ecarlsson@math.ucdavis.edu), 3000 Lillard dr. apt. 210, Davis, CA 95618. *Double coinvariants and affine Schubert calculus.*
I'll discuss a new result with Alexei Oblomkov which gives a filtration by submodules of the double coinvariant algebra over one of the sets of variables. We find an explicit presentation of these subquotients, a connection with the homology of the affine flag variety, and a monomial basis which realizes the Haglund-Loehr conjecture, first proved by myself and Mellit. (Received February 12, 2018)

1138-05-306 **Stefan HM van Zwam*** (svanzwam@math.lsu.edu) and **Kevin Grace**. *Working with templates.*
In 2015, Geelen, Gerards, and Whittle announced some results on the structure of the highly connected matroids in a minor-closed class of matroids representable over a finite field. In particular, these matroids will be bounded-rank perturbations of more highly structured matroids. Furthermore, they announced a more detailed description of these perturbations trough the introduction of templates. The proofs of these results are forthcoming, and based on their Matroid Structure Theorem.

In this talk, I will introduce their proposed results, discuss a necessary modification to deal with some unexpected structures, and outline how to use these templates through certain reduction operations. (Received February 12, 2018)

1138-05-310 **Michael Nelson*** (mnelso32@gmail.com). *Combinatorics related to Tonks projection.*
In 1995, Tonks found a natural cellular quotient map of n-dimensional complexes from the permutohedron to the associahedron, and that this map can be understood through the combinatorics of trees. More specifically, we can associate a specific tree on n-leaves, which we call non-degenerate P-trees, with each cell of the n-dimensional permutohedron. Similarly we can also associate a specific tree on n-leaves, which we call A-trees, with each cell of the n-dimensional associahedron. By contracting the internal nodes with only one child, we obtain a map from the set of non-degenerate P-trees on $n+2$ leaves to the set of A-trees on $n+2$ leaves, which corresponds precisely to the cellular quotient map. In this talk, we study the number of k-cells of the n-dimensional permutohedron which collapses to a 0-cell of the n-dimensional associahedron by counting the number of non-degenerate P-trees which collapses to the A-tree attached to that 0-cell. We also consider algebraic structures generated from these concepts, where individual P-trees and A-trees define compositions of binary and unary operations. (Received February 12, 2018)

1138-05-316 **John Maharry***, Ohio State University, Department of Mathematics, Columbus, OH 43210. *Recent progress in Splitter Theorems, Unavoidable Minor Theorems and Excluded Minor Theorems.*
We will discuss classic theorems and several recent results on graph structures inlcuding splitter theorems, unavoidable minors theorems and excluded minor theorems. (Received February 12, 2018)

1138-05-318 **Zechun Yang*** (zzy0009@auburn.edu). *A Lower Estimate of the Independence Number of the Hypergraph of p-Term Cyclic Arithmetic Progressions on the Integers Modulo p^n, For Odd Primes p.* Preliminary report.
If $m > k \geq 3$, k-term cyclic arithmetic progression modulo m are defined just as ordinary arithmetic progressions are defined, except that the elements of the progressions are congruence classes mod m. For instance, $4, 8, 1$ is a 3-term cyclic arithmetic progression modulo 11, if we allow $0, \ldots, 10$ to represent the congruence classes mod 11. In this paper, it is shown that for every odd prime p and integer $n > 1$, there is a set B of congruence classes

modulo p^n such that $|B| = (p-1)^n$, and B contains no p-term cyclic arithmetic progression mod p^n. (Received February 12, 2018)

1138-05-321 **Ross K Berkowitz*** (ross.berkowitz@yale.edu). *How many triangles are in a random graph and other local questions.*

What is the probability that an Erdős-Renyi random graph has exactly the average number of triangles? What if we ask about the average plus ten, or plus two standard deviations? There has been a tremendous amount of research into proving central limit theorems for such combinatorial random variables. We will talk about some analytic tools to determine when these results may be extended to local limit theorems. (Received February 12, 2018)

1138-05-322 **Dieter Mitsche**, **Michael Molloy*** (molloy@cs.toronto.edu) and **Pawel Pralat**. *Regular subgraphs of a random graph.*

The threshold for a random graph to have a subgraph with minimum degree $k \geq 3$ (i.e. a k-core) has been well understood for decades: Pittel, Spencer and Wormald determined that it is equal to $c_k n$ for a particular constant c_k. The threshold for a random graph to have a k-regular subgraph still eludes us. Bollobas, Kim and Verstraete conjecture that the two thresholds are different and prove this for $k = 3$.

We prove that the thresholds are very close: the regular subgraph threshold is at most $(c_k + e^{-k/100})n$ for large k. (Received February 12, 2018)

1138-05-323 **Hein van der Holst*** (hvanderholst@gsu.edu), Park Place 25, Atlanta, GA 30302, and **Serguei Norine** and **Robin Thomas**. *On the second homology group of the configuration space of two particles on a graph.*

For a graph $G = (V, E)$, a 2-cycle is a bilinear form $d : E \times E \to \mathbb{Z}$ such that $d(e, f) = 0$ if e and f have a common vertex, and $d(\cdot, e)$ and $(e, \cdot)$ are circulations for each edge e. Examples of 2-cycles are 2-cycles coming from pairs of disjoint cycles of G. Also on each subgraph of G that is a subdivision of K_5 or $K_{3,3}$, there are 2-cycles. It had been a conjecture that each 2-cycle can be written as a sum of these types of 2-cycles. This has recently been disproved by Barnett.

In this talk, we give a finite list of types of 2-cycles such that each 2-cycle is a sum of 2-cycles from this list. We also show that for Kuratowski-connected graphs, it suffices to have 2-cycles coming from pairs of disjoint cycles of G and 2-cycles on subgraphs of G that are subdivisions of K_5 or $K_{3,3}$.

This provides a structure theorem for the second homology group of the configuration space of two particles on a graph. (Received February 12, 2018)

1138-05-324 **Mark N Ellingham**, **Songling Shan**, **Ryan Solava*** (ryan.w.solava@vanderbilt.edu) and **Xiaowei Yu**. *New bounds on the locally irregular chromatic index.*

A graph is *locally irregular* if the degree of every vertex is distinct from the degrees of all of its neighbors. A *locally irregular edge-coloring* of a graph G is an (improper) edge-coloring such that the graph consisting of the edges of any color class is locally irregular. It is conjectured that every graph has a locally irregular edge-coloring using at most three colors. Recently, Bensmail et al. proved that 328 colors sufficed, the first constant upper bound for the problem. Borut et al. later improved this result to 220. We improve the bound on bipartite graphs to five and as a consequence improve the upper bound on general graphs to 183. (Received February 12, 2018)

1138-05-325 **Martin Rolek*** (msrolek@wm.edu), Department of Mathematics, College of William & Mary, P.O. Box 8795, Williamsburg, VA 23187-8795, and **Zi-Xia Song**. *Clique minors in double-critical graphs.*

A connected t-chromatic graph G is *double-critical* if $G - \{u, v\}$ is $(t-2)$-colorable for each edge $uv \in E(G)$. A long standing conjecture of Erdős and Lovász that the complete graphs are the only double-critical t-chromatic graphs remains open for all $t \geq 6$. Given the difficulty in settling Erdős and Lovász's conjecture, and motivated by the well-known Hadwiger's conjecture, Kawarabayashi, Pedersen, and Toft proposed a weaker conjecture that every double-critical t-chromatic graph contains a K_t minor and verified their conjecture for $t \leq 7$. A computer-assisted proof of their conjecture for $t = 8$ has been given by Albar and Gonçalves. We provide a shorter, computer-free proof for the cases $t \leq 8$ and prove the next step by showing that every double-critical t-chromatic graph contains a K_9 minor for all $t \geq 9$. (Received February 12, 2018)

1138-05-326 **Guoli Ding**, **Sooyeon Lee** and **Haidong Wu*** (hwu@olemiss.edu). *Variations of Some Chain Theorems for Matroids.* Preliminary report.

Coullard and Oxley proved a variation of Tutte's Wheels and Whirls theorem for 3-connected matroids. We prove similar variations of some chain theorems for higher connected matroids. (Received February 12, 2018)

1138-05-342 **Peter Nelson** and **Jorn van der Pol*** (jornvanderpol@gmail.com). *Doubly exponentially many Ingleton matroids.*

The rank function of a representable matroid satisfies a linear inequality known as Ingleton's Inequality. We call a matroid Ingleton if it satisfies Ingleton's Inequality. Although every representable matroid is Ingleton, it is not true that every Ingleton matroid is representable. This raises the question how well Ingleton's Inequality characterises representable matroids.

We show that there are many more Ingleton matroids than there are representable matroids. More precisely, we show that the number of Ingleton matroids grows doubly exponentially as a function of the size of the ground set, which is much faster than the (singly exponential) growth of representable matroids. It follows that almost every Ingleton matroid is non-representable. (Received February 12, 2018)

1138-05-346 **Jonah Blasiak*** (jblasiak@gmail.com). *Catalan polynomials and k-Schur functions.*

Li-Chung Chen and Mark Haiman studied a family of symmetric functions indexed by pairs consisting of a partition contained in the staircase $(n-1,\ldots,1,0)$ (of which there are Catalan many) and a weight in $\mathbb{Z}^n$. These *Catalan polynomials* include the Hall-Littlewood polynomials and their parabolic generalizations and can be viewed as GL_n-equivariant Euler characteristics of vector bundles on the flag variety. Chen-Haiman conjectured that the k-Schur functions are a subclass of Catalan polynomials. We settle their conjecture and deduce several exciting consequences. This is joint work with Jennifer Morse, Anna Pun, and Dan Summers. (Received February 12, 2018)

1138-05-347 **Jian Cheng*** (jicheng@udel.edu), Department of Mathematical Sciences, University of Delaware, 303 Ewing Hall, Newark, DE 19716. *Integer Flows of Graphs Embedded on Non-orientable Surfaces.*

A signed graph (G,σ) is a graph G together with a sign $\sigma : E(G) \to \{\pm 1\}$. An edge is positive if it is assigned with 1 and otherwise it is negative. In 1983, Bouchet generalized the concept of integer flows to signed graphs and conjectured that every flow-admissible signed graph admits a nowhere-zero 6-flow. Let G be a graph embedded on a nonorientable surface Σ. Denote by σ_Σ an induced sign of G from its embedding on Σ, where an edge is negative if and only if it passes through a crosscap. It is well known that every graph embedded on the projective plane or Klein bottle is 6-colorable. By the coloring-flow duality, every such graph satisfies Bouchet's 6-flow conjecture. In this talk, more results and open problems regarding flows on embedded graphs will be presented and investigated. (Received February 12, 2018)

1138-05-349 **Amin Bahmanian*** (mbahman@ilstu.edu), IL , and **Sadegheh Haghshenas**, IL. *Extending edge-colorings of complete hypergraphs into regular colorings.*

Let $\binom{X}{h}$ be the collection of all h-subsets of an n-set $X \supseteq Y$. Given a coloring (partition) of a set $S \subseteq \binom{X}{h}$, we are interested in finding conditions under which this coloring is extendible to a coloring of $\binom{X}{h}$ so that the number of times each element of X appears in each color class (all sets of the same color) is the same number r. The case $S=\varnothing, r=1$ was studied by Sylvester in the 18th century, and remained open until the 1970s. The case $h=2, r=1$ is extensively studied in the literature and is closely related to completing partial symmetric Latin squares.

For $S=\binom{Y}{h}$, we settle the cases $h=4, |X| \geq 4.847323|Y|$, and $h=5, |X| \geq 6.285214|Y|$ completely. Moreover, we make partial progress toward solving the case where $S=\binom{X}{h}\setminus\binom{Y}{h}$. These results can be seen as extensions of the famous Baranyai's theorem, and make progress toward settling a 40-year-old problem posed by Cameron. (Received February 13, 2018)

1138-05-352 **Patrick Bennett***, 1903 Western Michigan Avenue, Kalamazoo, MI 49008, and **Deepak Bal**. *The bipartite $K_{2,2}$-free process and bipartite Ramsey numbers.*

The smallest n such that every red-blue edge-coloring of $K_{n,n}$ contains a blue $K_{2,2}$ or a red $K_{t,t}$ is known as the two color bipartite Ramsey number, $br(2,t)$. In the bipartite $K_{2,2}$-free process, beginning with an empty graph on vertex set $A \cup B$ where $|A|=|B|=n$, random edges from A to B are sequentially added under the restriction that no $K_{2,2}$ is formed. We use the technique of dynamic concentration to analyze this process and show how the resulting graph improves the previously best known lower bound by Caro and Rousseau on $br(2,t)$ for large t. This is joint work with Deepak Bal. (Received February 13, 2018)

1138-05-355 **Alexander Hoyer*** (ahoyer3@gatech.edu) and **Robin Thomas**. *The Edge-Independent Spanning Tree Conjecture.*

For a graph G, a set of subtrees of G are edge-independent with root $r \in V(G)$ if, for every vertex $v \in V(G)$, the paths between v and r in each tree are edge-disjoint. A set of k such trees represent a set of redundant broadcasts from r which can withstand $k-1$ edge failures. It is easy to see that k-edge-connectivity is a necessary condition for the existence of a set of k edge-independent spanning trees for all possible roots. Itai and Rodeh have conjectured that this condition is also sufficient. This had previously been proven for $k = 2, 3$. We prove the case $k = 4$ using a decomposition of the graph similar to an ear decomposition. (Received February 13, 2018)

1138-05-360 **James Oxley** and **Simon Pfeil***, simon.pfeil@snc.edu, and **Charles Semple** and **Geoff Whittle**. *Matroids with many small circuits and cocircuits.*

Tutte proved that a non-empty 3-connected matroid with every element in a 3-element circuit and a 3-element cocircuit is either a whirl or the cycle matroid of a wheel. This result led to the Splitter Theorem. More recently, Miller proved that a matroid of sufficient size with every pair of elements in a 4-element circuit and a 4-element cocircuit is a tipless spike. This result simplifies the proof of Rota's conjecture for GF(4). Here we investigate matroids having similar restrictions on their small circuits and cocircuits. In particular, we completely determine the 3-connected matroids with every pair of elements in a 4-element circuit and every element in a 3-element cocircuit, as well as the 4-connected matroids with every pair of elements in a 4-element circuit and every element in a 4-element cocircuit. (Received February 13, 2018)

1138-05-362 **Hongliang Lu**, **Yan Wang** and **Xingxing Yu*** (yu@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Minimum co-degree condition for perfect matchings in k-partite k-graphs.*

Let H be a k-partite k-graph with n vertices in each partition class, and let $\delta_{k-1}(H)$ denote the minimum co-degree of H. We characterize those H with $\delta_{k-1}(H) \geq n/2$ and with no perfect matching. As a consequence we give an affirmative answer to the following question of Rödl and Ruciński: If k is even or $n \not\equiv 2 \pmod 4$, does $\delta_{k-1}(H) \geq n/2$ imply that H has a perfect matching? We also give an example indicating that it is not sufficient to impose this degree bound on only two types of $(k-1)$-sets. (Received February 13, 2018)

1138-05-364 **Rosa Orellana** and **Mike Zabrocki*** (zabrocki@mathstat.yorku.ca), Toronto, ON , Canada. *A multiset partition algebra and diagonal action on polynomials.*

The partition algebra $P_r(n)$ arises as the commutant algebra of the symmetric group S_n when it acts on $V^{\otimes r}$ where $V = \mathrm{span}\{v_1, v_2, \ldots, v_n\}$ is the permutation module. In this talk we will introduce a multiset partition algebra as the commutant algebra of S_n when it acts on the space of polynomials of degree r in variables $\{x_{ij} : 1 \leq i \leq n, 1 \leq j \leq k\}$ and where S_n acts on the first subscript of the variables. An RSK algorithm on multiset partitions helps us to describe how the space decomposes into irreducibles. (Received February 13, 2018)

1138-05-368 **Victor Falgas-Ravry**, **Kelly O'Connell** and **Andrew Uzzell*** (uzzellan@grinnell.edu). *Multicolor hypergraph containers.*

The hypergraph container method is a technique for solving combinatorial problems that can be phrased in terms of independent sets in hypergraphs. In particular, hypergraph containers have been used to determine the number and typical structure of graphs in various families. A *k-colored graph* is a complete graph whose edges are labeled with one of k colors. We use hypergraph containers to determine the asymptotic number of k-colored graphs in a hereditary family, as well as to characterize the typical structure of graphs in such a family. As an application, for certain directed graphs H, we determine the asymptotic number of H-free directed graphs on n vertices. This generalizes a result of Kühn, Osthus, Townsend, and Zhao. (Received February 13, 2018)

1138-05-371 **Jinko Kanno**, **Tanya Lueder** and **Bogdan Oporowski*** (bogdan@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *A characterization of nearly-outerplanar graphs.* Preliminary report.

A graph is *nearly-outerplanar* if it is edgeless, or has an edge whose deletion results in an outerplanar graph. We characterize the class of nearly-outerplanar graphs by describing all topologically minimal graphs that are not in the class. (Received February 13, 2018)

1138-05-372 **Songling Shan*** (songling.shan@vanderbilt.edu), Nashville, TN 37203. *Toughness and Spanning k-walks in K_4-minor-free and planar graphs.*

A k-walk is a closed walk with each vertex repeated at most k times. Jackson and Wormald conjectured in 1990 that for $k \geq 2$, every $\frac{1}{k-1}$-tough graph contains a spanning k-walk. We confirm this conjecture for K_4-minor-free graphs and planar graphs. Our main proof uses a technique where we incorporate toughness-related information into weights associated with vertices and cutsets. (Received February 13, 2018)

1138-05-397 **J Blasiak** and **J Morse*** (morsej@virginia.edu), Kerchof Hall, Department of Math, Charlottesville, VA 22911, and **A Pun** and **D Summers**. *Combinatorics, computing, and k-Schur functions.*

Combinatorial structures have been used to give efficient and elegant constructions for polynomial coefficients going all the way back to the binomial theorem. In turn, a wide spectrum of problems can be converted to computations with appropriate polynomials. We will see how this plays out on examples from representation theory and geometry.

The k-Schur functions, (symmetric) polynomials defined using the Bruhat order poset on the type-A affine Weyl group, are a key example. Over the last two decades, calculations with these polynomials have been tied to finding string theory invariants named for Gromov and Witten, to characterizing the irreducible decomposition of the Garsia-Haiman bigraded modules, and to Schubert structure constants for the (quantum) cohomology of the flag variety. However, the intricacy of the k-Schur definition has been a major obstruction to finding the sought-after computational rules. We will discuss these developments and a new hope. (Received February 13, 2018)

11 ► Number theory

1138-11-6 **Sebastian Troncoso*** (sitronco@bsc.edu), Birmingham-Southern College, Mathematics Department, 900 Arkadelphia Road / Box 549032, Birmingham, AL 35254, and **Jung Kyu Canci** (jungkyu.canci@unibas.ch) and **Solomon Vishkautsan** (wishcow@gmail.com). *Scarcity of finite orbits for rational functions over a number fields.*

Let $\phi : \mathbb{P}_1 \to \mathbb{P}_1$ be a endomorphism of degree $d \geq 2$ defined over a number field K. Let S be the set of places of bad reduction for ϕ, including the archimedean places, and $PrePer(\phi, K)$ be the set of K-rational preperiodic points of ϕ.

The present paper presents two main results. The first result is a bound for $|PrePer(\phi, K)|$ in terms of the number of places of bad reduction $|S|$ and the degree d of the endomorphism ϕ. This bound is *quadratic* in terms of d which is a significant improvement to all previous bound for $|PrePer(\phi, K)|$ in terms of d.

For the second result, if we assume that there is a K-rational periodic point of minimal period at least two then a bound for the cardinality of the set $PrePer(\phi, K)$ can be given which is *linear* in terms of d. (Received September 28, 2017)

1138-11-317 **Paul Balister*** (pbalistr@memphis.edu), **Béla Bollobás** and **Robert Morris**. *The sharp threshold for making squares.*

Many of the fastest known algorithms for factoring large integers rely on finding subsequences of randomly generated sequences of integers whose product is a perfect square. Motivated by this, in 1994 Pomerance posed the problem of determining the threshold of the event that a random sequence of N integers, each chosen uniformly from the set $\{1 \ldots, x\}$, contains a subsequence, the product of whose elements is a perfect square. In 1996, Pomerance gave good bounds on this threshold and also conjectured that it is sharp.

In a paper published in Annals of Mathematics in 2012, Croot, Granville, Pemantle and Tetali significantly improved these bounds, and stated a conjecture as to the location of this sharp threshold. In recent work, we have confirmed this conjecture. In this talk I shall give a brief overview of some of the ideas used in the proof, which relies on techniques from number theory, combinatorics, and stochastic processes. (Received February 12, 2018)

12 ► Field theory and polynomials

1138-12-151 **Jiuzu Hong*** (jiuzu@email.unc.edu). *Conformal blocks for Galois covers of algebraic curves.* Preliminary report.

Given an algebraic curve with finite many marked points, we attach an irreducible integrable highest weight representation to each marked point. The space of conformal blocks associated to these representations on the algebraic curve is a finite dimensional vector space. It has many nice properties, including propagation of vacua and factorization properties. A projectively flat connection structure occurs on the family of conformal blocks if we deform the marked curve, and very remarkably the dimension can be computed by celebrated Verlinde formula.

If we replace the algebraic curve by Galois cover, we can similarly attach the space of conformal blocks. Under some mild conditions, we also can show propagation of vacua and factorization properties, if we deform the Galois cover, a similar projectively flat connection will also arise. This talk will be based on the ongoing joint work with Shrawan Kumar. (Received February 07, 2018)

13 ► Commutative rings and algebras

1138-13-7 **Pedro de Carvalho Cayres Pinto**, **Hans-Christian Herbig**, **Daniel Herden** and **Christopher Seaton*** (seatonc@rhodes.edu), 2000 N. Parkway, Department of Mathematics and Computer Scienc, Memphis, TN 38112. *The Hilbert series of a reducible representation of* $\mathrm{SL}_2(\mathbb{C})$ *and its Laurent coefficients.*

Let $G = \mathrm{SL}_2(\mathbb{C})$, and let $V = \oplus_{k=1}^{r} V_{d_k}$ be a finite-dimensional representation of G where V_{d_k} denotes the unique irreducible representation of G of dimension $d_k + 1$ on binary forms of degree d_k. Let $\mathbb{C}[V]^G$ denote the graded algebra of polynomial G-invariants. Let $H_V(t)$ denote the Hilbert series of $\mathbb{C}[V]^G$, the generating function of the dimensions of the homogeneous components of $\mathbb{C}[V]^G$. It is well-known that $H_V(t)$ is a rational function with a pole at $t = 1$ of order $\dim \mathbb{C}[V]^G$. The lowest-degree coefficient $\gamma_0(V)$ of the Laurent series of $H_V(t)$ at $t = 1$ is sometimes called the *degree* of $\mathbb{C}[V]^G$.

When $r = 1$, i.e. $V = V_d$ is irreducible, a formula for $\gamma_0(V)$ was given by Hilbert, and several authors have developed algorithms to compute $H_V(t)$. We will present recent results for the case of an arbitrary finite-dimensional representation, including a general formula for the Hilbert series expressed as averages of rational functions over roots of unity, a corresponding algorithm to compute $H_V(t)$, and a closed formula for $\gamma_0(V)$ in terms of Schur polynomials of the weights. (Received November 03, 2017)

1138-13-13 **Robin Baidya***, Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303. *Forster–Swan for maps.* Preliminary report.

The Forster–Swan Theorem gives an upper bound on the global number of generators of a certain type of module, namely, a finitely generated right module M over a ring S that is a module-finite algebra over a commutative ring R. The theorem also assumes that R has a finite-dimensional Noetherian maximal spectrum. In this theorem, the global number of generators is expressed in terms of local numbers of generators and dimensions of prime ideals in j-Spec(R). If the local numbers of generators are sufficiently large, then the Eisenbud–Evans Basic Element Theorem states that there is an element of M that is part of a minimal generating set for M after localizing at any prime ideal in j-Spec(R). In this talk, we generalize Forster–Swan and Eisenbud–Evans by replacing elements of M with maps in $\mathrm{Hom}_S(N, M)$, where N is a direct summand of a direct sum of finitely presented right S-modules. We recover Forster–Swan and Eisenbud–Evans by setting $N = S$. (Received December 24, 2017)

1138-13-20 **Visu Makam*** (visu@umich.edu), 1960 Woodbury, Apt 4912, Ann Arbor, MI 48104, and **Harm Derksen**. *Algorithms for orbit closure separation for invariants and semi-invariants of matrices.*

For a rational representation V of a reductive group G, we are interested in giving efficient algorithms to detect if the orbit closures of two given points in V intersect. We give a polynomial time algorithm for the cases of matrix invariants and matrix semi-invariants in all characteristics. Moreover, when the orbit closures do not intersect, we provide an explicit separating invariant. This is joint work with Harm Derksen. (Received January 08, 2018)

1138-13-46 **Sandra Spiroff*** (spiroff@olemiss.edu), Department of Mathematics, Hume Hall 335, P.O. Box 1848, University, MS 38677-1848, and **Sean Sather-Wagstaff** and **Tony Se**. *Semi-dualizing modules of Ladder Determinantal rings, Part I.* Preliminary report.

We broaden the study of the set of isomorphism classes of semidualizing modules from determinantal rings to ladder determinantal rings. One might suspect that this set is determined by the ladder's shape and number of corners. We discuss some results, defining the relevant terms in the process. This talk is introductory in nature. A second talk by Tony Se will further discuss the topic and our results. This is joint work with Sean Sather-Wagstaff and Tony Se. (Received January 23, 2018)

1138-13-47 **Sean Sather-Wagstaff**, **Tony Se*** (ttse@olemiss.edu) and **Sandra Spiroff**. *Semidualizing modules of ladder determinantal rings, Part II.* Preliminary report.

Semidualizing modules are generalizations of dualizing modules. Currently, not much is known about the class of semidualizing modules of an arbitrary ring. We aim to determine the semidualizing modules of ladder determinantal rings. We will describe our result that only a particular construction produces nontrivial semidualizing modules, provide some concrete examples and explain how some of the machinery is used in our work. This is joint work with Sean Sather-Wagstaff and Sandra Spiroff, and our talk is a continuation of the introductory talk on the topic by Sandra Spiroff. (Received January 23, 2018)

1138-13-49 **Saeed Nasseh*** (snasseh@georgiasouthern.edu), **Sean Sather-Wagstaff**, **Ryo Takahashi** and **Keller VandeBogert**. *Applications of local rings with decomposable maximal ideals.* Preliminary report.

We investigate homological properties of local rings with decomposable maximal ideals and discuss some applications of these rings. We also characterize the Cohen-Macaulay local rings with decomposable maximal ideals of finite Cohen-Macaulay type. (Received January 24, 2018)

1138-13-65 **Thomas Polstra*** (polstra@math.utah.edu), 304 E Beryl Ave, Salt Lake City, UT 84115, and **Pham Hung Quy**. *Nilpotence of Frobenius actions on local cohomology modules and Frobenius closure of ideals.*

The Frobenius endomorphism of a local ring of prime characteristic gives rise to Frobenius actions on local cohomology modules. In this talk we will discuss interesting connections between these Frobenius actions, tight closure, and Frobenius closure. All new results presented are from joint work with Pham Hung Quy. (Received January 28, 2018)

1138-13-82 **Jack Jeffries*** (jackjeff@umich.edu). *The Smith-Van den Bergh functors.*

In their work on differential operators in positive characteristic, Smith and Van den Bergh define and study the derived functors of differential operators; they arise naturally as obstructions to differential operators reducing to positive characteristic. We will discuss formulas for the ring of differential operators as well as these derived functors of differential operators in terms of local cohomology. One can use this description to relate questions on the behavior of differential operators under base change to questions on p-torsion in local cohomology. We will also connect the vanishing of these functors to some interesting properties of singularities. (Received January 30, 2018)

1138-13-91 **Parangama Sarkar***, 810 E. Rollins Street, 202 Math Sciences Building, University of Missouri, Columbia, MO 65211, and **Jugal Verma**, 101-C, Department of Mathematics, Indian Institute of Technology Bombay, Mumbai, India. *Local cohomology of multi-Rees algebras, joint reduction vectors and product of complete ideals.*

We find conditions on the local cohomology modules of multi-Rees algebras of admissible filtrations which enable us to predict joint reduction vectors. As a consequence we are able to prove a generalization of a result of Reid-Roberts-Vitulli in the setting of analytically unramified local rings for completeness of power products of complete ideals. (Received February 01, 2018)

1138-13-95 **Rankeya Datta*** (rankeya@umich.edu), Ann Arbor, MI 48103. *Uniform approximation of valuation ideals in prime characteristic.*

Following their influential work on symbolic powers of ideals, Ein, Lazarsfeld and Smith used asymptotic multiplier ideals in another ingenious way to prove uniform estimates for valuation ideals associated to a real-valued Abhyankar valuation centered on a smooth variety of characteristic 0. In this talk, we will explain how to prove an analogue of their result for smooth varieties over perfect ground fields of prime characteristic, even in the absence of resolution of singularities and deep vanishing theorems. (Received February 02, 2018)

1138-13-98 **Irina Georgeana Ilioaea*** (iilioaea1@gsu.edu) and **Florian Enescu** (fenescu@gsu.edu). *Strong test ideals associated to Cartier algebras.* Preliminary report.

In this talk, Cartier algebras are used to produce a large class of strong test ideals for a local F-finite reduced ring of positive characteristic. Results of Vraciu and Takagi are recovered under this new framework.

The main result of the talk states that the number of generators of the test ideal associated to pairs of Stanley-Reisner rings and linear maps is actually the number of facets of the simplicial complex associated to the Stanley-Reisner ideal.

Moreover, we will show how our results motivated us to introduce a new class of rings, called *n-tight* rings. (Received February 03, 2018)

1138-13-100 **Ilya Smirnov***, Department of Mathematics, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *F-signature and Cartier closure.* Preliminary report.

In their celebrated work, Hochster and Huneke showed how the Frobenius map yields the concepts of Hilbert-Kunz multiplicity, tight closure, and F-regularity and connections between them. More recently, a parallel theory emerged by considering Cartier maps, with F-signature and strong F-regularity as the corresponding notions.

I will fill a remaining gap by describing a version of tight closure that characterizes strongly F-regular rings and show how it connects with F-signature in a familiar way. (Received February 03, 2018)

1138-13-102 **Patricia Klein**, **Linquan Ma*** (lquanma@math.utah.edu), **Quy Hung Pham**, **Ilya Smirnov** and **Yongwei Yao**. *Lech's inequality and Stuckrad-Vogel's conjecture.* Preliminary report.

Let (R, m) be a Noetherian local ring of dimension d and let M be a finitely generated R-module of dimension d. We prove that the set l(M/IM)/e(I,M) (when I runs through all m-primary ideals) is bounded below by 1/d!e(R). Moreover, when the completion of M is equidimensional, this set is bounded above by a finite constant depending only on M. The lower bound extends a classical inequality of Lech, and the upper bound answers a question of Stuckrad-Vogel in the affirmative. (Received February 04, 2018)

1138-13-115 **Adela Vraciu*** (vraciu@math.sc.edu). *Totally acyclic complexes over tensor products of algebras.* Preliminary report.

A doubly infinite complex of free modules over a Noetherian local ring is called totally acyclic if it is acyclic and its dual is also acyclic. A syzyzgy in such a complex is called a totally reflexive module. A ring is called G-regular if the only totally reflexive modules are free.

Let R, S be local Artinian algebras of finite type over a field k and let $T = R \otimes_k S$. We investigate the following questions:

1. If $\mathcal{F}$ is a totally acyclic complex over T, does it follow that $\overline{\mathcal{F}} = \mathcal{F} \otimes_T (k \otimes_k S)$ is a totally acyclic complex over S?

2. If R and S are G-regular, does it follow that T is G-regular?

We prove that these questions have an affirmative answer if R belongs to a special class of G-regular rings which we call strictly G-regular.

An example of a strictly G-regular ring is $R = k[y_1, \ldots, y_n]/(y_1, \ldots, y_n)^2$, and as a consequence of our result we recover Tracy-Rangel's description of all the totally reflexive modules over the ring

$$\frac{k[x, y_1, \ldots, y_n]}{(x^2, (y_1, \ldots, y_n)^2)} = \frac{k[x]}{(x^2)} \otimes_k \frac{k[y_1, \ldots, y_n]}{(y_1, \ldots, y_n)^2}$$

(Received February 05, 2018)

1138-13-121 **Mark R. Johnson*** (markj@uark.edu), Department of Mathematical Sciences, 1 University of Arkansas, Fayetteville, AR 72701. *Splitting the conormal module.*

We discuss the question of when the conormal module of an ideal in a local ring has a free summand, with special attention to the case for ideals in the linkage class of a complete intersection. (Received February 06, 2018)

1138-13-156 **Sema Gunturkun*** (gunturku@umich.edu) and **Mel Hochster**. *On the Eisenbud-Green-Harris conjecture.* Preliminary report.

A generalization of the Macaulay's theorem on the growth of Hilbert functions of homogeneous ideals in $K[x_1, \ldots, x_n]$ is given by the Eisenbud-Green-Harris(EGH) conjecture. It states that the lex-plus-powers ideals show extremal behavior among the homogenous ideals containing regular sequences. Although there has been some progress on the conjecture, it still remains widely open. In this talk, we discuss a case of the EGH conjecture for the homogeneous ideals generated by $n + 2$ quadrics containing a full length regular sequence of quadratic forms. This is a joint work with Mel Hochster. (Received February 08, 2018)

1138-13-163 **Geir Agnarsson** (geir@math.gmu.edu), George Mason University, Fairfax, VA 22030, and **Neil Epstein*** (nepstei2@gmu.edu), George Mason University, Fairfax, VA 22030. *Reconstructing a monomial ideal from its socle.*

Let S be a finite set of monomials in $k[x_1, \ldots, x_d]$, k a field, such that no element of S divides any other. We show that there is a unique finite colength monomial ideal I whose socle is generated by S. This is done by analyzing the lattice structure of the monoid $\mathbb{N}^d$. We then use this to analyze zero-dimensional monomial ideals with small type, and we note that uniqueness is lost if the finite colength assumption is dropped. (Received February 08, 2018)

1138-13-206 **Janet Vassilev*** (jvassil@math.unm.edu), Department of Mathematics and Statistics, MSC01 1115, Albuquerque, NM 87131. *Tight Closure, Tight Interior and other closely related ideals.* Preliminary report.

In a recent paper, Epstein and Schwede introduce the tight interior of a submodule, a dual notion to the tight closure of a submodule. We will mainly focus on discussing the tight interior of ideals of a ring and the closely related ideals the $*$-co-reductions and the $*$-hulls. We exhibit some interesting connections in certain rings between the tight closure and the $*$-hull and the tight interior and the $*$-core. (Received February 09, 2018)

1138-13-215 **Shuenn Siang Ng*** (sng4@gsu.edu), 25 Park Pl Office 1338, Atlanta, GA 30303. *Characterization of F-rationality via Canonical Module.*

Let R be a F-finite Cohen Macaulay ring (not necessarily local) of prime characteristic with canonical module ω. We try to characterize F-rationality of R by studying the module structure via the Frobenius homomorphism of ${}^eM$ and homomorphisms from ${}^eM$ to ω, in which M is a finitely generated faithful module. We obtained some conditions involving ${}^eM$ and ω that are equivalent to R being F-rational. For example, one of such equivalent conditions is that R is normal and for every prime ideal P with height at least 2, there exists $e > 0$ such that ω_P is a homomorphic image of a direct sum of ${}^e(P\omega)_P$. (Received February 09, 2018)

1138-13-233 **William D. Taylor*** (wdtaylor@uark.edu). *New Closures Related to s-multiplicity.*

The integral closure and tight closure of ideals are extremely useful tools in commutative algebra, and have been used to solve many difficult and fascinating problems. The Hilbert-Samuel and Hilbert-Kunz multiplicities are numerical invariants of ideals intimately related to integral closure and tight closure of ideals, respectively. In this talk we will define and explore a family of closures that lie between these two classical closures and are parameterized by a real parameter. We will see how these closures arise naturally in the study of s-multiplicity, which is a family of multiplicity-like functions that interpolates between Hilbert-Samuel and Hilbert-Kunz multiplicity. We will see that these new closures are related to the s-multiplicity in precisely the same way that the two previous closures are related to the Hilbert-Samuel and Hilbert-Kunz multiplicity. We will address some of the difficulties that arise when working with this more general theory, in particular with extending certain results past the domain case. (Received February 10, 2018)

1138-13-271 **Rasoul Ahangari Maleki** and **Liana Şega*** (segal@umkc.edu). *The absolutely Koszul and Backelin-Roos properties for spaces of quadrics of small codimension.*

Let k be a field and let R be a quadratic standard graded k-algebra with $\dim_k R_2 \leq 3$. We construct a graded surjective Golod homomorphism $\varphi \colon P \to R$ such that P is a complete intersection of codimension at most 3. Furthemore, we show that R is absolutely Koszul (that is, every finitely generated R-module has finite linearity defect) if and only if R is Koszul if and only if R is not a trivial fiber extension of a non-Koszul quadratic algebra of embedding dimension 3. In particular, we recover earlier results on the Koszul property of Backelin, Conca and D'Alì. (Received February 12, 2018)

1138-13-379 **Jared L Painter*** (jpainter@una.edu), Department of Mathematics, UNA Box 5051, Florence, AL 35632, and **David Jorgensen**. *Power Variants for Strongly Golod Monomial Products.* Preliminary report.

We will explore conditions on monomial ideals I and J in a polynomial ring S for which IJ is and is not strongly Golod. A ring S/I is said to be strongly Golod if $\partial(I)^2 \subset I$. Herzog and Huneke proved that if an ideal is strongly Golod, then it is Golod. They also showed that if two ideals I and J are strongly Golod, then the product IJ is strongly Golod. However, the converse does not hold. In fact, if even one ideal is not strongly Golod, then the product need not be strongly Golod. We will outline a complete description of when products of monomial ideals in $\Bbbk[x, y]$ are strongly Golod and explore similar conditions for monomial ideals in $\Bbbk[x, y, z]$. (Received February 13, 2018)

14 ► Algebraic geometry

1138-14-40 **Jesse Leo Kass***, Department of Mathematics, University of South Carolina, 1523 Greene Street, Columbia, SC 29208. *How to count curves equivariantly.*

A big theme in modern algebraic geometry is that it is often productive to analyze a counting problem ("how many singular curves?") by identifying the desired count as an invariant in algebraic topology and then studying it using tools from topology. Focusing on the accessible case of pencils of plane conics, I will explain how equivariant homotopy theory provides useful tools for carrying out this idea in a way that records interesting information about symmetries. (Received January 23, 2018)

1138-14-53 **Jonathan Hauenstein** and **Tingting Tang*** (ttang@nd.edu). *Application of algebraic geometry in semi-definite positive problems.* Preliminary report.

In this talk, I show that solving a family of semidefinite programming (SDP) problems under affine perturbations can be converted to solving a system of quasilinear partial differential equations (PDEs) utilizing the Davidenko differential equations within the maximal perturbation set. We develop a second-order sweeping Euler scheme to approximate the boundary of the maximal set of perturbations and solve the SDPs within this set. We prove local and global error bounds for this second-order sweeping Euler scheme and demonstrate numerical results on several examples. (Received January 25, 2018)

1138-14-105 **Eric Canton***, Department of Mathematics, University of Nebraska - Lincoln, 203 Avery Hall, Lincoln, NE 68588. *Log Canonical Thresholds of Graded Sequences of Ideals in Positive Characteristic.*

Log canonical thresholds (LCTs) are a fundamental invariant of (graded sequences of) ideals on varieties, usually defined in terms of resolutions of singularities. In positive characteristics, where such resolutions are not known to exist, potential splittings of the Frobenius morphism can be used to effectively study LCTs by inducing log discrepancy functions on valuation spaces. I will present some of my recent work in this direction, extending to positive characteristics several difficult theorems regarding LCTs of graded sequences due to Jonsson and Mustata in characteristic zero. (Received February 04, 2018)

1138-14-128 **Seth Baldwin*** (seth.baldwin@unc.edu) and **Shrawan Kumar**. *Positivity in T-equivariant K-theory of flag varieties associated to Kac-Moody groups.*

The cohomology ring of flag varieties has long been known to exhibit positivity properties. One such property is that the structure constants of the Schubert basis with respect to the cup product are non-negative. Brion (2002) and Anderson-Griffeth-Miller (2011) have shown that positivity extends to K-theory and T-equivariant K-theory, respectively. In this talk I will discuss recent work (joint with Shrawan Kumar) which generalizes these results to the case of Kac-Moody groups. (Received February 06, 2018)

1138-14-132 **Paolo Aluffi*** (aluffi@math.fsu.edu), Tallahassee, FL 32306. *Degrees of projections of rank loci.*

We provide formulas for the degrees of the projections of the locus of square matrices with given rank from linear spaces spanned by a choice of matrix entries. The motivation for these computations stem from applications to 'matrix rigidity'. These degrees appear to arise in many other contexts with no apparent direct connection to the enumerative geometry of rank conditions—for example, they match the numbers of Kekulé structures of certain benzenoid hydrocarbons. (Received February 07, 2018)

1138-14-171 **Austin Conner**, **J.M. Landsberg** and **Emanuele Ventura*** (emanueleventura.sw@gmail.com), 4302 College Main St. apt. 132, Bryan, TX 77801, and **Yao Wang**. *Tight tensors.*

To study the complexity of the matrix multiplication tensor, Strassen introduced a class of tensors that vastly generalize it, the tight tensors. Tight tensors are essentially tensors with a "good" positive dimensional symmetry group. In this talk, I will discuss combinatorial and geometric consequences of tightness. This is joint work with A. Conner, JM Landsberg, and Y. Wang. (Received February 08, 2018)

1138-14-176 **David E Anderson*** (anderson.2804@osu.edu). *Degeneracy loci and the degree of semidefinite programming.*

In recent and ongoing work with William Fulton, we have found new formulas for symplectic degeneracy loci. For instance, our results include compact expressions for the degree of the variety of symmetric matrices of rank at most r. I will describe how to apply these formulas to compute the algebraic degree of semidefinite programming, providing a new perspective on work by Graf von Bothmer, Nie, Ranestad, and Sturmfels from 10-12 years ago. (Received February 08, 2018)

1138-14-180 **Rares Rasdeaconu*** (rares.rasdeaconu@vanderbilt.edu), 1326 Stevenson Center, Department of Mathematics, Vanderbilt University, Nashville, TN 37240. *Counting real rational curves on K3 surfaces.*

In real enumerative geometry, as the number of real solutions of a given counting problem may depend on the configuration of the conditions imposed, finding non-trivial bounds plays an important role. When counting curves on algebraic manifolds defined over the reals, the natural upper bound provided by the corresponding complex counting can be computed in many cases by the Gromov-Witten invariant. A non-trivial lower bound was discovered in symplectic setting by J.-Y. Welschinger, and it is a deformation invariant counting with signs of real rational curves. In this talk, an interpretation of the Welschinger's signs in algebraic setting is discussed, and invariants counting with signs real rational curves in complete, primitive linear systems on real K3 surfaces are proposed. These invariants satisfy an analog of the Yau-Zaslow formula. As a consequence, it follows that with respect to the degree of the polarization, at logarithmic scale, the number of the real rational curves counted grows as the corresponding number of complex rational curves (up to a constant factor). The talk is based on a joint work with V. Kharlamov. (Received February 09, 2018)

1138-14-182 **Alicia Harper***, 176 Waterman Street, Apt. 4, Providence, RI 02906. *Factorization for Deligne-Mumford stacks.*

The weak factorization theorem allows one to relate a pair of birational smooth projective varieties by means of a sequence of blow-ups and blow-downs. Recent work of Abramovich and Temkin enables one to carry out weak factorization for birational representable morphisms from of Deligne-Mumford stacks. If one drops the hypothesis of representability, one is forced to deal with new and intrinsically stacky phenomena. Using Bergh's recent result on destackifcation, we give a generalization of the weak factorization theorem to non-representable morphisms of Deligne-Mumford stacks. As an application, we prove a form of simple homotopy invariance for the boundary complex of a pair (X,D) extending results of Danilov, Stepanov, and Payne. (Received February 09, 2018)

1138-14-190 **Jerzy M Weyman*** (jerzy.weyman@uconn.edu), Department of Mathematics, University of Connecticut, 341 Mansfield Road U1009, Storrs, CT 06269. *Finite Free Resolutions and Root Systems.*

I will describe the construction of generic rings $\hat{R}_{gen}$ for finite free resolutions

$$0 \to F_3 \to F_2 \to F_1 \to F_0$$

of length three over Noetherian commutative rings. The key role is played by the defect Lie algebra which turns out to be a parabolic Lie algebra in a Kac-Moody Lie algebra related to a T-shaped graph $T_{p,q,r}$. If r_1, r_2, r_3 are three ranks of maps in our free resolution then $(p,q,r) = (r_1+1, r_2-1, r_3+1)$.

The ring $\hat{R}_{gen}$ deforms to a ring $\hat{R}_{Spec}$ which has a multiplicity free action of Lie algebra $gl(F_0) \times gl(F_2) \times g(T_{p,q,r})$. In particular the ring $\hat{R}_{gen}$ is Noetherian if and only if the graph $T_{p,q,r}$ is Dynkin.

If time permits I will discuss the possible consequences for the structure of perfect ideals of codimension three. (Received February 09, 2018)

1138-14-196 **Christopher Manon*** (christopher.manon@uky.edu). *Introduction to Spherical Tropicalization.*

Tropicalization is a powerful tool for linking algebraic geometry and combinatorics. Questions about moduli problems, intersection theory, and degenerations can be translated into questions about polyhedral objects, while at the same time discrete objects can be linked to underlying geometry which allows them to be softened or deformed. The structure of a torus as an algebraic group underlies basic constructions in tropical geometry, which suggests corresponding constructions for more complicated groups should be possible. I will give an introduction to one such generalization, where the algebraic torus is replaced by a homogeneous spherical variety of a connected reductive group. I'll introduce the fundamental theorem of tropical geometry in this context, and show how several representation theoretic objects can be viewed as spherical tropical varieties. (Received February 09, 2018)

15 ► *Linear and multilinear algebra; matrix theory*

1138-15-166 **Lek-Heng Lim** (lekheng@galton.uchicago.edu), 5747 South Ellis Avenue, Jones 122B, IL 60637, and **Yang Qi*** (yangqi@galton.uchicago.edu), 5747 South Ellis Avenue, Jones 114, Chicago, IL 60637. *On the rank preserving property of special linear sections and its applications in tensors.*

In this talk, we study the rank preserving property of linear sections of projective varieties, which is motivated by important problems arising from signal processing and computer science. We give sufficient conditions under which a linear section of a projective variety has the general rank preserving property. As corollaries, we show Comon's conjecture is true for a general symmetric rank-r tensor, i.e., a general symmetric rank-r tensor has rank r, and Strassen's direct sum conjecture is true for general tensors T and T', i.e., the rank of $T \oplus T'$ is the sum of the rank of T and the rank of T' for general tensors T and T'. We also present some progress on the border rank version of Comon's conjecture. This is joint work with Lek-Heng Lim. (Received February 08, 2018)

1138-15-400 **Joshua Boone*** (joshua.boone@lmunet.edu). *Integer Powers of General Matrices with Applications.* Preliminary report.

We say a 2×2 matrix A has *projective order* n if n is the smallest integer such that $A^n = \lambda I$, a multiple of the identity matrix. In this talk, new formulae for integer powers of 2×2, 3×3, and 4×4 matrices is presented, along with the above motivation. Examples and extensions of the concept of projective order to the 3×3 and 4×4 cases are presented, as time allows. (Received February 14, 2018)

17 ► Nonassociative rings and algebras

1138-17-144 **Thomas Creutzig**, **Shashank Kanade** and **Robert McRae*** (robert.h.mcrae@vanderbilt.edu). *Applications of braided tensor categories to vertex operator superalgebra extensions.*

If a vertex operator algebra V has a braided tensor category $\mathcal{C}$ of representations, then Huang, Kirillov, and Lepowsky showed that vertex operator algebra extensions of V in $\mathcal{C}$ correspond essentially to commutative associative algebras A in the braided tensor category $\mathcal{C}$. Similarly, a vertex operator superalgebra can be realized as a commutative associative algebra in a braided supercategory of representations of its even part. Here, we apply these results to study representations of the extended (super)algebra A via an induction functor from $\mathcal{C}$ to a category of generalized representations of A. In particular, we obtain Verlinde formulae and modular character transformations for regular vertex operator superalgebras, classification of irreducible modules and fusion rules for lattice vertex algebra cosets, and some results on twisted representations associated to finite group orbifold extensions. (Received February 07, 2018)

18 ► Category theory; homological algebra

1138-18-8 **Cain Edie-Michell**, **Corey Jones** and **Julia Plavnik*** (julia@math.tamu.edu). *Gauging by Z_2 permutation actions of Deligne products.* Preliminary report.

The classification of modular categories is important for applications to physics; for example, it gives a classification of certain topological phases of matter. At the moment, such a classification seems out of reach. Therefore, finding new examples of modular categories is important. Given a unitary modular category with a symmetry, we can construct a new unitary modular category via the gauging procedure. One interesting example is given by the Deligne product of two copies of a modular tensor category with the Z_2 action induced by swapping the factors. During this talk, we will explain how to compute the fusion rules for this case. Moreover, we will show some new modular categories that arise as a gauging by the permutation action of known examples in low rank. (Received November 11, 2017)

1138-18-21 **Marcel Bishoff** (bischoff@ohio.edu), Department of Mathematics, Ohio University, Athens, OH 45701, and **Alexei Davydov*** (davydov@ohio.edu), Department of Mathematics, Ohio University, Athens, OH 45701. *Maximally symmetric Lagrangian algebras.* Preliminary report.

Lagrangian algebras in braided tensor categories play the role of a 'coordinate system", identifying the ambient category with a monoidal centre. We call a Lagrangian algebra maximally symmetric if the dimension of its endomorphism space coincides with the dimension of the algebra. Maximally symmetric Lagrangian algebras admit classification in group theoretical terms. (Received February 07, 2018)

1138-18-108 **Daniel Bravo**, **Sergio Estrada**, **Alina Iacob*** (aiacob@georgiasouthern.edu) and **Marco Perez**. *FP_n-injective and FP_n-flat covers and preenvelopes; Gorenstein AC-flat covers.*

We prove that, for any $n \geq 2$, the classes of FP_n-injective modules and of FP_n-flat modules are both covering and preenveloping over any ring R. Then we define a generalization of the class of Gorenstein flat modules - the Gorenstein AC-flat modules. Assuming closure under extensions for Gorenstein AC-flat modules, we construct a model structure on $R - Mod$ in which these modules are the cofibrant objects. (Received February 04, 2018)

1138-18-193 **Eric Carson Rowell***, rowell@math.tamu.edu. *Metaplectic Modular Categories, Gauging and Property F.* Preliminary report.

Metaplectic modular categories, unitary modular categories with the same fusion rules as $SO(N)_2$ for some N, are some of the best weakly integral categories that we know of. I will describe the classification and enumeration of these amazing categories in terms of gauging and discuss the images of the corresponding braid group representations. In the case that $8 \mid N$ these categories seem to fit into a sequence of $\mathbb{Z}_2$-gaugings, and I will discuss preliminary results in this direction. Various parts of the talk will be based on joint work with terrific co-authors including Plavnik, Wang, Bruillard, Wenzl, Ruan, Gustafson, Wenzl, Ardonne and Cheng. (Received February 09, 2018)

1138-18-227 **Kenichi Shimizu*** (kshimizu@shibaura-it.ac.jp), Department of Mathematical Sciences, Shibaura Institute of Technology, 307 Fukasaku, Minuma-ku, Saitama, 337-8570, Japan. *Class functions of tensor categories.*

By generalizing the well-known notion of class functions of a group, one can define the space of class functions of finite tensor categories. In the recent study of tensor categories and its applications to CFT and TQFT, it is important to study the space of class functions. For example, if $\mathcal{C}$ is a modular tensor category (in the sense of Lyubashenko), then the modular group $\mathrm{SL}_2(\mathbb{Z})$ acts projectively on the space of class functions of $\mathcal{C}$. In this talk, I will review recent results on the structure of the space of class functions and its relation to the higher Reynolds ideals. I will also give several computational examples. (Received February 10, 2018)

1138-18-344 **Qing Zhang*** (zhangqing@math.tamu.edu). *On the classification of super-modular categories by rank.*

A super-modular category is a unitary ribbon fusion category with Müger center equivalent to the unitary symmetric ribbon category of super-vector spaces. In this talk, we will explain a super-modular analog of the Ng-Schauenburg Congruence Subgroup Theorem. We will also discuss the classification of super-modular categories by rank. This talk is based on the joint work with P. Bonderson, P. Bruillard, J. Plavnik, E. Rowell, and Z. Wang. (Received February 12, 2018)

1138-18-393 **Paul Bruillard*** (paul.bruillard@pnnl.gov), 902 Battelle Blvd., Richland, WA 99352, and **Paul Gustafson**, **Julia Yael Plavnik** and **Eric C. Rowell**. *Metaplectic Modular Categories.*

In this talk we will explore the classification of metaplectic modular categories, i.e., modular categories Grothendieck equivalent to $SO(N)_2$. We will show that such catgories will be characterized through equivariantization and gauging. Furthermore, we will discuss connections to categorical dimension. Specifically, we will consider the classification of modular categories of dimension p^3m and $16m$ where m is square-free. (Received February 13, 2018)

19 ► K-theory

1138-19-52 **John D Berman*** (jdb8pc@virginia.edu). *Group Cohomology via Morita Theory.*

Morita theory was designed to address the question: When do two rings have equivalent categories of modules? We will begin with a similar question: When do two groups have equivalent categories of modules? Classical Morita theory can be used to study ring homology theories (including K-theory and Hochschild homology) via *noncommutative motives*. Our goal is to reproduce noncommutative motives for group homology theories (of which examples are ordinary group homology or equivariant homotopy theory itself), culminating in a duality between genuine and naive equivariance. (Received January 25, 2018)

1138-19-213 **Juan S. Villeta-Garcia*** (jvillet@emory.edu). *Stabilizing Spectral Functors of Exact Categories.*

Algebraic K-Theory is often thought of as "the" universal additive invariant of rings (or more generally, exact categories). Often, however, functors on exact categories don't satisfy additivity. We will describe a procedure that constructs a functor's universal additive approximation, and apply it to different local coefficient systems, recovering known invariants of rings (K-Theory, THH, etc.). We will talk about what happens when we push these constructions to the world of spectra, and tie in work of Lindenstrauss and McCarthy on the Taylor tower of Algebraic K-Theory. (Received February 09, 2018)

20 ► Group theory and generalizations

1138-20-25 **Bena Tshishiku*** (tshishikub@gmail.com) and **Genevieve Walsh**. *Relatively hyperbolic groups with boundary a 2-sphere.*

Bestvina-Mess showed that the duality properties of a group G are encoded in any boundary that gives a Z-set compactification of G; for example, a hyperbolic group with Gromov boundary an n-sphere is a $\mathrm{PD}(n+1)$ group.

For relatively hyperbolic pairs (G, P), the natural boundary – the Bowditch boundary – does not give a Z-set compactification of G. Nevertheless we show that if the Bowditch boundary of (G, P) is a 2-sphere, then (G, P) is a PD(3) pair. This is joint work with Genevieve Walsh. (Received January 09, 2018)

1138-20-32 **Joseph Maher*** (joseph.maher@csi.cuny.edu) and **Alessandro Sisto**. *Random subgroups of acylindrical groups.*

We consider a simple model of random subgroups of an acylindrical group, in which the group is generated by independent random walks. We show that random subgroups are hyperbolically embedded and satisfy a small cancellation condition with asymptotic probability one. (Received January 18, 2018)

1138-20-34 **Sang-hyun Kim** and **Thomas Koberda*** (thomas.koberda@gmail.com). *Diffeomorphism groups of critical regularity.*

I will describe a construction of finitely generated groups acting on the circle and on the interval of prescribed regularity $\alpha \in [1, \infty)$ and which admit no smoothing to higher regularity. I will give some applications to continuous groups of diffeomorphisms and to foliation theory. (Received January 18, 2018)

1138-20-48 **Heejoung Kim*** (hkim404@illinois.edu), 1409 West Green Street, UIUC Department of Mathematics, Urbana, IL 61801. *Generalizations of quasiconvexity in a word-hyperbolic group.*

In recent years, there have been lots of studies to generalize the theory of a word-hyperbolic group as it applies to an ambient finitely generated group. In particular, we have two notions for a subgroup of a finitely generated group, a stable subgroup and a Morse or strongly quasiconvex subgroup, which are two generalizations of a quasiconvex subgroup of a word-hyperbolic group. In this talk, we will discuss these two notions and understand them in non-positively curved groups and mapping class groups. In particular, the two notions are equivalent in the case of mapping class groups. (Received February 12, 2018)

1138-20-68 **Ilya Kapovich*** (kapovich@math.uiuc.edu), 1409 West Green Street, UIUC Department of Mathematics, Urbana, IL 61801, and **Michael Hull** and **Catherine Pfaff**. *Counting conjugacy classes of fully irreducibles in $Out(F_r)$.*

Inspired by results of Eskin and Mirzakhani counting closed geodesics of length $\leq L$ in the moduli space of a closed surface Σ_g of genus $g \geq 2$, we consider a similar question in the $Out(F_r)$ setting. Let $h = 6g-6$. The Eskin-Mirzakhani result, giving the asymptotics of $\frac{e^{hL}}{hL}$, can be equivalently stated in terms of counting the number of $MCG(\Sigma_g)$-conjugacy classes of pseudo-Anosovs $\phi \in MCG(\Sigma_g)$ with dilatation $\lambda(\phi)$ satisfying $\log \lambda(\phi) \leq L$. For $L \geq 0$ let $\mathfrak{N}_r(L)$ denote the number of $Out(F_r)$-conjugacy classes of fully irreducibles $\phi \in Out(F_r)$ with dilatation $\lambda(\phi)$ satisfying $\log \lambda(\phi) \leq L$. In a joint result with Catherine Pfaff, we prove for $r \geq 3$ that as $L \to \infty$, the number $\mathfrak{N}_r(L)$ has double exponential (in L) lower and upper bounds. We also obtain a companion result, joint with Michael Hull, and show that of distinct $Out(F_r)$-conjugacy classes of fully irreducibles ϕ from an L-ball in the Cayley graph of $Out(F_r)$ with $\log \lambda(\phi)$ on the order of L grows exponentially in L. (Received January 29, 2018)

1138-20-76 **Hoang Thanh Nguyen*** (nguyen36@uwm.edu). *Distortion of surfaces in 3–manifolds.*

In the \$3\$–manifold theory, a great deal of interest has focused on the study of immersed surfaces in \$3\$–manifolds in last decades. One reason is that studying immersed surfaces will help us to understand the structures of \$3\$–manifolds. For instance, cubulation is used in the work of Wise and Agol to resolve the Virtuallly Haken conjecture on the hyperbolic manifolds. Wise observed that the following problem is important in the study of of cubulations of \$3\$–manifold groups: Determine the distortion of surface subgroups in \$3\$–manifold groups. The answer to this problem has been answered by Bonahon–Thurston in the hyperbolic case. In this talk, I will give a solution to this problem in the non-geometric \$3\$–manifold case. (Received January 30, 2018)

1138-20-84 **Edgar A. Bering IV*** (edgar.bering@temple.edu), Department of Mathematics, Wachman Hall, 1805 North Broad Street, Philadelphia, PA 19122. *A uniform McCarthy-type theorem for linearly growing outer automorphisms of a free group.*

In his proof of the Tits alternative for the mapping class group of a surface, McCarthy also proved that given any two mapping classes σ and τ, there exists an integer N such that the group generated by $\langle \sigma^N, \tau^N \rangle$ is either free of rank two or abelian. In the setting of $Out(F_r)$, whether or not such a statement is true remains open, though there are many partial results. Later work in the mapping class group setting due to Hamidi-Tehrani showed that for Dehn twists the power N is uniform, which Mangahas used to prove that the mapping class groups have uniform-uniform exponential growth. I will present an $Out(F_r)$ analog of Hamidi-Tehrani's result. (Received January 31, 2018)

1138-20-126 **Bin Sun*** (bin.sun@vanderbilt.edu), 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240. *A dynamical characterization of acylindrically hyperbolic groups.*

The notion of an acylindrically hyperbolic group was introduced by Osin as a generalization of non-elementary hyperbolic and relative hyperbolic groups. This class of groups not only contains plenty of interesting examples, for instance groups with deficiency at least two and outer automorphism groups of non-abelian free groups, but also has various nice algebraic, geometric and analytic properties so that useful tools such as Monod-Shalom rigidity theory, group theoretic Dehn surgery and small cancellation theory can be applied to yield beautiful results. In this talk, I would like to define a condition on group actions on topological spaces and prove its equivalence with acylindrical hyperbolicity. As an application, I shall show that non-elementary convergence groups are acylindrically hyperbolic. (Received February 06, 2018)

1138-20-136 **Carolyn Abbott**, **Sahana H Balasubramanya*** (hbsahana@gmail.com) and **Denis Osin**. *$\mathcal{H}-$ and $\mathcal{AH}-$ accessibility.*

For every group G, we introduce the set of *hyperbolic structures* on G, denoted $\mathcal{H}(G)$, which consists of equivalence classes of (possibly infinite) generating sets of G such that the corresponding Cayley graph is hyperbolic; two generating sets of G are *equivalent* if the corresponding word metrics on G are bi-Lipschitz equivalent. We are especially interested in the subset $\mathcal{AH}(G) \subseteq \mathcal{H}(G)$ of *acylindrically hyperbolic structures* on G, i.e., hyperbolic structures corresponding to acylindrical actions.

One interesting notion developed in this work is that of *accessibility.* A group G is said to be *$\mathcal{H}$-accessible* (respectively *$\mathcal{AH}$-accessible*) if the poset $\mathcal{H}(G)$ (respectively $\mathcal{AH}(G)$) contains the largest element. I will discuss the relation between these notions, and give several examples of accessible and inaccessible groups. (Joint work with C. Abbott and D. Osin.) (Received February 07, 2018)

1138-20-145 **Pallavi Dani***, pdani@math.lsu.edu, and **Timothy Riley**. *Subgroup distortion in hyperbolic groups.*

The distortion function of a subgroup measures the extent to which the intrinsic word metric of the subgroup differs from the metric induced by the ambient group. Olshanskii showed that there are almost no restrictions on which functions arise as distortion functions of subgroups of finitely presented groups. This prompts one to ask what happens if one forces the ambient group to be particularly nice, say, for example, to be hyperbolic. I will survey which functions are known to be distortion functions of subgroups of hyperbolic groups. I will then describe joint work with Tim Riley which adds to this list: we construct free subgroups of hyperbolic groups with distortion functions $2^{n^{p/q}}$, for all integers $p > q > 0$. (Received February 07, 2018)

1138-20-187 **Tim Susse***, tsusse@simons-rock.edu, and **Andrew Sale**. *Outer automorphism groups of right-angled Coxeter groups.*

We will discuss recent results on the structure of the outer automorphism group of a right-angled Coxeter group (RACG), comparing these with known results for the mapping class group, $\mathrm{Out}(F_n)$ and outer automorphism groups of RAAGs. We will show that outer automorphism groups of RACGs either large or virtually abelian, and give a condition on the defining graph that distinguishes these cases. As a consequence, we show that such a group property (T) if and only if it is finite. This is joint work with Andrew Sale. (Received February 09, 2018)

1138-20-230 **Hung Cong Tran*** (hung.tran@uga.edu), 1023 D. W. Brooks Drive, Athens, GA 30605. *On strongly quasiconvex subgroups.* Preliminary report.

We introduce the concept of strongly quasiconvex subgroups of an arbitrary finitely generated group. Strong quasiconvexity generalizes quasiconvexity in hyperbolic groups and is preserved under quasi-isometry. We prove that strongly quasiconvex subgroups have many properties analogous to those of quasiconvex subgroups of hyperbolic groups. We study strong quasiconvexity and stability in relatively hyperbolic groups, two dimensional right-angled Coxeter groups, and right-angled Artin groups. We note that the result on right-angled Artin groups strengthens the work of Koberda-Mangahas-Taylor on characterizing purely loxodromic subgroups of right-angled Artin groups. (Received February 12, 2018)

1138-20-236 **Jason F Manning***, Department of Mathematics, Cornell University, Ithaca, NY 14853, and **Oliver Wang**. *Cohomology of Bowditch boundaries.*

A relatively hyperbolic group pair has a boundary at infinity called the Bowditch boundary. For a geometrically finite Kleinian group with peripheral structure given by the maximal parabolics, this boundary coincides with the limit set. We show that the cohomology of this boundary can be described entirely group theoretically, generalizing work of Bestvina-Mess and M. Kapovich. In the case of a Poincare duality pair, we show the boundary is a homology manifold. (Received February 10, 2018)

1138-20-238 **Carolyn R 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. This is joint work with François Dahmani. (Received February 10, 2018)

1138-20-244 **Justin Lanier*** (jlanier8@gatech.edu) and **Dan Margalit**. *Normal generators for mapping class groups are abundant.* Preliminary report.

Under what conditions do a group element and all of its conjugates form a generating set for the ambient group? Such an element is called a normal generator. For mapping class groups of surfaces, we give a number of geometric criteria that ensure that a mapping class is a normal generator. With these criteria in hand, we show that every nontrivial periodic element in a mapping class group (except for a hyperelliptic involution) is a normal generator. We also show that if the stretch factor of a pseudo-Anosov mapping class is sufficiently small, then it is a normal generator. Our pseudo-Anosov examples answer a question of Darren Long from 1986. This is joint work with Dan Margalit. (Received February 10, 2018)

1138-20-278 **Tarik Aougab*** (tarik_aougab@brown.edu), 151 Thayer Street, Department of Mathematics, Brown University, Providence, RI 02912, and **Matt Clay** and **Yo'av Rieck**. *Thermodynamic metrics for moduli of graphs.*

We study a pair of Riemannian metrics moduli spaces of metric graphs resembling the Weil-Petersson metric on the moduli space of curves. Generalizing results of Policott-Sharp and Kao, we prove that for any graph, these metrics are incomplete. For a rose, we characterize the metric completion and demonstrate that it is a direct analog of the Deligne-Mumford compactification. This represents joint work with Matt Clay and Yo'av Rieck. (Received February 12, 2018)

1138-20-296 **Bakul Sathaye*** (sathaye.2@osu.edu). *Obstructions to Riemannian smoothings of locally CAT(0) manifolds.*

In this talk I will focus on obstructions in dimension = 4 to Riemannian smoothings of a locally CAT(0) manifold. I will discuss the obstruction given by Davis-Januszkiewicz-Lafont and show how their methods can be extended to construct more examples of locally CAT(0) 4-manifolds M that do not support Riemannian metric with non-positive sectional curvature. Universal covers of the manifolds we construct satisfy the isolated flats condition and contain a collection of 2-dimensional flats with the property that their boundaries at infinity form non-trivial links in the boundary 3-sphere. (Received February 12, 2018)

1138-20-329 **Mehrdad Kalantar*** (kalantar@math.uh.edu). *Topological π-boundary actions.*

For each unitary representation π of a discrete group Γ we introduce a notion of topological π-boundary actions of Γ. We call the universal π-boundary, which is a unital invariant C*-subalgebra of $B(H_\pi)$ (and does always exists), the Furstenberg-Hamana boundary of π. We show that this boundary satisfies the natural properties that are expected. In the case of quasi-regular representations, the Furstenberg-Hamana boundary is commutative, hence of the form $C(X)$ for some compact Γ-space X, which should be thought of the "Furstenberg boundary of the quotient". We give several applications and examples.

Based on joint work with Alex Bearden and Yair Hartman. (Received February 12, 2018)

1138-20-339 **Kim E Ruane*** (kim.ruane@tufts.edu), 503 Boston Avenue, Department of Mathematics, Tufts University, Medford, MA 02155, and **Chris Hruska**. *Boundaries and Splittings of CAT(0) Groups.*

We discuss recent joint work with C. Hruska where we study the relationship between peripheral splittings of CAT(0) groups with the Isolated Flats Property and the topology of the boundary of such a group. In particular, for this class of groups, we provide a full converse to a result of Mihalik-Ruane which says that certain geometric splittings of a CAT(0) group imply any CAT(0) boundary for that group is locally connected. (Received February 12, 2018)

1138-20-345 **G Christopher Hruska*** (chruska@uwm.edu) and **Kim Ruane**. *Graphs of groups and corresponding splittings of spaces.*

If a group G acts "nicely" on a space X and also splits as a graph of groups $\mathcal{G}$, we can often decompose X into geometrically natural pieces corresponding to the vertex and edge groups of the splitting. Using this idea, one discovers that if G is finitely presented and splits over finitely presented subgroups, then the vertex groups must also be finitely presented. Similar phenomena occur for FP_n groups splitting over FP_n subgroups (Bieri), hyperbolic groups splitting over quasiconvex subgroups (Bowditch) and CAT(0) groups splitting over convex subgroups (Hruska–Ruane). We will also see some connections with Świątkowski's notion of trees of compacta, which can be used to describe analogous decompositions of boundaries into pieces. (Received February 12, 2018)

1138-20-348 **Catherine Pfaff*** (cpfaff@math.ucsb.edu), **Yael Algom-Kfir** and **Ilya Kapovich**. *Geodesics in Outer Space.*

Outer automorphisms of free groups are often studied via their action on Culler-Vogtmann Outer Space. One of the more interesting aspects of the interplay between these outer automorphisms and Outer Space is the relationship between automorphisms and geodesics in Outer Space. In fact, unlike hyperbolic spaces and Teichmueller spaces, a given automorphisms can have many geodesics canonically associated to it. The properties of outer automorphisms with only a single associated geodesic are only now being understood. Specifically, we show that having certain invariant values is an "almost open" condition. Since the fact that it is not exactly an open condition differs from the Teichmueller space setting, we give examples contradicting openness and prove results further elucidating this situation. Our hope is that better understanding such behavior of geodesics will lead to new dynamical and genericity results emulating those in the hyperbolic and Teichmuller space settings. This is joint work with Yael Algom-Kfir and Ilya Kapovich. (Received February 13, 2018)

1138-20-395 **Mark B Greer*** (mgreer@una.edu), University of North Alabama, One Harrison Plaza, BOX 5051, Florence, AL 35632. *Quasigroups and their associated quandles.*

Quasigroups are magmas (groupoids) with both left and right translations being bijections. Quandles are self distributive, left (right) idempotent quasigroups with every left (right) bijection an automorphism. Historically, quandles have been of interest due to their connection with Knot Theory. This talk will focus on results dealing with certain varieties of quasigroups and their associated quandles. (Received February 13, 2018)

1138-20-396 **Lee Raney*** (lraney@una.edu), Florence, AL , and **Mark Greer** (mgreer@una.edu), Florence, AL. *Γ-loops of order p^2q.* Preliminary report.

Γ-loops are commutative loops which often arise from finite groups of odd order via a construction known as the Baer trick. Utilizing a known correspondence between certain classes of Γ-loops and Bruck loops, we provide structural results on Γ-loops of order p^2q (where p and q are odd primes) and determine whether such a loop is an automorphic loop. (Received February 13, 2018)

22 ► Topological groups, Lie groups

1138-22-159 **Nicolas Ressayre*** (ressayre@math.univ-lyon1.fr), Université Claude Bernard Lyon 1, Institut Camille Jordan (ICJ), 43 boulevard du 11 novembre 1918, 69622 Villeurbanne, France. *On the tensor semigroup of affine Kac-Moody Lie algebras.*

In this talk, we are interested in the decomposition of the tensor product of two representations of a symmetrizable Kac-Moody Lie algebra $\mathfrak{g}$. Let P_+ be the set of dominant integral weights. For $\lambda \in P_+$, $L(\lambda)$ denotes the irreducible, integrable, highest weight representation of $\mathfrak{g}$ with highest weight λ. Consider the *tensor cone*

$$\Gamma(\mathfrak{g}) := \{(\lambda_1, \lambda_2, \mu) \in P_+^3 \mid \exists N > 1 \quad L(N\mu) \subset L(N\lambda_1) \otimes L(N\lambda_2)\}.$$

If $\mathfrak{g}$ is finite dimensional, $\Gamma(\mathfrak{g})$ is a polyhedral convex cone described by Belkale-Kumar by an explicit finite list of inequalities. In general, $\Gamma(\mathfrak{g})$ is nor polyhedral, nor closed. We will describe the closure of $\Gamma(\mathfrak{g})$ by an explicit countable family of linear inequalities, when $\mathfrak{g}$ is untwisted affine. This solves a Brown-Kumar's conjecture in this case. (Received February 08, 2018)

1138-22-216 **Alex Furman*** (furman@uic.edu), MSCS dept (m/c 249), 851 S. Morgan Str, Chicago, IL 60607. *Some applications of ergodic ideas to geometric group theory.* Preliminary report.

In this talk we will discuss some applications of ergodic theoretic ideas to obtain some purely group-theoretic results. (Received February 09, 2018)

28 ► Measure and integration

1138-28-154 **Jason Bentley*** (jason.bentley@ucf.edu) and **Piotr Mikusinski** (piotr.mikusinski@ucf.edu). *Transfunctions As Generalized Functions.* Preliminary report.

A transfunction is a function which maps between sets of finite measures on measurable spaces, defined by Mikusiński in 2015.

Push-forward operators form an important class of examples of transfunctions that can be identified with measurable functions. There are naturally arising transfunctions with nice properties which are not measurable functions. Transfunctions which are σ-weakly additive between separable metric spaces are of particular interest. We study such transfunctions which are localized: sending source measures carried by small open sets to target measures also carried by small open sets. We characterize transfunctions that correspond to continuous functions and measurable functions and we show that the behavior of localized transfunctions can be approximated spatially by measurable functions or even by continuous functions, but only up to some extent/error.

We are interested in applications of transfunctions to Monge-Kantorovich transport problems. In particular, we characterize transfunctions that correspond to transport plans with prescribed marginals. We also propose transfunctions as possible models for population dynamics. (Received February 08, 2018)

30 ► Functions of a complex variable

1138-30-28 **William T Ross*** (wross@richmond.edu). *Zero sets for spaces of analytic functions.*

In this joint work with R. Cheng and J. Mashreghi, we explore the zero sets for the space of analytic functions on the open unit disk whose power series coefficients belong to little-l-p. Our characterization was inspired by Beurling's idea about inner functions in the Hardy space and uses a notation of orthogonality in Banach spaces due to Birkhoff and James. (Received January 17, 2018)

1138-30-88 **Daniel H Luecking*** (luecking@uark.edu), Dept. of Mathematical Sciences, 1 University of Arkansas, Fayetteville, AR 72701. *Interpolating sequences that are not uniformly discrete for certain weighted Bergman spaces.*

In previous work we showed that, if the notion of interpolation is suitably generalized, then we can characterize interpolating sequences for Bergman spaces in the unit disk, without the sequence having to be uniformly discrete in the hyperbolic metric. 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). In his talk, we discuss the extension of this result to weighted Bergman space with weights of the form $e^{-\phi}/(1-|z|^2)$ for certain subharmonic functions ϕ. Similar results on sampling sequences will also be discussed. (Received January 31, 2018)

1138-30-169 **Tim Ferguson*** (tjferguson1@ua.edu). *Uniform Approximation of Extremal Functions in Weighted Bergman Spaces.*

We discuss approximation of extremal functions by polynomials in the weighted Bergman spaces A^p_α where $-1 < \alpha < \min(0, p-2)$. We obtain bounds on how close the approximation is to the true extremal function in the A^p_α and uniform norms. We also prove several results on the relation between the Bergman modulus of continuity of a function and how quickly its best polynomial approximants converge to it. (Received February 08, 2018)

31 ► Potential theory

1138-31-293 **Guilherme Silva*** (silvag@umich.edu), 530 Church Street, University of Michigan, Department of Mathematics, Ann Arbor, MI 48108. *Spectral curves and equilibrium problems for random matrix model with external source.*

In this talk we plan to discuss the limiting eigenvalue distribution of the hermitian plus external source random matrix model for arbitrary (that is, non-symmetric) polynomial potentials, when the external source has exactly two distinct eigenvalues. Starting from the existence of an appropriate algebraic equation, known as the spectral curve of the matrix model, we construct a vector of measures that should ultimately describe the limiting eigenvalues distribution of the matrix model. This vector of measures is a saddle point of an energy functional involving three measures and containing both attractive and repulsive interactions, plus appropriate external fields. The first two measures live on the real line and the third measure lives on the so-called S-contour, whose existence is one of our main results.

Also as a consequence of our results, we are able to describe all possible critical behaviors in the matrix model under consideration.

This is a joint work with Andrei Martínez-Finkelshtein (Universidad de Almería - Spain) (Received February 12, 2018)

33 ► Special functions

1138-33-283 **Laura Colmenarejo***, laura.colmenarejo.hernando@gmail.com, and **Jean-Gabriel Luque** and **Charles F. Dunkl**. *Macdonald polynomials: from vector-valued polynomials to scalar polynomials.*

We analyze conditions under which a projection from the vector-valued Macdonald polynomials to scalar polynomials has useful properties, especially commuting with the actions of the Hecke algebra, and with the Cherednik operators for which these polynomials are eigenfunctions. (Received February 12, 2018)

34 ► Ordinary differential equations

1138-34-73 **Zhilan Feng*** (zfeng@math.purdue.edu), 150 N. University Street, Department of Mathematics, Purdue University, West Lafayette, IN 47907. *Plant toxins and trophic cascades alter fire regime and succession on a boreal forest landscape.*

Earlier models of plant-herbivore interactions relied on forms of functional response that related rates of ingestion by herbivores to mechanical or physical attributes such as bite size and rate. These models fail to predict a growing number of findings that implicate chemical toxins as important determinants of plant-herbivore dynamics. Specifically, considerable evidence suggests that toxins set upper limits on food intake for many species of herbivorous vertebrates. Herbivores feeding on toxin-containing plants must avoid saturating their detoxification systems. We developed mathematical models with toxin-determined functional responses to study the effects of inter-specific plant competition, herbivory, and a plant's toxic defenses against herbivores on vegetation dynamics. The new models exhibit much more complex dynamics including Hopf and homoclinic bifurcations. We used the model to estimate the effects of different levels of wolf control. Simulations indicated that management reductions in wolf densities could reduce the mean time to transition from deciduous to spruce by more than 10 years, thereby increasing landscape flammability. The integrated model can be useful in estimating ecosystem impacts of wolf control and moose harvesting in central Alaska. (Received January 29, 2018)

1138-34-127 **Xiaochuan Hu*** (xiaochuan.hu@ttu.edu) and **Sophia Jang**. *Optimal treatments in cancer immunotherapy.*

We apply optimal control theory to a model of interactions between cancer cells, $CD4^+$ T cells, cytokines and host cells to devise a best immunotherapy for treating cancer. The $CD4^+$ T cells cannot kill cancer cells directly but use the cytokines produced to suppress tumor growth. The immunotherapy implemented is modeled as a control agent and it can be either transferring of $CD4^+$ T cells, cytokines or both. We establish existence and uniqueness of the optimal control. The optimal treatment strategy is then solved numerically under different scenarios. Our numerical results provide best protocols in terms of strengths and timing of the treatments. (Received February 06, 2018)

1138-34-137 **Zachariah Sinkala*** (zachariah.sinkala@mtsu.edu), Department of Mathematical sciences, Murfreesboro, TN 37132, and **Zack Jones**, TN. *Model Selection in the ecology in chronic myeloid leukemia using adapting the ABC distance function.*

Computational models are increasingly being used to study chronic myeloid leukemia (CML), a blood disease that disrupts normal function of the hematopoietic system. Despite the great progress made in terms of molecular therapies for CML, there still remain large gaps in our understanding. By comparing mathematical models that describe CML progression and etiology we sought to identify those models that provide the best description of disease dynamics and their underlying mechanisms. It is a difficult task to evaluate these models against data with low sample size, high variance and strong fragmentation. This work examines model selection based on an approximate Bayesian computation(ABC) algorithms which adaptively update summary statistics weights. We use Data for two clinical outcomes disease remission or relapse are considered. Results support evidence that we discard models that fail to take niche effects into account and reveals mechanic differences between disease outcome and progression. Our analysis support the importance of further mapping of the bone marrow hematopoietic niche microenvironment as the ecological interactions between cells in this niche appear to be intricately linked to disease outcome. (Received February 07, 2018)

1138-34-398 **Xianbo Sun*** (xsun244@uwo.ca) and **Pei Yu**, Western University, Middlesex College Room 25, 1151 Richmond Street, London, Canada. *Bifurcation Graph in a three-parameter perturbation of hyperelliptic Hamiltonian.* Preliminary report.

In this work, we present an algebraic-geometric method to determine the bifurcation graph in a three-parameter perturbation to a hyper-elliptic Hamiltonian. We give the algebraic set of the double limit cycle curve. (Received February 13, 2018)

35 ► Partial differential equations

1138-35-16 **Mikhail Feldman** and **Adrian Tudorascu*** (adriant@math.wvu.edu), Department of Mathematics, 320 Armstrong Hall, Morgantown, WV 26506. *The Semi-Geostrophic system on the 2D torus: Weak-Strong uniqueness under uniform convexity.*

The Semi-Geostrophic (SG) equations (Eliassen 1948, Hoskins 1975) are used by meteorologists to describe how fronts arise in large scale weather patterns. They model rotation-dominated atmospheric flow, and can be obtained from the Boussinesq equations under the assumption of a small Rossby number. We are interested in solutions satisfying the Cullen-Purser stability condition, which has been related to a physical stability condition required for the Semi-Geostrophic approximation to remain appropriate (Cullen & Shutts 1987). Uniqueness of such solutions is a long standing open problem, with only two results published so far; both on the 2D torus and each proving uniqueness in some class of sufficiently regular solutions. I will present the main ideas of a recent proof of weak-strong uniqueness for SG on the 2D torus under uniform convexity for the strong solution. This generalizes both previous results. (Based on joint work with Mikhail Feldman). (Received January 04, 2018)

1138-35-64 **Giles Auchmuty***, auchmuty@uh.edu. *Variational Methods for Constructing Bases of Hilbert Subspaces.*

This talk will describe the use of variational methods to construct orthogonal bases of certain real Hilbert Sobolev spaces. These bases are constructed using a sequence of variational principles for eigenvalues of bilinear forms. The associated minimizers will be eigenfunctions of non-standard eigenproblems. The primary question is what subspaces are spanned by the eigenfunctions and are they maximal orthogonal subsets?

The results will be illustrated by the construction of Steklov eigenfunctions for the biharmonic operator and the SVD of the Poisson kernel for Laplace's equation. (Received January 27, 2018)

1138-35-101 **Keng Deng***, Department of Mathematics, University of Louisiana at Lafayette, P.O. Box 43568, Lafayette, LA 70504-3568, and **Yixiang Wu**. *Global Attractivity of a Delayed Reaction-Diffusion Equation with Variable Coefficients.*

In this talk, we consider a reaction-diffusion equation with continuous delay and spatial variable coefficients which models the evolution of a single species. We establish a sharp threshold dynamic result: there exists a critical value λ such that if $\lambda < 1$ the positive steady state solution of the equation is globally attractive, while if $\lambda \geq 1$ the trivial steady state is globally attractive. To this end, we analyze the *non-invariant* ω-limit set of the equation and prove that it is a singleton. (Received February 03, 2018)

1138-35-103 **Changyou Wang***, 150 N. University Street, West Lafayette, IN 47907. *Analysis of hydrodynamic of biaxial nematics.* Preliminary report.

In this talk, I will describe a simplified model of hydrodynamics of biaxial nematic, which is an extension of the Ericksen-Leslie system for rod-like uniaxial nematic liquid crystals. I will then present the existence and uniqueness result in dimension two. (Received February 04, 2018)

1138-35-111 **Pierre Magal*** (pierre.magal@u-bordeaux.fr), Institut de Mathématiques de Bordeaux, Université de Bordeaux, 351 cours de la libération, 33400 Talence, France. *Epidemic Mathematical SIR Models: Analysis and Comparison with Data.*

In the first part of this presentation we will consider SIR epidemic models without entering flux of individuals. For the single group case, we will discuss the comparison of the with real data. Therefore we will identify the parameter of the system as well as the initial value of the system. We will note that our analysis is strongly based on the computation of the final size for the SIR model with classical mass action law. Therefore the similar question are still fully open for a general non-linear functional response.

Next, we will discuss SIR epidemic with multiple groups. The main question addressed in our the computation of the final size of the epidemic. We will also discuss the asymptotic behavior, and we will apply the results to the SARS epidemic in Singapore in 2003, where it is shown that the two-peak evolution of the infected population can be attributed to a two-group formulation of transmission.

In the last part of the presentation we will consider the spreading of influenza in Puerto-Rico. The goal of this last part is to incorporate data structured by city and to connect the data with the spreading of pathogen locally in space. (Received February 05, 2018)

1138-35-119 **Dat T Cao***, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, and **Luan T Hoang**, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409. *Long-time asymptotic expansions for solutions of Navier-Stokes equations with time-dependent forces.*

We study the large time behavior of solutions to Navier-Stokes equations with periodic boundary conditions in 3D. The body forces decay in time algebraically. The asymptotic expansions of Foias-Saut-type for all Leray-Hopf weak solutions are obtained. We show that if the force has an asymptotic expansion, as time tends to infinity, in terms of negative-power functions in Gevrey spaces, then any weak solution admits an asymptotic expansion of the same type. This is an extension of Foias-Saut's results for the case of potential forces in Sobolev spaces. (Received February 06, 2018)

1138-35-123 **Dipendra Regmi*** (dipendra.regmi@ung.edu), University of North Georgia, 3820 Mundy Mill, Oakwood, GA 30566. *Global regularity for the 2D magneto-micropolar equations with partial dissipation.*

We study the global existence and regularity of classical solutions to the 2D incompressible magneto-micropolar equations with partial dissipation. When there is only partial dissipation, the global regularity problem can be quite difficult. We are able to single out three special partial dissipation cases and establish the global regularity for each case. As special consequences, the 2D Navier-Stokes equations, the 2D magnetohydrodynamic equations, and the 2D micropolar equations with several types of partial dissipation always possess global classical solutions. This is a joint work with Dr. Jiahong Wu. (Received February 06, 2018)

1138-35-138 **Manuela Girotti*** (manuela.girotti@colostate.edu), Colorado State University, Mathematics Department, 1874 campus delivery, Fort Collins, CO 80523, and **Ken McLaughlin**. *Rigorous asymptotics of the soliton gas.* Preliminary report.

We analytically study the long time and large space asymptotics of a KdV soliton gas. A soliton gas can be thought as an infinite collection of interacting solitons randomly distributed on the line. The concept was originally introduced by Zakharov (1971). From a 2×2 Riemann-Hilbert problem and via non-linear steepest descent techniques, we are able to extract meaningful information for the solution of the KdV equation in such (random) setting. (Received February 07, 2018)

1138-35-147 **Tatsuki Kawakami*** (kawakami@math.ryukoku.ac.jp), Department of Applied Mathematics, and Informatics, Ryukoku University, Otsu, Shiga 520-2194, Japan. *A semilinear elliptic equation with a dynamical boundary condition.*

We consider the nonnegative solution of a semilinear elliptic equation with a dynamical boundary condition. In this talk we treat the two unbounded domains
(i) the N-dim half space,
(ii) the exterior of the unit ball,
and discuss results on existence, nonexistence and large-time behavior of small solutions. Furthermore, we show that local solvability of problem is equivalent to global solvability of problem and solvability of the stationary problem.
This talk is based on the joint work with M. Fila (Comenius Univ.) and K. Ishige (Univ. of Tokyo). (Received February 07, 2018)

1138-35-152 **Ken Abe*** (kabe@sci.osaka-cu.ac.jp). *Axisymmetric flows in an exterior domain.*

We consider the three-dimensional Navier-Stokes equations for axisymmetric initial data. It is known that the Cauchy problem is globally well-posed for large axisymmetric initial data in L_3 with finite energy, if the swirl component of initial velocity is identically zero (with no swirl). However, unique solvability is unknown in general for the case with swirl. In this talk, we study axisymmetric flows with swirl in an exterior domain subject to the slip boundary condition. We report unique existence of global solutions for large axisymmetric data in L_3 with finite energy, satisfying a decay condition of the swirl component. This talk is based on a joint work with G. Seregin (St. Petersburg/ Oxford U.). (Received February 07, 2018)

1138-35-173 **Zhaosheng Feng*** (zhaosheng.feng@utrgv.edu), 1201 W. University Drive, Edinburg, TX 78539. *Degenerate Reaction-Diffusion Systems.*

In this talk, we study the case that some species migrate from densely populated areas into sparsely populated areas to avoid crowding, and investigate a more general reaction-diffusion system by considering density-dependent dispersion as a regulatory mechanism of the cyclic changes. Here the probability that an animal moves from the point x1 to x2 depends on the density at x1. Under certain conditions, we apply the higher terms in the Taylor series and the center manifold method to obtain the local behavior around a non-hyperbolic point of codimension one in the phase plane, and use the Lie symmetry reduction method to explore bounded traveling wave solutions. Numerical simulation and biological explanation are presented. (Received February 08, 2018)

1138-35-175 **Norisuke Ioku*** (ioku@ehime-u.ac.jp). *Canceling effects in higher-order Hardy-Sobolev inequalities.*

A classical Hardy-Sobolev type inequality involving weighted norms depending on powers of the distance function from the boundary $d(x)$ asserts that if Ω is a bounded Lipschitz domain, and $\alpha \neq p-1$, then there exists a constant C such that

$$\left\| \frac{u}{d} \right\|_{L^p(\Omega, d^\alpha)} \leq C \left(\|u\|_{L^p(\Omega,d^\alpha)} + \|\nabla u\|_{L^p(\Omega,d^\alpha)} \right) \tag{1}$$

for every $u \in C_0^\infty(\Omega)$, where $\|u\|_{L^p(\Omega,d^\alpha)} := \left(\int_\Omega d(x)^\alpha |u(x)|^p dx \right)^{\frac{1}{p}}$. On the other hand, inequality (1) fails for the critical value $\alpha = p-1$. The main purpose of this talk is to show that, this notwithstanding, suitable higher-order versions of inequality (1), which cannot just be obtained from (1) via iteration, do hold even when $\alpha = p-1$.

This is a joint work with Professor Andrea Cianchi (University of Florence). (Received February 08, 2018)

1138-35-183 **Daisuke Naimen*** (naimen@mmm.muroran-it.ac.jp). *Blow-up analysis for nodal radial solutions in Trudinger-Moser critical equations in $\mathbb{R}^2$.*

We consider low energy nodal radial solutions of Trudinger-Moser critical equations in $\mathbb{R}^2$. We study the asymptotic behavior of them as the growth rate of the nonlinearity goes to a threshold between the existence and nonexistence of nodal radial solutions. The solution exhibits a multiple concentration behavior together with a convergence to the least energy solution of a critical problem. We also observe that each concentration part, with an appropriate scaling, converges to a solution of the classical Liouville problem in $\mathbb{R}^2$. This talk is based on a joint work with Massimo Grossi at Sapienza University of Rome. (Received February 09, 2018)

1138-35-195 **Giusy Mazzone*** (giusy.mazzone@vanderbilt.edu), Department of Mathematics, 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240. *On the motion of rigid bodies with a fluid-filled gap.*

We consider the fluid-solid interactions occurring when a viscous incompressible fluid is confined to move in a bounded domain between two rotating rigid bodies. The motion of the fluid is governed by the Navier-Stokes equations. The movements of the solids are described by the balances of their angular momenta. We prove existence of weak solutions to the equations of motion for the whole system of rigid bodies with the fluid-filled gap, for a large class of initial data having (arbitrary) finite kinetic energy. Existence of local strong solutions will be discussed. We show that the equations of motion admit a unique maximal solution for initial data in critical spaces. These critical spaces are characterized by the property that their homogeneous version, for the fluid component, is scaling invariant for the Navier-Stokes equations.

If time permits, some results about long-time behavior of weak solutions and stability of steady-states for the whole system will be presented. (Received February 09, 2018)

1138-35-203 **H. Dong** and **T. Phan*** (phan@math.utk.edu). *Regularity theory for weak solutions of parabolic equations with singular degenerate coefficients.*

In this talk, we study regularity and solvability in weighted Sobolev spaces for a class of parabolic equations in divergence form with singular and degenerate coefficients. We are particularly interested in the case that the coefficients are measurable in all of their variables but singular or degenerate in one space variable direction. An example of our class of equations is Grushin type singular degenerate equations in which the degeneracy or singularity appears at the boundary of the considered domains. Under certain conditions, reverse Holder's inequalities are established. Lipschitz estimates for weak solutions are proved for a class of homogeneous equations whose coefficients depend only on one space variable, but they can be singular and degenerate. These estimates are then used to establish interior, boundary, and global estimates of the Calderon-Zygmund type for weak solutions assuming that the coefficients are partially VMO (vanishing mean oscillation) with respect to the considered weights. The solvability in weighted Sobolev spaces for this class of equations is also achieved. Our results recover and generalize well-known results when coefficients are uniformly elliptic. The talk is based on the joint work with H. Dong (Brown University). (Received February 09, 2018)

1138-35-208 **Alim Sukhtayev*** (sukhtaa@miamioh.edu), 123 Bachelor Hall, 301 S. Patterson Ave., Oxford, OH 45056, and **Margaret Beck**, **Graham Cox**, **Chris Jones** and **Yuri Latushkin**. *A dynamical approach to semilinear elliptic equations.*

We describe a procedure for reducing a semilinear elliptic PDE to an (infinite-dimensional) dynamical system on the boundary of some fixed bounded domain $\Omega \subset \mathbb{R}^n$.

Suppose u satisfies the equation $\Delta u + F(x,u) = 0$ on $\mathbb{R}^n$. When the domain is deformed through a one-parameter family $\{\Omega_t\}$, it is shown that the Cauchy data of u on $\partial\Omega_t$ satisfies a Hamiltonian evolution equation. If Ω is deformed smoothly to a point, this equation admits an exponential dichotomy, with the unstable subspace at time t corresponding to the Cauchy data of weak solutions to the PDE on Ω_t. (Received February 09, 2018)

1138-35-214 **Michael Goldberg*** (goldbeml@ucmail.uc.edu). *Time-weighted Strichartz inequalities.*

The original Strichartz estimate for solutions of the linear Schrödinger equation is a dual statement of the Stein-Tomas restriction theorem for the paraboloid. It provides L^p decay over time but without an explicit polynomial rate. Using similar principles, we prove that the time-weighted solution $te^{-it\Delta}u_0(x)$ can be approximated by a single unweighted solution, with the remainder controlled by a Strichartz-like bound. This is joint work with Dmitriy Stolyarov. (Received February 09, 2018)

1138-35-226 **Yohei Fujishima*** (fujishima@shizuoka.ac.jp). *Global in time existence of solutions for the heat equation with a superlinear source term.*

This talk is devoted to the study of the global in time existence of solutions for a nonlinear heat equation with general nonlinearity. We introduce a generalization of a self-similar transformation, and exhibit a scale invariant integral under this transformation. As a result, we show the global in time existence of solutions with small initial data. (Received February 10, 2018)

1138-35-246 **Hidemitsu Wadade*** (wadade@se.kanazawa-u.ac.jp), Institute of Science and Engineering, Kanazawa University, Kakuma-machi, Kanazawa, Ishikawa 920-1192, Japan, and **Michinori Ishiwata** (ishiwata@sigmath.es.osaka-u.ac.jp), Graduate School of Engineering Science, Osaka University, Toyonaka, Osaka 560-8531, Japan. *On a maximizing problem of the Sobolev embedding related to the space of bounded variation.*

In this talk, we consider the maximizing problem associated with Sobolev embedding related to the space of bounded variation of BV-functions, which is a substitute of the Sobolev space of the marginal case. In our setting of the maximizing problem, we suffer from the non-compactness due to the vanishing phenomenon and the non-reflexivity of the space of BV-functions. In order to overcome these difficulties, we use the fact that the family of maximizers of the Sobolev embedding with BV-functions is the set of characteristic functions on balls. Simultaneously, we give a characterization of maximizers of our problem to prove that the maximizers must form characteristic functions on balls and specify their radii and heights exactly. This is a joint work with Prof. Michinori Ishiwata in Osaka University. (Received February 11, 2018)

1138-35-272 **Futoshi Takahashi*** (futoshi@sci.osaka-cu.ac.jp), 3-3-138 Sugimoto, Sumiyoshi-ku, Osaka, Osaka, 558-8585, Japan. *Hardy's inequality in a limiting case on general bounded domains.*

In this talk, we study Hardy's inequality in a limiting case:

$$\int_\Omega |\nabla u|^N dx \geq C_N(\Omega) \int_\Omega \frac{|u(x)|^N}{|x|^N \left(\log \frac{R}{|x|}\right)^N} dx$$

for functions $u \in W_0^{1,N}(\Omega)$, where Ω is a bounded domain in $\mathbb{R}^N$ with $R = \sup_{x\in\Omega}|x|$. We study the attainability of the best constant $C_N(\Omega)$ in several cases. We provide sufficient conditions that assure $C_N(\Omega) > C_N(B_R)$ and $C_N(\Omega)$ is attained, here B_R is the N-dimensional ball with center the origin and radius R. Also we provide an example of $\Omega \subset \mathbb{R}^2$ such that $C_2(\Omega) > C_2(B_R) = 1/4$ and $C_2(\Omega)$ is not attained. This talk is based on a joint work with Jaeyoung Byeon (KAIST). (Received February 12, 2018)

1138-35-276 **Mihai Tohaneanu*** (mihai.tohaneanu@uky.edu), 107 Johnston Blvd, Lexington, KY 40503. *Quasilinear wave equations on Schwarzschild and Kerr.*

We study the quasilinear wave equation $\Box_g u = 0$, where the metric g depends on u and equals either the Schwarzschild metric or Kerr metric with small angular momentum when u is identically 0. Under a couple of assumptions on the metric g near the trapped set and the light cone, we prove global existence of solutions. This is joint work with Hans Lindblad. (Received February 12, 2018)

1138-35-279 **Abbas Moameni*** (momeni@math.carleton.ca), ottawa, k1s5b6, Canada. *Principle of symmetric criticality revisited; Critical point theory on convex sets.* Preliminary report.

In a wide range of mathematical problems the existence of a solution is equivalent to the existence of a fi xed point for a suitable map or a critical point for an appropriate variational or hemi-variational problem. In this talk we shall provide a principle that allows us to study problems of the general form $0 \in F(u)$, for a possibly multi-valued map F on a given convex set K. This variational principle has many applications in partial differential equations while uni fes and generalizes several results in nonlinear Analysis such as some fixed point theorems, critical point theory on convex sets and the principle of symmetric criticality. (Received February 12, 2018)

1138-35-297 **Yongki Lee*** (yongkilee@georgiasouthern.edu), Mathematical Sciences, 1332 Southern Drive, Statesboro, GA 30458. *Thresholds for shock formation in traffic flow models with nonlocal-concave-convex flux.*

We identify sub-thresholds for finite time shock formation in a class of non-local conservation law with concavity changing flux. From a class of non-local conservation laws, the Riccati-type ODE system that governs a solution's gradient is obtained. The changes in concavity of the flux function correspond to the sign changes in the leading coefficient functions of the ODE system. We identify the blow-up condition of this structurally generalized Riccati-type ODE. The method is illustrated via the traffic flow models with nonlocal-convave-convex flux. The techniques and ideas developed in this research is applicable to a large class of non-local conservation laws. (Received February 12, 2018)

1138-35-313 **Gisele Ruiz Goldstein*** (ggoldste@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152, and **Jerome Arthur Goldstein** (jgoldste@memphis.edu), **Rosa Maria Minini** (rosamaria.minini@uniba.it) and **Silvia Romanelli** (silvia.romanelli@uniba.it). *The PDEs of Mathematical Finance.*

Of concern is the parabolic pde

$$\frac{\partial u}{\partial t} = \alpha x^k \frac{\partial^2 u}{\partial x^2} + (\beta + \gamma x) \frac{\partial u}{\partial x} + (\delta + \varepsilon x)\, u$$

for $t > 0$, $x \in J$. Here all constants are real and $\alpha > 0$. The generalized heat equation corresponds to $J = \mathbb{R}$, $k = 0$, $\gamma = \varepsilon = 0$; the generalized Black-Scholes equation corresponds to $J = (0, \infty)$, $k = 2$, $\beta = \varepsilon = 0$. The Cox-Ingersoll-Ross (CIR) equation corresponds to $J = (0, \infty)$, $k = 1$, $\delta = 0$, and β, γ both nonzero. These are deterministic equations with stochastic backgrounds in mathematical finance. The equations are studied on weighted sup norm spaces with various positive weights w,

$$Y_w = \{f \in C(J) : wf \in C_0(J)\}.$$

Results to be presented include semigroup generation for the Black-Scholes and CIR equations, chaos for the generalized heat and Black-Scholes equations, a new Feynman-Kac type formula for the CIR equation, and extensions of the CIR equation to more general potentials. This work is joint with J. A. Goldstein, R. Mininni, and S. Romanelli. (Received February 12, 2018)

1138-35-319 **Gisèle Ruiz Goldstein** (ggoldste@memphis.edu) and **Jerome A. Goldstein*** (jgoldste@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152, and **Michel Pierre** (michael.pierre@ens-rennes.fr). *The Agmon-Douglis-Nirenberg problem for dynamic boundary conditions.*

Of concern are certain reaction-diffusion systems wth total mass bounded in the L^1 norm. The solution of this problem requires new results from the study of a heat equation involving a symmetric uniformly elliptic operator on a bounded domain, with Wentzell (or dynamic) boundary conditions incorporating the Laplace-Beltrami operator. We prove that the semigroup governing this linear problem is analytic in the right half plane in L^p for $1 \leq p \leq \infty$ and for C in the sup norm. The proof is quite long and delicate. We will sketch it. (Received February 12, 2018)

1138-35-327 **Willie W.-Y. Wong*** (wongwwy@math.msu.edu). *A novel vector-field approach to the dispersive estimate for 2D wave equations.*

A long standing difficulty for the study of nonlinear wave equations in two spatial dimensions using the physical-space-based vector field method is the inability to capture the dispersive decay of the solution itself (as opposed to its higher derivatives). In this talk I will present a modified vector field method that proves an almost-sharp (with a logarithmic loss in time) interior decay estimate for solutions to the linear wave equation with compactly supported initial data in two dimensions. The same method also yields minor improvements over the classical vector field method in higher dimensions, which will be briefly described. Time permitting, applications will be sketched. (Received February 12, 2018)

1138-35-336 **Ramjee Sharma*** (ramjee.sharma@ung.edu), University of North Georgia, 3820 Mundy Mill Rd, Oakwood, GA 30566. *Improved Geometric Criteria for the global regularity of 2d inviscid Surface Quasigeostrophic Equations.*

The inviscid 2D surface quasigeostrophic equations are evolution equations for scalars which are carried by a fluid flow and are given as

$$\theta_t + u \cdot \nabla\theta = 0, \quad \nabla \cdot u = 0, \quad \theta(x, 0) = \theta_0(x),$$

where $\theta = \theta(x, t)$ and $x \in R^2$ or $x \in T^2$, a periodic box. The vector u is the velocity field and $u = (u_1, u_2)$. Since u is divergence free, there exists a potential function ψ such that

$$u = (-\partial_{x_2}\psi, \partial_{x_1}\psi)$$

The scalar θ is related to ψ through the relation

$$(-\Delta)^{\frac{1}{2}}\psi = \theta$$

In this presentation, we will discuss various relations between the geometry of the level curves and the regularity of the solutions. (Received February 12, 2018)

1138-35-340 **Juraj Foldes*** (foldes@virginia.edu), **Denis Bonheure**, **Hugo Tavares**, **Alberto Saldana** and **Ederson Moreira dos Santos**. *Uniqueness of critical points and applications to evolution problems.*

In order to understand the evolution of a system, it is critical to investigate stability properties of equilibria. These are often characterized as minimizers or critical points of certain functionals such as energy, entropy etc. Although basic properties include their existence, uniqueness, and regularity of critical points, the literature provide only very basic criteria for the uniqueness . To close this gap, we prove a unified and general criterion for the uniqueness of critical points of a functional in or without the presence of constraints such as positivity, boundedness, or fixed mass. Our method relies on convexity properties along suitable paths and significantly generalizes well-known uniqueness theorems. Due to the flexibility in the construction of the paths, our approach does not depend on the convexity of the domain and can be used to prove uniqueness in subsets, even if it does not hold globally. The results apply to all critical points and not only to minimizers, thus they provide uniqueness of solutions to the corresponding Euler-Lagrange equations. (Received February 12, 2018)

1138-35-350 **Guher Camliyurt*** (camliyur@usc.edu), 3620 S. Vermont Ave. Math Department, KAP 104, Los Angeles, CA 90089, **Igor Kukavica** (kukavica@usc.edu), 3620 S. Vermont Ave. KAP 104, Los Angeles, CA 90089, and **Vlad Vicol** (vvicol@math.princeton.edu), Department of Mathematics, Princeton University, Fine Hall, Washington Road, Princeton, NJ 08544. *Analyticity Results for the Euler and Navier-Stokes Equations.*

We revisit the preservation of analyticity and Gevrey regularity for the Euler equation. We provide a result on preservation of Gevrey norm and analyticity in Lagrangian formulation of the Euler equation and discuss the validity of the result in the Eulerian variables.

Next, we consider the Navier–Stokes equations posed on the half space, with Dirichlet boundary conditions. We give a direct energy based proof for the instantaneous space-time analyticity and Gevrey class regularity of the solutions, uniformly up to the boundary of the half space. (Received February 13, 2018)

1138-35-367 **Jeremy S LeCrone*** (jlecrone@richmond.edu) and **Gieri Simonett**. *Stability of cylinders in surface diffusion flow under general perturbations.*

The surface diffusion flow is a geometric evolution equation which prescribes the normal velocity of points on immersed, oriented manifolds to equal the Laplace-Beltrami operator acting on the mean curvature at the point. Given a parameter- ization for the manifold, the morphological evolution of the parameterization is expressed by a fourth-order, quasilinear, parabolic pde. In this talk, I will discuss results regarding well–posedness of surface diffusion under weak regularity assumptions on initial data and stability of unbounded cylinders (as stationary solutions to surface diffusion flow) under general perturbations with periodicity along the cylindrical axis. (Received February 13, 2018)

1138-35-369 **Yuanzhen Shao*** (yshao@georgiasouthern.edu), 65 Georgia Ave., Room 3041, Statesboro, GA 30460-8093, and **Changyou Wang**. *The harmonic map heat flow on conic manifolds.*

The aim of this talk is to discuss the evolution of the harmonic map heat flow from a manifold with conic singularities to a closed manifold. In particular, I will present the short time existence and uniqueness of solutions as well as the existence of global solutions into manifolds with non-positive sectional curvature. (Received February 13, 2018)

1138-35-383 **Nourridine Siewe***, nourridine@aims.ac.za, and **Avner Friedman**. *Chronic Hepatitis B Virus and Liver Fibrosis: A Mathematical Model.*

Hepatitis B virus (HBV) infection is a liver disorder that can result in cirrhosis, liver failure and hepatocellular carcinoma. HBV infection remains a major global health problem, as it affects more 350 million people chronically and kills roughly 600,000 people annually. Drugs currently used against HBV include IFN-α that decreases viremia, inflammation and the growth of liver fibrosis, and adefovir that decreases the viral load. Each of these drugs can have severe side-effects. In the present paper, we consider the treatment of chronic HBV by a combination of IFN-α and adefovir, and raise the following question: What should be the optimal ratio between IFN-α and adefovir in order to achieve the best 'efficacy' under constraints on the total amount of the drugs; here the efficacy is measured by the reduction of the levels of inflammation and of fibrosis? We develop a mathematical model of HBV pathogenesis by a system of partial differential equations (PDEs) and use the model to simulate a 'synergy map' which addresses the above question. (Received February 13, 2018)

1138-35-399 **Shangbing Ai*** (`ais@uah.edu`), Department of Mathematical Sciences, University of Alabama in Huntsville, Huntsville, AL 35899, and **Craig Cowan** (`craig.cowan@umanitoba.ca`). *Perturbation of the Lane-Emden equation $\Delta u + u^p = 0$ in the critical case of $p = \frac{n+2}{n-2}$.* Preliminary report.

In this paper we use the ODE technique to examine the solvability of (positive classical solution)

$$\begin{aligned} -\Delta u(r) &= (1+g(r))u(r)^p \qquad 0<r<R, \\ u(R) &= 0 \end{aligned}$$

where $p = \frac{n+2}{n-2}$. In particular, we show the existence of solutions for

$$\begin{aligned} -\Delta u(r) &= (1+br)u(r)^p \qquad 0<r<1, \\ u(1) &= 0 \end{aligned}$$

for any $b > 0$. (Received February 13, 2018)

1138-35-401 **Mimi Dai*** (`mdai@uic.edu`). *Well-posedness problems for the magneto-hydrodynamics models.*

We will talk about some recent results on the well-posedness problems in Sobolev spaces for the magneto-hydrodynamics with and without Hall effect, i.e., the Hall MHD and classical MHD models. One of the purposes of the work is to search the optimal Sobolev space of well-posedness for the two models. Another purpose is to understand the nonlinear Hall term $\nabla \times ((\nabla \times b) \times b)$ in the Hall MHD, which appears more singular than $u \cdot \nabla u$ in the NSE, but with special geometry. (Received February 14, 2018)

1138-35-402 **Peter Constantin**, **Theodore Drivas** and **Huy Nguyen*** (`qn@math.princeton.edu`), Department of Mathematics, Fine Hall, Washington Road, Princeton University, Princeton, NJ 08544, and **Federico Pasqualotto**. *Global Regularity For One-Dimensional Viscous Compressible Fluid Models With Degenerate Viscosity.*

We will discuss a family of 1D isentropic compressible Navier-Stokes type equations in which the viscosity depends on and degenerates with the "density". Applications include isentropic compressible Naiver-Stokes equation for gases, shallow water waves, and a model describing slender jets of fluids. The main results include a blow-up criterion merely in terms of "density", and global regularity for large data. (Received February 14, 2018)

37 ► Dynamical systems and ergodic theory

1138-37-10 **J. Ding*** (`jiu.ding@usm.edu`), Department of Mathematics, University of Southern Mississippi, Hattiesburg, MS 39406, and **Congming Jin** and **Tulsi Upadhyay**. *A linear spline maximum entropy method for random maps.*

We develop a maximum entropy method for the computation of stationary densities of random maps, using linear splines. We give a convergence analysis and error estimates for the method, and some numerical experiments are also presented. (Received December 06, 2017)

1138-37-33 **Vaibhav Gadre** and **Joseph Maher*** (joseph.maher@csi.cuny.edu). *Random mapping class group elements have generic foliations.*

A pseudo-Anosov element of the mapping class group determines a quadratic differential, which lies in the principal stratum if all zeroes are simple, equivalently, if the corresponding foliations have trivalent singularities. We show that this occurs with asymptotic probability one for random walks on the mapping class group, and furthermore, the hitting measure on the boundary gives weight zero to foliations with saddle connections. (Received January 18, 2018)

1138-37-54 **Osama Khalil*** (khalil.37@osu.edu). *Divergent Trajectories and Expanding Curves on Homogeneous Spaces.*

Many problems in (intrinsic) Diophantine approximation on differentiable curves in $\mathbb{R}^n$ can be recast in terms of the behavior of certain diagonalizable flows on appropriate homogeneous spaces. The dynamical problems that arise in this way take the following form: for a 1-parameter diagonalizable subgroup g_t and a lattice Γ in a Lie group G, one embeds the curve of interest into the unstable horospherical subgroup for g_t. For a certain class of such curves, we prove an upper bound on the Hausdorff dimension of the set of points along the curve whose trajectory under g_t spends 0 percent of its time in any compact subset of G/Γ. These trajectories correspond to points for which the conclusion of an appropriate version of Dirichlet's theorem can be infinitely improved. (Received January 26, 2018)

1138-37-72 **Yinshu Wu*** (yinshu.wu@aamu.edu), Math department, 4900 Meridian Street North, Normal, AL 35762. *The SIR Modeling for the Biological Flu using Artificial Neural Network.*

Millions of people in the United States get the flu each year. About 36,000 people die each year of problems from the flu. The biological flu is a disease spread by contact with infected individuals. Individuals recover from the disease and gain further immunity from it. For this work, the SIR (Susceptible, Infected, and Recovered) model is utilized. Weekly data of 2012-2017 in USA from Centers for Disease Control and Prevention was used to estimate the groups of population for the next year by Artificial Neural Network (ANN). Machine learning is the general method for artificial neural networks which is based on the concept of self-adjustment of internal control parameters. The prediction from previous simulation demonstrates ANN is very effective. The predicted infection rate for the future provides an effective way to estimate the spread of the flu. (Received January 29, 2018)

1138-37-79 **Natalie P Frank** (nafrank@vassar.edu) and **E. Arthur Robinson, Jr.*** (robinson@gwu.edu). *A family of infinite local complexity tiling flows with countable Lebesgue spectrum.*

For $R > 1$, we consider a 1-parameter family of 1-dimensional tiling substitutions, and the underlying discrete substitution on the Hilbert cube $[1, R+1]^{\mathbb{Z}}$. These substitutions generalize the well known Fibonacci substitution $s \to \ell; \ell \to \ell s$. But in the new susbstitution, s: "short", and ℓ "long", are not constant, but satisfy $s \in [1, R]$ and $\ell \in [R, R+1]$.

To perform the substitution, we first expand each length by $\lambda = (R+1)/R$. Then λs becomes ℓ, but $\lambda\ell$ becomes ℓ then s, where now s and ℓ satisfy $\ell/s = R$. We study the resulting Hilbert cube subshifts and the corresponding tiling dynamical systems.

We show that the choice of the R determines whether the tiling space has finite or infinite local complexity, which happens except for a countable set of R. $R = (1/2)(1+\sqrt{5})$ gives the locally-finite Fibonacci substitution, with pure discrete spectrum. Other locally-finite values of R are weakly mixing but not strongly mixing.

But we show that for all the locally-infinite cases we get countable Lebesgue spectrum, and thus are strongly mixing. All the examples, however, have entropy zero. (Received January 30, 2018)

1138-37-80 **Alena Erchenko*** (axe930@psu.edu). *Flexibility questions in dynamical systems and their connections with geometry.*

We introduce the flexibility program proposed by A. Katok and discuss first results. We show the flexibility of the entropy with respect to the Liouville measure and topological entropy for geodesic flow on negatively curved surfaces with fixed genus and total area (joint with A. Katok). Also, we point out some restrictions which come from additionally fixing a conformal class of metrics (joint with T. Barthelmé). In both settings we point out connections with flexibility of geometric data. (Received January 30, 2018)

1138-37-87 **Yunping Jiang*** (yunping.jiang@qc.cuny.edu), Department of Mathematics, Queens College of CUNY, 65-30 Kissena Blvd, Flsuhing, NY 11367. *A Simple Proof of Ruelle's Perron-Frobenius Theorem and Its Applications to Equilibrium Measures and Correlations in Dynamics.*

In this talk I will give a simple proof of Ruelle's Perron-Frobenius Theorem. After that I will talk about some applications of this theorem in the study of equilibrium measures and decay rates of correlations for uniformly expanding and non-uniformly expanding dynamical systems. Finally, I will mention a conjecture about second eigenvalues of Ruelle operators. (Received January 31, 2018)

1138-37-89 **Jon Chaika*** (chaika@math.utah.edu), DEPARTMENT OF MATHEMATICS, 155 SOUTH 1400 EAST, JWB 233, Salt Lake City, UT 84112, and **John Smillie** (j.smillie@warwick.ac.uk) and **Barak Weiss** (barakw@post.tau.ac.il). *Horocycle orbits in strata of translation surfaces.*

Ratner, Margulis, Dani and many others, showed that the horocycle flow on homogeneous spaces has strong measure theoretic and topological rigidity properties. Eskin-Mirzakhani and Eskin-Mirzakhani-Mohommadi, showed that the action of SL(2,R) and the upper triangular subgroup of SL(2,R) on strata of translation surfaces have similar rigidity properties. We will describe how some of these results fail for the horocycle flow on strata of translation surfaces. In particular,

1) There exist horocycle orbit closures with fractional Hausdorff dimension. 2) There exist points which do not equidistribute under the horocycle flow with respect to any measure. 3) There exist points which equidistribute distribute under the horocycle flow to a measure, but they are not in the topological support of that measure.

This is joint work with John Smillie and Barak Weiss. (Received February 01, 2018)

1138-37-109 **Sergey Bezuglyi*** (sergii-bezuglyi@uiowa.edu), **Olena Karpel** and **Jan Kwiatkowski**. *Exact number of ergodic invariant measures for Bratteli diagrams.*

We study the simplex $M_1(B)$ of probability measures on a Bratteli diagram B which are invariant with respect to the tail equivalence relation. We prove a criterion of unique ergodicity of a Bratteli diagram. In case when a finite rank k Bratteli diagram B has $l \leq k$ ergodic invariant measures, we describe the structures of the diagram and the subdiagrams which support these measures. We find conditions under which the extension of a measure from a uniquely ergodic subdiagram is a finite ergodic measure. (Received February 04, 2018)

1138-37-168 **Ilya Gekhtman*** (ilyagekh@gmail.com) and **Arie Levit** (arie.levit@gmail.com). *Critical exponents of invariant random subgroups in negative curvature.*

Invariant random subgroups (IRS) are conjugacy invariant probability measures on the space of subgroups in a given group G. They can be regarded as a generalization both of normal subgroups and of lattices lattices. As such, it is interesting to extend results from the theories of normal subgroups and of lattices to the IRS setting.

We prove such a result: the critical exponent of a hyperbolic group or an isometry group of a CAT(-1) space (such as a rank 1 symmetric space) is greater than half the dimension of the boundary. The proof uses some ergodic theorems for actions of hyperbolic groups. This is joint work with Arie Levit. (Received February 08, 2018)

1138-37-170 **Nandor J Simanyi*** (simanyi@uab.edu) and **Caleb C Moxley**. *Asymptotic Homotopical Complexity of a Sequence of 2D Billiards.* Preliminary report.

We are studying the asymptotic behavior of the homotopical rotation sets and the topological entropy for a sequence of billiard flows on the $2D$ flat torus $\mathbb{T}^2$ with n disjoint, circular scatterers, as n tends to infinity. Constant upper and lower bounds have been found for the internal and external radial sizes of the homotopical rotation sets, whereas for the topological entropy, logarithmic lower and upper bounds are presented, so that they differ only by a constant factor. Furthermore, computer simulation has been done for the computation of $\lim_{n\to\infty} \frac{h_{top}}{\ln n}$, as n tends to infinity, if we rely upon the so called admissible billiard trajectories. (Received February 08, 2018)

1138-37-186 **Scott R Kaschner*** (skaschne@butler.edu) and **Roland K.W. Roeder**. *Superstable Manifolds of Invariant Circles.*

In this talk, I will discuss the dynamics of dominant, meromorphic self-maps of complex manifolds of dimension $n > 1$. Specifically, I will focus on the situation in which there is an invariant embedded copy of $\mathbb{CP}^1$ that also contains an invariant real circle. I will describe the regularity the of superstable manifolds of this circle and how they relate to global properties of the embedded $\mathbb{CP}^1$. Also, there is a physical interpretation to one of the maps described; I will explain how this is related and how it motivated this work. (Received February 09, 2018)

1138-37-211 **Anton Lukyanenko*** (alukyane@gmu.edu) and **Joseph Vandehey**. *Ergodicity of Iwasawa continued fractions via markable geodesics.* Preliminary report.

Continued fractions in $\mathbb{R}$ have a well-studied connection to both dynamical systems and hyperbolic geometry. We describe a broad framework of higher-dimensional *Iwasawa continued fractions* that retains both of these connections, and corresponding markings on "markable" geodesics in the associated hyperbolic geometry. Building a section for markable geodesics, we obtain ergodicity for geometrically complete Iwasawa continued fractions, which include most one-dimensional continued fraction algorithms and certain variants of both the Hurwitz complex continued fractions and Heisenberg continued fractions. (Received February 09, 2018)

1138-37-223 **Jane Wang*** (janeyw@mit.edu). *An Introduction to Dilation Surfaces.* Preliminary report.
Translation surfaces are surfaces that can be formed by identifying the sides of polygons by translation. They are well-studied objects in dynamics and geometry, and are important objects in the study of mathematical billiards and Teichmuller theory. In this talk, we'll introduce a cousin of the translation surface called a dilation surface, which can be formed by identifying the sides of polygons by translation and dilation. We'll discuss how these objects naturally could arise in the study of pseudo-Anosov maps, and compare the geometry and dynamics of dilation surfaces with that of translation surfaces. (Received February 09, 2018)

1138-37-224 **Benjamin Dozier*** (benjamin.dozier@gmail.com), Stanford University. *Translation surfaces with multiple short saddle connections.* Preliminary report.

I will discuss work in progress towards proving a natural conjecture on the volume of the subset of an affine invariant submanifold (of the moduli space of translation surfaces) where the translation surface has multiple independent short saddle connections. A key tool is the new compactification of the space of translation surfaces due to Bainbridge-Chen-Gendron-Grushevsky-Moeller, which can be used to explicitly understand how a translation surface can degenerate. The techniques are expected to be useful for other problems concerning affine invariant manifolds. (Received February 09, 2018)

1138-37-245 **Paul Apisa***, 5442 S Ellis Ave, Chicago, IL 60615, and **Hamid al-Saqban**, **Alena Erchenko**, **Osama Khalil**, **Shahriar Mirzadeh**, **Caglar Uyanik** and **Howard Masur**. *Hausdorff Dimension, Divergence, and Teichmuller Geodesic Flow!*

The moduli space of Riemann surfaces is an intrinsically inhomogeneous space (in a sense made precise by Farb and Weinberger), yet the dynamics of Teichmuller geodesic flow exhibit many hallmarks of homogeneous dynamics. What mechanism accounts for the homogeneity?

For example, given a quadratic differential there is a circle of directions in which to apply Teichmuller geodesic flow. By results of Eskin and Chaika, the set of directions that diverge on average (i.e. spend asymptotically no time in any compact set) is measure zero. In this talk I will describe new results that say that no matter which quadratic differential you choose, the set of directions that diverge on average always has Hausdorff dimension one-half.

The talk will begin with motivation from continued fractions and will assume no background on Teichmuller geodesic flow. The lower bound is joint work with Masur and the upper bound is joint work with al-Saqban, Erchenko, Khalil, Mirzadeh, and Uyanik. (Received February 11, 2018)

1138-37-253 **Florin P Boca*** (fboca@math.uiuc.edu) and **Christopher Linden**. *Minkowski type question mark functions associated with even or odd continued fractions.*

We discuss analogues of Minkowski's question mark function $?(x)$ related to continued fraction expansions with even or with odd partial quotients. We prove that these functions are Hölder continuous with precise exponents, and that they linearize the appropriate versions of the Gauss and Farey maps. (Received February 11, 2018)

1138-37-265 **Caleb Moxley*** (ccmoxley@bsc.edu), Birmingham-Southern College, 900 Arkadelphia Road, Birmingham, AL 35209. *Bounds for the topological entropy of a billiard flow.*

We construct bounds for the topological entropy of a billiard flow on the 3-D flat torus with two orthogonal, intersecting toroidal scatterers. The bounds are the consequence of inner and outer radial estimates of the homotopical rotation set of the billiard flow, its fundamental group, and a construction of a subset of the homotopical rotation set consisting of admissible trajectories. These admissible trajectories are constructed using the length minimizing variational method. (Received February 11, 2018)

1138-37-291 **Palle Jorgensen***, Dept Mathematics MLH, University of Iowa, Iowa City, IA. *Spectral theory of transfer operators; with applications.*

Speaker. Palle Jorgensen, Professor, University of Iowa. Abstract. By class of "transfer operators" refers to a family of operators which arise in diverse areas of dynamics, ranging from quantum theory to wavelet theory, to measurable dynamics, from fractals to signal analysis; from Markov operators in discrete as well as continuous settings. The appropriate transfer operators often arise in instances where Hilbert space is not given directly, and in any case, the spectral theory differs from that of more traditional settings, as will be outlined in the talk. (Received February 12, 2018)

1138-37-295 **Zhaosheng Feng*** (zhaosheng.feng@utrgv.edu), 1201 W. University Drive, Edinburg, TX 78539. *Dynamics of a diffusive plant invasion model.*

In this study, we consider a diffusive plant invasion model with delay under the homogeneous Neumann boundary condition. The qualitative properties, including the existence and uniqueness of a nonnegative solution, persistence property, and local asymptotic stability of the constant steady states are established. We investigate the Hopf bifurcation of this model and obtain some criteria by analyzing the associated characteristic equation and by taking τ as the bifurcation parameter. Under special circumstance, we also consider the system's discontinuous Hopf bifurcation. Then we explore the existence and non-existence of nonconstant positive steady states of this model through considering the effect of large diffusivity. Our simulations demonstrate that the numerically observed behaviors are in good agreement with the theoretically proposed results. (Received February 12, 2018)

1138-37-299 **Leonard Carapezza**, **Marco Antonio López*** (marco.lopez@unt.edu) and **Donald Robertson**. *Equilibrium states for α, β transformations.*

We consider interval maps of the form $x \mapsto \alpha + \beta x$ mod 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 February 12, 2018)

1138-37-305 **Judy A Kennedy*** (kennedy9905@gmail.com), Dept. Mathematics, Lamar University, Beaumont, TX 77706, and **Goran Erceg**. *A surprising topological entropy example.*

We define topological entropy for closed subsets of the square [0,1] x [0,1], and then give an example of a closed subset of the square that has 0 entropy, but if one point is added to the set, the new set has infinite entropy. This is joint work with Goran Erceg of the University of Split. (Received February 12, 2018)

1138-37-315 **Jason Atnip*** (jason.atnip@unt.edu). *An almost sure invariance principle for several classes of random dynamical systems.*

In this talk we deal with a large class of dynamical systems having a version of the spectral gap property. Our primary class of systems comes from random dynamics, but we also deal with the deterministic case. We show that if a random dynamical system has a fiberwise spectral gap property as well as an exponential decay of correlations in the base, then, developing on Gouëzel's approach, the system satisfies the almost sure invariance principle. The result is then applied to uniformly expanding random systems like those studied by Denker and Gordin and Mayer, Skorulski, and Urbański. (Received February 12, 2018)

1138-37-338 **Mrinal K Roychowdhury*** (mrinal.roychowdhury@utrgv.edu), University of Texas Rio Grande Valley, 1201 West University Drive, Edinburg, TX 78539. *Optimal quantization.*

Quantization for a probability distribution refers to the idea of estimating a given probability by a discrete probability supported by a set with finite number of points. It has broad applications in signal processing and data compression. It is also closely connected with data mining. In my talk, I will try to give an overview of optimal quantization for different probability distributions. (Received February 12, 2018)

1138-37-373 **Kariane Calta***, kacalta@vassar.edu. *Continued Fraction Algorithms for a set of Fuchsian Triangle Groups.*

I will speak on Continued Fraction Algorithms for a set of Fuchsian Triangle Groups (Received February 13, 2018)

1138-37-378 **Subhadip Chowdhury*** (subhadip@math.uchicago.edu), 5734 S. University Ave., Chicago, IL 60637. *Rotation Number, Ziggurat Fringes, and Fractal Boundary.*

In this talk, we discuss some interesting rigidity and rationality properties of Calegari-Walker *ziggurats* – i.e. the graphs of extremal rotation numbers associated to positive words in free groups acting on the circle. Specifically, we give an explicit formula for fringe length, revealing (partial) integral projective self-similarity in ziggurat fringes, which are low-dimensional projections of characteristic polyhedra on the bounded cohomology of free groups. We also describe some stability results in the interior of the ziggurat and further generalizations to arbitrary words. (Received February 13, 2018)

1138-37-389 **Tamara Kucherenko*** (tkucherenko@ccny.cuny.edu) and **Mrinal Kanti Roychowdhury**. *Quantization dimensions for general condensation systems.*

The quantization dimension is an important characterization of the quantization error which is induced by the approximation of a given probability measure with discrete probability measures of finite supports. It represents the speed with which the quantization error approaches zero as we increase the number of elements in the supports of approximating discrete measures. In this talk we focus on the quantization dimensions of inhomogeneous self-similar measures which arise as attracting measures for condensation systems. Our goal is to show that the quantization dimension of such measure could be computed in terms of the weights associated with the self-similar part of the measure and the dimension of the inhomogeneous part. (Received February 13, 2018)

39 ► Difference and functional equations

1138-39-99 **Lingju Kong*** (lingju-kong@utc.edu). *Solutions for a discrete fourth order boundary value problem.*

Applying variational method and critical point theory, several sufficient conditions are obtained for the existence of one and multiple solutions of the discrete fourth order boundary value problem

$$\begin{cases} \Delta^4 u(t-2) - \alpha\Delta^2 u(t-1) + \beta u(t) = f(t, u(t)), \quad t \in [1, N]_{\mathbb{Z}}, \\ u(-1) = \Delta u(-1) = 0, \quad u(N+1) = \Delta^2 u(N) = 0, \end{cases}$$

where $N \geq 1$ is an integer, $\alpha, \beta \geq 0$, and $f : [1, N]_{\mathbb{Z}} \times \mathbb{R} \to \mathbb{R}$ is continuous in the second argument. Examples are included to illustrate the results. (Received February 03, 2018)

41 ► Approximations and expansions

1138-41-24 **Deguang Han***, Department of Mathematics, University of Central Florida, Oralndo, FL 32816, and **Ted Juste**, Orlando, FL. *Exact phase-retrievable frames.*

We introduce the concepts of phase-retrievability redundancy and exact phase-retrievable frames. We prove the existence of exact phase-retrievable frames and discuss some characterizations of maximal phase-retrievable subspaces for non phase-retrievable frames. This is a joint work with Ted Juste, Youfa Li and Wenchang Sun. (Received January 09, 2018)

42 ► Fourier analysis

1138-42-23 **Arpad Benyi**, **Jose Maria Martell**, **Kabe Moen*** (kabe.moen@ua.edu), **Eric Statura** and **Rodolfo H Torres**. *A connection between commutators of BMO functions and weighted estimates.*

We present a unified method to obtain weighted estimates of linear and multilinear commutators with BMO functions, that is amenable to a plethora of operators and functional settings. Our approach elaborates on a commonly used Cauchy integral trick, recovering many known results but yielding also numerous new ones. (Received January 09, 2018)

1138-42-29 **Laurent Baratchart**, **Herbert Stahl** and **Maxim L Yattselev*** (maxyatts@iupui.edu). *Convergence of AAK approximants to algebraic functions.*

The n-th AAK approximant h_n to a bounded function f on the unit circle $\mathbb{T}$ is a meromorphic function with at most n poles in the unit disk and a bounded trace on $\mathbb{T}$ that satisfies

$$\|f - h_n\|_{\mathbb{T}} = \inf_h \|f - h\|_{\mathbb{T}},$$

where the infimum is taken over all such meromorphic functions. From the work of Adamyan, Arov, and Krein it is known that h_n is uniquely defined whenever f belongs to the Douglas algebra on $\mathbb{T}$. Moreover, the norm $\|f - h_n\|_{\mathbb{T}}$ is equal to the n-th singular value of the Hankel operator with symbol f. When f is holomorphic in some neighborhood of $\mathbb{T}$, it is known that these singular values decay exponentially. I shall discuss the behavior of the approximants h_n inside the unit disk when f is a restriction of a multi-valued function with finitely many branches and a polar singular set. (Received January 17, 2018)

1138-42-37 **Christina Frederick*** (christin@njit.edu). *Reconstructions and stability estimates for higher dimensional sampling.*

We consider sampling strategies for a class of multivariate $\Omega-$bandlimited functions, where $\Omega \subset \mathbb{R}^d$ is a bounded set that is a $k-$tiling of $\mathbb{R}^d$ when translated by the lattice $\Lambda = \mathbb{Z}^d$. We show that the reconstruction can be viewed as an iterative process involving certain Vandermonde matrices, resulting in a link between the invertibility of these matrices to the existence of certain sampling sets that guarantee a unique recovery. Estimates of inverse Vandermonde matrices can then be used to provide explicit L^2-stability estimates. (Received January 21, 2018)

1138-42-112 **Sara Leshen***, sara.j.leshen@vanderbilt.edu, and **Alexander Powell**. *A Balian-Low Type Theorem for Gabor Schauder Bases.*

The Uncertainty Principle implies that a function and its Fourier transform cannot both be well-localized. The Balian-Low theorem is a form of the Uncertainty Principle for Riesz bases. We prove a new version of the Balian-Low theorem for Gabor Schauder bases generated by compactly supported functions. Moreover, we show that the classical Balian-Low theorem for Riesz bases does not hold for Schauder bases. (Received February 05, 2018)

1138-42-260 **Cheng Cheng*** (cheng87@math.duke.edu) and **Qiyu Sun**. *Phaseless sampling and reconstruction of signals in shift-invariant spaces.*

In this talk, we consider that given the absolute values of function f which are sampled either on the Euclidean space or on a discrete set with finite sampling density, is it possible to recover the signal. We introduce an undirected graph to a signal and use connectivity of the graph to characterize whether the signal can be determined, up to a sign, from its magnitude measurements on the whole Euclidean space. We also propose a reconstruction algorithm which provides a suboptimal approximation to the original signal when its noisy phaseless samples are available only. (Received February 11, 2018)

1138-42-262 **Alex Iosevich*** (iosevich@gmail.com), 145 Dunrovin Ln, Rochester, NY 14618-4815, **Azita Mayeli**, New York, NY , and **Shahaf Nitzan**, Atlanta, GA. *Curvature, density and Gabor bases.*

We are going to discuss for which sets the indicator function may serve as the window for an orthogonal Gabor basis. (Received February 11, 2018)

1138-42-311 **Mark A Davenport*** (mdav@gatech.edu), Georgia Institute of Technology, School of Elec. & Comp. Engineering, 777 Atlantic Drive NW, Atlanta, GA 30332, and **Santhosh Karnik** and **Justin Romberg**. *Fast algorithms for prolate computations.*

The so-called prolate matrix is a structured matrix which arises in a wide variety of signal processing applications – in particular, when working with samples of a bandlimited signal that are taken over a finite time interval. The prolate matrix is highly ill-conditioned, which makes applying generic matrix algorithms ineffective. However, the eigenvalues of the prolate matrix have a highly structured and predictable behavior. In this talk, I will discuss the spectral properties of the prolate matrix and show how we can leverage these properties to yield fast algorithms for working with both uniformly spaced and non-uniformly spaced samples of a bandlimited signal. (Received February 12, 2018)

1138-42-312 **Azita Mayeli*** (amayeli@gc.cuny.edu), New York, NY 10016. *Non-separable lattices, Gabor orthonormal bases and Tilings.* Preliminary report.

Let K be a subset of $\mathbb{R}^d$ with positive and finite Lebesgue measure. Let $\Lambda = M(\mathbb{Z}^{2d})$ be a lattice in $\mathbb{R}^{2d}$ with density dens$(\Lambda) = 1$. It is well-known that if M is a diagonal block matrix with diagonal matrices A and B, then the Gabor system $\mathcal{G}(|K|^{-1/2}\chi_K, \Lambda)$ is an orthonormal basis for $L^2(\mathbb{R}^d)$ if and only if K tiles both by $A(\mathbb{Z}^d)$ and $B^{-t}(\mathbb{Z}^d)$. However, there has not been any intensive study when M is not a diagonal matrix. We investigate this problem for a large class of important cases of M. We also provide a constructive way for forming a Gabor window functions for a given upper triangular lattice. Our study is related to a Fuglede's type problem in Gabor setting and we give a partial answer to this problem in the case of lattices. This is a joint work with C. Lai. (Received February 12, 2018)

1138-42-328 **Jeff Ledford*** (jpledford@vcu.edu) and **Keaton Hamm** (keaton.hamm@vanderbilt.edu). *Interpolation in Quasi Shift-invariant Spaces.*

This talk will concern various interpolation results in quasi shift-invariant spaces, $V(\psi, \mathcal{X}) := \overline{\text{span}}^{L_2}\{\psi(\cdot - x_j) : j \in \mathbb{Z}\}$, where ψ is a nice enough *generator* and $\mathcal{X}$ is a complete interpolating sequence. Results on recovering target functions in $V(\psi, \mathcal{X})$ by using interpolants in $V(\phi, \mathcal{Y})$ will also be presented. (Received February 12, 2018)

1138-42-333 **Deguang Han**, **David R Larson**, **Sam L Scholze*** (scholzsl@uwec.edu) and **Wenchang Sun**. *Signal Reconstruction from Frame Erasures.*

In this talk, I will discuss three new, efficient methods of reconstruction from frame erasures. Where older reconstruction procedures require an $n \times n$ matrix inversion to reconstruct an n-dimensional signal from L erasures, each of these methods only requires an $L \times L$ matrix inversion. Algorithms for each reconstruction scheme will be presented. We will then discuss the stability of each reconstruction scheme in the presence of additive channel noise. Numerical experiments will also be presented pertaining to channel noise. (Received February 12, 2018)

1138-42-337 **Joseph W. Iverson***, Department of Mathematics, University of Maryland, College Park, MD 20742, and **John Jasper** and **Dustin G. Mixon**. *Incoherent frames from finite group actions.*

In applications such as compressed sensing and quantum information theory, it is critically important to find examples of frames whose vectors are spread wide apart, in the sense that they span lines with large interior angles between them. Put differently, we want to find unit norm frames with minimal coherence. This is an old problem, going back at least to the work of van Lint and Seidel in the 1960s, and it remains an active and challenging area of research today. In this talk, we will present a new recipe for converting transitive actions of finite groups into unit norm tight frames, many of which have optimal coherence. The main idea is to use an association scheme as a kind of converter to pass from the discrete world of permutation groups into the continuous setting of finite frames. This process is easy to implement in a computer program like GAP. We will present examples of optimally incoherent frames produced in this way, including the first infinite family of equiangular tight frames with Heisenberg symmetry. (These are not SIC-POVMs, but they appear to be related.) (Received February 12, 2018)

1138-42-394 **Michael C. Northington V** and **Josiah Park*** (jpark685@gatech.edu). *Finite Balian-Low Theorems in Higher Dimensions.* Preliminary report.

We study Balian-Low type theorems for finite systems in Euclidean spaces of dimension greater than one. Our results are generalizations of S. Nitzan and J.-F. Olsen's recent work and show that a quantity closely related to the Balian-Low Theorem has the same asymptotic growth rate, $O(\log N)$ for each dimension d. Joint work with Michael Northington V. (Received February 13, 2018)

45 ► Integral equations

1138-45-85 **James Scott***, 208 Ayres Hall, 1403 Circle Drive, Knoxville, TN 37916. *THE DIRICHLET PROBLEM FOR OPERATORS RELATED TO PERIDYNAMICS: WELL-POSEDNESS AND REGULARITY.*

The well-posedness of solutions to the Dirichlet Problem for a class of operators related to a linear peridynamic model will be presented. In peridynamics, nonlocal interactions are represented by a kernel. Typically, the kernel is a radially symmetric locally integrable compactly supported function. We consider the model equation and show well-posedness of the Dirichlet problem for kernels assumed to be only measurable functions. The existence and uniqueness of solutions is obtained using Hilbert space methods. For a special class of kernels bearing some resemblance to potentials in fractional diffusion equations, we obtain interior Sobolev regularity. Tools from harmonic analysis and potential theory are used to prove the regularity result. This talk comes from joint work with Tadele Mengesha. (Received January 31, 2018)

1138-45-257 **Zhengwei Liu*** (zhengweiliu@fas.harvard.edu), 17 Oxford Street, Cambridge, MA 02138. *A new program on quantum subgroups.* Preliminary report.

The A, D, E classification of subgroups and modules of quantum SU(2) has been achieved in subfactor theory in the 1980s. It is a quantum analogue of the McKay correspondence. We can study classical Lie theory using subgroups of quantum SU(2). We introduce a new program that our group at Harvard is developing: higher mathematics over quantum SU(n). (Received February 11, 2018)

46 ► Functional analysis

1138-46-66 **Leonard Tristan Huang*** (leonard.huang@colorado.edu) and **Jonathan Henry Brown** (jbrown10@udayton.edu). *Bundles of Generalized Fixed-Point Algebras for Proper Groupoid Dynamical Systems.*

In a groundbreaking 1990 paper, Marc Rieffel defined proper C^*-dynamical systems in order to describe proper actions of a locally compact Hausdorff group on a "non-commutative space". In his 2009 PhD thesis, Jonathan Brown generalized Rieffel's definition to groupoid dynamical systems. The most important aspect of a proper groupoid dynamical system is that we can construct a generalized fixed-point algebra from it. Recently, Brown and I discovered how to put an upper-semicontinuous C^*-algebraic bundle structure on a generalized fixed-point algebra in certain cases, thus completing the generalization of Rieffel's 1990 paper. In this talk, we will first see two applications of the concept of proper groupoid dynamical systems, one to continuous-trace C^*-algebras and the other to graph C^*-algebras. Then we will see how certain assumptions furnish us with an upper-semicontinuous C^*-algebraic bundle structure on a generalized fixed-point algebra, with each fiber C^*-algebra being a generalized fixed-point algebra itself. We will also describe the relevance of this result to future research. (Joint work with Jonathan Brown.) (Received January 29, 2018)

1138-46-90 **Longxiu Huang*** (longxiu.huang@vanderbilt.edu), Nashville, TN 37240, **Akram Aldroubi** (aldroubi@math.vanderbilt.edu), Nashville, TN 37240, and **Armenak Petrosyan** (petrosyana@ornl.gov), Oak Ridge, TN 37830. *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 $\mathcal{H}$. Additionally, we also study the connection between a semi-continuous frame $\{A^t g : g \in \mathcal{G}, t \in [0, L]\}$ and its discretization $\{A^{t_i} g\}_{g\in\mathcal{G},i\in I}$ 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 frame. (Received February 06, 2018)

1138-46-94 **Noah Snyder*** (nsnyder@gmail.com) and **Victor Ostrik**. *Diagrams and quantum G2 at roots of unity.* Preliminary report.

Kuperberg introduced a planar algebraic description of quantum G2 which agrees with the algebraic version when q is not a root of unity. When q is a root of unity the situation is more subtle. We show that unless q is one of a finite list of bad roots of unity, the Kuperberg spider agrees with the category of tilting modules for G2. In particular, the semisimplification of the Kuperberg spider agrees with the semisimplified quantum group category. Combining this result with the classification of trivalent categories from Peters-Morrison-Snyder, we get a Kazhdan-Wenzl-style recognition theorem for G2, which says that any tensor category which has the same fusion rules as G2 at a root of unity must be G2 at a root of unity. (Received February 02, 2018)

1138-46-97 **Remus Nicoara*** (rnicoara@utk.edu), 405 Circle Drive, University of Tennesse, Knoxville, TN 37966. *Analytic deformations of group commuting squares.*

Let G be a finite group and denote by $\mathfrak{C}_G$ the commuting square associated to G. The defect of the group G, given by the formula $d(G) = \sum_{g\in G} \frac{|G|}{order(g)}$, gives an upper bound for the number of linearly independent directions in which $\mathfrak{C}_G$ can be continuously deformed in the class of commuting squares. We show that this bound is actually attained, by constructing $d(G)$ analytic families of commuting squares containing $\mathfrak{C}_G$.

In the case $G = \mathbb{Z}_n$, the defect $d(\mathbb{Z}_n)$ can be interpreted as the dimension of the enveloping tangent space of the real algebraic manifold of $n \times n$ complex Hadamard matrices, at the Fourier matrix F_n. The dimension of the enveloping tangent space gives a natural upper bound on the number of continuous deformations of F_n by complex Hadamard matrices, of linearly independent directions of convergence. Our result shows that this bound is reached, which is rather surprising. In particular our construction yields new analytic families of complex Hadamard matrices stemming from F_n. (Received February 03, 2018)

1138-46-114 **Kelly Bickel**, Dept of Math, Bucknell University, Lewisburg, PA 17837, **Michael Hartz**, Dept. of Mathematics, Washington University, 1 Brookings Drive, St. Louis, MO 63130, and **John McCarthy*** (mccarthy@math.wustl.edu), Dept of Mathematics, 1 Brookings Drive, St. Louis, MO 63130. *Multiplier Algebra Functional Calculus.*

Let $\mathcal{H}$ be a reproducing kernel Hilbert space on the ball in $\mathbb{C}^d$, for $d \geq 1$. We discuss when d-tuples of commuting operators have a Mult($\mathcal{H}$) functional calculus. For the case of the Drury-Arveson space, this was done recently by Clouâtre and Davidson.

This is joint work with K. Bickel and M. Hartz. (Received February 05, 2018)

1138-46-141 **J. Alejandro Chávez-Domínguez***, Department of Mathematics, University of Oklahoma, Norman, OK 73019. *Isoperimetric and Sobolev inequalities on magnetic graphs.*

The classical isoperimetric problem on the plane, dating back to antiquity, asks for the region of maximal area having a fixed perimeter. It is well-known that the solution to this problem (and its higher-dimensional versions) is intimately related to inequalities that give the norm of the embedding of a Sobolev space into an L_p space (that is, Sobolev inequalities). In many practical situations, the domains of interest are not continuous regions but rather discrete sets of points. A very useful model is to take the domain to be a graph, and Sobolev-style inequalities in this context have found plenty of applications in subjects such as theoretical computer science and spectral graph theory. Some situations, e.g. the presence of a magnetic potential in some quantum-mechanic models of bonds between atoms, are modeled not just with a graph but also with an additional assignment of a complex number of modulus one for each edge of the graph. In this talk we define isoperimetric inequalities for such "magnetic" graphs, and show that they imply Sobolev-style inequalities. (Received February 07, 2018)

1138-46-161 **Donghai Ji** and **Khazhak Varazdat Navoyan*** (knavoyan@go.olemiss.edu), 125 Woodward Place, Oxford, MS 38655, and **Qingying Bu**. *Bases in the space of reguar multilinear operators on Banach lattices.*

For Banach lattices $E_1, \cdots, E_m$ and F with 1-unconditional bases, we show that the monomial sequence forms a 1-unconditional basis of $\mathcal{L}^r(E_1, \cdots, E_m; F)$, the Banach lattice of all regular m-linear operators from $E_1 \times \cdots \times E_m$ to F, if and only if each basis of $E_1, \cdots, E_m$ is shrinking and every positive m-linear operator from $E_1 \times \cdots \times E_m$ to F is weakly sequentially continuous. As a consequence, we obtain necessary and sufficient conditions for which the m-fold Fremlin projective tensor product $E_1 \hat{\otimes}_{|\pi|} \cdots \hat{\otimes}_{|\pi|} E_m$ (resp. the m-fold positive injective tensor product $E_1 \check{\otimes}_{|\epsilon|} \cdots \check{\otimes}_{|\epsilon|} E_m$) has a shrinking basis or a boundedly complete basis. (Received February 08, 2018)

1138-46-209 **Vaughan F.R. Jones*** (vaughan.f.jones@vanderbilt.edu), 155 Valley forge, Nashville, TN 37205. *The R. Thompson groups as local scaling transformations of quantum spin chains.*

I will discuss the possibility of a non continuum limit of quantum spin chains where the Thompson groups and their generalisations play the role of the diffeomorphism groups and Virasoro algebra as groups of local scale transformations. (Received February 09, 2018)

1138-46-218 **Yunxiang Ren*** (yren12@utk.edu), 227 Ayres Hall, 1403 Circle Drive, Department of Mathematics, Knoxville, TN 37996. *A new skein theory for One-way Yang-Baxter planar algebras.*

In this talk, we will introduce One-Way Yang-Baxter subfactor planar algebras which are a continuation of the classification program of subfactor planar algebras via skein theory started by Bisch and Jones. We will focus on discussing the subgroup subfactor $S_2 \times S_3 \subset S_5$ which is naturally related to Petersen graph and the rank 3 permutation group. We showed that this planar algebra is generated by its 2-box space and provide a new skein theory for this planar algebra. Moreover, we will show that each member of the family of subfactors $\{S_2 \times S_n \subset S_{n+2} : n \geq 3\}$ is also generated by its 2-box space and satisfies the similar type of skein theory in a uniform way. (Received February 09, 2018)

1138-46-241 **David Sherman*** (dsherman@virginia.edu). *Weak*-closed unitary orbits of self-adjoint operators in von Neumann factors.* Preliminary report.

We obtain a spectral description of the weak*-closure of the unitary orbit of a self-adjoint operator in a factor, and we contrast it with known results describing other closures. Perhaps most interesting is a "noncommutative Lyapunov phenomenon": the type I (atomic) case turns out to be qualitatively different from types II and III, in which the closed orbit is always convex. This is joint work with Chuck Akemann. (Received February 10, 2018)

1138-46-252 **Michael Hartglass*** (mhartglass@scu.edu), Department of Mathematics and Computer Scienc, 500 El Camino Real, Santa Clara, CA 95053-0290, and **Brent Nelson**. *Type III factors arising from graphs, and a connection to infinite-index subfactors.*

We associate a von Neumann algebra associated to a weighted graph, and, give necessary and sufficient conditions on factorality and its type. We will then focus on the case where type III factors are obtained, (in which case, the factor in question will always be a free Araki-Woods factor), and we will present an application of our work to some specific infinite-index subfactors studied by Dave Penneys and Corey Jones. This is joint work with Brent Nelson. (Received February 11, 2018)

1138-46-258 **Thomas Sinclair***, Department of Mathematics, 150 N University St, West Lafayette, IN 47907. *On the classification of group von Neumann algebras.*

I will discuss recent progress and future directions on structural and classification results for II_1 factors associated to countable, discrete groups. (Received February 11, 2018)

1138-46-277 **Christopher Schafhauser*** (cschafhauser@uwaterloo.ca), Pure Mathematics, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada. *AF-emeddings of exact C^*-algebras.* Preliminary report.

A well known result of Kirchberg and Phillips states that every separable, exact C^*-algebra embeds into the Cuntz algebra O_2. The following question of Blackadar and Kirchberg asks for a stronger result in the finite setting: does every separable, exact, quasidiagonal C*-algebra embed into an AF-algebra? I will discuss a recent partial solution to this question: every separable, exact C*-algebra which satisfies the UCT and admits a faithful, quasidiagonal trace embeds into an AF-algebra. In particular, every separable, simple, unital, exact, quasidiagonal C*-algebra satisfying the UCT embeds into an AF-algebra. (Received February 12, 2018)

1138-46-357 **Yi Wang*** (yiwangfdu@gmail.com), **Ronald G. Douglas**, **Kunyu Guo** and **Jingbo Xia**. *A harmonic analysis approach to the Arveson-Douglas Conjecture.*

Let I be a homogeneous ideal in the polynomial ring $\mathbb{C}[z_1, \ldots, z_n]$ and let $[I]$ be its closure either in the Drury-Arveson space H_n^2, the Hardy space $H^2(\mathbb{B}_n)$ or the Bergman space $L_a^2(\mathbb{B}_n)$. One defines a $\mathbb{C}[z_1, \ldots, z_n]$ module structure on $[I]$ by considering the restrictions $R_i = M_{z_i}|_{[I]}$. The Arveson-Douglas Conjecture says that the module actions are essentially normal, i.e., the cross commutators $[R_i, R_j^*]$ are compact. The form of these commutators resembles that of a Hankel operator but more is involved. I will present our recent results on this conjecture obtained using tools from harmonic analysis and several complex variables. (Received February 13, 2018)

47 ► Operator theory

1138-47-36 **Marcel Bischoff*** (bischoff@ohio.edu). *Generalized Twisted Orbifold Construction.* Preliminary report.

Given a finite subgroup G of the automorphism group of a holomorphic local conformal net, there is the notion of an anomaly, which is an obstruction of a certain G-kernel arising from G-twisted representations. If the anomaly vanishes one can construct a new holomorphic net, the twisted G-orbifold. I'll give a generalization, where the group G is replaced by a Hopf algebra or more general a subfactor (or planar algebra) using operator algebraic methods. (Received January 20, 2018)

1138-47-38 **Zeljko Cuckovic*** (zcuckovi@math.utoledo.edu), University of Toledo, Department of Mathematics and Statistics, 2801 W. Bancroft Street, Toledo, OH 43606. *Axler-Zheng theorem in $\mathbb{C}^n$.*

Axler-Zheng theorem characterizes the compactness of finite sums of finite products of Toeplitz operators acting on the Bergman space on the unit disk in terms of the Berezin transform of the operators. We prove a version of the Axler-Zheng's theorem for weighted Bergman spaces on smooth bounded pseudoconvex domains in $\mathbb{C}^n$. We also discuss the compactness of Hankel operators on these domains. The talk is based on a couple of joint works with Sonmez Sahutoglu and Yunus Zeytuncu. (Received January 21, 2018)

1138-47-45 **Minh Luan Doan**, **Le Hai Khoi** and **Trieu Le*** (trieu.le2@utoledo.edu). *Composition operators on Hilbert spaces of entire functions.*

In this talk we shall discuss composition operators acting on certain Hilbert spaces of entire functions in several variables. Depending on the defining weight sequence of the space, different criteria for the boundedness and compactness are developed. Our work extends several known results on the Fock space and its variations. (Received January 23, 2018)

1138-47-51 **Safeer H Khan*** (safeer@qu.edu.qa), Dept Math, Stat and Physics, Qatar University, Doha, 2713, Qatar. *On Existence and Approximation of Common Attractive Points (CAP).*

In this talk, we give some remarks on recently introduced idea of attractive points of nonlinear mappings in Hilbert spaces. We introduce the idea of Common Attractive Points (CAP). We deal with the existence and approximation of CAP through weak convergence. To do this, we first introduce a class of mappings which is more general than a number of existing ones for attractive points. Then we use an iterative process which has been established as faster than many well-known processes. (Received January 25, 2018)

1138-47-58 **Pamela Gorkin*** (pgorkin@bucknell.edu), Bucknell University, Department of Mathematics, Lewisburg, PA 17837, and **Jonathan R. Partington** (j.r.partington@leeds.ac.uk). *Numerical ranges of restricted shifts and norms of truncated Toeplitz operators.* Preliminary report.

We discuss numerical ranges of restricted shift operators and their unitary dilations, including methods to calculate numerical radii of such operators. Specific examples for lower-degree cases will be provided. We also consider related results on truncated Toeplitz operators

This talk will focus on joint work with Jonathan Partington. (Received January 26, 2018)

1138-47-63 **Nikolai Vasilevski*** (nvasilev@math.cinvestav.mx). *Algebras of Toeplitz operators on the unit ball.*

One of the common strategies in the study of Toeplitz operators consists in selecting of various special symbol classes $S \subset L_\infty$ so that the properties of both the individual Toeplitz operators T_a, with $a \in S$, and of the algebra generating by such Toeplitz operators can be characterized.

To make our approach more transparent we restrict the presentation to the case of the two-dimensional unit ball $\mathbb{B}^2$. We consider various sets S of symbols that are invariant under a certain subgroup of biholomorphisms of $\mathbb{B}^2$. Such an invariance permits us *to lower the problem dimension* and to give a recipe, supplied by various concrete examples, on how the known results for the unit disk $\mathbb{D}$ can be applied to the study of various algebras (both commutative and non-commutative) that are generated by Toeplitz operators on the two-dimensional ball $\mathbb{B}^2$.

Although we consider the operators acting on the weighted Bergman space on $\mathbb{B}^2$ with a *fixed* weight parameter, the Berezin quantization effects (caused by a *growing* weight parameter of the corresponding weighted Bergman spaces on the unit disk $\mathbb{D}$) have to be taken into account. (Received January 27, 2018)

1138-47-96 **Carl C. Cowen*** (ccowen@iupui.edu), IUPUI Dept of Mathematical Sciences, 402 N Blackford St, Indianapolis, IN 46202-3216. *Continuous Semigroups of Composition Operators on Function Spaces on the Disk.* Preliminary report.

An analytic map ϕ of the unit disk into itself defines a composition operator by $C_\phi f = f \circ \phi$. Writing ϕ_n for the n-fold composition of ϕ gives a discrete semigroup of operators $C_{\phi_j} C_{\phi_k} = C_{\phi_{j+k}}$. We consider the possibility of extending this to a continuous semigroup, C_{ϕ_t} for $t \geq 0$.

An old theorem says that if ϕ is an analytic map of the disk into itself with attractive fixed point a in the closed disk and $\phi'(a) \neq 0$, for each z in the disk, there is $\tau(z) \geq 0$ so that $\phi_t(z)$ can be defined for $t > \tau(z)$, so that

$$\{\phi_n(z) : n \geq 0\} \cup \{\phi_t(z) : t > \tau(z)\}$$

is a semigroup. If ϕ maps the disk into itself, $\phi(1) = \phi'(1) = 1$, and the power series for ϕ centered at 0 has only positive coefficients, there is a continuous semigroup $\phi_t(r)$ for $0 \leq r \leq 1$; that is, $\tau(r) = 0$ for $0 \leq r \leq 1$.

We discuss the question of extension to the disk: "If ϕ is a univalent, analytic map of the disk into itself with $\phi(1) = \phi'(1) = 1$, and the power series for ϕ centered at 0 has only positive coefficients, when does there exist a continuous semigroup, $\{C_{\phi_t} : 0 \leq t < \infty\}$?" (Received February 03, 2018)

1138-47-116 **Kristin Courtney***, kc2ea@virginia.edu, and **Tatiana Shulman**. *Finite-dimensional representations of C*-algebras and AF mapping telescopes.*

A residually finite-dimensional (RFD) C*-algebra is one for which the norm of every element equals the supremum of its norms under finite-dimensional representations. We consider the set of elements for which this supremum is a maximum: when is it dense, and when is it equal to the whole algebra? To answer the latter question, we develop a technique utilizing the projectivity of AF mapping telescopes. It turns out that this technique can be adapted to prove a variety of results, several of which will be highlighted. This is joint work with Tatiana Shulman. (Received February 05, 2018)

1138-47-125 **Cheng Chu*** (cheng.chu@vanderbilt.edu), 1326 Stevenson Center, NASHVILLE, TN 37240. *Sub-Bergman Hilbert spaces on the unit disk.*

For a bounded function b on the unit disk $\mathbb{D}$, let T_b be the Toeplitz operator on the Bergman space A^2. In case $||b||_\infty \leq 1$, the range of the operator $(I - T_bT_b^*)^{1/2}$ is denoted by $\mathcal{A}(b)$, and is endowed with the Hilbert space structure that makes the map $f \mapsto (I - T_bT_b^*)^{1/2}f$ a co-isometry. These spaces are analogues of de Branges-Rovnyak spaces in the Bergman space setting and are called sub-Bergman Hilbert spaces.

Kehe Zhu proved that if b is a finite Blaschke product then the space $\mathcal{A}(b)$ is the Hardy space H^2. In this talk, we will discuss an alternative approach to Zhu's theorem and obtain a stronger result. In addition, we show that the polynomials are dense in sub-Bergman Hilbert spaces. (Received February 06, 2018)

1138-47-178 **James Tener*** (jtener@math.ucsb.edu). *Subfactors, geometry, and conformal field theory.*

Conformal nets, vertex operator algebras, and Segal CFTs are independent axiomatizations of what is supposed to be the same physical idea: a chiral conformal field theory. In this talk, I will describe how to understand certain subfactors (which arise in the setting of conformal nets) using geometric insight obtained from the other formulations. (Received February 08, 2018)

1138-47-212 **Quanlei Fang** (quanlei.fang@bcc.cuny.edu), Bronx Community College, The City University of New York, 2155 University Ave., Bronx, NY 10453, and **Jingbo Xia*** (jxia@buffalo.edu), Department of Mathematics, State University of New York at Buffalo, Buffalo, NY 14260. *Hankel operators on weighted Bergman spaces and norm ideals.*

Consider Hankel operators H_f on the weighted Bergman space $L_a^2(\mathbf{B}, dv_\alpha)$. In this work we characterize the membership of $(H_f^*H_f)^{s/2} = |H_f|^s$ in the norm ideal $\mathcal{C}_\Phi$, where $0 < s \leq 1$ and the symmetric gauge function Φ is allowed to be arbitrary. (Received February 09, 2018)

1138-47-243 **Hyun Kwon***, hkwon@ua.edu, and **Kui Ji**, jikuikui@163.com. *A subclass of the Cowen-Douglas class.* Preliminary report.

We investigate the similarity between two operators in a subclass of the Cowen-Douglas class. The talk is based on joint work with Kui Ji. (Received February 10, 2018)

1138-47-247 **John H Clifford***, 4901 Evergreen Road, Dearborn, MI 48128, and **Michael Dabkowski**. *The Numerical Range of the Product of a Composition Operator with the Adjoint of the Composition Operator.*

In this talk we will look at the numerical range of the operator $C_\psi^* C_\varphi$ on the Hardy space. The numerical range of an operator T acting on a complex Hilbert space H is the set in the complex plane

$$W(T) = \{\langle Tx, x\rangle : \|x\| = 1 \text{ and } x \in H\}.$$

In particular we will focus on $\psi = (a\theta)^m$ and $\varphi = (b\theta)^n$ where θ is an inner function that fixes the origin and a, b are points in the unit disc. In the case that $|a| = |b| = 1$ we compute the numerical range. Also if the magnitude of $a^m b^n$ is sufficiently small we are able to compute the numerical range. This is joint work with Michael Dabkowski. (Received February 11, 2018)

1138-47-249 **Zhijian Wu*** (zhijian.wu@unlv.edu), Department of Mathematical Sciences, University of Nevada, Las Vegas, 4505 S. Maryland Parkway, Box 454020, Las Vegas, NV 89154. *A Note on Differences of Weighted Composition Operators on μ-weighted Bergman Spaces.* Preliminary report.

For a positive measure μ on the unit disk $\mathbb{D}$, The μ-weighted Bergman space A_μ is defined as the closure of analytic polynomials in $L^2(\mathbb{D}, \mu)$. For a μ measurable function u on $\mathbb{D}$ and an analytic self-map φ of $\mathbb{D}$, the operator $uC_\varphi : f \mapsto uf \circ \varphi$ on A_μ is called a weighted composition operator with weight u and symbol φ. Suppose every point in $\mathbb{D}$ is an analytic bounded point evaluation for μ. Under certain condition, we characterize the compactness of the difference of two weighted composition operators in terms of the weights, symbols and the reproducing kernel of A_μ. We also calculate the Hilbert-Schmidt norm of the difference operators. (Received February 11, 2018)

1138-47-254 **A. Aleman**, **M. Hartz**, **John McCarthy** and **S. Richter*** (srichter@utk.edu). *Weak products of complete Pick spaces.* Preliminary report.

Let $\mathcal{H}$ be the Drury-Arveson or Dirichlet space of the unit ball of $\mathbb{C}^d$. The weak product $\mathcal{H} \odot \mathcal{H}$ of $\mathcal{H}$ is the collection of all functions h that can be written as $h = \sum_{n=1}^\infty f_n g_n$, where $\sum_{n=1}^\infty \|f_n\|\|g_n\| < \infty$. We show that $\mathcal{H} \odot \mathcal{H}$ is contained in the Smirnov class of $\mathcal{H}$, i.e. every function in $\mathcal{H} \odot \mathcal{H}$ is a quotient of two multipliers of $\mathcal{H}$, where the function in the denominator can be chosen to be cyclic in $\mathcal{H}$. Furthermore, the maps $\eta : \mathcal{M} \to \mathcal{H} \cap \mathcal{M}$

and $\tau : \mathcal{N} \to Mult(\mathcal{H}) \cap \mathcal{N}$ establish 1-1 and onto correspondences between the multiplier invariant subspaces of $\mathcal{H} \odot \mathcal{H}$ and of $\mathcal{H}$, and the weak*closed ideals of the multipliers $Mult(\mathcal{H})$.

The results hold for many weighted Besov spaces $\mathcal{H}$ in the unit ball of $\mathbb{C}^d$ provided the reproducing kernel has the complete Pick property. (Received February 11, 2018)

1138-47-285 **Benjamin Hayes*** (brh5c@virginia.edu), 141 Cabell Drive, Kerchof Hall, P.O. Box 400137, Charlottesville, VA 22904. *1-Bounded Entropy with applications to structure of von Neumann algebras.*

I will discuss the 1-bounded entropy, which is a modification of free entropy dimension that ends up being an actual invariant. I will discuss how this invariant allows one to prove some structural/indecomposability results for certain von Neumann algebras, as well as shed some light on well known conjectures in the field. (Received February 12, 2018)

1138-47-301 **Artem V. Hulko*** (ahulko@uncc.edu). *On the Number of Eigenvalues of the Biharmonic Operator on $\mathbb{R}^3$.*

In this talk I would like to look at the biharmonic operator on $\mathbb{R}^3$ perturbed by a complex potential, which decays exponentially at infinity. In this talk I will present the bounds I obtained for the total number of eigenvalues of the aforementioned operator, located outside of the essential spectrum. These kind of estimates exist for the self-adjoint case, that is when the potential is real-valued. However, in the non-self-adjoint case such results have not yet been achieved. (Received February 12, 2018)

1138-47-307 **Michael T. Jury*** (mjury@ufl.edu) and **Robert T.W. Martin** (rtwmartin@gmail.com). *The Smirnov class for the Drury-Arveson and Fock spaces.* Preliminary report.

A theorem of Alpay, Bolotnikov and Kaptonoğlu shows that every function in the Drury-Arveson space H^2_d is the ratio of a multiplier and an outer multiplier. We give another proof of this result (and obtain a somewhat stronger conclusion), by first proving an analogous theorem for free (noncommutative) holomorphic functions associated to the Fock space, and then taking free lifts. In particular we show that every $f \in H^2_d$ can be factored as $f = b/a$ where a, b are multipliers of H^2_d which lift to contractive free functions A, B forming an "inner-outer pair." The proof rests on the observation that each $f \in H^2_d$ gives rise to a densely defined (but in general unbounded) multiplication operator in H^2_d. (Received February 12, 2018)

1138-47-331 **Gabriel T Prajitura***, 350 New Campus Drive, Brockport, NY 14420, and **Ruhan Zhao** and **Lifang Zhou**. *On Berezin type operators and Toeplitz operators.* Preliminary report.

In this talk we introduce a type of integral operators associated with a positive measure and resembling the Berezin transforms on the unit ball. Boundedness and compactness of these Berezin type operators between weighted Bergman spaces are characterized using Carleson measures. It has been found that the results are closely relative to those of Toeplitz operators between weighted Bergman spaces. This is a joint work with Ruhan Zhao and Lifang Zhou. (Received February 12, 2018)

1138-47-358 **Greg Knese*** (geknese@wustl.edu), Washington University in St. Louis, One Brookings Drive, Dept of Math, CB 1146, Saint Louis, MO 63130. *Global bounds on stable polynomials.*

A classical inequality of Szász bounds polynomials with no zeros in the upper half plane entirely in terms of their first few coefficients. Borcea-Brändén generalized this result to several variables as a piece of their characterization of linear maps on polynomials preserving stability. In this talk, we discuss improvements to Szász's original inequality, use determinantal representations to prove Szász type inequalities in two variables, and then prove that one can use the two variable inequality to prove an inequality for several variables. (Received February 13, 2018)

49 ► Calculus of variations and optimal control; optimization

1138-49-5 **S. S. Ravindran*** (ravinds@uah.edu), 301 Sparkman drive, Department of Mathematical Sciences, UAH, Huntsville, AL 35899. *Finite element approximation of Dirichlet control using boundary penalty method for unsteady Navier–Stokes equations.*

This paper is concerned with the analysis of the finite element approximations of Dirichlet control problem using boundary penalty method for unsteady Navier–Stokes equations. Boundary penalty method has been used as a computationally convenient approach alternative to Dirichlet boundary control problems governed by Navier–Stokes equations due to its variational properties. Analysis of the mixed Galerkin finite element method applied to the spatial semi-discretization of the optimality system, from which optimal control can be computed, is presented. An optimal L∞(L2) error estimate of the numerical approximations of the optimality system is derived. Feasibility and applicability of the approach are illustrated by numerically solving a canonical flow control problem (Received September 26, 2017)

51 ► Geometry

1138-51-162 **Martin Bobb***, mbobb@math.utexas.edu. *Bending Convex Projective Manifolds to Achieve New Geometry in Cusps.*

Ballas, Cooper, and Leitner give a classification of convex projective cusps into finitely many types. Ballas and Marquis were able to apply bending to hyperbolic manifolds to achieve one of these cusp types. In this talk, I will discuss an extension of this technique to achieve all but one type of convex projective cusps as ends of deformed arithmetic hyperbolic manifolds. (Received February 08, 2018)

1138-51-177 **Ian Alexander Frankel*** (ian@math.uchicago.edu). *A Comparison of Period Coordinates and Teichmüller Distance.*

The moduli space of Riemann surfaces $\mathcal{M}_{g,n}$ naturally carries a metric, known as the Teichmüller metric d_T, which measures the extent to which a positively oriented homeomorphism between two Riemann surfaces must fail to be conformal.

Points in cotangent bundle of $\mathcal{M}_{g,n}$ that do not belong to the zero section give rise to half-translation surfaces, which are closed oriented surfaces built by gluing polygons in the plane by identifying parallel or anti-parallel sides. We refer to this space as $QD(\mathcal{M}_{g,n})$, because they are associated with quadratic differentials.

$\mathcal{M}_{g,n}$ can be given a "Euclidean" metric d_E described by the Euclidean geometry of a good choice of polygons. Our theorem is that the natural map of metric spaces

$$(QD(\mathcal{M}_{g,n}), d_E) \to (\mathcal{M}_{g,n}, d_T)$$

is a locally Hölder map. (Received February 08, 2018)

1138-51-191 **Sarah C Mousley*** (mousley2@illinois.edu). *Exotic limit sets of Teichmuller geodesic rays.*

We will present our result that a geodesic ray in Teichmuller space does not necessarily converge to a unique point in the hierarchically hyperbolic space (HHS) boundary of Teichmuller space. In fact, the limit set of a geodesic ray can be almost anything allowed by topology. This stands in contrast to the situation for Gromov hyperbolic spaces where each geodesic ray converges to a unique point in the HHS boundary (which happens to agree with the Gromov boundary). (Received February 09, 2018)

1138-51-220 **Anja Randecker*** (anja@math.toronto.edu). *Average diameter of translation surfaces.*

Translation surfaces are naturally stratified by the number and order of their singularities. We focus on the strata of translation surfaces with one singularity and investigate the asymptotics of the average diameter of translation surfaces in these strata when the genus goes to infinity. The presented work is joint with Howard Masur and Kasra Rafi. (Received February 09, 2018)

53 ► Differential geometry

1138-53-62 **Caner Koca*** (ckoca@citytech.cuny.edu), NYC College of Technology, Department of Mathematics, 300 Jay Street, Brooklyn, NY 11201. *Einstein-Maxwell Metrics on Ruled Surfaces.*

In Riemannian geometry, the Einstein-Maxwell Equations, which originate from physics, can be thought of as a geometric PDE for Riemannian metrics on oriented 4-manifolds. Einstein metrics and constant-scalar-curvature-Kähler metrics are among the (trivial) solutions of this PDE. In this talk, we will construct families of non-trivial solutions on complex higher-genera minimal ruled surfaces. These solutions are non-Kähler, but conformally Kähler. This is a joint work with Christina Tønnesen-Friedman. (Received January 26, 2018)

1138-53-113 **Amir Babak Aazami** and **Gideon Maschler*** (gmaschler@clarku.edu), Dept. of Mathematics and Computer Science, Clark University, Worcester, MA 01610. *Kähler metrics from Lorentzian geometric data in dimension four.*

We give a construction associating a family of Kähler metrics to any semi-Riemannian metric g on a four-manifold M which is equipped with two distinguished vector fields satisfying properties defined via shear, twist and other Lie bracket conditions. In most of our examples the domain of such a Kähler metric g_K coincides with M. Under certain conditions the metrics g_K and g share various first order properties, like a joint Killing field.

Our examples are Lorentzian, including de Sitter spacetime, gravitational plane waves and Petrov type D metrics such as the Kerr metric. For SKR-type Kähler metrics, which include the classical extremal metric conformal to Page's Einstein metric, we provide an ansatz which inverts the construction: it produces Lorentzian metrics to which the SKR metric is associated. (Received February 12, 2018)

1138-53-133 **Benjamin C. Sibley*** (bsibley@math.umd.edu). *A complex analytic structure on the compactification of Hermitian-Yang-Mills moduli space.*

A key aspect of gauge theory is finding a suitable compactification for the moduli space instantons. For instantons on higher dimensional manifolds, a rough compactification has been defined by Tian, analogous to Uhlenbeck's compactification of the moduli space of anti-self-dual connections on a four-manifold. In the case when the base manifold is Kähler, and the bundle in question is hermitian, instantons which are unitary and give rise to a holomorphic structures are Hermitian-Yang-Mills connections. A sequence of such connections is known to bubble at most along a codimension 2 analytic subvariety, and so one might hope that the resulting compactification has the structure of a complex analytic space. I will attempt to explain why this true in the case when the base is projective. This gives a higher dimensional analogue of a theorem of Jun Li for algebraic surfaces. This is joint work in progress with Daniel Greb, Matei Toma, and Richard Wentworth. (Received February 07, 2018)

1138-53-172 **Lars Martin Sektnan*** (lars.sektnan@cirget.ca). *On some perturbation problems in complex geometry.*

In this talk I will be discussing various perturbation problems for canonical metrics in complex geometry. Two classical such problems are the theorems of Arezzo-Pacard (and their generalizations) for the existence of extremal metrics on blow-ups of Kähler manifolds, as well as theorems of Fine, Hong and Lu-Seyyadali on the existence of constant scalar curvature or extremal Kähler metrics in adiabatic classes on the total space of certain fibrations. In these problems, the basic idea is to construct a good approximate solution, then establish good control over the linearised operator in order to perturb to a genuine solution.

I will be discussing some results in other related settings for constructing canonical metrics on blow-ups and in adiabatic classes. The basic strategy is the same, but I will try to highlight and discuss what the main differences are in each case. This is joint work with R. Dervan. (Received February 08, 2018)

1138-53-234 **Xiuxiong Chen** and **Jingrui Cheng*** (jrcheng@math.wisc.edu), 480 Lincoln Drive, Madison, WI 53706. *Estimates of constant scalar curvature Kähler metrics with applications to existence.*

We develop new apriori estimates for scalar curvature type equations on a compact Kähler manifold. As applications, we show that properness of K-energy with respect to the L^1 geodesic distance implies the existence of constant scalar curvature Kähler metrics. We also show that the non-existence of constant scalar curvature Kähler metrics is equivalent to K-energy being asymptotically non-increasing along some (weak)geodesic ray. This is joint work with Xiuxiong Chen. (Received February 10, 2018)

1138-53-284 **Jiyuan Han***, UW-Madison Department of Mathematics, Van Vleck Hall, 480 Lincoln Drive, Madison, WI 53706. *On closedness of ALE SFK metrics on minimal ALE Kähler surfaces.*

For certain cases with some topological assumption that gives the boundedness of Sobolev constant, we construct the space of ALE SFK metrics on minimal ALE Kähler surfaces asymptotic to $\mathbb{C}^2/G$, where G is a finite subgroup of $U(2)$. This is a joint work with Jeff Viaclovsky. (Received February 12, 2018)

1138-53-287 **Abdellah Lahdili*** (lahdili.abdellah@courrier.uqam.ca), Département de Mathématiques UQAM, C.P. 8888 Succursale centre-ville, Montréal, Québec H2X 3Y3, Canada. *Conformally Kähler, Einstein–Maxwell metrics and boundedness of the modified Mabuchi functional.*

We prove that if a compact smooth polarized complex manifold admits in the corresponding Hodge Kähler class a conformally Kähler, Einstein–Maxwell metric, or more generally, a Kähler metric of constant (ξ, a, p)-scalar curvature, then this metric minimizes the (ξ, a, p)-Mabuchi functional. Our method of proof extends the approach introduced by Donaldson and developed by Li and Sano–Tipler, via finite dimensional approximations and generalized balanced metrics. As an application of our result and the recent construction of Koca–Tønnesen-Friedman, we describe the Kähler classes on a geometrically ruled complex surface of genus greater than 2, which admit conformally Kähler, Einstein-Maxwell metrics. (Received February 12, 2018)

55 ► Algebraic topology

1138-55-9 **Nick Gurski**, **Niles Johnson*** (niles@math.osu.edu) and **Angélica M. Osorno**. *The 2-dimensional stable homotopy hypothesis.*

We prove that the homotopy theory of Picard 2-categories is equivalent to that of stable 2-types. (Received December 02, 2017)

1138-55-39 **Cary Malkiewich** and **Mona Merling*** (mmerling@jhu.edu), 1931 17th St apt 302, Washington, DC 20009. *Toward an equivariant stable parametrized h-cobordism theorem.* Preliminary report.

Waldhausen's introduction of A-theory of spaces revolutionized the early study of pseudo-isotopy theory. Waldhausen proved that the A-theory of a manifold splits as its suspension spectrum and a factor Wh(M) whose first delooping is the space of stable h-cobordisms, and its second delooping is the space of stable pseudo-isotopies. I will describe a joint project with C. Malkiewich aimed at telling the equivariant story if one starts with a manifold M with group action by a finite group G. (Received January 23, 2018)

1138-55-59 **Julie Bergner*** (jeb2md@virginia.edu), **Angelica Osorno**, **Viktoriya Ozornova**, **Martina Rovelli** and **Claudia Scheimbauer**. *The Waldhausen S-construction as an equivalence of homotopy theories.*

The notion of unital 2-Segal space was defined independently by Dyckerhoff-Kapranov and Galvez-Carrillo-Kock-Tonks as a generalization of a category up to homotopy. The notion of unital 2-Segal space was defined independently by Dyckerhoff-Kapranov and Galvez-Carrillo-Kock-Tonks as a generalization of a category up to homotopy. A key example of both sets of authors is that the output of applying Waldhausen's S-construction to an exact category is a unital 2-Segal space. We expand the input of this construction to augmented stable double Segal spaces and prove that it induces an equivalence on the level of homotopy theories. Furthermore, we prove that exact categories and their homotopical counterparts can be recovered as special cases of augmented stable double Segal spaces (Received January 26, 2018)

1138-55-60 **Nicholas J. Kuhn*** (njk4x@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22904. *Split Hopf algebras and the cohomology of $\Omega\Sigma X$.*

The algebra structure of $H_*(\Omega\Sigma X;\mathbb{F}_p)$ is well known to be freely generated by $\tilde{H}_*(X;\mathbb{F}_p)$. The algebra structure of $H^*(\Omega\Sigma X;\mathbb{F}_p)$ is the less well known *quasi-shuffle algebra* generated by $\tilde{H}^*(X;\mathbb{F}_p)$.

I'll give an example of two spaces X and Z such that $H^*(\Omega\Sigma X;\mathbb{F}_2)$ and $H^*(\Omega Z;\mathbb{F}_2)$ are isomorphic as both algebras and coalgebras, but not as Hopf algebras. In spite of this, we show: **Theorem** Let $A = H^*(\Omega\Sigma X;\mathbb{F}_p)$ and $B = H^*(\Omega\Sigma Y;\mathbb{F}_p)$. Then $A \simeq B$ as Hopf algebras $\Leftrightarrow$ $A \simeq B$ as algebras $\Leftrightarrow$ $H^*(X;\mathbb{F}_p) \simeq H^*(Y;\mathbb{F}_p)$ as graded vector spaces equipped with a Frobenius map.

Hopf algebras like these are graded connected commutative Hopf algebras over $\mathbb{F}_p$ that are cofree as coalgebras. They turn out to have an additional property that I term *split*, and I completely classify these, leading to the proof of the theorem above. I make use of the 'non-commutative Witt vectors' of Goerss-Lannes-Morel. (Received January 26, 2018)

1138-55-131 **Prasit Bhattacharya*** (pb9wh@virginia.edu), 701 East High Street, Apt 219, Charlottesville, VA 22902. *On the P_2^1 Margolis homology of tmf.*

P_2^1 is a certain element of the Steenrod algebra which squares to zero and is contained in the subalgebra $A(2)$. In this talk we give a complete calculation of the P_2^1 Margolis homology of the homology of tmf which is isomorphic to $A//A(2)$. The P_2^1 Margolis homology computation is necessary to identify the free HF_2 summands of $tmf \wedge tmf$. This project is motivated by the height 1 case, where identifying the free HF_2 summands of $bo \wedge bo$ is essential for computing the E_2-page of bo-based Adams spectral sequence for the sphere spectrum. The difficulty in computing P_2^1 Margolis homology is that the action of P_2^1 does not follow the Leibniz rule. The computation is carried out via a spectral sequence using a few combinatorial tricks. This is joint work with Irina Bobkova and Brian Thomas. (Received February 07, 2018)

1138-55-140 **Bertrand J Guillou*** (bertguillou@uky.edu), Lexington, KY 40506, and **Carolyn Yarnall**. *The slice filtration for certain $RO(K_4)$-graded suspensions of HF_2.*

A space X can be described by its Postnikov tower, whose stages have only the homotopy groups of X in a range. Equivariantly, there is an analogue of the Postnikov filtration called the slice filtration. I will describe the slice filtration for twisted Eilenberg-Mac Lane spectra when the group of equivariance is K_4, the Klein four group. This is joint work with C. Yarnall. (Received February 07, 2018)

1138-55-150 **Jesse Leo Kass** and **Kirsten Graham Wickelgren*** (kwickelgren3@math.gatech.edu). *An arithmetic count of the lines on a cubic surface.*

A celebrated 19th century result of Cayley and Salmon is that a smooth cubic surface over the complex numbers contains exactly 27 lines. Over the real numbers, it is a lovely result of Finashin–Kharlamov and Okonek–Teleman that while the number of real lines depends on the surface, a certain signed count of lines is always 3. We extend this count to an arbitrary field k using an Euler number in A1-homotopy theory. The resulting count is valued in the Grothendieck-Witt group of non-degenerate symmetric bilinear forms. This is joint work with Jesse Kass. (Received February 07, 2018)

1138-55-160 **Martina Rovelli*** (mrovell1@jhu.edu), Department of Mathematics, 404 Krieger Hall, 3400 N. Charles Street, Baltimore, MD 21218. *Characteristic classes as complete obstructions.*

We propose a uniform interpretation of characteristic classes as complete obstructions to the reduction of the structure group of a principal bundle, and to the existence of an equivariant extension of a certain homomorphism defined a priori only on a single fiber. By plugging in the correct parameters, we recover several classical theorems. We then define a family of invariants for principal bundles that detect the number of group reductions associated to characteristic classes that a principal bundle admits. (Received February 08, 2018)

1138-55-165 **Henry Yi-Wei Chan** and **Ayelet Lindenstrauss*** (alindens@indiana.edu). *The Topological Hochschild Homology of Maximal Orders in Simple Algebras over the Rationals.*

I will discuss a calculation of the homotopy groups of THH(U) where U is a maximal order in a simple algebra over the rationals. In positive dimensions, these groups consist of torsion and so can be studied locally. For a maximal order A in a simple algebra over $\mathbb{Q}_p$, we show that the homotopy groups of THH(A/p) can be simply expressed in terms of the Hochschild homology groups of A/p. That allows a calculation of the homotopy groups of THH($A; A/p$) using a spectral sequence of Morten Brun, from which the relevant torsion in the homotopy groups of THH(A) can be calculated by comparisons with the known topological Hochschild homology of the center of A and of the valuation ring in a maximal unramified extension field of the center of the simple algebra within that algebra.

As in the case of number rings, the topological Hochschild homology groups for these maximal orders look somewhat similar to their Hochschild homology groups, but linearization induces the zero map in large enough dimensions. So this calculation shows that the classical Dennis trace map vanishes in high enough dimensions, but proposes a substitute to which the topological version of the Dennis trace could map nontrivially. (Received February 08, 2018)

1138-55-185 **Daniel G. Davis*** (dgdavis@louisiana.edu) and **Vojislav Petrovic**. *A long exact sequence for the E_2-term of the homotopy fixed point spectral sequence for a tower of concrete discrete G-spectra.* Preliminary report.

Let G be a profinite group and let $\{X_i\}_i$ be a tower of concrete discrete G-spectra. It is not known that the E_2-term of the homotopy fixed point spectral sequence (hfpSS) for $(\mathrm{holim}_i\, X_i)^{hG}$ has E_2-term always given by continuous cohomology, but we show that there is a long exact sequence where the "term in the middle" is the E_2-term and the "term on the right" is continuous cohomology. A special case of this hfpSS is the well-known $K(n)$-local E_n-Adams spectral sequence (KEASS) for $L_{K(n)}X$, where X is an arbitrary spectrum, and so our long exact sequence gives a new criterion for when the KEASS has E_2-term given by the continuous cohomology of the extended Morava stabilizer group. We discuss the relationship between this general criterion and some previous results in the literature about when the KEASS has the aforementioned nice form. (Received February 09, 2018)

1138-55-189 **Sune Precht Reeh**, **Tomer M Schlank** and **Nathaniel Stapleton*** (nat.j.stapleton@uky.edu). *A formula for p-completion by way of the Segal conjecture.*

The Segal conjecture describes stable maps between classifying spaces in terms of (virtual) bisets for the finite groups in question. Along these lines, we give an algebraic formula for the p-completion functor applied to stable maps between classifying spaces purely in terms of fusion data and Burnside modules. (Received February 09, 2018)

1138-55-192 **Kate Ponto*** (kate.ponto@uky.edu), 715 Patterson Office Tower, Lexington, KY 40508. *Fixed point theory and topological Hochschild homology.*

While not the classical perspective, we now recognize that important topological fixed point invariants take values in topological Hochschild homology. This suggests new approaches to fixed point theory using powerful tools from trace methods in algebraic K-theory. In particular we can use these ideas to define refinements of familiar invariants that may carry richer topological information.

In this talk I will focus on the connection between the Reidemeister trace and the corresponding trace from algebraic K-theory and THH. (Received February 09, 2018)

1138-55-201 **Peter Bonventre*** (peterbonventre@uky.edu) and **Luis Pereira**. *Models for the homotopy theory of equivariant operads.*

Homotopically commutative ring spectra are ubiquitous in modern algebraic topology. When working equivariantly, there are multiple possible generalizations of this notion, determined by which multiplicative norm maps are present. Each version can be encoded as an algebra structure over an associated operad, and the homotopy theory of equivariant operads should differentiate those operads which determine different types of structured ring spectra. In this talk, I will present a square of Quillen equivalent categories, each of which models such a homotopy theory. From this, I will introduce a model for weak equivariant operads, built from the combinatorics of equivariant forests. This work is joint with Luis Pereira. (Received February 09, 2018)

1138-55-221 **Carmen Rovi*** (crovi@indiana.edu), 831 E 3rd Street, Rawles Hall, office 315, Bloomington, IN 47405. *The reinterpretation of Davis-Lueck equivariant homology in terms of L-theory and an application to the Farrell-Jones conjecture.*

The K-theory $K_n(\mathbb{Z}G)$ and quadratic L-theory $L_n(\mathbb{Z}G)$ functors provide information about the algebraic and geometric topology of a smooth manifold X with fundamental group $G = \pi_1(X, x_0)$. Both K- and L-theory are difficult to compute in general and assembly maps give important information about these functors. Ranicki developed a combinatorial version of assembly by describing L-theory over additive bordism categories indexed over simplicial complexes. In this talk, I will present current work with Jim Davis where we define an equivariant version of Ranicki's local/global assembly map and identify our local/global assembly map with the map on equivariant homology defined by Davis and Lueck.

It is a folklore result that the L-theoretic Farrell-Jones Conjecture holds for $G = H \rtimes_\alpha \mathbb{Z}$ assuming that it holds for the group H. Nonetheless, a satisfactory proof of this often used result has never been given. I will give an insight into how we use our investigation of the equivariant assembly maps to prove this result. (Received February 09, 2018)

1138-55-237 **Jonathan A Campbell*** (j.campbell@vanderbilt.edu). *The Cyclotomic Trace and Fixed Point Invariant.*

In this talk I'll discuss how the circle of ideas related to the cyclotomic trace is tightly linked with invariants that fixed point theorists have been using for years. This is a report on work in progress with Kate Ponto. (Received February 10, 2018)

1138-55-374 **Jesse T. Prince-Lubawy*** (jprincelubawy@una.edu). *The geometric visualization of cyclic group actions on handlebodies of genus g.* Preliminary report.

There has been extensive work building the foundation that allows us to study handlebody orbifolds O using the associated graph of groups $(\Gamma, \mathbf{G})$ along with finite injective epimorphisms $\lambda : \pi_1^{orb}(O) \longrightarrow \mathbf{G}$. This has allowed for an algebraic enumeration when $\mathbf{G} = \mathbb{Z}_p$ and when $\mathbf{G} = \mathbb{Z}_{p^2}$. We will discuss methods using GAP that will allow us to begin the process of visualizing $\mathbb{Z}_n$-actions for the handlebody V_2 of genus $g = 2$. (Received February 13, 2018)

57 ► Manifolds and cell complexes

1138-57-17 **Arpan Kabiraj*** (arpan.into@gmail.com), Department of Mathematics, Ben-Gurion University, 8410501 Beer- Sheva, Israel. *Center of the Goldman Lie algebra.*

In 1980s Goldman introduced a Lie algebra structure on the free vector space generated by the free homotopy classes of oriented closed curves in any orientable surface F. This Lie bracket is known as the Goldman bracket and the Lie algebra is known as the Goldman Lie algebra.

In this talk I will discuss some basic properties of Goldman bracket and its relation with Teichmüller space. I will also show how techniques from geometric group theory could be used to compute center of the Goldman Lie algebra. I will mention some open problems related to Goldman bracket. (Received January 04, 2018)

1138-57-130 **Craig R Guilbault*** (craigg@uwm.edu) and **Molly A Moran** (mmoran@coloradocollege.edu). *Proper homotopy types and Z-boundaries of spaces admitting geometric group actions.*

We extend some techniques and theorems from geometric group theory to actions on arbitrary ARs. Previous work often required actions on CW complexes, manifolds, or CAT(0) spaces. We also eliminate a common freeness requirement that excluded groups with torsion. Here is a sampling:

Theorem. *If quasi-isometric groups G and H act geometrically on proper metric ARs X and Y, resp., then X is proper homotopy equivalent to Y.*

Theorem. *If quasi-isometric groups G and H act geometrically on proper metric ARs X and Y, resp., and Y can be compactified to a $\mathcal{Z}$-structure $(\overline{Y}, Z)$ for H, then the same boundary can be added to X to obtain a $\mathcal{Z}$-structure for G.*

Theorem. *If quasi-isometric groups G and H admit $\mathcal{Z}$-structures $(\overline{X}, Z_1)$ and $(\overline{Y}, Z_2)$, resp., then Z_1 and Z_2 are shape equivalent.* (Received February 07, 2018)

1138-57-155 **Nicholas G Vlamis*** (vlamis@umich.edu), 530 Church St, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Dense conjugacy classes in mapping class groups.* Preliminary report.

The mapping class group of a surface carries a natural topology which is inherited from the compact-open topology on the group of self-homeomorphisms. We will discuss recent results regarding the topology of mapping class groups and give an example of a surface (of infinite type) whose mapping class group has a dense conjugacy class. (Received February 08, 2018)

1138-57-273 **Shawn X Cui*** (xingshan@stanford.edu). *Four Dimensional Topological Quantum Field Theories.*

We give an introduction to topological quantum field theories (TQFTs), which have wide applications in low dimensional topology, representation theory, and topological quantum computing. In particular, TQFTs provide invariants of smooth manifolds. We give an explicit construction of a family of four dimensional TQFTs. The input to the construction is a class of tensor categories called G-crossed braided fusion categories where G is any finite group. We show that our TQFTs generalize most known examples such as Yetter's TQFT and the Crane-Yetter TQFT. It remains to check if the resulting invariant of 4-manifolds is sensitive to smooth structures. It is expected that the most general four dimensional TQFTs should arise from spherical fusion 2-categories, the proper definition of which has not been universally agreed upon. Indeed, we prove that a G-crossed braided fusion category corresponds to a 2-category which does not satisfy the criteria to be a spherical fusion 2-category as defined by Mackaay. Thus the question of what axioms properly define a spherical fusion 2-category is open. (Received February 12, 2018)

1138-57-290 **Ivan Levcovitz*** (ilevcovitz@gradcenter.cuny.edu). *Coarse geometry of right-angled Coxeter groups.*

A main goal of geometric group theory is to understand finitely generated groups up to a coarse equivalence (quasi-isometry) of their Cayley graphs. Right-angled Coxeter groups, in particular, are important classical objects that have been unexpectedly linked to the theory of hyperbolic 3-manifolds through recent results, including those of Agol and Wise. I will give a brief background of what is currently known regarding the quasi-isometric classification of right-angled Coxeter groups. I will then describe a new computable quasi-isometry invariant, the hypergraph index, and its relation to other invariants such as divergence and thickness. (Received February 12, 2018)

60 ► *Probability theory and stochastic processes*

1138-60-14 **Mei Yin*** (mei.yin@du.edu), **Alessandro Rinaldo** and **Sukhada Fadnavis**. *Asymptotic quantization of exponential random graphs.*

We describe the asymptotic properties of the edge-triangle exponential random graph model as the natural parameters diverge along straight lines. We show that as we continuously vary the slopes of these lines, a typical graph drawn from this model exhibits quantized behavior, jumping from one complete multipartite graph to another, and the jumps happen precisely at the normal lines of a polyhedral set with infinitely many facets. As a result, we provide a complete description of all asymptotic extremal behaviors of the model. (Received December 25, 2017)

1138-60-19 **Andrey Sarantsev*** (sarantsev@pstat.ucsb.edu), South Hall 5607A, Dept of Statistics and Applied Probability, University of California, Santa Barbara, CA 93106. *Concentration of Measure for Stochastic Partial Differential Equations.* Preliminary report.

We derive Talagrand concentration of measure inequalities for stochastic partial differential equations, including the stochastic heat equation. Joint work with Davar Khoshnevisan. (Received January 08, 2018)

1138-60-30 **Jonathan Novak***, 9500 Gilman Drive, La Jolla, CA 92101. *A moment method for invariant ensembles.*

I will explain an analogue of Wigner's moment method which targets the invariant ensembles of Random Matrix Theory. (Received January 17, 2018)

1138-60-157 **Ben Jaye*** (bjaye@clemson.edu), Clemson University, Clemson, SC 29631. *On the probability that a stationary Gaussian process with spectral gap remains non-negative on a long interval.*

Let f be a continuous stationary Gaussian process on $\mathbb{R}$ whose spectral measure vanishes in a δ-neighborhood of the origin. We shall prove that the probability that f stays non-negative on an interval of length L is at most $e^{-c\delta^2 L^2}$ with some absolute $c > 0$ and that the result is sharp without additional assumptions. Joint work with Naomi Feldheim, Ohad Feldheim, Fedor Nazarov, and Shahaf Nitzan. (Received February 08, 2018)

1138-60-256 **Laura Eslava*** (laura.eslava@math.gatech.edu), 686 Cherry Street NW, Atlanta, GA 30332, and **Lutz Warnke**. *The size of the giant component in the random d-process.* Preliminary report.

Graph processes $(G(i), i \geq 0)$ are usually defined as follows. Starting from the empty graph on n vertices, at each step i a random edge is added from a set of available edges. For the d-process, edges are chosen uniformly at random among all edges joining vertices of current degree at most $d-1$.

The fact that, during the process, vertices become 'inactive' when reaching degree d makes the process depend heavily on its history. However, it shares several qualitative properties with the classical Erdos-Renyi graph process. For example, there exists a critical time t_c at which a giant component emerges, whp (that is, the largest component in $G(tn)$ goes from logarithmic to linear order).

In this talk we consider $d \geq 3$ fixed and describe the growth of the size of the giant component. In particular, we show that whp the largest component in $G((t_c + \varepsilon)n)$ has asymptotic size cn, where $c \sim c_d \varepsilon$ is a function of time ε as $\varepsilon \to 0+$. (Received February 11, 2018)

1138-60-266 **Saugata Basu**, **Antonio Lerario**, **Erik Lundberg*** (elundber@fau.edu) and **Chris Peterson**. *Random matrices arising in the study of random fields.*

This talk will discuss some problems in random fields, such as studying the solutions to a random system of equations (e.g., the critical points of a random potential energy landscape) as well as recent investigations concerning the solutions to problems in enumerative geometry (e.g., the number of lines on a random cubic surface). We will emphasize connections to random matrix theory, including some new open problems that are simple to state. (Received February 11, 2018)

1138-60-269 **Sevak Mkrtchyan*** (sevak.mkrtchyan@rochester.edu). *Turning point processes in plane partitions with periodic weights of arbitrary period.*

In the thermodynamic limit of the lozenge tiling model the frozen boundary develops special points where the liquid region meets with two different frozen regions. These are called turning points. It was conjectured by Okounkov and Reshetikhin that in the scaling limit of the model the local point process near turning points should converge to the GUE corners process.

We will discuss the appearance of frozen regions of arbitrary rational slope when weights in the model are periodic in one direction with arbitrary fixed finite period, and what these new frozen regions mean for the turning process. (Received February 12, 2018)

1138-60-282 **Tankut Can*** (tcan@gc.cuny.edu), Initiative for the Theoretical Sciences, The Graduate Center, 365 5th Ave, New York, NY 10016. *Coulomb Plasma on a Singular Surface.*

Motivated by the connection to the fractional quantum Hall (FQH) effect, we study the 2D Coulomb plasma on a surface with curvature singularities. Employing a large N limit, we compute the dependence of the partition function on the complex structure moduli of the surface. The resulting variational formula is controlled by exact sum rules, which we find using a Ward identity (aka loop equation). Despite the fast decay of density correlations in the screening phase of the plasma, we find that geometric singularities exhibit power law correlations, indicating the emergence of conformal symmetry. As conformal primaries, the singularities are characterized by a conformal dimension, which is fixed by a sum rule. In the FQH setting, the conformal dimension corresponds to an intrinsic angular momentum of a curvature singularity, while the power law correlations encode the Berry phase picked up by the FQH wave function upon braiding singularities. (Received February 12, 2018)

1138-60-334 **Jinho Baik** and **Zhipeng Liu*** (`zhipeng@ku.edu`). *Multi-point distribution of periodic TASEP.*

The height fluctuations of the models in the KPZ class are expected to converge to a universal process. The spatial process at equal time is known to converge to the Airy process or its variations. However, the temporal process, or more generally the two-dimensional space-time fluctuation field, is less well understood. We consider this question for the periodic TASEP (totally asymmetric simple exclusion process). For a particular initial condition, we evaluate the multi-time and multi-location distribution explicitly in terms of a multiple integral involving a Fredholm determinant. We then evaluate the large time limit in the so-called relaxation time scale. We also discuss some new results for other initial conditions. (Received February 12, 2018)

1138-60-335 **Robert Buckingham*** (`buckinrt@uc.edu`), Department of Mathematical Sciences, The University of Cincinnati, Cincinnati, OH 45221, and **Karl Liechty**. *Nonintersecting Brownian bridges on the unit circle with drift.*

Nonintersecting Brownian bridges on the unit circle form a determinantal stochastic process exhibiting random matrix statistics for large numbers of walkers. We investigate the effect of adding a drift term to walkers on the circle conditioned to start and end at the same position. We compute the asymptotic distribution of total winding numbers in the scaling regime in which the expected total winding is finite. Furthermore, we show that an appropriate double scaling of the drift and return time leads to a generalization of the tacnode process expressed in terms of generalized Hastings-McLeod functions. Our results follow from Riemann-Hilbert analysis of a family of discrete orthogonal polynomials with a complex weight. This is joint work with Karl Liechty. (Received February 12, 2018)

1138-60-343 **Andrew Newman**, **Hoi Nguyen** and **Elliot Paquette*** (`paquette.30@osu.edu`). *Algebraic questions about combinatorial random matrices.*

We present a few models and some recent progress about combinatorial random matrices. Broadly, in these models, we consider matrices of a fixed number of rows where independent columns are added one at a time. We then ask for the threshold for a variety of algebraic properties. For example, one question is to find the threshold for the surjectivity of the matrix over the integers. Another is to find the threshold for the matrix to have no torsion, i.e. so the cokernel of the matrix has no finite order elements. (Received February 12, 2018)

1138-60-354 **Patrick T Waters*** (`tug30692@temple.edu`), 1123 Green St, Philadelphia, PA 19123. *Feynman-Kac formula for the stochastic Bessel operator.*

We introduce a stochastic process and functional that should describe the semigroup generated by the stochastic Bessel operator. Recently Gorin and Shkolnikov showed that the largest eigenvalues for certain random matrix ensembles with soft edge behavior can be understood by analyzing large powers of tridiagonal matrices, which converge to operators in the stochastic Airy semigroup. In this article we make some progress towards realizing Gorin and Shkolnikov's program at the random matrix hard edge. We analyze large powers of a suitable tridiagonal matrix model (a slight modification of the β-Laguerre ensemble). For finite n we represent the matrix powers using a Feynman-Kac type formula, which identifies a sequence of stochastic processes X_n and functionals Φ_n. We show that $\Phi_n(X_n)$ converges in probability to the limiting functional $\Phi(X)$ for our proposed stochastic Bessel semigroup. We also discuss how the semigroup method may be used to understand transitions from a hard edge to a soft edge in the β-Laguerre models. (Received February 13, 2018)

1138-60-363 **Tom Claeys**, **Arno Kuijlaars**, **Karl Liechty*** (`kliechty@depaul.edu`) and **Dong Wang**. *Propagation of singular behavior for Gaussian perturbations of random matrices.*

It is a well known and celebrated fact that the eigenvalues of random Hermitian matrices from a unitary ensemble form a determinantal point process with correlation kernel given in terms of a system of orthogonal polynomials on the real line. It is a much more recent fact that the eigenvalues of the sum of such a random matrix with a matrix from the Gaussian unitary ensemble (GUE) also forms a determinantal point process, with the kernel given in terms of the Weierstrass transform of the original kernel. I'll talk about the case in which the limiting distribution of eigenvalues is critical in the sense that there is a non-trivial scaling limit for the correlation kernel, and discuss the effect of a Gaussian perturbation on the limiting critical kernel. This is joint work with Tom Claeys, Arno Kuijlaars, and Dong Wang. (Received February 13, 2018)

1138-60-376 **Santanu Chakraborty*** (santanu.chakraborty@utrgv.edu), School of Math. and Stat. Sciences, University of Texas Rio Grande Valley, 1201 West University Drive, Edinburg, TX 78539, **Mrinal Kanti Roychowdhury** (mrinal.roychowdhury@utrgv.edu), School of Math. and Stat. Sciences, University of Texas Rio Grande Valley, 1201 West University Drive, Edinburg, TX 78539, and **Josef Sifuentes** (josef.sifuentes@utrgv.edu), School of Math. and Stat. Sciences, University of Texas Rio Grande Valley, 1201 West University Drive, Edinburg, TX 78539. *HIGH PRECISION NUMERICAL COMPUTATION OF PRINCIPAL POINTS FOR UNIVARIATE DISTRIBUTIONS.*

Principal points were first introduced by Flury: for a positive integer n, n principal points of a random variable are the n points that minimize the mean squared distance between the random variable and the nearest of the n points. In this paper, we determine the n principal points and the corresponding values of mean squared distance for different values of n for some univariate absolutely continuous distributions. (Received February 13, 2018)

1138-60-391 **Máté Wierdl*** (wierdlmate@gmail.com), Department of Mathematical Sciences, The University of Memphis, memphis, TN 38152. *Simultaneous recurrence of stationary random walks.* Preliminary report.

The talk is about a problem raised by M. Boshernitzan: Does a stationary random walk simultaneously revisit the origin infinitely often along two different step sizes?

Let us be precise: Let (Ω, Σ, P) be a probability space; $T : \Omega \to \Omega$ an invertible, ergodic m.p.t.; $F : \Omega \to \mathbb{Z}$ measurable. Define the random walk F^n defined by

$$F^n(\omega) = \begin{cases} \sum_{0 \le k < n} F(T^k\omega), & \text{for } n > 0; \\ 0, & \text{for } n = 0; \\ \sum_{n \le k < 0} F(T^k\omega), & \text{for } n < 0. \end{cases}$$

It is well known that if $\int F = 0$ then almost surely $F^n = 0$ for infinitely many n.

Boshernitzan's question is if the random walks (F^n) and (F^{2n}) almost surely return to the origin *simultaneously*, that is almsot surely, are there infinitely many n so that $F^n = F^{2n} = 0$?

Presently, we cannot answer the question, but we will examine some special cases, and present evidence that the answer to Boshernitzan's question is, in general, no.

We also show that simultaneous *triple* return to the origin is, in general, doesn't happen. The counterexample is provided in case (T^nF) is an iid sequence. (Received February 13, 2018)

62 ► Statistics

1138-62-320 **Subhadeep Paul*** (paul.963@osu.edu), **Olgica Milenkovic**, **Yuguo Chen** and **Xiao Su**. *Higher-order structures based spectral clustering under a superimposed stochastic block model: Preliminary report.* Preliminary report.

We consider a higher-order structures based spectral clustering method which attempts to find clusters in networks based on particular structures or motifs. We investigate the asymptotic consistency properties of the method under a signal and noise superimposition framework to generate random graph models for networks with over-abundance of certain network motifs or subgraphs. The signal model is a higher-order structure based model to resemble most relevant aspects of higher-order organization of the datasets under consideration, e.g., the widely used "triangle" motif or the "bi-fan" motif. The noise component is a dyadic random graph; either Erdos-Renyi random graph or directed and weighted extensions of that. We further propose a superimposed Stochastic Block Model (SBM) where the block structure is present only in the signal component and not in the noise component. We derive conditions on the maximum expected degree of a node in the graph for which the method is consistent under the superimposition SBM. We also prove that this condition can be relaxed if a regularization is performed. As a byproduct of our analysis, we prove consistency results of the higher-order spectral clustering method under the non-uniform hypergraph SBM. (Received February 12, 2018)

1138-62-330 **Hau-tieng Wu*** (hauwu@math.duke.edu), 140 Science Drive, unit 207, Durham, NC 27705. *Alternating or commutative diffusion? Fetal ECG as an example.* Preliminary report.

Alternating diffusion has been considered in several previous studies. In this talk, we discuss some recent progress in this direction, and show its usefulness in the fetal ECG analysis. This is a joint work with Professor Ronen Talmon and Tal Shnitzer. (Received February 12, 2018)

1138-62-386 **Roy R. Lederman***, roy@math.princeton.edu. *Inverse Problems and Unsupervised Learning with applications to Cryo-Electron Microscopy.*

Cryo-Electron Microscopy (cryo-EM) is an imaging technology that is revolutionizing structural biology; the Nobel Prize in Chemistry 2017 was recently awarded "for developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution". While some alternative methods, such as x-ray crystallography and NMR, measure ensembles of molecules, cryo-electron microscopes produce images of individual molecules. Therefore, cryo-EM could potentially be used to study mixtures of different conformations of molecules. Current algorithms have been very successful at analyzing homogeneous samples, and can recover some distinct conformations mixed in solutions, but, the determination of multiple conformations, and in particular, continuums of similar conformations (continuous heterogeneity), remains one of the open problems in cryo-EM. I will talk about different components which we are introducing in order to address the problem of continuous heterogeneity in cryo-EM: 1. "hyper-molecules," the mathematical formulation of truly continuously heterogeneous molecules, 2. Computational tools for expressing associated priors, and 3. Bayesian algorithms for inverse problems with an unsupervised-learning component for recovering such hyper-molecules. (Received February 13, 2018)

65 ► Numerical analysis

1138-65-57 **Vani Cheruvu*** (`vani.cheruvu@utoledo.edu`), Department of Mathematics and Statistics, The University of Toledo, Toledo, OH 43606. *Spectra of boundary integral operators defined on the unit sphere for the modified Laplace equation.*

We consider a modified Laplace equation on a unit sphere. Spherical harmonics are used for the expansion of the unknown function. We show that on the unit sphere, both modified Laplace single and double layer operators diagonalize in spherical harmonic basis. The analytic expressions for evaluating the operators away from the boundary are also derived. Currently, we are working on the numerical aspects. In this talk, we present both the analytical and numerical results of our work. (Received February 12, 2018)

1138-65-86 **Andrea L Bertozzi***, 520 Portola Plaza, Department of Mathematics, Los Angeles, CA 90095. *Geometric graph-based methods for high dimensional data.*

We present methods for segmentation of large datasets with graph based structure. The methods combine ideas from classical nonlinear PDE-based image segmentation with fast and accessible linear algebra methods for computing information about the spectrum of the graph Laplacian. The goal of the algorithms is to solve semi-supervised and unsupervised graph cut optimization problems. The methods make parallels between geometric ideas in Euclidean space such as motion by mean curvature, ported to a graphical framework. These ideas can be made rigorous through total variation minimization, and gamma convergence results, and convergence of time stepping methods in numerical analysis. I will show diverse examples including image processing applications such as image and video labeling and hyperspectral video segmentation, and machine learning and community detection in social networks, including modularity optimization posed as a graph total variation minimization problem. (Received January 31, 2018)

1138-65-288 **Yuan Liu***, Allen 438, 175 President circle, Mississippi State, MS. *High order discontinuous Galerkin methods on sparse grid.* Preliminary report.

In this talk, we will talk about a class of novel numerical methods on sparse grid for solving high dimensional reaction-diffusion equations arising from biological systems. (Received February 12, 2018)

1138-65-298 **Ming-Jun Lai** (`mjlai@uga.edu`), Prof. Ming-Jun Lai, 540 Boyd Graduate Studies Building, Athens, GA 30602, and **Clayton Mersmann*** (`mersmann@uga.edu`), Clayton Mersmann, 524A Boyd Graduate Studies Building, Athens, GA 30602. *Spline Solutions to the Helmholtz Equation with High Wave Number.*

We study the mathematics of wave phenomena arising from the Maxwell equations. In the time-harmonic regime, the Maxwell equations reduce to the time-invariant Helmholtz equation. We use bivariate splines of arbitrary degree and smoothness to solve the Helmholtz equation with high wave number, while keeping the size of the underlying triangulation reasonable.

It is known that for linear finite elements, the wave number k and the size h of triangulation satisfies a stubborn relation $k^2h = 1$. For high order finite elements, so-called hp version of internal penalty discontinuous Galerkin (IPDG) methods, the relation is $k^3h^2 = O(p^2)$ for polynomial degree p. For continuous internal penalty finite element method (CIP-FEM), the relation is $O(k^{2p+1}h^{2p}) = O((k^{1+1/(2p)}h)^p$. Bivariate splines enable us to have very accurate solution for $kh \leq p/2$. No pollution phenomenon is observed in our experiments as long as $kh = p/2$. (Received February 12, 2018)

1138-65-381 **Josef Sifuentes*** (josef.sifuentes@utrgv.edu), Mathematics, 1201 West University Dr., Edinburg, TX 78539, and **Mrinal Roychowdhury** and **Santanu Chakraborty**. *High precision numerical computation of principal points for univariate distributions.* Preliminary report.

Quantization for probability distributions concerns the best approximation of a probability measure P defined on a metric space by a measure supported on a finite number of points, or in other words, the best approximation of a d-dimensional random vector X with distribution P by a random vector Y with at most n-values in its image. In this paper, we determine the optimal sets of n-means and the nth quantization errors for different values of n for some common univariate absolutely continuous distributions. (Received February 13, 2018)

68 ► Computer science

1138-68-12 **Joseph (JM) Landsberg*** (jml@math.tamu.edu), Department of Mathematics, Texas A&M University, Mailstop 3368, College Station, TX 77843-3368. *On the geometry of matrix multiplication.*

Our story begins with a spectacular failure: The standard algorithm to multiply two nxn matrices uses n^3 multiplications. In 1969, while attempting to show that the standard algorithm was optimal, V. Strassen discovered an explicit algorithm to multiply 2x2 matrices using 7 multiplications rather than $8 = 2^3$. It is a central question to determine just how efficiently one can multiply nxn matrices, both practically and asymptotically.

In this talk, I will present a history of the problem, both of upper and lower complexity bounds I will discuss how geometry, more precisely algebraic geometry and representation theory, are used. In particular, I will explain how, had someone asked him 100 years ago, the algebraic geometer Terracini could have predicted Strassen's algorithm. The talk will conclude with the recent use of representation theory to construct algorithms, more precisely, rank decompositions.

For those who can't wait for the talk, a detailed history and the state of the art appears in Landsberg, J. (2017). Geometry and Complexity Theory (Cambridge Studies in Advanced Mathematics 169). (Received December 21, 2017)

1138-68-129 **Qiang Wu*** (qwu@mtsu.edu), 1301 E Main Street, MTSU Box 34, Murfreesboro, TN 37132. *Kernel Methods for Distributed Regression.*

Distributed learning provides effective tools for big data processing. It received increasing attention in recent years. In this talk, I will focus on regression analysis, present several kernel methods for distributed regression, and discuss their minimax optimality. (Received February 06, 2018)

1138-68-181 **Michael A Forbes*** (miforbes@illinois.edu). *Explicit Dimension Reduction for Varieties, and the Polynomial Identity Testing Problem.*

We consider the task of mapping a large ambient space $\mathbb{C}^n$ to small space $\mathbb{C}^m$ so that a given variety X inside $\mathbb{C}^n$ of dimension $\sim m$ has its relevant properties preserved under this map. In particular, a random linear map from $\mathbb{C}^n \to \mathbb{C}^m$ often suffices. Our challenge is to deterministically and efficiently construct such a linear map for interesting varieties.

(Mulmuley 2012) observed that for all "explicit" varieties this task is equivalent to the problem of developing deterministic algorithms for the polynomial identity testing (PIT) problem: given an algebraic circuit, decide whether this circuit computes the zero polynomial. I shall define the PIT problem, explain the connection to the above challenge, and outline why developing such deterministic algorithms is difficult. I will then define the ring of invariants for simultaneous conjugation of an r-tuple of $(n \times n)$-matrices and instantiate Mulmuley's result in this case, showing how one can express dimension reduction for this ring in the language of PIT. I will then describe how a deterministic PIT algorithm of (Forbes and Shpilka 2013) can give a near-solution to explicit dimension reduction for this ring.

Based on work with Amir Shpilka. (Received February 09, 2018)

1138-68-281 **Daniel Cranston**, **Luke Postle**, **Chenxiao Xue** and **Carl Yerger*** (cayerger@davidson.edu). *Class 0 and Complexity Bounds for Graph Pebbling.*

Given a configuration of pebbles on the vertices of a connected graph G, a *pebbling move* removes two pebbles from some vertex and places one pebble on an adjacent vertex. The *pebbling number* of a graph G is the smallest integer k such that for each vertex v and each configuration of k pebbles on G, there exists a sequence of pebbling moves that places at least one pebble on v. If the pebbling number of G equals the number of vertices of G, we say the graph is *Class 0*. In this talk, we investigate and improve on bounds related to the minimum number of edges in a Class 0 graph via a discharging approach. We also discuss some recent results related to the complexity of the Class 0 decision problem for specific classes of graphs. (Received February 12, 2018)

1138-68-300 **Rafael Oliveira*** (rafael@cs.toronto.edu), rafael@cs.toronto.edu, and **Klim Efremenko**, **Ankit Garg** and **Avi Wigderson**. *Barriers for Rank Methods in Arithmetic Complexity.*

Arithmetic complexity is simpler than Boolean complexity. And we seem to have more lower bound techniques and results in arithmetic complexity than in Boolean complexity. Despite rapid progress, foundational challenges, like proving super-polynomial lower bounds on circuit size for explicit polynomials, or super-linear lower bounds on explicit 3-dimensional tensors, remain elusive. At the same time, barrier results explain why we failed to prove basic lower bounds in Boolean complexity. Despite previous attempts we have no such barriers in arithmetic complexity. In this talk we give the first unconditional barriers for rank methods, which were long recognized as encompassing almost all known arithmetic lower bounds to-date. We show that rank methods cannot prove lower bounds better than:

- $\Omega_d(n^{\{}\lfloor d/2\rfloor\})$ on the tensor rank of any d-dimensional tensor of side n. (In particular, they cannot even prove a $> 6n$ lower bound for any 3-dimensional tensors.)
- $\Omega_d(n^{\{}\lfloor d/2\rfloor\})$ on the Waring rank of any n-variate polynomial of degree d.

These bounds nearly match the best explicit bounds we know for these models, and hence explain why rank methods got stuck there. (Received February 13, 2018)

1138-68-388 **Erik D Demaine**, **Timothy D Goodrich*** (tdgoodri@ncsu.edu), **Abida Haque**, **Kyle Kloster**, **Brian Lavallee**, **Quanquan Liu**, **Blair D Sullivan**, **Ali Vakilian** and **Andrew van der Poel**. *Leveraging Approximately-Ideal Structure for Faster Algorithms.* Preliminary report.

Many fast algorithms exist for NP-complete problems when restricted to ideal graph classes, such as planar graphs and graphs with bounded treewidth. We consider a generalization where the instance graph has *approximately-ideal* structure – the problem instance graph has a small edit distance to a graph within the ideal structure class. We study how such an edit set may be found, how the problem can be solved with the ideal structure, and how edits may be reintroduced and rounded into the solution. As a proof of concept we consider editing to bounded degeneracy (e.g. k-cores), where we prove APX-hardness and provide a bicriteria approximation algorithm based on the local ratio theorem. Finally, we show how these tools may be used for developing approximation algorithms, and identify other suitable ideal structures for future results. (Received February 13, 2018)

1138-68-392 **Russell F Thackston***, rthackston@georgiasouthern.edu, and **Ryan C Fortenberry**. *An efficient algorithm for the determination of force constants and displacements in numerical definitions of a large, general order Taylor series expansion.*

Taylor series expansions are commonly used in modeling complicated computational and quantum chemistry functions. However, brute force algorithms for generating the required force constant definitions and subsequent displacements are frequently used by researchers not formally trained in mathematics or computer science. These naive algorithms severely limit the number of variables that may be used in higher-order implementations. This research explores an algorithm based on a "lazy cartesian product" which intelligently generates the required force constant definitions and displacements with few extraneous computations. Large blocks of wasted computations – as found in brute force solutions – are bypassed with only non-zero rows of the cartesian product being calculated and produced, resulting in orders of magnitude gains in efficiency. This algorithm also provides researchers the ability to both parallelize and balance the workload across clusters of computational resources, opening the use of Taylor expansions to previously impossibly large molecules. A sample implementation using Python will be presented. (Received February 13, 2018)

76 ► Fluid mechanics

1138-76-27 **David E Amundsen*** (dave@math.carleton.ca), School of Mathematics and Statistics, Carleton University, Ottawa, Ontario K1S 5B6, Canada. *Resonance in Bounded Media.*

Resonant phenomena in bounded domains can pose distinct challenges both from physical and mathematical standpoints. It is well known that resonant behaviour can arise in bounded domains under weak forcing, leading to significant amplifications in the response. Canonical examples include acoustic resonance in open and closed tubes and other geometries. Exactly how this resonant behaviour manifests itself depends crucially on the underlying features of the system –i.e. is it continuous, is it shocked etc. In order to gain a better understanding of this process and the underlying mathematical features which drive the outcomes, we will present and discuss a simple class of nonlinear PDE model systems. Through continuous variation of the system structure and parameters key features, such as the commensurate or incommensurate nature of the underlying linear spectrum, emerge. These are then studied in more detail both from an analytical and numerical perspective. Of particular interest will be the description and characterization of the transition between various response regimes.

This is joint work with Taqi Shatnawi (Hashemite University, Jordan) (Received January 14, 2018)

81 ► Quantum theory

1138-81-158 **Matthias Christandl** and **Burak Sahinoglu*** (`sahinoglu@caltech.edu`), 1200 E. California Blvd., MC 306-15, Pasadena, CA 91125, and **Michael Walter**. *Recoupling coefficients and quantum entropies.*

We prove that the asymptotic behavior of the recoupling coefficients of the symmetric group is characterized by a quantum marginal problem – namely, by the existence of quantum states of three particles with given eigenvalues for their reduced density operators. This generalizes Wigner's observation that the semiclassical behavior of the 6j-symbols for SU(2) – fundamental to the quantum theory of angular momentum – is governed by the existence of Euclidean tetrahedra. As a corollary, we deduce solely from symmetry considerations the strong subadditivity property of the von Neumann entropy. Lastly, we show that the problem of characterizing the eigenvalues of partial sums of Hermitian matrices arises as a special case of the quantum marginal problem. We establish a corresponding relation between the recoupling coefficients of the unitary and symmetric groups, generalizing a classical result of Littlewood and Murnaghan. (Received February 08, 2018)

1138-81-332 **Yilong Wang*** (`wang.3003@osu.edu`). *Integrality for $SO(p)_2$ TQFTs for once punctured torus.*

We will establish the integrality result for the $\mathrm{SO}(p)_2$ TQFTs for once punctured torus and discuss the topological information encoded therein. (Received February 12, 2018)

1138-81-359 **Rinat Kedem*** (`rinat@illinois.edu`), Department of Mathematics MC-382, University of Illinois, Urbana, IL 61801. *Integrable difference equations for generalized Hall Littlewood functions from Q-systems.*

The characters of generic fusion products of Kirillov-Reshetikhin modules, as defined by Feigin and Loktev, can be constructed from the solutions of the quantum Q-system. This is a discrete evolution equation for non-commuting variables with commuting conserved quantities, which makes it integrable. Using these conserved quantities acting on the characters above, one obtains Hamiltonian difference equations, which, in the special case of fusion of fundamental KR-modules, gives a q-difference Toda equations. This talk will present the basic construction and list open problems related to it. This is joint work with Philippe Di Francesco. (Received February 13, 2018)

82 ► Statistical mechanics, structure of matter

1138-82-104 **Pavel Bleher*** (`pbleher@iupui.edu`), Department of Mathematical Sciences, IUPUI, 402 N. Blackford Street, Indianapolis, IN 46202. *Pfaffian Sign Theorem and Exact Solution of the Dimer Model on a Triangular Lattice.*

We will discuss an exact solution for the partition function and the monomer-monomer correlation function for the dimer model on the triangular lattice. We prove the Pfaffian Sign Theorem, and as an application we obtain an asymptotic behavior of the partition function with periodic boundary conditions with an exponentially small error term. In the second part of the talk we will discuss the long distance asymptotic behavior of the monomer-monomer correlation function. The first part of the talk is based on a joint work with Brad Elwood and Dražen Petrović, and the second one on a joint work with Estelle Basor. (Received February 04, 2018)

1138-82-268 **Seung-Yeop Lee*** (lees3@usf.edu), 4202 East Fowler Ave, CMC342, University of South Florida, Tampa, FL 33620, and **Meng Yang**, 4202 East Fowler Ave, CMC342, University of South Florida, Tampa, FL 33620. *Riemann-Hilbert problem for Planar Orthogonal Polynomials.*

I will talk about certain planar orthogonal polynomials that appears in relation to random normal matrices. Especially, I will show that such polynomials are multiple orthogonal polynomials of Type II or, equivalently, Hermite-Padé polynomials of Type II, hence can be a solution to a matrix Riemann-Hilbert problem. This is a joint work with Meng Yang. (Received February 11, 2018)

1138-82-302 **Thomas J Bothner*** (bothner@umich.edu), 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *The scaling function constant problem in the two-dimensional Ising model.*

We present a a simple derivation of the constant factor in the short-distance asymptotics of the τ-function associated with the 2-point function of the two-dimensional Ising model. This factor was first computed by Tracy in [2] via an exponential series expansion of the correlation function. Further simplifications in the analysis are due to Tracy and Widom [3] using Fredholm determinant representations of the correlation function and Wiener-Hopf approximation results for the resolvent operator. Our method relies on an action integral representation of the τ-function and asymptotic results for the underlying Painlevé-III transcendent from [1].

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(Received February 12, 2018)

1138-82-375 **Dennis G. Collins*** (d_collins_pr@hotmail.com), 1519 S. State Rd, 119, Apt. 2, Winamac, IN 46996-8550. *Toward the thermodynamics and emergy of picture and other puzzle solving.* Preliminary report.

Toward the Thermodynamics and Emergy of Picture and Other Puzzle Solving.

This talk follows up on the Author's and Scienceman's paper "Clusters of High Transformity Individuals" Chapter 36 in Emergy Synthesis 9 (CEP Gainesville, FL 2017). Here instead of substrate being converted into product by a generalization of Michaelis-Menton enzyme kinetics, the interest is in pieces of a puzzle being converted into a finished picture by features as enzymes. Other applications involve returning and re-connecting people to their homes after a storm or flood, or restoration of electrical grid after a hurricane, or assembling DNA in one dimension. At the start of putting together a, say 1000-piece puzzle, there are 1000 components, and clusters are gradually built up as pieces are fitted together, until if successful there is only one giant cluster or component with all 1000 pieces (or say the electrical grid is restored). Thermodynamically the problem involves completely distinguishable particles as perhaps a modification of Fermi-Dirac statistics, since each piece goes in exactly one place. Attempts to measure entropy can involve measuring the work required to add each piece, and topological properties, such as Betti numbers be studied, (Received February 13, 2018)

83 ► Relativity and gravitational theory

1138-83-385 **Hayriye Gulbudak*** (hayriye.gulbudak@louisiana.edu) and **Joshua S. Weitz**. *Modeling Heterogeneous Viral Infection Modes in Virus-Microbe Systems.*

Viruses of microbes, including bacterial viruses (phage), archaeal viruses, and eukaryotic viruses, can influence the fate of individual microbes and entire populations. Here, we model distinct modes of virus-host interactions and study their impact on the abundance and diversity of both viruses and their microbial hosts. We consider two distinct viral populations infecting the same microbial population via two different strategies: lytic and chronic. The long-term association of virus and microbe in the chronic mode drives differences in selective pressures with respect to the lytic mode. We utilize invasion analysis of the corresponding nonlinear differential equation model to study the ecology and evolution of heterogenous viral strategies. We first investigate stability of equilibria, and characterize oscillatory and bistable dynamics in some parameter regions. Then, we derive fitness quantities for both virus types and investigate conditions for competitive exclusion and coexistence. In so doing we find unexpected results, including a regime in which the chronic virus requires the lytic virus for survival and invasion. (Received February 13, 2018)

86 ► Geophysics

1138-86-351 **Hashim AM Saber*** (hashim.saber@ung.edu), Department of Mathematics, University of North Georgia, 3800 Mundy Mill Road, Oakwood, GA 30566, and **Amer Awad** (amer.awad@advisian.com), 151 Canada Olympic Road SW, Calgary, Calgary AB T3B 6B7, Canada. *Mathematical Modelling of Tailing Under High Pressure.*

Tailings are the materials left over after the process of separating the valuable fraction from the uneconomic fraction of an ore. This paper focuses on the study the mechanical characteristics of the tailings material under high pressures with the objective of gaining knowledge about the tail behavior under consolidation. The problem is treated into two stages, the first stage is determining the sliding mass. The second stage is when failing occurs. We propose a model for the first stage with an adaptive constitutive equation and then analyze the second stage by considering flow properties under consolidation. We developed a two-dimensional (2D) model for the analysis of the propagation of landslides involving a fluidized material such as debris and mud flows. Preliminary numerical results of the proposed algorithm will be presented. The performance of the algorithm and the analysis of the results suggest the use of the method to solve real problems of tailings under high pressure. (Received February 13, 2018)

92 ► Biology and other natural sciences

1138-92-15 **William E Fitzgibbon*** (fitz@uh.edu), Department of Mathematics, University of Houston, Houston, TX 77204-3008, and **Jeffrey J Morgan**, **Glenn F Webb** and **Yixiang Wu**. *A Vector-Host Epidemic Model With Spatial Structure and Age of Infection.*

We are concerned with a diffusive age structured model describing spatio-temporal evolution of a disease within geographic region. The disease is transmitted between host and vector populations following a crisscross pattern with an age structure accounting for a period of incubation within the host population. Dispersion of both the host and vector populations with the region is modeled by Fickian Diffusion. Our motivation is to describe the introduction of vector borne diseases such as Zika into previously disease free regions via the introduction of infected hosts. (Received December 27, 2017)

1138-92-35 **Zhisheng Shuai*** (shuai@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Effects of asymmetric movements on infectious disease dynamics.* Preliminary report.

Many recent outbreaks and spatial spread of infectious diseases have been influenced by human movement over air, sea and land transport networks, and/or anthropogenic-induced pathogen/vector movement. These spatial movements in heterogeneous environments and networks are often asymmetric (biased). The effects of asymmetric movement versus symmetric movement will be investigated using several epidemiological models from the literature. These investigations provide a better understanding of disease transmission and control in the real life application. (Received January 20, 2018)

1138-92-50 **Esaias J Janse van Rensburg*** (rensburg@yorku.ca), Mathematics & Statistics, York University, Toronto, Ontario M3J 1P3, Canada. *Mean Field Analysis of Algorithms for Scale-Free Networks in Molecular Biology.*

Scale free networks in Molecular Biology are normally grown by recursive algorithms which add and delete nodes and bonds. Examples are the Barabasi-Albert algorithm, the Duplication-Divergence algorithm, the Solé algorithm and the iSite algorithm. In this talk a mean field approach to the analysis of these algorithms is presented. I will in particular focus on the iSite algorithm, and give mean field values of the scaling exponent of the degree distribution. I will also describe some variations on the algorithm, and estimate the scaling exponent numerically. (Received January 24, 2018)

1138-92-77 **Inne Singgih***, 618 Pickens Street, Apt 5, Columbia, SC 29201, and **Kiki Ariyanti Sugeng** and **Denny Riama Silaban**. *DNA graph characterization for line digraph of dicycle with one chord.*

Characterization of DNA graph gives important contribution in completing the computational step of Sequencing by Hybridization (SBH). Some graphs are already characterized as DNA graph using (α, k)-labeling. Dicycle and dipath are DNA graphs, while rooted trees and self adjoint digraphs are DNA graphs if and only if their maximum degree is not greater than four. In this paper we also use (α, k)-labeling to characterize line digraph of dicycle with one chord C_n^t as DNA graph and show that for $m, n \in \mathbb{N},\ t = \lfloor \frac{n}{2} \rfloor, L^m(C_n^t)$ are DNA graphs.
(Received January 30, 2018)

1138-92-78 **Xi Huo*** (x.huo@math.miami.edu). *Dynamical behaviors of antimicrobial de-escalation and continuation systems.* Preliminary report.

Antimicrobial de-escalation is a widely practiced drug use strategy in hospitals, but its advantages in comparison with the conventional strategy (continuation) are not well understood. We have developed mathematical models and have numerically showed that de-escalation is only superior to continuation under certain parameter sets which cannot be mathematically characterized due to the complexity of the models. Recently, we simplify our previous models and analyze their dynamical behaviors and bifurcation phenomena. We are thus able to quantify the conditions for de-escalation being superior to continuation, and explain this medical problem mathematically. (Received January 30, 2018)

1138-92-117 **Jingsai Liang*** (jliang@westminstercollege.edu), Westminster College, 1840 S 1300 E, Salt Lake City, UT 84105, and **Don Hong** (don.hong@mtsu.edu), Middle Tennessee State University, Box 34, Murfreesboro, TN 37132. *Non-Gaussian Penalized PARAFAC Analysis of fMRI Data.*

Independent Component Analysis (ICA) method has been used successfully in fMRI data analysis. As an extension of the ICA, Tensorial Probabilistic ICA (TPICA) is used to decompose fMRI group data into three-mode of subject, temporal, and spatial. But due to the independent constraint of the spatial components, TPICA is not very efficient in the presence of overlapping of active regions of different spatial components. Parallel Factor Analysis (PARAFAC) is another method used to process three-mode data and can be solved by alternating least-squares. PARAFAC may converge into some degenerate solutions if the matrix of one mode is collinear. However, it is reasonable to find significant collinear relationships within subject mode of two similar subjects in group fMRI data. Thus both TPICA and PARAFAC have unavoidable drawbacks. In this presentation, we try to alleviate both overlapping and collinear issues by integrating the characters of PARAFAC and TPICA together, which imposes a non-Gaussian penalty term to each spatial component under the PARAFAC framework. The results of this proposed algorithm outperform TPICA and PARAFAC on the simulation data and real fMRI data. (Received February 08, 2018)

1138-92-135 **Qingyan Shi*** (shiqingyan3@163.com), 1449 N Mount Vernon Ave.A, Williamsburg, VA 23185, and **Junping Shi** and **Yongli Song**. *Hopf bifurcation and pattern formation in a delayed diffusive logistic model with spatial heterogeneity.*

Logistic differential equation models have been used to describe the growth and dispersal of population, and a time delay is often incorporated into the model because of the maturation time for reproduction or other biological process. When the resource function in the model is spatially homogeneous, the dynamics of the model has been thoroughly known: a large time delay will destabilize the constant equilibrium and temporal oscillations can be observed. Here, we study the dynamics of a delayed diffusive logistic model with spatially heterogeneous resource supply under Neumann boundary condition. It is shown that for large diffusion coefficient, a supercritical Hopf bifurcation occurs near the non-homogeneous positive steady state at a critical time delay value, and the dependence of corresponding spatiotemporal patterns on the heterogeneous resource function is demonstrated via numerical simulations. Moreover, it is proved that the heterogeneous resource supply contributes to the increase of the temporal average of total biomass of the population even though the total biomass oscillates periodically in time. (Received February 07, 2018)

1138-92-146 **Jin Wang***, Department of Mathematics, University of Tennessee at Chattanooga, Chattanooga, TN 37403. *Analyzing the intrinsic bacterial dynamics in waterborne infections.*

The intrinsic dynamics of pathogenic bacteria often play an important role in the transmission and spread of waterborne infectious diseases. We present mathematical models for waterborne infections and analyze two types of nonlinear bacterial dynamics: logistic growth, and growth with Allee effects. For the model with logistic growth, we find that regular threshold dynamics take place, and the basic reproduction number can be used to characterize disease extinction and persistence. In contrast, the model with Allee effects exhibits much more complex dynamics, including the existence of multiple endemic equilibria and the presence of backward bifurcation and forward hysteresis. (Received February 07, 2018)

1138-92-149 **Mihiri De Silva**, Lubbock, TX 79409, and **Sophia Jang*** (sophia.jang@ttu.edu), Lubbock, TX 79409. *Deterministic and stochastic modeling of phytoplankton-zooplankton interactions.*

We present deterministic and stochastic three-compartment mathematical models of interactions between non-toxic phytoplankton (NTP), toxin producing phytoplankton (TPP), and zooplankton to investigate various mechanisms upon population coexistence. In these models, mutual interference between predator zooplankton and avoidance of TPP by zooplankton are considered. Our analytical findings for the deterministic models indicate that mutual interference of the zooplankton can stabilize the interactions. Numerical simulations with parameter values taken from existing literature are performed to illustrate complexities of the population interactions and to validate our analytical findings. For the parallel models of Ito stochastic differential equations, we apply the Euler-Maruyama numerical method to approximate the models and to investigate probability distributions of the plankton populations. It is concluded that randomness of the environment can make the populations more likely to go extinct. (Received February 07, 2018)

1138-92-179 **Xueliang Li*** (lxl@nankai.edu.cn), Center for Combinatorics, Nankai University, Tianjin, Peoples Rep of China. *Oriented graphs with extremal skew energy.*

An oriented graph has a skew symmetric adjacency matrix. The skew energy of an oriented graph is the sum of the norms of the eigenvalues of its skew symmetric adjacency matrix. In this talk we will survey the results about oriented graphs with maximum or minimum skew energy. Some open questions are also presented. (Received February 08, 2018)

1138-92-184 **Yu Jin*** (yjin6@unl.edu), Department of Mathematics, Lincoln, NE 68588. *Spatial population dynamics in meandering rivers.*

We present a novel model that considers the longitudinal variation as introduced by the sinuosity of a meandering river where a main channel is laterally extended to point bars in bends. These regions offer different habitat conditions for aquatic populations and therefore may enhance population persistence. Our model is a nonstandard reaction–advection–diffusion model where the domain of definition consists of the real line (representing the main channel) with periodically added intervals (representing the point bars). We study population persistence as the (in-) stability of the trivial solution and population spread as the minimal wave speed of traveling periodic waves. We conduct a sensitivity analysis to highlight the importance of each parameter on the model outcome and find that sinuosity can enhance species persistence. (Received February 09, 2018)

1138-92-202 **Bingtuan Li*** (bing.li@louisville.edu). *Multiple Invasion Speeds in a Two-Species Integro-Difference Competition Model.*

We discuss an integro-difference competition model for the case that two species consecutively invade a habitat. We show that if a species spreads into a traveling wave of its rival, or if two species expand their spatial ranges in both directions, in a direction where open space is available, the species with larger invasion speed can always establish a wave moving into open space with its own speed. We demonstrate that when one species is stronger in competition, under appropriate conditions, the speeds at which the boundaries between two species move can be analytically determined. In general there are multiple invasion speeds in the model. It is possible for a species to develop two separate waves propagating with different invasion speeds. It is also possible for each species to establish a single wave spreading with distinct speeds in both directions. The mathematical analysis relies on linear determinacy and new techniques developed (Received February 09, 2018)

1138-92-231 **Chenwei Tian**, **Xinping Cui** and **Junping Shi*** (jxshix@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23187, and **Qingyan Shi**. *Spatiotemporal dynamics of a reaction-diffusion model on pollen tube tip growth.*

A reaction-diffusion model is proposed to describe the evolution of spatial distributions of ROP1 and calcium on the pollen tube tip. The cytoplasmic ROP1 activate ROP1 on the membrane and the calcium ions inhibit ROP1, while ROP1 controls calcium influx with a time delay. Lateral movement of molecules on the membrane are depicted by diffusion. It is shown that bistable or oscillatory dynamics could exist even in the non-spatial model, and time delay can also promote oscillation. Stationary and oscillatory spatiotemporal patterns are found in the full spatial model which resemble the experimental data of pollen tube tip. (Received February 10, 2018)

1138-92-263 **Elizaveta Latash*** (elatash1@student.gsu.edu), elatash1@student.gsu.edu, and **Hangue Park**, **William Barnett**, **Alexander N Klishko**, **Boris I Prilutsky** and **Yaroslav Molkov**. *Frontal plane dynamics of quadrupedal locomotion on a split-belt treadmill.*

Dynamic stability of human locomotion in the frontal plane was investigated using an inverse pendulum model and notion of center of mass (COM). The goal of this study was to determine if an inverted pendulum model could be used to accurately describe the frontal plane dynamics of cat COM during split-belt locomotion and to examine if the model can explain previously obtained experimental results.

We developed a mathematical model of the balance control system based on inverted pendulum model dynamics, controlled by shifting the pendulum pivot point when the COM approached thresholds of dynamic stability. These thresholds were computed using Bayesian inference based on data from different experimental conditions. Experimental data included 3D full body cat kinematics and ground reaction forces recorded during split-belt locomotion at different speeds and anesthesia of ipsilateral paws (Park et al., 2016).

The inverted pendulum model described the experimental dynamics of the cat COM in the frontal plane with high accuracy. The model revealed a mechanism of controlling dynamic stability in the frontal plane. This mechanism produces frontal plane oscillations of the COM during locomotion that are synchronized with transitions between specific locomotor phases. (Received February 14, 2018)

1138-92-267 **Yan Wang*** (ywang36@email.wm.edu), 1449 N Mount Vernon Ave., Apt A, williamsburg, VA 23185, and **Junping Shi**. *Persistence and Extinction of Population in Reaction-Diffusion-Advection Model with Strong Allee Effect Growth.* Preliminary report.

A reaction-diffusion-advection equation with strong Allee effect growth rate is proposed to model a single species stream population in a unidirectional flow. Here random undirected movement of individuals in the environment is described by passive diffusion, and an advective term is used to describe the directed movement in a river caused by the flow. Under biologically reasonable boundary conditions, the existence of multiple positive steady states are shown when both the diffusion coefficient and the advection rate are small, which lead to different asymptotic behavior for different initial conditions. On the other hand, when the advection rate is large, the population becomes extinct regardless of initial condition under most boundary conditions. (Received February 11, 2018)

1138-92-270 **Shantia Yarahmadian*** (syarahmadian@math.msstate.edu), 410 Allen Hall, Mississippi State University, Mississippi State, MS 39762. *A Mathematical Model for Amyloid- β Aggregation in the Presence of Metal Ions.* Preliminary report.

The aggregation of amyloid-β (Aβ) proteins through their self-assembly into oligomers, fibrils, or senile plaques is advocated as a key process of Alzheimer's disease. Recent studies have revealed that metal ions play an essential role in modulating the aggregation rate of amyloid-β (Aβ) into senile plaques because of high binding affinity between Aβ proteins and metal ions. Here, we proposed a mathematical model as a system of coupled kinetic equations that simulates the self-assembly of amyloid-β (Aβ) proteins in the presence of metal ions. The numerical simulations capture four timescales in the Aβ dynamics associated with three important events which include the formation of the amyloid-metal complex, the homogeneous aggregation of the amyloid-metal complexes, and the non-homogeneous aggregation of the amyloid-metal complexes. (Received February 12, 2018)

1138-92-309 **Rachel Leander*** (rachel.leander@mtsu.edu), **Zack Jones**, **Vito Quaranta**, **Leonard Harris** and **Darren Tyson**. *A Drift-Diffusion Checkpoint Model Predicts a Highly Variable and Growth-Factor-Sensitive Portion of the Cell Cycle G1 Phase.*

Even among isogenic cells, the time to progress through the cell cycle, or the intermitotic time (IMT), is highly variable. This variability has been a topic of research for several decades and numerous mathematical models have been proposed to explain it. Recently, we developed a stochastic model of cell cycle progression as it is determined by sequential cell cycle checkpoints. This model, which describes each checkpoint as a drift-diffusion process coupled to a threshold, is called the drift-diffusion threshold (DDT) model. In this talk, I will discuss a custom numerical method for the estimation of the DDT model's parameters, and then present descriptive and predictive results obtained by applying the model to individual-cell data. (Received February 12, 2018)

1138-92-314 **Nigar Karimli***, nigar.karimli042@topper.wku.edu, and **Ayush Prasad** and **Richard Schugart**. *Parameter Estimation and Optimal Design Techniques to Analyze a Mathematical Model in Wound Healing.*

In this work, we utilized a previously developed mathematical model describing the interactions among matrix metalloproteinases, their inhibitors, extracellular matrix, and fibroblasts (Krishna et al., 2015). We estimate parameter values using ordinary least-squares for the model curve-fitted to individual patient data from Muller et al. (2008). However, these model parameters can be estimated more efficiently and accurately by implementing an optimal design method that calculates optimal observation times for collecting clinical data. We introduce an SE-optimal design (standard-error optimal-design) by using a Fisher Information Matrix (FIM) to determine the optimal time evolution of sensitivity values. The goal of this work is to quantify and understand differences between patients to predict future responses and individualize treatment for each patient. Moreover, additional results using various parameter estimation techniques will also be presented. (Received February 12, 2018)

1138-92-341 **Rachel Leander*** (rachel.leander@mtsu.edu), **John Ford**, **Jasmin Laurel**, **Christian Devine**, **Leonard Harris** and **Darren Tyson**. *Evaluating the role of memory in cell cycle progression.* Preliminary report.

Recent work suggests that "memories" of mitotic signaling are passed from mother to daughter cell and can heavily influence the dynamics with which a cell progresses through the cell cycle. Motivated by these experimental findings, we investigate alternative models for the role of memory in stochastic cell cycle progression and evaluate the ability of such models to describe both division time distributions and correlations in the division times of related cells. (Received February 12, 2018)

1138-92-353 **Cameron J Browne***, cambrowne@louisiana.edu. *Modeling immune escape in intra-host HIV and CTL networks.*

During HIV infection, an array of CTL immune response populations recognize specific epitopes (viral proteins) presented on the surface of infected cells to effectively mediate their killing. However HIV can rapidly evolve resistance to CTL attack at different epitopes, inducing a dynamic network of viral and immune response variants. We consider models for the network of virus and immune response populations. Our analysis provides insights on viral immune escape from multiple epitopes. In the "binary allele" setting, we prove that if the viral fitness costs for gaining resistance to each of n epitopes are equal, then the system of 2^n virus strains converges to a "perfectly nested network" with less than or equal to $n + 1$ persistent virus strains. Overall, our results suggest that *immunodominance*, i.e. relative strength of immune response to an epitope, is the most important factor determining viral escape pathway of HIV against multiple CTL populations. To conclude, I briefly discuss ongoing collaborative work to connect the models with intra-host SIV/immune response data. (Received February 13, 2018)

1138-92-361 **Aurelie A Akossi*** (aakossi1@gsu.edu), Room 1337, 25 Park Place, Atlanta, GA 30303, and **Gerardo Chowell** and **Alexandra Smirnova**. *On Stable Estimation of Time Dependent Transmission Rate in an SEIR System and Implications for Forecasting.* Preliminary report.

The estimation of disease parameters and the design of adequate disease-forecasting systems are thematic issues in epidemiology. Public health officials and government agencies need reliable quantification of transmission pathways in order to accurately predict, and effectively respond to epidemic outbreaks. Compartmental models describe the dynamic progression of individuals between epidemiological classes. Within SEIR models, the transmission rate is an especially important parameter. It can be defined as the effective contact rate, that is, the probability of infection given contact between an infectious and susceptible individual multiplied by the average rate of contacts between these groups. Our goal is to recover the time dependent transmission rate by assuming specific functional forms that depend on a few parameters. Specifically, we compare three model transmission-rate functions with limited number of parameters in terms of their ability to fit incidence data and to provide accurate short term forecasting. Given noise contaminated epidemiological data, the inverse problem involves minimization with respect to model function parameters and results in a non-linear least squares problem. Numerical simulations with synthetic and real incident case data will be presented. (Received February 13, 2018)

1138-92-380 **Junyuan Yang*** (yangjunyuan00@126.com). *AN AGE-STRUCTURED-LIKE MODEL FOR NON-MARKOVIAN SEXUALLY TRANSMITTED DISEASES IN THE COUPLED NETWORK.*

In most models of sexually transmitted diseases (STDs) spreading in networks, it is assumed that the transmission and recovery processes are Markovian; that is, the transmission and recovery times per event are exponentially distributed, which is generally not true in a realistic situation. In the paper, we propose a general Edge-Based Age-structured-like Compartmental Model for STDs (EBACMS) allowing for general transmission and recovery times distributions in a coupled conguration network. We consider transmissions between homosexual men (MSM) with heterosexual contacts. We study the basic reproduction number R_0, the global stability of disease-free equilibrium when R_0 ¡ 1, and the final epidemic size F when $R_0 > 1$ of the model. Numerical simulations indicate that given a fixed exponential transmission time distribution, a higher variance in general recovery time distribution gives smaller R_0 and F. Sensitivity analysis on R_0 and F in terms of the parameters illustrates that the MSM route has a greater impact on R_0 and F than the heterosexual transmission route when the transmission process is Markovian and the recovery process is arbitrary. Our results provide excellent guidance to develop appropriate prevention and control strategies. (Received February 13, 2018)

1138-92-382 **Suzanne Lenhart*** (slenhart@utk.edu), University of Tennessee, Knoxville, TN 37996-3410. *Optimal control of vaccination in a vector-borne reaction-diffusion model applied to Zika virus.* Preliminary report.

We formulate a reaction diffusion model that considers spatial movement of humans and mosquito vectors, with local contact transmission of Zika virus. Vaccination is introduced as a control variable, giving immunity to susceptible humans, in order to characterize an optimal vaccination strategy that minimizes the costs associated with infections and vaccines. Parameter estimation and numerical simulations are carried out using data for the initial 2015 Zika outbreak in the state of Rio Grande do Norte in Brazil. (Received February 13, 2018)

1138-92-384 **Azmy S Ackleh***, Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504, and **Amy Veprauskas**, Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504. *Examining the effect of evolution in response to a disturbance on population dynamics.*

When exposed to a prolonged disturbance, short-lived species may possess the potential to rapidly evolve in response to the disturbance, thus mitigating its effects. This evolution may result in changes in population dynamics, such as allowing a population to persist at higher levels of a toxicant than is possible without evolution. Here we apply evolutionary game theory to Leslie matrix models to obtain Darwinian equations that couple population and evolutionary dynamics. We then analyze the resulting evolutionary models to understand the change in population dynamics due to evolution. We show that evolution in response to a disturbance may alter persistence outcomes as well as the complexity of the population dynamics. (Received February 13, 2018)

1138-92-390 **Lauren M Childs** and **Olivia F Prosper*** (olivia.prosper@uky.edu), 715 Patterson Office Tower, Lexington, KY 40506. *A stochastic model for the generation of Plasmodium falciparum parasite diversity.*

The malaria parasite Plasmodium falciparum requires a vertebrate host, such as a human, and a vector host, the Anopholes mosquito, to complete a full life cycle, with sexual reproduction occurring in the vector host. This sexual stage of the parasite life cycle creates opportunities for the production of genetically novel parasites. In the meantime, a mosquito's biology creates bottlenecks in the infecting parasites' development. We constructed a two-stage stochastic model to better understand the role of mosquito biology in mediating the generation of parasite diversity. The first stage is a stochastic model of parasite development within the mosquito, and the second is a model of sequence diversity generation via reassortment and recombination. Despite the bottlenecks, our framework shows that the possibility for reassortment and recombination ultimately increases the diversity of the parasite population within the mosquito at the sporozoite stage, the stage in which parasites are transmissible to humans. In fact, if the initial blood meal entering the mosquito is composed of only two parasite genotypes, the probability that more than two unique genotypes is transmitted from the mosquito to a human is over 50% for a wide range of initial gametocyte densities. (Received February 13, 2018)

93 ► *Systems theory; control*

1138-93-93 **Sivapragasam Sathananthan*** (satha@coe.tsuniv.edu), 3500, John Merritt Blvd, Tennessee State University, Nashville, TN 37209. *Robust Stabilization of Regime Switching Genetic Regulatory Networks.*

A problem of robust stability and stabilization of a class of genetic regulatory networks (GRNs) with both intrinsic and extrinsic stochastic perturbations (noise) are investigated under Markovian regime switching. The non-linear regulatory function is assumed to satisfy a sector-like condition and the jump Markovian switching is modeled by a discrete-time Markov chain with partial information on transition probability matrix. We proposed a stability criterion by utilizing Lyapunov second method, an improved-free weighting matrix method and the Lur'e system approach with partially or completely unknown transition probability matrix. LMI based sufficient conditions for stability and stabilization are obtained. A numerical example is given to demonstrate the merits of the obtained results (Received February 02, 2018)

1138-93-370 **Pengcheng Xiao*** (px3@evansville.edu), 1800 Lincoln Ave, Evansville, IN 47722, and **Zeyu Zhang** (zz5@evansville.edu). *Qualitative Analysis of a smoking model.*

The smoking behaviors have been considered as a critical problem on both health and social aspects for a long time. We propose and analyze mathematical model to explore the dynamics of smoking behavior with health educational campaigns involved. Stability analysis and numerical simulation are both discussed in this work.
(Received February 13, 2018)

94 ► Information and communication, circuits

1138-94-92 **Peter J Curry*** (peter.j.curry@navy.mil), 177 Brady St, Daniel Island, SC 29492, and **Laura C Tolliver**, **Scott C Batson** and **Grant C Eastland**. *On Underwater Communication with Spiral Acoustic Waves.* Preliminary report.

Spiral acoustic waves have been introduced recently as a wave that transmits orbital angular momentum which may contain encoded information. In 2011, this form of wave was used to build an underwater navigation beacon by using the phase of a received signal. Our research seeks to investigate the application of spiral acoustic waves in an underwater communication system. Specifically, there are two primary components to our research: the physics-based modeling behind a proof-of-concept that these waves are capable of supporting underwater communication links, and the encoding of transmission waveforms. In this talk we will introduce spiral acoustic waves through mathematical models of various transducer configurations, and then present a preliminary analysis of these models. Finally, we will identify current challenges and discuss directions for future work. (Received February 05, 2018)

1138-94-143 **Ilya A Krishtal***, Department of Mathematics, Watson Hall 320, DeKalb, IL 60115. *Phaseless reconstruction in Dynamical sampling.*

The talk is about the problem of phaseless reconstruction in the context of dynamical sampling in finite dimensional spaces. We will discuss a sufficient condition for phaseless reconstruction that involves a possibly new class of matrices. The talk is based on joint research with A. Aldroubi and S. Tang. (Received February 07, 2018)

1138-94-274 **Kaifeng Bu** and **Arthur Jaffe*** (jaffe@g.harvard.edu), Harvard University, Cambridge, MA 02138, and **Zhengwei Liu**. *De Finetti Theorems for Braiding Parafermions.*

We present de Finetti theorems to characterize states on a perafermion algebra that are invariant under a natural four-string braid group. (Received February 12, 2018)

97 ► Mathematics education

1138-97-365 **Ramjee P Sharma** (ramjee.sharma@ung.edu), 3820 Mundy Mill Road, Oakwood, GA 30566, **Kashi N Neupane*** (kashi.neupane@ung.edu), 3820 Mundy Mill Road, Oakwood, GA 30566, and **Dipendra N Regmi** (dipendra.regmi@ung.edu), 3820 Mundy Mill Road, Oakwood, GA 30566. *A Comparative Study of Online and In-class Assignments in Undergraduate Math Classes.* Preliminary report.

Existing data shows that there is usually a big difference between students' online homework grades and the corresponding in-class test/quiz grades in undergraduate mathematics courses. In this study, multiple undergraduate math courses have been selected to study the efficacy of online help tools, and the relationship between the students' online engagement and their grades from the in-class tests/quizzes. Additionally, the data has been collected from these courses to study the relationship among the online homework grades, the number of attempts made in the homework, and the grades from the corresponding in-class test/quizzes. In this presentation, we will share some preliminary results obtained from our studies. (Received February 13, 2018)

BOSTON, MA, April 21–22, 2018

Abstracts of the 1139th Meeting.

00 ► General

1139-00-3 **Maryna Viazovska*** (viazovska.maryna@epfl.ch), École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland. *The sphere packings and modular forms.*

The sphere packing problem asks for the densest configuration of non-intersecting open unit balls at the Euclidean space. This classical geometric problem is solved only in dimensions 1, 2, 3, 8, and 24. In this talk, we will present a solution of the sphere packing problem in dimensions 8 and 24. It seems that each dimension has its own features and requires a different approach. One method of estimating the density of a sphere packing from above was suggested by H. Cohn and N. Elkies in 2003. Their approach is based on Fourier optimization. Namely, they showed that the existence of a function satisfying certain inequalities for the function itself and for its Fourier transform leads to an upper bound of the density of a sphere packing. Using this method Cohn and Elkies were able to prove almost sharp bounds in dimensions 8 and 24. We will show that functions providing exact bounds can be constructed explicitly. The key ingredient of our construction is the theory of modular forms. (Received April 12, 2017)

1139-00-194 **Oliver Knill*** (knill@math.harvard.edu), Department of Mathematics, Cambridge, MA 02138-2901. *The amazing world of finite abstract simplicial complexes.*

Defined by a single axiom only, finite abstract simplicial complexes belong to the simplest constructs in mathematics. It can surprise how much of classical geometry and dynamics is mirrored in the discrete. Classical dynamical systems like partial differential equations can be studied in a finite world. There is also new geometry: an example is the Wu characteristics. It is a combinatorial invariant which comes with its own calculus, cohomology and Gauss-Bonnet theorem. Unlike simplicial cohomology which is a homotopy invariant, the cohomology of Wu characteristic is finer. It allows to distinguish the Möbius strip from the cylinder for example. Especially remarkable is the connection Laplacian L. It is always an unimodular matrix. It can be inverted explicitly in terms of stars. It also allows to express the Euler characteristics in terms of eigenvalues. For one-dimensional refined complexes, one can get the cohomology from the spectrum; furthermore the spectrum S of L^2 satisfies $S = 1/S$, leading to a functional equation for the zeta function. An application of this analysis are spectral radius estimates for graph Laplacians. Interesting is the Barycentric refinement limit. Its almost periodic but still discrete nature makes it appear both quantized as well as integrable. (Received February 10, 2018)

1139-00-281 **Edward Frenkel***, Dept of Mathematics, University of California, Berkeley, CA 94720. *Imagination and knowledge.*

In this Einstein Public Lecture, I would like to talk about the essence of our profession, its role in today's world, and the responsibilities that come with it.

Einstein said, "Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world." In my talk, I will give examples from the history of mathematics that support Einstein's view, showing how imagination provides bursts of insight that enable mathematicians to make new advances and to abandon what was taken for granted as well known and well understood. We see that in the discovery of imaginary numbers in Cardano's book "Ars Magna"; in Ramanujan's marvelous formulas that he said were written by Goddess Namagiri in his dreams; in the ideas of the Langlands Program, and much more.

We need to acknowledge, embrace, and utilize our capacity to imagine in order to navigate this brave new world, in which AI-powered information technology is being used to modify and control our behavior while we are being told that life is just an algorithm and a human is nothing but a sequence of 0's and 1's. Imagination has always been humanity's best antidote to fear, dogma and oppression.

Dare to imagine. (Received February 13, 2018)

1139-00-429 **Delaram Kahrobaei*** (dk2572@nyu.edu). *Post-quantum Group-based Cryptography and Hidden Subgroup Problem.* Preliminary report.

The National Security Agency (NSA) in August 2015 announced plans for transition to post-quantum algorithms. Currently, Suite B cryptographic algorithms are specified by the National Institute of Standards and

Technology (NIST) and are used by NSA's Information Assurance Directorate in solutions approved for protecting classified and unclassified National Security Systems (NSS). "Below, we announce preliminary plans for transitioning to quantum resistant algorithms Shortly thereafter the National Institute of Standardization and Technology announced a call to select standards for post-quantum public-key cryptosystems." The academic and industrial communities have suggested the following as potentially quantum-resistant primitives: lattice-based, multivariate, code-based, hash-based, isogeny-based, and group-based primitives. Group-based primitives is the main topic of my talk with an emphasis on problems such as the hidden subgroup problem that cut across all these areas. (Received February 18, 2018)

1139-00-479 **Sophie E Jackson*** (`sej13@cam.ac.uk`), Department of Chemistry, Lensfield Road, Cambridge, CB2 1EW, United Kingdom. *Protein Knots: Experimental Studies on Stability, Folding, Degradation and Design.*

A brief introduction on knotted proteins will be given followed by a summary of what experimental and computational studies over the last ten years have revealed about the general properties and folding pathways of knotted proteins. The second part of the talk will focus on the reasons why it might be advantageous for proteins to have knotted structures will be discussed and how the knot affects the thermodynamic, kinetic, mechanical and in vivo stability of the proteins will be illustrated with examples.

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1139-00-494 **Ilker Kocyigit*** (`ilkerk@gmail.com`). *l1 minimization-based imaging with multiple measurements.*

In this talk, we discuss some of the recent developments in l1 minimization-based imaging methods, in particular, the cases where "multiple measurements" are available. We discuss the conditions under which these multiple data can be useful to improve quality of the reconstructions and the usage of multiple data in reweighted schemes where the unknown does not satisfy sparsity conditions. (Received February 19, 2018)

1139-00-691 **L. Bourouiba*** (`lbouro@mit.edu`). *Disease transmission.*

The mechanisms governing the transfer of pathogens between infected and non-infected members of a population are critical in shaping the outcome of an epidemic. Despite major efforts aimed at the mathematical modeling and mitigation of infectious diseases, the fundamental mechanisms of pathogen spreading for most infectious diseases remain poorly understood. Drawing upon clinical data, fluid experiments and multi-scale mathematical modeling I will discuss the dynamics of transmission of various pathogens through the lens of fundamental fluid fragmentation and instability dynamics. (Received February 20, 2018)

01 ► History and biography

1139-01-19 **Scott B Guthery*** (`sbg@acw.com`), 2400 Beacon #208, Chestnut Hill, MA 02467. *Conservation Equations of Mathematical Practitioners.*

This talk draws on two works, one about heating and ventilation by Thomas Tredgold (1788-1829) and the other on gear trains for grist mills by Oliver Evans (1755-1819), to elucidate an expository technique found in nineteenth-century mathematical treatises. Having established a general-purpose conservation equation early in a discourse, the authors instantiate the equation in problem-specific contexts throughout the remainder of the text. In each case, the teaching would be founded on analyzing how a change in a variable on one side of the equation would be offset by a change in the value of a variable on the other side thereby highlighting a practical cause-and-effect relationship between the two. These conservation equations were often derived by constructing two expressions for the same quantity and then setting them equal to each other. (Received December 09, 2017)

1139-01-61 **Chris Rorres*** (`crorres@comcast.net`). *Finding the Center of a Circular Starting Line in an Ancient Greek Stadium.*

Two methods for finding the center and radius of a circular starting line of a racetrack in an ancient Greek stadium are presented and compared. The first is a method employed by the archaeologists who surveyed the starting line and the second is a least-squares method leading to a maximum-likelihood circle. A knowledge of the center and radius of the starting line is useful for determining units of length and angle used by the ancient Greeks, in addition to providing information on how ancient racetracks were laid out. (Received January 24, 2018)

1139-01-72 **Maria R Zack*** (mzack@pointloma.edu), MICS Department, Point Loma Nazarene University, 3900 Lomaland Drive, San Diego, CA 92106. *Christopher Wren, John Wallis and the Cycloid.*

In De Cycloide (1659) John Wallis describes a very interesting geometric proof of the length of the cycloid curve. This work was, in fact, the work of architect and polymath Christopher Wren and is the most significant published mathematical result attributed to Wren. This talk will describe a surprising proof which is accessible to first-year undergraduate students. (Received January 28, 2018)

1139-01-90 **Peggy Aldrich Kidwell*** (kidwellp@si.edu), MRC671, NMAH, Smithsonian Institution, P.O. Box 20013-7012, Washington, DC 20013-7012. *Mathematical Instruments at the Columbian Exposition of 1893 – Early Fruits of Technical Education.*

In 1893, 125 years ago, exhibitors from around the world gathered in Chicago to present their ideas – and their wares – to those who attended the Columbian Exposition. This vast world's fair included the first Ferris wheel, the first commercial movie theater, and the mounting for the Yerkes telescope. Sections on liberal arts and on instruments of precision were of special interest to the mathematically inclined. Several scholars, most notably Karen Parshall and David Rowe, have pointed out the importance of the German educational exhibit at the fair, particularly the exhibition of mathematical models by the firm of Ludwig Brill. A consideration of these models, as well as other objects exhibited in Chicago, points up the importance of objects in late nineteenth century mathematical pedagogy, particularly in technical schools and universities. (Received February 01, 2018)

1139-01-143 **Tom Bannon** and **Walter J. Meyer*** (meyer1@adelphi.edu). *Calculus 1875-1920: The Lay of the Land.* Preliminary report.

The era of our talk is interesting for a number of reasons. The one that motivates our work is that it is an era in which engineering enrollments soared and provided much of the audience for calculus courses. It is reasonable to wonder whether calculus authors catered to this new audience. Before studying this we felt that we should look at the wider context of calculus in that era. This has proved unexpectedly interesting and will form the bulk of this talk. The work is based on examination of calculus textbooks. The picture that emerges is that of a course, not yet standardized, and whose books and authors show considerable variation. (Received February 06, 2018)

1139-01-205 **Maryam Vulis*** (maryam@vulis.net), 67-67 Burns Street, Apr 4K, Forest Hills, NY 11375. *Life and Work of the Ukrainian Mathematician Volodimir (Wlodzimiez) Levitsky.* Preliminary report.

This presentation was inspired by Fred Rickey.

The Ukrainian mathematician Volodimir Levitsky is considered to be a founder of the Ukrainian mathematical culture. Prof Levistsky created mathematical terminology in Ukrainian was the author of the High School Physics textbook and co-author of the High School Algebra textbook in Ukrainian language. He also translated foreign texts into Ukrainian. Prof. Levitsky published articles on analytical functions, and was member of several foreign mathematical societies. Interestingly, in the 1930s he refused to move to the Soviet Ukraine, and for good reason – would he survive the purges? Volodimir Levitsky was a star in Western Ukraine (if it was not even called Western Ukraine at all times. (Received February 10, 2018)

1139-01-212 **Eugene Boman*** (ecb5@psu.edu), 777 W. Harrisburg Pike, Middletown, PA 17057. *The History of Calculus as a Guide to Teaching Calculus.*

Most Calculus texts written since the mid 1950s invert the history of the subject by first presenting concepts and definitions which were developed after the fact, solely to "rigorize" the topic. Thus, for example, the modern definition of the limit, first stated by Weierstrauss in the late 1800s, is the first topic in a modern textbook, whereas Leibniz's "useful fiction" of a differential quantity (dx) is normally ignored completely, despite the fact that it was the defacto foundation of Differential Calculus (hence the name) for nearly 200 years.

My intention is to present the idea and goal of using the history of Calculus as a guide to its teaching. I will discuss why I believe this is a useful, even natural, approach.

Robert Rogers of SUNY, Fredonia and I have taken on the task of writing a Calculus text which specifically incorporates the history of the topic into its teaching. This will serve as a framework for our discussion. (Received February 11, 2018)

1139-01-302 **Eisso J Atzema*** (eisso.atzema@maine.edu), Department of Mathematics and Statistics, University of Maine, Orono, ME 04469. *Educating the Irish: The Case of the Mathematician and Engineer John Gregory (1783-1880).* Preliminary report.

In 1831, the British government established the system of so-called National Schools for the whole of the territory of Ireland. As part of this system, a sequence of textbooks was developed. All books were published anonymously and as cheaply as possible, with the authors forfeiting any rights to royalties.

In mathematics, the National Curriculum included an advanced arithmetic text and a text on mensuration. Various secondary sources indicate that the author of these two texts was a John Gregory (1783-1880). Leaving aside the question whether either book was at the appropriate level for the intended audiences, both are fairly sound pedagogically and remarkably systematic. Other than that Gregory was also the author of a standard work on civil engineering, not much can be found about him in the standard sources. Through a series of lucky coincidences, however, I managed to piece together quite a bit about his life.

In my talk, I intend to present a succinct biography of John Gregory, with a focus on his involvement in the creation of the mathematical textbooks that were part of the National Curriculum, the existing sources that he used, his ideas about pedagogy, and their alignment with the overall philosophy behind the National Schools system. (Received February 14, 2018)

1139-01-337 **Cihan Can***, 512 McKeithen Street, Apt 3, Tallahassee, FL 32304. *Demathematizing Mathematics: Searching for Success in Mathematics Education.* Preliminary report.

Despite the recent efforts to promote student-centered practices in undergraduate mathematics instruction, lecture is still the most common method of teaching in universities (Blair, Kirkman, & Maxwell, 2013). Instructors' reasons for preferring one-way communication while teaching needs investigation, but I argue that the commonality of lecture can also be explained by the dominant view of mathematics in the society: "formal, precise, ordered, and abstract. It's broken into definitions, theorems, and remarks. [...] [It is] taken as a self-subsistent entity" (Hersh, 1998, p. 36). In this static view of mathematics, lecture is not only a pedagogical choice of the instructor, but an expected or inevitable result. If the role of the instructor is to transmit knowledge to students, why should she inquire about the views of the students? In this regard, Sfard's (2008) theory of mathematics as a discourse, a communicational approach to mathematics, can provide the foundational motivation for instructors to communicate with their students in their classrooms. I will share the preliminary results of a case study where I investigated the pedagogy of an instructor who has been using primary historical sources for her teaching from a discursive point of view. (Received February 15, 2018)

1139-01-462 **Lawrence Arthur D'Antonio*** (ldant@ramapo.edu). *The Nature of Proof: an Historical Perspective.*

In this talk we undertake a brief historical survey of the changing role of proofs in mathematics and in the classroom. For example, when did it become common to ask undergraduate students to be able to do proofs? One would expect to find exercises requiring proofs in geometry texts, but what about algebra or calculus texts of the past? We also discuss the expectations of instructors with regard to proofs by examining the debate between William Fogg Osgood and E. V. Huntington on whether or not there is a student standard of proof in mathematics. (Received February 18, 2018)

1139-01-480 **Emily Timmons Hamilton Redman*** (eredman@history.umass.edu). *Unintentional Consequences: Mathematics Pedagogy and the Rise of the Standards Movement in American Education.*

Even as the legacy of the new math is often questioned by math educators and historians of education, the era is generally remembered in idealized terms of reformers boldly reimagining the nation's math classrooms—seemingly a far cry from contemporary education policy centered on large-scale accountability through widespread student testing and federal incentive programs like the Systemic State Initiatives, NCLB, and Common Core that guide pedagogy. This paper argues there is a clear historical continuity from the new math era reforms to the present, with the mathematics education community adapting to a changing political climate to enact change in the math classroom. Specifically, this paper examines the changing role of the federal government in math education reform, from NSF funding to the shifting authority of the Dept. of Ed; to federally funded data collection on classroom inequities and policy reactions to the publication of NCTM's Standards. The evolving relationship between the math education community and the federal government from the middle of the 20th century is not only a history of ideological stability in terms of pedagogical aims of reformers, but it was also the efforts in math education in particular that shaped U.S. educational policy across disciplines. (Received February 19, 2018)

1139-01-545 **Kathleen M Clark*** (kclark@fsu.edu), 1114 W Call Street, School of Teacher Education, Tallahassee, FL 32306-4459. *History, Pedagogy, and Mathematics in Mathematics Education: Innovation and Participation in a Community of Scholars and Practitioners.*

I have three goals for this talk. First, I will briefly describe the aims and activities of the International Study Group on the Relations between History and Pedagogy of Mathematics ("HPM Group"), an affiliated group the International Commission on Mathematical Instruction (ICMI). Second, I will share highlights from some of the most recent scholarship contributing to the field of history of mathematics in mathematics education. And, finally, I will preview the plenary panel discussion taking place this summer at the Eighth European Summer University (ESU-8) in Oslo, Norway. In particular, I hope that audience members at this sectional meeting will be able to contribute to the advance preparation for the panel, even if participation in Oslo is not possible. (Received February 19, 2018)

1139-01-657 **Colin Bryan Powell McKinney*** (mckinnec@wabash.edu), Wabash College, 301 W Wabash Avenue, Crawfordsville, IN 47933. *Polar coordinates and history through video games.* Preliminary report.

This talk will concentrate on the mathematical aspects of two recent video games, *Kerbal Space Program* and *Engare*, and how this mathematics can fit into university mathematics curricula. It will also discuss how these games and their mathematical content can be used as a bridge to motivate the study of the history of mathematics, particularly the works of Kepler, Ptolemy, and al Tusi. (Received February 20, 2018)

1139-01-671 **Brit Shields***, Skirkanich Hall, Suite 240, University of Pennsylvania, Philadelphia, PA 19104. *Emergency Training: Mathematics for the Engineer during the Second World War.*

During the Second World War, the US Department of Education offered emergency training courses through its Engineering, Science and Management War Training program. The program was meant to alleviate a shortage of engineers in defense related fields by providing the essential skills to new people entering the field or more advanced courses for those already in engineering. In the context of the war, the courses were condensed in format, essential in content, and free in tuition. This paper will analyze the ideology behind the program and how that impacted the mathematical training of engineers during the war. (Received February 20, 2018)

1139-01-683 **Stuart Moskowitz*** (stuart@humboldt.edu), Humboldt State University, Dept of Mathematics, Arcata, CA 95521. *Lewis Carroll should have taught sixth grade math.*

In the late 1800s, Charles L Dodgson, aka Lewis Carroll, was a lecturer and tutor of Mathematics at Oxford University. Many historians, however, consider him uninspiring as a teacher. Of course, he will be remembered always as the author of Alice in Wonderland. But Dodgson also wrote on mathematics and logic, invented and collected mathematical puzzles and games, and was a prolific writer of letters and diaries. His register of all the letters he sent and received, numbered to 98,721, and his diaries, now published, fill ten volumes. This presentation will show how his puzzles and games and letters enliven mathematics, making it meaningful, understandable, and even playful. After Dodgson visited an Oxford high school, Evelyn Hatch wrote: "...my old friend Mr. Dodgson offered to come and give us a lecture on logic. My fellow students prepared to meet the famous mathematical tutor...armed with notebooks and pencils. To their surprise the lecturer appeared with a large black handbag, from which he proceeded to draw a number of white envelopes to be distributed among the audience......we were to play a game!" Dodgson followed the guidelines within the new Common Core Mathematical Standards 100 years before they were written! (Received February 20, 2018)

1139-01-686 **Theodora J Dryer*** (tdryer@ucsd.edu). *Military calculating machines 1920-1945.*

What can study of mathematical practices in military planning such as the creation of probability tables teach us about the larger culture of militarism and impacts of war? Calculating machines—including intervalometers, clocks, slide rules, nomograms, and bombsight calculators—were used to stabilize this data collection and organization process. Motivated by a growing desire for certainty over the future, specifically for managing one of the fastest growing economies in modern history. During WWII, the first stage of the bomb idealization process was to draw nomograms depicting a bombing scenario as a geometric relationship between number of bombs dropped, radius of the bomb, and width of the beach, etc. Nomograms represented bombing scenarios as simple mathematical relationships between a small set of factors. These mathematical diagrams provided context for military personnel and statistical workers to engage each other on discrete points of military strategy such as the space intervals between planes in a given bombing run. Nomograms therefore became technical representations that served as meeting points for military and mathematical expertise. (Received February 20, 2018)

1139-01-687 **Andrew B Perry*** (aperry@springfieldcollege.edu). *Cajori's three great arithmeticians: Pike, Daboll, and Adams.*

In his 1890 book The Teaching and History of the mathematics in the United States, historian Florian Cajori identified "three great arithmeticians" of the early nineteenth century, each of them them with wildly popular textbooks. Nicholas Pike wrote A New and Complete System of Arithmetic (Composed for the Citizens of the United States); Nathan Daboll wrote the Schoolmaster's Assistant; and Daniel Adams wrote the Scholar's Arithmetic. We will compare and contrast the content of these three books which collectively dominated the arithmetic textbook market in the early days of the United States of America. (Received February 20, 2018)

1139-01-689 **Malgorzata Aneta Marciniak*** (mmarciniak@lagcc.cuny.edu), 31-10 Thomson Avenue, MEC Department, room E223N, Long Island City, NY 11101. *The importance of historical remarks in upper level undergraduate math classes: Calculus 3, Linear Algebra and Differential Equations.*

The general motivation for providing appropriate math terminology is to create a connection of the concept and the meaning. But sometimes the ideas behind the concepts may be so particular and exquisite that modern education does not furnish students with suitable knowledge necessary to make this connection. Using terminology such as line integral, the echelon form or transient solution may bring some confusion especially to non-native speakers. In such a case, math terminology may become a true burden unless it is used as an excuse to expose students to new historically relevant topics. The presentation will provide and justify the circumstances when bringing meaningful historical background to math classroom is highly desired, if not necessary. (Received February 20, 2018)

1139-01-693 **Clare Kim*** (clarek@mit.edu), Building E51-098, 77 Massachusetts Avenue, Cambridge, MA 02139. *Forms of Perception, Perceptions of Form: Mathematics and the Arts at Black Mountain College.* Preliminary report.

How should mathematics be presented? As an endless continuation of facts and drills? As enabling an open-mode of reasoning? Answers to such questions throughout history have been tethered to the changing relationship between the nature of mathematical knowledge and the role mathematics might play in broader intellectual life. The wide-ranging pedagogies of mathematics that proliferated in the 1950s and 1960s would realize American mathematicians' assertions of the exceptional status of mathematics as a category of knowledge, as well as their fascination with generalization and axiomatic formalism. As mathematician Max Dehn noted, "mathematics is the only instructional material that can be presented in an entirely undogmatic way." In light of these transformations, this talk considers the meaning that one experimental form of mathematical instruction had for artists at Black Mountain College, a progressive liberal arts institution in rural Appalachia during the mid-twentieth century. I analyze students' engagements with the "Geometry for Artists" curriculum and its development by mathematicians in order to demonstrate how mathematical instruction was also conditioned by mid-century modernist concerns over artistic forms. (Received February 20, 2018)

05 ► Combinatorics

1139-05-10 **John T. Saccoman*** (john.saccoman2@shu.edu), Seton Hall University, Dept. of Mathematics and Computer Science, South Orange, NJ 07079. *A Spanning Tree-Reducing Surgery and Partial Factor Majorization.*

A graph G is a threshold graph if, for all pairs of nodes u and v in G, the neighborhood of u excluding v is completely contained in the neighborhood of v excluding u whenever $deg(u) \leq deg(v)$. It is known that threshold graphs provide the best lower bound on the number of spanning trees and all-terminal reliability for graphs in a particular class. There exist surgeries that lower these invariants for certain threshold graphs, but they do not work in all cases. We present a new surgery that will transform a threshold graph with minimum degree of 2 or greater, meeting other conditions, to a threshold graph with a lower number of spanning trees. In doing so we apply a majorization technique to the graphs' respective Temperley's B-matrix eigenvalues.

Keywords: spanning trees, eigenvalues, majorization, threshold graphs, spectral graph theory (Received October 24, 2017)

1139-05-11 **Mahir Bilen Can** and **Ozlem Ugurlu*** (ougurlu@tulane.edu), 6823 St Charles Ave, New Orleans, LA 70118. *The genesis of involutions.*

Let G be a complex semisimple algebraic group and B be a Borel subgroup of G. There are many situations where it is necessary to study the Borel orbits in G/G^θ, where θ is an involutory automorphism. This is equivalent to analyze $K = G^\theta$ orbits in the flag variety G/B. In fact, their geometry is of importance in the study of Harish-Chandra modules and their closures can be considered as Schubert varieties. The focus of this talk will be on the enumeration problem of Borel orbits in the symmetric space $SL(n,\mathbb{C})/S(GL(p,\mathbb{C})\times GL(q,\mathbb{C}))$. We will show that the Borel orbits are parameterized by the lattice paths in a $p+1$ by $q+1$ grid moving by horizontal, vertical and diagonal steps weighted by an appropriate statistic. In addition we will present various t-analogues of the rank generating function for the inclusion poset of Borel orbit closures. (Received October 31, 2017)

1139-05-25 **Danial Dervovic*** (d.dervovic@cs.ucl.ac.uk). *For every quantum walk there is a (classical) lifted Markov chain with the same mixing time.*

Quantum walks on graphs have been shown in certain cases to mix quadratically faster than their classical counterparts. Lifted Markov chains, consisting of a Markov chain on an extended state space which is projected back down to the original state space, also show considerable speedups in mixing time. Here, we construct a lifted Markov chain on a graph with n^2T^3 vertices that mixes to the average mixing distribution of a quantum walk on any graph with n vertices over T timesteps. Moreover, we prove that the mixing time of this chain is T, the number of timesteps in the quantum walk. As an immediate consequence, for every quantum walk there is a lifted Markov chain with the same mixing time.

arXiv reference: arXiv:1712.02318 (Received January 05, 2018)

1139-05-26 **Ajay Arora*** (ajayarora1235@gmail.com) and **Eddie Cheng**. *Matching preclusion of the generalized Petersen graph.*

The matching preclusion number of a graph with even number of vertices is the minimum number of edges whose deletion results in a graph with no perfect matchings. In this talk, we discuss the matching preclusion problem for the generalized Petersen graph $P(n,k)$. (Received January 05, 2018)

1139-05-37 **Ada Chan*** (ssachan@yorku.ca), **Coutinho Gabriel**, **Christino Tamon**, **Luc Vinet** and **Hanmeng Zhan**. *Fractional revival in continuous-time quantum walk.*

In the continuous-time quantum walk on a graph X, fractional revival from u to v occurs at time τ if

$$e^{-i\tau A} = \alpha e_u + \beta e_v,$$

for some $\alpha,\beta\in\mathbb{C}$. Here e_u and e_v denote the characteristic vectors of vertices u and v, respectively.

Perfect state transfer from u to v and periodicity at u are two special cases of fractional revival with $\alpha = 0$ and $\beta = 0$, respectively. These two properties have been extensively studied but not so much for fractional revival when both α and β are nonzero.

In this talk, we focus on fractional revival between strongly cospectral vertices. We show that, in addition to the few paths and cycles that admit perfect state transfer, there is only one more path and one more cycle that admit fractional revival.

This is joint work with Gabriel Coutinho, Christino Tamon, Luc Vinet and Harmony Zhan. (Received January 15, 2018)

1139-05-109 **Tamar Friedmann*** (tamarf1@yahoo.com), **Phil Hanlon**, **Richard P. Stanley** and **Michelle L. Wachs**. *The action of the symmetric group on a generalization of the free Lie algebra: a CataLAnKe Theorem.*

The free Lie algebra is a natural mathematical construction that is central in algebraic combinatorics and has applications in other fields. I will discuss a generalization of the free Lie algebra based on an n-ary commutator. The action of the symmetric group on its multilinear component generalizes the well-known representation Lie(k). I will discuss results and conjectures about this generalization of Lie(k), including a representation whose dimension is the Catalan number. (Received February 04, 2018)

1139-05-121 **Anna E Weigandt*** (weigndt2@illinois.edu), 1409 W Green St, Urbana, IL 61801. *Prism tableaux and alternating sign matrices.*

A prism tableau is an overlay of semistandard tableaux. In joint work with A. Yong, prism tableaux were used to provide a formula for Schubert polynomials. This expression directly generalizes the tableau rule for Schur polynomials. We will discuss fillings of more general prism shapes. The resulting polynomials are multiplicity free sums of Schubert polynomials. The terms in this sum are determined by an associated alternating sign matrix. We use this connection to give a prism formula for the multidegrees of alternating sign matrix varieties. (Received February 05, 2018)

1139-05-122 **Joel O Moreira*** (joel.moreira@northwestern.edu), **Florian Karl Richter** and **Donald Robertson**. *The Erdos sumset conjecture.*

Erdos conjectured that every set $A \subset \mathbb{N}$ with positive density contains a sum $B + C := \{b + c : b \in B, c \in C\}$ of two infinite sets. I will talk about an approach to this conjecture using ideas from ergodic theory as a guide, including an intersectivity theorem of Bergelson, the splitting of an arbitrary function into an almost periodic and a weak mixing components, and some borrowed techniques from Beiglbock's proof of Jin's theorem. (Received February 05, 2018)

1139-05-142 **Ayush Agarwal** and **Christian Gaetz*** (gaetz@mit.edu). *Differential posets, Cayley graphs, and critical groups of group representations.*

In recent work, Benkart, Klivans, and Reiner defined the critical group of a faithful representation of a finite group, which is analogous to the critical group of a graph. I will discuss maps between critical groups induced by injective group homomorphisms and in particular the map induced by restriction of the representation to a subgroup. We prove that in the abelian group case the critical groups are isomorphic to the critical groups of a certain Cayley graph and that the restriction map corresponds to a graph covering map. We also prove that when the group is an element in a differential tower of groups, critical groups of certain representations are closely related to words of up-down maps in the associated differential poset. This information is used to generalize an explicit formula for the critical group of the permutation representation of the symmetric group given by the second author, and to enumerate the factors in such critical groups. (Received February 06, 2018)

1139-05-146 **David W Stoner*** (dstoner@college.harvard.edu), 422 Leverett Mailing Center, 28 DeWolfe Street, Cambrdge, MA 02138, and **Mehtaab Sawhney**. *Hypercube Packings and Coverings with Higher Dimensional Rooks.*

We introduce a generalization of classical q-ary codes by allowing points to cover other points that are Hamming distance 1 or 2 in a freely chosen subset of all directions. More specifically, we generalize the notion of 1-covering, 1-packing, and 2-packing in the case of q-ary codes. In the covering case, we establish the analog of the sphere-packing bound and in the packing case, we establish an analog of the singleton bound. Given these analogs, in the covering case we establish that the sphere-packing bound is asymptotically never tight except in trivial cases. This is in essence an analog of a seminal result of Rodemich regarding q-ary codes. We establish for the 1-packing and 2-packing cases that the analog of the singleton bound is tight in several possible cases and conjecture that these bounds are optimal in general. (Received February 06, 2018)

1139-05-152 **Alexander Barvinok*** (barvinok@umich.edu), 2074 East Hall, 530 Church Street, Ann Arbor, MI 48019-1043. *Computing permanents of complex diagonally dominated matrices and tensors.*

We prove that for any $\lambda > 1$, fixed in advance, the permanent of an $n \times n$ complex matrix, where the absolute value of each diagonal entry is at least λ times bigger than the sum of the absolute values of all other entries in the same row, can be approximated within any relative error $0 < \epsilon < 1$ in quasi-polynomial $n^{O(\ln n - \ln \epsilon)}$ time. We extend this result to multidimensional permanents of tensors and apply it to weighted counting of perfect matchings in hypergraphs. (Received February 07, 2018)

1139-05-162 **Larry Guth*** (larryg@mit.edu), 77 Mass Ave, Cambridge, MA 02139. *Introduction to the polynomial method in incidence geometry.*

Over the last decade, the polynomial method has resolved several longstanding problems in incidence geometry. This will be a survey talk, describing some of the methods as well as some challenges and open problems. (Received February 07, 2018)

1139-05-187 **Laura Escobar*** (lescobar@illinois.edu), **Benjamin Wyser** and **Alexander Yong**. *K-orbit closures and Barbasch-Evens-Magyar Varieties.*

We define the Barbasch-Evens-Magyar varieties as a fiber product of certain flag varieties. They are isomorphic to the manifolds of D. Barbasch-S. Evens, which provide desingularizations of symmetric orbit closures. This parallels P. Magyar's description of the Bott-Samelson variety. We analyze the moment polytope, which we connect to the moment polytope of a Bott-Samelson variety. Joint work with Benjamin J. Wyser and Alexander Yong. (Received February 09, 2018)

1139-05-203 **Noga Alon**, **Jacob Fox** and **Yufei Zhao*** (yufeiz@mit.edu). *Efficient arithmetic regularity and removal lemmas for induced bipartite patterns.*

Let G be an abelian group of bounded exponent and $A \subset G$. We show that if the collection of translates of A has VC dimension at most d, then for every $\epsilon > 0$ there is a subgroup H of G of index at most $\epsilon^{-d-o(1)}$ such that one can add or delete at most $\epsilon|G|$ elements to A to make it a union of H-cosets.

We also establish a removal lemma with polynomial bounds, with applications to property testing, for induced bipartite patterns in a finite abelian group with bounded exponent. (Received February 10, 2018)

1139-05-214 **Samantha Dahlberg*** (samadahl@math.ubc.ca), Mathematics Department, 1984 Mathematics Road, Vancouver, BC V6T 1Z2, Canada. *Chromatic symmetric functions and e-positivity.*

Richard Stanley introduced the chromatic symmetric function X_G of a simple graph G, which is the sum of all possible proper colorings with colors $\{1, 2, 3, \dots\}$ coded as monomials in commuting variables. These formal power series are symmetric functions and generalize the chromatic polynomial. In this talk we discuss which graphs G have a X_G that can be written as a non-negative sum of elementary symmetric functions, and additionally we will also resolve Stanley's e-Positivity of Claw-Contractible-Free Graphs. This is joint work with Angele Foley and Stephanie van Willigenburg. (Received February 11, 2018)

1139-05-231 **Nicholas James Proudfoot*** (njp@uoregon.edu), **Max Wakefield** and **Ben Young**. *Kazhdan-Lusztig polynomials of matroids.*

I will give a brief introduction to the theory of Kazhdan-Lusztig polynomials of matroids, including the definition, a statement of the major open problems, and an explicit calculation in the case of uniform matroids. (Received February 12, 2018)

1139-05-242 **Vinoth Nandakumar**, **Daniele Rosso*** (drosso@iu.edu) and **Neil Saunders**. *Irreducible components of exotic Springer fibers and Robinson-Schensted algorithm.*

Kato defined an exotic version of the Springer resolution of the nilpotent cone in type C to obtain nicer properties that are more similar to the type A case. We give an explicit combinatorial description of the irreducible components of the exotic Springer fibers and as a consequence we derive an exotic Robinson-Schensted bijection between the Weyl group of type C and pairs of standard Young bitableaux of the same shape. (Received February 12, 2018)

1139-05-246 **Alexander Garver*** (alexander.garver@gmail.com), Alexander Garver, 10-2030 rue Chomedey, Montreal, QC H3H2A9, Canada, and **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 February 12, 2018)

1139-05-249 **Greta Panova*** (panova@math.upenn.edu), 1 Einstein Drive, IAS Mathematics, Princeton, NJ 08540. *Asymptotics and bounds of skew SYTs, Kronecker and Littlewood-Richardson coefficients.*

We will discuss various known results and approaches to estimating the number of skew standard Young tableaux, structure constants (Kronecker and Littlewood-Richardson coefficients).

The methods range from Naruse hook-length formula to character identities.

Based on several joint works with Alejandro Morales and Igor Pak. (Received February 12, 2018)

1139-05-261 **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 three-part series will generalize these results to the other cominuscule types. (Received February 13, 2018)

1139-05-264 **Juan B Gil***, 3000 Ivyside Park, Altoona, PA 16601. *On rooted planar maps and Dyck paths.*

In one of his seminal papers from the early 60's, W. T. Tutte established a link between the enumeration of rooted planar maps and the enumeration of their nonseparable elements. Motivated by Tutte's result, in this talk we give a bijection between the set of rooted planar maps with n edges and the set of Dyck paths of semilength 2n having ascents of even length and such that each 2j-ascent may be labeled with a rooted nonseparable map with j edges. Our bijection relies on the representation of rooted planar maps as shuffles of Dyck words. This is joint work with Daniel Birmajer and Michael Weiner. (Received February 13, 2018)

1139-05-273 **Seth Sullivant*** (smsulli2@ncsu.edu). *Maximum agreement subtrees.*

Probability distributions on the set of trees are fundamental in evolutionary biology, as models for speciation processes. These probability models for random trees have interesting mathematical features and lead to difficult questions at the boundary of combinatorics and probability. This talk will be concerned with the question of how much two random trees have in common, where the measure of commonality is the size of the largest agreement subtree. The case of maximum agreement subtrees of pairs of random comb trees is equivalent to studying longest increasing subsequences of random permutations, and has connections to random matrices. This elementary talk will try to give a sense of what is known (not very much) and what is unknown (lots!) about this problem. (Received February 13, 2018)

1139-05-300 **Caroline Accurso**, **Vitaliy Chernyshov**, **Leaha Hand** and **Sogol Jahanbekam***, sxjsma@rit.edu, and **Paul Wenger**. *Weak Dynamic Coloring of Planar Graphs.*

The *k-weak-dynamic number* of a graph G is the smallest number of colors we need to color the vertices of G in such a way that each vertex v of degree $d(v)$ sees at least $\min\{k, d(v)\}$ colors on its neighborhood. We use reducible configurations and list coloring of graphs to prove that all planar graphs have 3-weak-dynamic number at most 6. (Received February 14, 2018)

1139-05-311 **Alexander Garver**, **Rebecca Patrias** and **Hugh Thomas***
(hugh.ross.thomas@gmail.com). *Reverse plane partitions via representations of quivers III.*

I will explain how to extend the map discussed in the two previous talks so as to define it on objects in an orbit category of the derived category of representations of a Dynkin quiver. This allows us to give a uniform proof of the periodicity of piecewise-linear promotion on minuscule posets, by showing that promotion corresponds to Auslander-Reiten translation in the orbit category. (Received February 15, 2018)

1139-05-314 **Florian Frick** and **Shira Zerbib*** (zerbib@umich.edu). *Colorful coverings of polytopes – the hidden topological truth behind different colorful phenomena.* Preliminary report.

The topological KKMS Theorem is a powerful extension of Brouwer's Fixed-Point Theorem, proved by Shapley in 1973 in the context of game theory. We prove a colorful and polytopal generalization of the KKMS Theorem, and show that our theorem implies some seemingly unrelated results in discrete geometry and combinatorics involving colorful settings. For example, we apply our theorem to provide a new proof of the Colorful Caratheodory Theorem due to Barany, and also to obtain an upper bound on the piercing numbers in colorful d-interval families, extending results of Tardos, Kaiser and Alon. We further apply our theorem to questions regarding envy-free fair division of goods among a set of players. Joint with Florian Frick. (Received February 15, 2018)

1139-05-323 **Annie Raymond*** (annieraymond@umass.edu), **James Saunderson**, **Mohit Singh** and **Rekha Thomas**. *Symmetric Sums of Squares over k-Subset Hypercubes.*

Polynomial optimization over hypercubes has important applications in combinatorial optimization. We develop a symmetry-reduction method that finds sums of squares certificates for non-negative symmetric polynomials over k-subset hypercubes that improves on a technique due to Gatermann and Parrilo. For every symmetric polynomial that has a sos expression of a fixed degree, our method finds a succinct sos expression whose size depends only on the degree and not on the number of variables. Our results relate naturally to Razborov's flag algebra calculus for solving problems in extremal combinatorics. This leads to new results involving flags and their power in finding sos certificates. This is joint work with James Saunderson, Mohit Singh and Rekha Thomas. (Received February 15, 2018)

1139-05-334 **Ruth Luo*** (ruthluo2@illinois.edu) and **Alexandr Kostochka**. *Uniform hypergraphs without long Berge cycles are sparse.*

The Erdős–Gallai theorem gives an upper bound for the maximum number of edges in a graph with bounded circumference. We prove an analogue of this theorem for hypergraphs: for any $k \geq 4$ and $n > r \geq k+1$, every n-vertex r-uniform hypergraph with no Berge cycle of length at least k has at most $\frac{(k-1)(n-1)}{r}$ edges. Furthermore, this bound is sharp and we describe the extremal hypergraphs. The result also implies as a corollary the theorem of Győri, Katona and Lemons that for $n > r \geq k \geq 3$, every n-vertex r-uniform hypergraph with no Berge path of length k has at most $\frac{(k-1)n}{r+1}$ edges. (Received February 15, 2018)

1139-05-349 **Daniel Glasscock*** (d.glasscock@neu.edu), Boston, MA 02131. *A density polynomial Hales-Jewett theorem: improbable or ineluctable?*

The 1963 theorem of Alfred Hales and Robert Jewett (HJ) maintains to this day a central position in partition Ramsey Theory. Two outstanding generalizations of HJ – the density Hales-Jewett theorem (DHJ) of Furstenberg and Katznelson and the polynomial Hales-Jewett theorem (PHJ) of Bergelson and Leibman – now each have multiple distinct proofs and are well understood. Despite this, extremely little is known about the obvious common generalization between the two: a density polynomial Hales-Jewett (DPHJ) theorem. In this talk, I will briefly recount this history, state the putative DPHJ theorem, demonstrate how such a theorem would be used to quickly derive very strong forms of other combinatorial theorems, and make a call for progress on this beautiful open problem. (Received February 16, 2018)

1139-05-359 **Richard Kenyon*** (rkenyon@math.brown.edu) and **Aaron Abrams**. *Rectangulations with rational-area rectangles.*

We study tilings of polygons with rectangles of rational area. We give number theoretic necessary conditions for tileability, and study the space of deformations changing areas. (Received February 16, 2018)

1139-05-365 **Emily Barnard*** (e.barnard@northeastern.edu) and **Thomas McConville**. *Lattices from Graph Associahedra.* Preliminary report.

Given a graph G on n vertices, Postnikov defined a graph associahedron P_G as an example of a *generalized permutohedron*, a polytope whose normal fan coarsens the braid arrangement. Combinatorially, each face of P_G corresponds to certain collections of compatible subgraphs of G called tubings. Graph associahedra were introduced independently by Carr and Devadoss and by Davis, Januszkiewicz, and Scott. In this talk, we consider the poset obtained by orienting the one-skeleton of P_G according to a (generic) linear functional and its relationship to the weak order on S_n. (Received February 16, 2018)

1139-05-370 **Zhao Wang**, **Chris Melekian*** (ccmeleki@oakland.edu), **Eddie Cheng** and **Yaping Mao**. *Matching preclusion number in product graphs.*

The matching preclusion number of a graph is the minimum number of edges whose deletion results in a graph that has no perfect matchings or almost-perfect matchings. For many interconnection networks, the matching preclusion number is equal to the minimum degree of a vertex in the network, and the sets of edges attaining the minimum are precisely those incident to a single vertex of minimum degree; we say such networks are super matched. In this paper we derive upper and lower bounds for the matching preclusion number for networks constructed using a variety of binary graph operations, and give sufficient conditions for such networks to be super matched. (Received February 16, 2018)

1139-05-404 **Jonah Blasiak*** (jblasiak@gmail.com), **Jennifer Morse**, **Anna Pun** and **Dan Summers**. *Catalan polynomials and k-Schur functions.*

Li-Chung Chen and Mark Haiman studied a family of symmetric functions indexed by pairs consisting of a partition contained in the staircase $(n-1,\ldots,1,0)$ (of which there are Catalan many) and a weight in $\mathbb{Z}^n$. These *Catalan polynomials* include the Hall-Littlewood polynomials and their parabolic generalizations and can be viewed as GL_n-equivariant Euler characteristics of vector bundles on the flag variety. Chen-Haiman conjectured that the k-Schur functions are a subclass of Catalan polynomials. We settle their conjecture and deduce several exciting consequences. (Received February 17, 2018)

1139-05-408 **Steven Simon*** (ssimon@bard.edu). *Hyperplane Equipartitions Plus Constraints.*

While equivariant methods have seen many fruitful applications in geometric combinatorics, their inability to answer the now settled Topological Tverberg Conjecture has made apparent the need to move beyond the use of Borsuk-Ulam type theorems alone. This impression holds as well for one of the most famous problems in the field, dating back to at least 1960, which seeks the minimum dimension $d := \Delta(m;k)$ such that any m mass distributions in $\mathbb{R}^d$ can be simultaneous equipartitioned by k hyperplanes. Precise values of $\Delta(m;k)$ have been obtained in only few cases, and the best-known general upper bound $U(m;k)$ typically far exceeds the conjectured-tight lower bound arising from degrees of freedom. By analogy with the "constraint method" of Blagojević, Frick, and Ziegler for Tverberg-type results, we show how the imposition of further conditions – on the hyperplane arrangements themselves (e.g., orthogonality, prescribed flat containment) and/or the equipartition of additionally prescribed collections of masses by successively fewer hyperplanes ("cascades") – yields a variety optimal results in dimension $U(m;k)$, including in dimensions *below* $\Delta(m+1;k)$, which are still extractable via equivariance. (Received February 17, 2018)

1139-05-419 **Thomas W. Tucker*** (ttucker@colgate.edu), 406 Williston Rd, PO Box 163, Sagamore Beach, MA 02562, and **Undine Leopold**. *Orientation-Reversing Euclidean Symmetry of Closed Surfaces Immersed in 3-Space.* Preliminary report.

Given a finite orientation-reversing isometry group G of Euclidean 3-space E^3, we find which generalized Riemann-Hurwitz equations for G acting on a surface S are realized by an immersion $f : S \to E^3$ in G-general position. The authors had previously done this when G is orientation-preserving, where there are five possibilities for G. For orientation-reversing G, there are nine possibilities. The five where every rotation axis is contained in a reflection plane behave exactly the same as the orientation-preserving case, using standard models for immersions of S/G in E^3/G. The other four possibilities require different ideas. (Received February 18, 2018)

1139-05-427 **Ben Lund*** (lund.ben@gmail.com). *Geometric methods for sum-product problems.*

Erdős and Szemerédi conjectured that, for any finite set A of integers, either the set of sums of pairs of elements of A is nearly as large as possible, or the set of products of pairs of elements of A is nearly as large as possible. This is known as the sum-product conjecture, and many variations have been studied. For finite sets of real or complex numbers, the best results have been obtained by using a geometric approach first developed by Solymosi, and later improved by Konyagin and Shkredov. I will discuss these methods, in the context of giving lower bounds on the size of $(A+A)/(A+A)$. (Received February 18, 2018)

1139-05-443 **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. *Combinatorics of Kostka-Foulkes polynomials.*

Lusztig defined the Kostka-Foulkes polynomial $K_{\lambda\mu}(t)$ as a t-analogue of the multiplicity of a weight μ in the irreducible representation of highest weight λ of a semisimple Lie algebra. This polynomial has remarkable properties, such as being an affine Kazhdan-Lusztig polynomial. Finding combinatorial formulas for $K_{\lambda\mu}(t)$ beyond type A_n has been a long-standing problem. We give the first such formula, for $K_{\lambda,0}(t)$ in type C_n; the special case $\mu = 0$ is, in fact, the most complex one. We use combinatorics of Kashiwara's crystal graphs, as well as a recent non-stable branching rule for the symplectic group due to J.-H. Kwon. Related aspects and applications will also be discussed. (Received February 18, 2018)

1139-05-464 **Marcelo Aguiar*** (maguiar@math.cornell.edu) and **Swapneel Mahajan**. *Möbius functions for real hyperplane arrangements.*

We initiate a theory of noncommutative Möbius functions. The departing point is a classical result of Solomon which states that the algebra of a lattice is split-semisimple. We consider left regular bands, a certain class of idempotent semigroups which arise in connection to real hyperplane arrangements. Such semigroups may be regarded as "noncommutative lattices". Geometry motivates the introduction of objects such as faces, flats, and lunes. Flats and lunes constitute the objects and morphisms of a category. Its incidence algebra contains two distinguished affine subspaces of equal dimension, one of noncommutative zeta functions and the other of noncommutative Möbius functions. The two are in bijection under inversion. Solomon's result and classical facts about Möbius functions are recovered when the semigroup is commutative (and hence a lattice). (Received February 18, 2018)

1139-05-466 **Gabriel Coutinho*** (gabriel@dcc.ufmg.br), Belo Horizonte, MG , Brazil. *Extremal quantum walks.*

This talk will definitely not be about extremal graph theory and will hardly be about quantum walks. But I will introduce some graph properties that are necessary to attain certain quantum walk phenomena and I will ask extremal type of questions about them. I will try to answer some, as well as leave some others to the audience. (Received February 18, 2018)

1139-05-473 **Caroline Terry***, 4176 Campus Drive, College Park, MD 20742. *Jumps in speeds of hereditary properties in finite relational languages.*

A hereditary graph property is a class of finite graphs closed under isomorphism and induced subgraphs. Given a hereditary graph property $\mathcal{H}$, the *speed* of $\mathcal{H}$ is the function which sends n to the number of distinct elements in $\mathcal{H}$ with underlying set $\{1,\dots,n\}$. Not just any function can occur as the speed of hereditary graph property. Specifically, there are discrete "jumps" in the possible speeds. Study of these jumps began with work of

Scheinerman and Zito in the 90's, and culminated in a serious of papers from the 2000's by Balogh, Bollobás, and Weinreich, in which essentially all possible speeds of a hereditary graph property were characterized. In contrast to this, many aspects of this problem in the hypergraph setting have remained unknown. In this talk we present new hypergraph analogues of many of the jumps from the graph setting, specifically those involving the polynomial, exponential, and factorial speeds. The jumps in the factorial range turned out to have surprising connections to model theory, which we also discuss. This is joint work with Chris Laskowski. (Received February 19, 2018)

1139-05-486 **Hiroshi Miki**, **Satoshi Tsujimoto** and **Luc Vinet*** (vinet@crm.umontreal.ca). *Quantum walks on graphs of the ordered 2-Hamming scheme and spin networks.*

It is shown that the hopping of a single excitation on certain triangular spin lattices with non-uniform couplings and local magnetic fields can be described as the projection of quantum walks on graphs of the ordered 2-Hamming scheme. For some values of the parameters the models exhibit perfect state transfer between two summits of the lattice. The bivariate Krawtchouk polynomials of the Tratnik type that form the eigenvalue matrices of the 2-Hamming scheme give the overlaps between the energy eigenstates and the occupational basis vectors. (Received February 19, 2018)

1139-05-496 **Franklin H. J. Kenter*** (kenter@usna.edu) and **Jephian C.-H. Lin**. *On the error of a priori sampling: zero forcing sets and propagation time.*

Zero forcing is an iterative process on a graph used to bound the maximum nullity. The process begins with select vertices colored; the remaining vertices can become colored under a color change rule. The goal is to find a minimum set of vertices such that after iteratively applying the rule, all of the vertices become colored. Of particular interest is the propagation time, the number of steps the rule must be applied in order to color all the vertices of a graph.

We give a purely linear algebraic interpretation of zero forcing: Find a set of vertices S such that for any weighted adjacency matrix $\mathbf{A}$, whenever $\mathbf{A}\mathbf{x} = \mathbf{0}$, the entirety of of $\mathbf{x}$ can be recovered using only $\mathbf{x}_S$, the entries corresponding to S. The key here is that S must be chosen before $\mathbf{A}$. In this light, we are able to give a linear algebraic interpretation of the propagation time: Any error in $\mathbf{x}_S$ effects the error of $\mathbf{x}$ exponentially in the propagation time. This error can be quantitatively measured using newly defined parameters. In this sense, the quality of two zero forcing sets can objectively be compared even if the sets are the same size and their propagation time is the same. Examples and constructions are given. (Received February 19, 2018)

1139-05-497 **Laura Escobar*** (lescobar@illinois.edu) and **Bernd Schober**. *Bijections between symmetric and antisymmetric matrices.* Preliminary report.

We consider matrices with entries in the finite field with q elements where q is a prime power. In [Lewis-Liu-Morales-Panova-Sam-Zhang '11] it is shown that the following sets have the same cardinality and ask for a bijection: invertible $n \times n$ skew-symmetric matrices, invertible $n \times n$ symmetric matrices with zero diagonal, and invertible $(n-1) \times (n-1)$ symmetric matrices. I will describe techniques from Schubert geometry to construct bijections between these sets. Based on joint work with Bernd Schober. (Received February 19, 2018)

1139-05-506 **Andrew T Wilson*** (atwilson0328@gmail.com). *Symmetric group representations and Macdonald eigenoperators.*

We will give an overview of the various symmetric group representations that have come out of the study of Macdonald eigenoperators and discuss what work is still to be done. (Received February 19, 2018)

1139-05-510 **Emanuele Delucchi***, Chemin du Musée 23, 1700 Fribourg, Switzerland. *On posets of components of Abelian arrangements.*

The set of intersection subspaces determined by a finite set of linear hyperplanes has a natural partial order with a rich and well-studied structure. In particular, these posets belong to the class of geometric lattices. Among their many properties there are some of topological flavour, mostly related to the notion of shellability – which, among other things, implies that the order complexes of such posets are Cohen-Macaulay.

The corresponding posets in the more general setting of Abelian arrangements (including the linear, toric and elliptic case) are less well understood. In this talk I will recall their definition and discuss what is known about their structure. I will then focus on topological properties. We prove EL-shellability for arrangements of Weyl type, but we can show that Cohen-Macauleyness holds in general. The main tool for this is a study of group actions on posets. This is joint work with Alessio d'Alì, Noriane Girard and Giovanni Paolini. (Received February 19, 2018)

1139-05-533 **Christin Bibby*** (bibby@umich.edu). *Supersolvable posets.* Preliminary report.
The structure of a supersolvable 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. Based on joint work with Emanuele Delucchi. (Received February 19, 2018)

1139-05-539 **Jonathan Cutler*** (jonathan.cutler@montclair.edu) and **A. J. Radcliffe**.
Supersaturation in extremal enumeration.
Turán's theorem states that the maximum number of edges in 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 $\mathrm{ex}(n, K_{r+1})$, the extremal number of K_{r+1}. Supersaturation in graphs asks 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 G, let $\mathrm{ex}_G(n, H)$ be the maximum number of copies of G 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 February 19, 2018)

1139-05-540 **Michael J Falk***, michael.falk@nau.edu. *Higher resonance in the braid arrangement.* Preliminary report.
We exhibit a new, or newly observed, weak map on the cycle matroid of the complete graph, and examine the consequences for resonance varieties of the braid arrangement, the existence of linear systems providing foliations of configuration space, and the critical locus of $\prod_{i<j}(x_i - x_j)^{a_{ij}}$ for special values of a_{ij}. (Received February 19, 2018)

1139-05-546 **Hanmeng Zhan*** (h3zhan@uwaterloo.ca), Department of Combinatorics and Optimization, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada. *Recent Progress in Discrete Quantum Walks.*
Discrete quantum walks are natural quantization of discrete random walks—we replace the doubly stochastic transition matrix, which updates the probabilities, by a unitary transition matrix U, which updates the amplitudes. With this unitarity requirement, however, U has to act on the arcs rather than the vertices. Thus, more inputs are required to build a discrete quantum walk, apart from the underlying graph. We will construct quantum walks from various combinatorial objects, and explore the connections between properties of these buildings blocks and properties of quantum walks. (Received February 19, 2018)

1139-05-556 **Nadia Lafrenière**, **Franco V Saliola*** (saliola.franco@uqam.ca) and **Stéphanie Schanck**. *Spectral properties of shuffling operators in symmetric group algebras.* Preliminary report.
We present recent progress on our ongoing project to study spectral properties of certain elements of group algebras of symmetric groups. These elements include the random-to-random shuffling operators (Dieker-Saliola, 2018) as well as the symmetrized shuffling operators studied by Reiner, Saliola and Welker (2014). (Received February 19, 2018)

1139-05-605 **Caroline Klivans*** (klivans@brown.edu). *Simplicial resolutions and no k-equal spaces.*
In this talk I will consider the topology of real no k-equal spaces via combinatorial simplicial resolutions. Using this method, we are able to equate the Betti number of the real no k-equal space with the size of a cellular spanning tree of the hypercube. The result demonstrates a new approach to determining the topology of complements of arrangements using combinatorial considerations but with no need of poset analysis.

Joint work with Yuliy Baryshnikov and Nicholas Kosar. (Received February 20, 2018)

1139-05-609 **Rosa Orellana** and **Mike Zabrocki***, York University, 4700 Keele St., Toronto, ON M5B1B4, Canada. *Howe duality and a multiset partition insertion algorithm.*
The partition algebra $P_r(n)$ arises as the commutant algebra of the symmetric group S_n when it acts on $V^{\otimes r}$ and where $V = \mathrm{span}\{v_1, v_2, \ldots, v_n\}$ is the permutation module. We encode this duality in an RSK algorithm on multiset partitions that describes the decomposition. If we look at the extension of how this RSK algorithm is applied to elements in the space of polynomials of degree r in variables $\{x_{ij} : 1 \leq i \leq n, 1 \leq j \leq k\}$, then the commutant of the S_n action on the first index is a multiset partition algebra. (Received February 20, 2018)

1139-05-610 **Karola Mészáros**, Ithaca, NY 14850, and **Alejandro H. Morales***, ahmorales@math.umass.edu, Amherst, MA 01003. *Computing volumes of flow polytopes and Kostant partition functions.*

Flow polytopes of graphs is a rich family of polytopes that include the Pitman-Stanley polytope and the Chan-Robbins-Yuen polytope. Their lattice points are counted by Kostant's vector partition function from Lie theory. In the early 2000s, Postnikov-Stanley and Baldoni-Vergne gave remarkable formulas for their volume and lattice points using the Elliott-MacMahon algorithm and residue computations respectively.

In this talk we will describe the combinatorics of these formulas, including a proof using subdivisions. We will illustrate the subdivision with known and new examples of flow polytopes with surprising volumes.

This is based on joint work with Karola Mészáros. (Received February 20, 2018)

1139-05-617 **Jia Huang**, **Brendon Rhoades*** (`bprhoades@math.ucsd.edu`) and **Travis Scrimshaw** (`tcscrims@gmail.com`). *Symmetric group and Hecke algebra actions on ordered set partitions.*

The *coinvariant algebra* R_n is a graded module for the symmetric group S_n whose properties are governed by the combinatorics of permutations. Given two positive integers $k \leq n$, Haglund, Rhoades, and Shimozono have generalized R_n to a ring $R_{n,k}$ whose properties are governed by the combinatorics of ordered set partitions. We study $R_{n,k}$, together with its 0-Hecke and full Hecke relatives, and describe a 'quantum analog' of the Garsia-Procesi machine for constructing graded modules. Joint with Jia Huang and Travis Scrimshaw. (Received February 20, 2018)

1139-05-635 **William J. Martin*** (`martin@wpi.edu`), Department of Mathematical Sciences, 100 Institute Road, Worcester, MA 01609. *Scaffolds.* Preliminary report.

Star-triangle diagrams are a useful but poorly understood tool in the theory of association schemes. Similar ideas have been used to rule out distance-regular graphs using different language. Meanwhile the same object is encoded in the partition function of link diagrams in the development of spin models.

Let X be a nonempty finite set and let $\mathbb{A}$ be a vector subspace of $\mathsf{Mat}_X(\mathbb{C})$. Consider a digraph $G = (V(G), E(G))$ with edge weight function $w : E(G) \to \mathbb{A}$ and a set $R \subseteq V(G)$ of distinguished nodes. For $|R| = m$, the *scaffold* $\mathsf{S}(G; w, R)$ is then defined as the m^{th} order tensor

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

where $\hat{x}$ is the standard basis vector in $\mathbb{C}^X$ indexed by $x \in X$.

The aim of this talk is to outline a basic theory of scaffolds in the case where $\mathbb{A}$ is the Bose-Mesner algebra of some association scheme. Topics to be discussed include spin models for link invariants, triple intersection numbers for distance-regular graphs and structure theorems for Q-polynomial association schemes. (Received February 20, 2018)

1139-05-636 **Christin Bibby*** (`bibby@umich.edu`). *Toric arrangements associated to root systems.*

From a root system, one can define an arrangement of subtori inside a complex torus. The collection of connected components of intersections of the subtori forms a partially ordered set, called the poset of layers. The Weyl group acts on the complement of the arrangement and on its poset of layers, and we study the (co)homology of each as a representation of the group. Of particular interest are types A, B, C, and D, where the representations stabilize. (Received February 20, 2018)

1139-05-647 **Eugenia O'Reilly-Regueiro*** (`eugenia@im.unam.mx`), Instituto de Matematicas, UNAM, Circuito de la Investigacion Cientifica, Ciudad Universitaria, 04510 Coyoacan, CDMX, Mexico. *Neighbour-transitive codes in odd graphs.*

Let $k \geq 2$ and $\Omega := \{1, \ldots, 2k+1\}$. Then the *Odd graph* O_k *of order* k is the graph whose vertices are the k-subsets of Ω and two vertices are adjacent if and only if they are disjoint. The automorphism group $\mathrm{Aut}(O_k)$ of the odd graph of order k is the symmetric group S_{2k+1} in its natural action on the k-sets of Ω. Now let Γ be a simple graph. A *code* in Γ is a subset C of its vertices, and the *neighbour set* C_1 of C is the set of vertices at distance 1 of C. The automorphism group $\mathrm{Aut}(C)$ of a code C in a graph Γ is the setwise stabiliser of C in $\mathrm{Aut}(\Gamma)$, that is, $\mathrm{Aut}(C)$=$\mathrm{Aut}(\Gamma)_C$. We are interested in codes C within odd graphs for which $G \leq$$\mathrm{Aut}(C)$ is transitive on the set of neighbours C_1. We call codes with an automorphism group G acting this way G-*neighbour-transitive codes*. In this talk we will present some results regarding the possibilities for G and some examples. (Received February 20, 2018)

1139-05-648 **Angela Hicks*** (anh316@lehigh.edu), **Cristina Ballantine**, **Zajj Daugherty**, **Sarah Mason** and **Elizabeth Niese**. *Computing with the Quasisymmetric Power Sums.*

The symmetric functions (SYM) have a number of well known bases: the monomials are dual to the complete homogeneous functions, the forgotten basis is dual to the elementary bases, while the Schur functions and the power sums (up to rescaling) are each self dual. Two related spaces, the quasisymmetric functions (QSYM) and the noncommutative symmetric functions (NSYM) are dual as combinatorial Hopf algebras, and most of these well known bases of SYM have analogues in at least one of QSYM and NSYM. In Gelfand et. al's 1995 paper, they define not just one but two analogues of the power sum basis in NSYM using generating functions. The duals of their bases, up to scaling, are naturally the quasisymmetric power sums, the subject of this talk. In contrast to the simplicity of the symmetric power sums, or the other well known bases of the quasisymmetric functions, the quasisymmetric power sums have a more complex combinatorial description. Thus, although symmetric function proofs often translate directly to quasisymmetric analogues, this is not the case for quasisymmetric power sums. We discuss joint work with Ballantine, Daugherty, Mason, and Niese which explores the properties of these two families of quasisymmetric power sums. (Received February 20, 2018)

1139-05-652 **Aaron Abrams*** (abrams.aaron@gmail.com), Mathematics Department, Washington and Lee University, Lexington, VA 24450. *Some germ-maximal 1-dimensional discrete packings.* Preliminary report.

We investigate some packing problems and distance-avoiding problems in the natural numbers. For a finite set $D \subset \mathbf{N}$ (of distances), a D-avoiding set is a set $S \subseteq \mathbf{N}$ such that if $j, k \in S$ then $j - k \notin D$. J. Propp has defined a partial order on subsets of natural numbers, the *germ order*, that refines both cardinality (for finite sets) and density (in the usual sense); Propp showed that if there exists a germ-maximal D-avoiding set S, then S must be eventually periodic.

We give a collection of D's for which there is a unique germ-maximal S which in addition is periodic (including e.g. any D with $|D| = 2$). We also give examples of D for which there is a unique germ-maximal S which is not periodic; local improvements near the boundary cause only eventual periodicity. It is not known whether every D has a germ-maximal S. (Received February 20, 2018)

1139-05-667 **Deepak Bal*** (deepak.bal@montclair.edu) and **Patrick Bennett**. *The bipartite $K_{2,2}$-free process and Ramsey numbers.* Preliminary report.

The smallest n such that every red-blue edge-coloring of $K_{n,n}$ contains a red $K_{2,2}$ or a blue $K_{t,t}$ is known as the two color bipartite Ramsey number, $br(2,t)$. In the bipartite $K_{2,2}$-free process, we begin with an empty graph on vertex set $A \cup B$, $|A| = |B| = n$. At each step, a random edge from $A \times B$ is added under the restriction that no $K_{2,2}$ is formed. This step is repeated until no more edges can be added. We use the technique of dynamic concentration to analyze this process and show how the resulting graph can be used to improve the best known lower bound on $br(2,t)$. This is joint work with Patrick Bennett. (Received February 20, 2018)

1139-05-677 **Tan Nhat Tran*** (trannhattan@math.sci.hokudai.ac.jp), Sapporo, Japan. *G-Tutte polynomials via arithmetics, combinatorics and topology.*

We introduce and study the notion of the G-Tutte polynomial for a list of elements in a finitely generated abelian group and an abelian group G through arithmetical, combinatorial and topological aspects. The G-Tutte polynomial establishes a common generalization of several "Tutte-like" polynomials such as the Tutte, arithmetic Tutte polynomials and the Tutte, characteristic quasi-polynomials. In the study through its arithmetics, we obtain a connection between the intersection posets of layers of a toric arrangement and the corresponding chromatic quasi-polynomials. About combinatorial consideration, we generalize the notion of characteristic polynomials of hyperplane and toric arrangements to those of abelian Lie group arrangements and give details of the corresponding characteristic polynomials. From the topological viewpoint, we prove that the G-Tutte polynomial is the main character in the formulation of the Poincaré polynomial of a certain abelian Lie group arrangement, which is a generalization of many other classical formulas. This talk is based on two recent joint works with Ye Liu and Masahiko Yoshinaga. (Received February 20, 2018)

06 ► Order, lattices, ordered algebraic structures

1139-06-111 **Cristóbal Rivas*** (cristobal.rivas@usach.cl), Departamento de Matemáticas, Las Sophoras 173, Estación Central, Santiago, RM, Chile. *No positive cone on a hyperbolic surface group is regular (either).* Preliminary report.

A positive cone on a group is the set of positive elements in a left-multiplication invariant total order on the group.

It is known that no positive cone in the fundamental group of a hyperbolic surface is finitely generated as a semigroup (Alonso, Brum, Rivas 2017). In this talk, we will follow the work of Hermiller and Sunic (2017) to show that, moreover, no positive cone on a hyperbolic surface group is determined by a finite-state automaton. (Received February 04, 2018)

1139-06-430 **Jim Lawrence*** (lawrence@gmu.edu), Department of Mathematical Sciences, George Mason University, Fairfax, VA 22030-4444. *Parity representations of posets.*

The notion of a *parity representation* makes transparent some interesting aspects of the *interval poset* (poset of all intervals under inclusion) of a poset. The definition is given and the connection to interval posets is described. The connection is illustrated by reference to the examples of binary partition polytopes and their relatives. (Received February 18, 2018)

1139-06-472 **Michelle Rabideau***, Department of Mathematics, University of Connecticut, 341 Mansfield Road U1009, Storrs, CT 06269-1009, and **Ralf Schiffler**. *Orderings on the Markov numbers.*

Markov numbers are integers that appear in the solution triples of the Diophantine equation, $x^2+y^2+z^2=3xyz$, called the Markov equation. A classical topic in number theory, these numbers are related to many areas of mathematics such as combinatorics, hyperbolic geometry, approximation theory and cluster algebras. In this talk, we consider two conjectures seen in Martin Aigner's book, Markov's theorem and 100 years of the uniqueness conjecture, and proved in our paper that determine an ordering on subsets of the Markov numbers based on their corresponding rational. The proof uses the cluster algebra of the torus with one puncture and a resulting reformulation of the conjectures in terms of continued fractions. (Received February 19, 2018)

11 ► Number theory

1139-11-47 **Andrew Bridy***, andrewbridy@tamu.edu, and **Derek Garton**, gartondw@pdx.edu. *The cycle structure of unicritical polynomials in finite fields.*

Let $f(x)=x^k+a\in\mathbb{Z}[x]$ for $k\geq 2$. Consider the family of dynamical systems given by the action of f on $\mathbb{F}_p$ as p varies among primes. The question of how and in what sense this family approximates a random family of dynamical systems has been studied extensively, motivated in part by Pollard's "rho" algorithm for integer factorization. We show that for most choices of $a\in\mathbb{Z}$, the cycle structure in this family is "as random as possible" in an appropriate sense. As a corollary, we show that most members of these families have many cycles. (Received January 19, 2018)

1139-11-55 **Jacqueline Anderson*** (jacqueline.anderson@bridgew.edu), **Spencer Hamblen**, **Bjorn Poonen** and **Laura Walton**. *Local Arboreal Representations.*

Let $f(z)=z^d-c$ be a separable polynomial over a field K complete with respect to a discrete valuation v and with residue field of characteristic p, and let $a\in K$. Let $f^n(z)$ denote the n-th iterate of f. We examine the Galois groups and ramification groups obtained from the extensions of K containing all of the roots of the polynomial $f^n(z)-a$ in both tame ($p\nmid d$) and wild ($d=p$) cases. The behavior depends upon $v(c)$, and we find that it shifts dramatically as $v(c)$ crosses a certain value: 0 in the tame case and $-p/(p-1)$ in the wild case. (Received January 24, 2018)

1139-11-59 **Xander Faber*** (awfaber@super.org). *Generalizing the Ax/Tate Theorem and Applications to Semi-Stable Reduction.* Preliminary report.

The Ax–Tate theorem (generalized by Sen) describes the fixed points of the action of $G_p=\mathrm{Gal}(\bar{\mathbb{Q}}_p/\mathbb{Q}_p)$ on $\mathbb{C}_p$, the completion of an algebraic closure of $\mathbb{Q}_p$. The G_p-action naturally extends to an action on the Berkovich projective line over $\mathbb{C}_p$, and Bob Rumely and I have been working toward a complete description of the G_p-invariant locus in this more general setting. I will report on our progress, as well as on applications of our work for the theory of semi-stable reduction of dynamical systems. (Received January 24, 2018)

1139-11-64 **Kenneth Allen**, **David DeMark** and **Clayton Petsche*** (petschec@math.oregonstate.edu). *Non-Archimedean Hénon maps, attractors, and horseshoes.*

We study the dynamics of the Hénon map defined over complete, locally compact non-Archimedean fields of odd residue characteristic. We establish basic properties of its one-sided and two-sided filled Julia sets, and we determine, for each Hénon map, whether these sets are empty or nonempty, whether they are bounded or unbounded, and whether they are equal to the unit ball or not. On a certain region of the parameter space we show that the filled Julia set is an attractor. We prove that, for infinitely many distinct Hénon maps over $\mathbb{Q}_3$, this attractor is infinite and supports an SRB-type measure describing the distribution of all nearby forward orbits. We include some numerical calculations which suggest the existence of such infinite attractors over $\mathbb{Q}_5$ and $\mathbb{Q}_7$ as well. On a different region of the parameter space, we show that the Hénon map is topologically conjugate on its filled Julia set to the two-sided shift map on the space of bisequences in two symbols. (Received January 25, 2018)

1139-11-83 **Michael Tobin*** (m.tobin@gmail.com), 1700 Bolton Street, Baltimore, MD 21217. *Advances in Transcendental Number Theory Since the Proof of the Gelfond-Schneider Theorem.*

A survey of the literature of transcendence theory since the proof of the Gelfond-Schnieder Theorem (1934) reveals two divergent tendencies manifested in the work of Alan Baker and Boris Zilber and presaged by the work of Hermite and Cantor, respectively. The first "school," embodied in the work of Baker, uses auxiliary functions to approximate transcendental numbers to natural numbers. The second, represented by Zilber and, distantly, Cantor, seeks to approximate transcendental numbers to complex numbers. The evolution of these somewhat divergent techniques is observed in the ensuing literature and analyzed. The synthetic ramifications of a turn toward computer science modeling and thinking are accounted for and evaluated, especially the research that was sparked by the appearance of Daniel Richardson's (1968) "Some Undecidable Elementary Functions of a Real Variable." An ambient assessment of the current state of transcendence theory is made on this basis, specifically in regard to the synthetic implications of computer science applications in the field. (Received January 30, 2018)

1139-11-108 **David S Dummit**, **John Voight*** (jvoight@gmail.com) and **Richard Foote**. *The 2-Selmer group of a number field and heuristics for narrow class groups and signature ranks of units.*

We investigate in detail a homomorphism which we call the 2-Selmer signature map from the 2-Selmer group of a number field K to a nondegenerate symmetric space, in particular proving the image is a maximal totally isotropic subspace. Applications include precise predictions on the density of fields K with given narrow class group 2-rank and with given unit group signature rank. In addition to theoretical evidence, extensive computations for totally real cubic and quintic fields are presented that match the predictions extremely well. (Received February 04, 2018)

1139-11-120 **John Cullinan***, Department of Mathematics, Bard College, Annandale-On-Hudson, NY 12504. *On the local-global principle for torsion on elliptic curves.* Preliminary report.

Fix an integer $m > 1$. Let E be an elliptic curve over $\mathbf{Q}$ with the property that $\#E(\mathbf{F}_p)$ is divisible by m for all but finitely many primes p. While E is isogenous to an elliptic curve E' such that $\#E'(\mathbf{Q})_{\text{tors}}$ is divisible by m, but it may not be the case that $\#E(\mathbf{Q})_{\text{tors}}$ is divisible by m. Ordered by height, we show the probability that a curve with $m \mid \#E(\mathbf{F}_p)$ also has $m \mid \#E(\mathbf{Q})_{\text{tors}}$ is nonzero and we compute the probability explicitly in several cases. This is joint work with John Voight. (Received February 05, 2018)

1139-11-130 **Eva Bayer-Fluckiger*** (eva.bayer@epfl.ch), **Tingyu Lee** and **Raman Parimala**. *Hasse Principles for Multinorm Equations.*

A classical result of Hasse states that the norm principle holds for finite cyclic extensions of global fields, in other words local norms are global norms. We investigate the norm principle for finite dimensional commutative etale algebras over global fields; since such an algebra is a product of separable extensions, this is often called the multinorm principle. Under the assumption that the etale algebra contains a cyclic factor, we give a necessary and sufficient condition for the Hasse principle to hold, in terms of an explicitly constructed element of a a finite abelian group. This can be seen as an explicit description of the Brauer-Manin obstruction to the Hasse principle. (Received February 05, 2018)

1139-11-138 **Ted Chinburg*** (ted@math.upenn.edu), Dept. of Math, U. Penn., 209 S. 33rd Street, Philadelphia, PA 19104. *Higher codimension Iwasawa theory.* Preliminary report.

This will be a report on recent work with F. Bleher, R. Greenberg, M. Kakde, R. Sharifi and M. J. Taylor on the higher dimensional support of Iwasawa modules. This support has to do with the leading term in the growth of various arithmetic invariants of number fields when the first order terms vanish. I will describe a result about codimension two support over arbitrary CM fields, generalizing prior work over imaginary quadratic fields. (Received February 06, 2018)

1139-11-166 **Jamie Juul*** (jjuul@amherst.edu) and **Robert L Benedetto**. *Odoni's Conjecture.* Preliminary report.

Let K be a field and $f(x) \in K[x]$ be a polynomial of degree $d > 1$. We can consider extensions of K formed by adjoining preimages of any point $x_0 \in K$ under iterates of $f(x)$, $K(f^{-n}(x_0))$. In 1985, Odoni showed that the Galois group $\mathrm{Gal}(K(f^{-n}(x_0))/K)$ can be embedded in $[S_d]^n$. In the same paper, Odoni conjectured for any $d > 1$ and number field or function field (or more generally, Hilbertian field) K, there is at least one $f(x) \in K[x]$ of degree d so that $\mathrm{Gal}(K(f^{-n}(0))/K) \cong [S_d]^n$ for all n. We discuss recent progress on this conjecture. This is joint work with Rob Benedetto. (Received February 07, 2018)

1139-11-234 **Nicole Romain Looper*** (nlooper@math.northwestern.edu), Department of Mathematics, Northwestern University, 2033 Sheridan Road, Evanston, IL 60208. *A lower bound on the canonical height for polynomials.*

The canonical height associated to a rational function defined over a number field measures arithmetic information about the forward orbits of points under that function. Silverman conjectured that given any number field K and degree d at least 2, there is a uniform lower bound on the canonical heights associated to degree d rational functions defined over K, evaluated at points of K having infinite forward orbit. I will discuss a proof of such a lower bound across large families of polynomials. (Received February 12, 2018)

1139-11-237 **Wade Hindes*** (whindes@gc.cuny.edu). *Integral points, primitive primes, and arithmetic distances in characteristic p.* Preliminary report.

Let K be a global field of positive characteristic. We use Riccati equations to define a Zariski open subset of Rat_d on which one can estimate certain arithmetic distance functions for points in orbits. In particular, we use these estimates to prove a version of Silverman's integral point theorem in this setting. Moreover, with some additional information coming from deformation theory, we outline how one might prove a primitive prime divisor theorem for rational functions. (Received February 12, 2018)

1139-11-244 **Brandon Alberts*** (blalberts@math.wisc.edu). *Certain Unramified Metabelian Extensions Using Lemmermeyer Factorizations.*

We study solutions to the Brauer embedding problem with restricted ramification. More specifically, suppose G and A are finite abelian groups, E is a central extension of G by A, and $f : \mathrm{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \to G$ is a continuous homomorphism. We determine conditions on the discriminant of f that are equivalent to the existence of an unramified lift $\widetilde{f} : \mathrm{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \to E$ of f.

As a consquence, we use conditions on the discriminant of an abelian extension $K/\mathbb{Q}$ to classify unramified extensions L/K normal over $\mathbb{Q}$ where the (nontrivial) commutator subgroup of $\mathrm{Gal}(L/\mathbb{Q})$ is contained in its center. This generalizes a result due to Lemmermeyer stating that the quadratic field of discriminant d, $\mathbb{Q}(\sqrt{d})$, has an unramified extension $M/\mathbb{Q}(\sqrt{d})$ normal over $\mathbb{Q}$ with $\mathrm{Gal}(M/\mathbb{Q}(\sqrt{d})) = H_8$ (the quaternion group) if and only if the discriminant factors $d = d_1d_2d_3$ into a product of three coprime discriminants, at most one of which is negative, satisfying

$$\left(\frac{d_id_j}{p_k}\right) = 1$$

for each choice of $\{i,j,k\} = \{1,2,3\}$ and prime $p_k \mid d_k$. (Received February 12, 2018)

1139-11-270 **Lauren Heller**, **Ján Mináč** and **Andrew Schultz*** (andrew.c.schultz@gmail.com), 106 Central St., Department of Mathematics, Wellesley, MA 02481. *Module structure of Artin-Scheier theory for rank 2 elementary p-abelian extensions.* Preliminary report.

We discuss recent progress in computing the Galois module structure of $K/\wp(K)$ when $\mathrm{Gal}(K/F) \simeq \mathbb{Z}/p \oplus \mathbb{Z}/p$; here K is a field of characteristic p, and $K/\wp(K)$ is the classifying space for elementary p-abelian extensions of K. When viewed as a Galois module, this space parameterizes those elementary p-abelian extensions of K that are additionally Galois over F. This project is one of the few in which the module structure for such a parameterizing space has been computed when the base extension is non-cyclic, though the results we obtain have a similar flavor to analogous results in the cyclic case. We also present current work in extending these results to groups of higher rank. (Received February 13, 2018)

1139-11-313 **Sara Checcoli***, 100, rue des maths, 38610 Gières, Grenoble, France. *Fields of algebraic numbers with non-uniformly bounded local degrees and their Galois groups.*

It is known that, if K is a number field and L/K is an infinite Galois extension, then the local degrees of L are uniformly bounded at all rational primes if and only if $\mathrm{Gal}(L/K)$ has finite exponent.

Also motivated by some problems concerning the Bogomolov property (on the existence of a lower bound for the elements of non-zero height in a field), one can ask whether the simple non-uniform boundedness of the local degrees is still equivalent to some (weaker) group theoretical property.

We will show that this is not the case in general, by exhibiting several groups that admit two different realisations over a given number field, one with bounded local degrees at a given set of primes and one with infinite local degrees at the same primes. (Received February 15, 2018)

1139-11-374 **Benjamin K Breen*** (benjamin.k.breen.gr@dartmouth.edu). *Heuristics for narrow class groups in number fields of even degree.* Preliminary report.

We extend the work of Dummit-Voight on heuristics for narrow class groups and unit signature ranks of number fields of odd degree to the case of even degree. In this case an obstruction occurs from classes of the 2-Selmer group represented by rational numbers. We explore how this affects our model and provide computational evidence for our heuristics in the case of totally real quartic fields with Galois closure S4. (Received February 16, 2018)

1139-11-405 **Cara Mullen***, cmullen@harpercollege.edu. *p-adic Hubbard Trees.*

In one-dimensional complex dynamics, the forward orbit of the critical points completely determine the dynamical behavior of a polynomial f. If all such orbits are finite, the polynomial is *post-critically finite* (PCF), and it has an associated Hubbard tree which can capture that behavior. In particular, the Hubbard tree illustrates the *orbit type* of a critical point α, the minimal pair (m, n) such that $f^{m+n}(\alpha) = f^m(\alpha)$, and the geometry of these orbits within the Julia set of f. Hubbard trees have been well studied, and a full classification of finite critical orbit trees is known in this setting. The goal of this talk is to begin to answer the question: What are the analogous objects in a non-Archimedean setting? We explore the critical orbits and corresponding trees for quadratic polynomials of the form $f_c(z) = z^2 + c$ defined over $\mathbb{Z}_p$. (Received February 17, 2018)

1139-11-415 **Patrick M Ingram*** (pingram@yorku.ca). *Laurent polynomials and critical heights of singular perturbations.* Preliminary report.

A singular perturbation of a polynomial $P(z) \in \mathbb{C}[z]$ is a rational function of the form $f(z) = P(z) + \frac{\epsilon}{(z-\beta)^e}$, where β is often taken to be a periodic and/or critical point for P. We investigate what one can say about the arithmetic complexity of the critical orbits of f compared to those of P. (Received February 18, 2018)

1139-11-436 **Henri R Darmon*** (henri.darmon@mcgill.ca) and **Jan Vonk**. *Values of meromorphic cocycles and fourier coefficients of p-adic modular forms.*

Recently the authors made a numerical study of the values at "real multiplication points" of certain rigid meromorphic cocycles on the Drinfeld upper-half plane, conjecturing that these values generate class fields of real quadratic fields. We explain how they can be expressed as the fourier coefficients of certain p-adic modular forms, and how this leads to evidence for their algebraicity, following an old strategy of Siegel which will be recalled. (Received February 18, 2018)

1139-11-441 **Jiuya Wang*** (jiuyawang@math.wisc.edu), jiuyawang@math.wisc.edu, Madison, WI 53705. *Malle's conjecture for compositum of number fields.*

Malle's conjecture is a conjecture on the asymptotic distribution of number fields with bounded discriminant. We propose a general framework to prove Malle's conjecture for compositum of number fields based on known examples of Malle's conjecture and good uniformity estimates. By this method, we prove Malle's conjecture for $S_n \times A$ number fields for $n = 3, 4, 5$ and A in an infinite family of abelian groups. As a corollary, we show that Malle's conjecture is true for $C_3 \wr C_2$ in its S_9 representation, whereas its S_6 representation is the first counter example of Malle's conjecture given by Kl üners. (Received February 18, 2018)

1139-11-463 **Nigel Boston*** (boston@math.wisc.edu), Department of Mathematics, University of Wisconsin, Madison, WI 53706, and **Michael R. Bush** and **Farshid Hajir**. *Heuristics for p-class towers.* Preliminary report.

In previous work the authors developed heuristics for the Galois group of the p-class tower of K as K runs through imaginary quadratic or real quadratic fields (p an odd prime). We now report on investigations and possible heuristics for more general familes of fields K. In particular we consider in detail the case of K a cyclic cubic field (where p is a prime other than 3). (Received February 18, 2018)

1139-11-515 **Thomas J Tucker*** (tjtucker@gmail.com), Math Dept, University of Rochester, Rochester, NY 14627, and **Wayne Peng**, Math Dept, University of Rochester, Rochester, NY 14627. *When can two arboreal representations be isomorphic?*

Let K be a number field. Let f and g be polynomials of degree greater than one over K, let a and b two elements of K, and let $T_f(a)$ and $T_g(b)$ be the rooted tree of inverse images of a and b under iteration of f and g. We present a conjecture on when $T_f(a)$ and $T_g(b)$ can be Galois isomorphic. This may be seen as an a dynamical analog of the Tate isogeny theorem. (Received February 19, 2018)

1139-11-520 **Laura S. Walton***, 151 Thayer Street, Box 1917, Providence, RI 02912. *Counting periodic points on quotients of varieties over* $\mathbb{F}_q$.

Let V be a quasiprojective variety defined over $\mathbb{F}_q$, and let $\phi : V \to V$ be an endomorphism of V that is also defined over $\mathbb{F}_q$. Let G be a finite subgroup of $\mathrm{Aut}_{\mathbb{F}_q}(V)$ with the property that ϕ commutes with every element of G. We show that periodic point counts for the endomorphism on V/G induced by ϕ are related to periodic point counts on V and all of its twists by G. (Received February 19, 2018)

1139-11-566 **Rafe Jones*** (rfjones@carleton.edu) and **Wade Hindes**. *Primitive prime divisors in polynomial orbits over function fields.*

We prove, for a large class of polynomials defined over a function field K of any characteristic, that an infinite orbit must have only finitely many terms without a primitive prime divisor. The key step is to show that points in backwards orbits cannot satisfy certain first-order differential equations known as Riccatti equations. As an application, we study the arboreal representation of some families of non-isotrivial polynomials over function fields of characteristic p, and show in some cases their image has finite index in the automorphism group of the appropriate rooted tree. These are the first large-image examples we know of in the characteristic p, non-isotrivial case. (Received February 19, 2018)

1139-11-573 **Adam D Towsley*** (adtsma@rit.edu), 59 Cheswell Way, Brighton, NY 14610. *Randomness in* $\bmod p$ *orbits.*

Let $\varphi(x) = x^3 + c$ and S be the set of primes which are $2 \bmod 3$. Consider a prime $p \in S$, the polynomial φ induces as permutation of $\mathbb{F}_p$. If we allow p to vary in S the permuation of $\mathbb{F}_p$ induced by $\varphi(x)$ seems to exhibit random behavior. We present several properties, along with supporting data, that would be observed if the induced permuations change randomly. (Received February 19, 2018)

1139-11-585 **Yuan Liu*** (yliu@math.wisc.edu). *A Non-abelian Version of the Cohen-Lenstra Probability Measure.*

We construct a model of random groups that is a non-abelian version of the random groups that feature in the Cohen-Lenstra heuristics. This random group is obtained from, as n goes to infinity, the free group on n generators modulo $n + u$ random relations. In this talk, we will use this model to define a probability measure on the space of profinite groups and discuss known results about the distribution of non-abelian analogs of class groups that motivate our work. This is a joint work with Melanie Metchatt Wood. (Received February 20, 2018)

1139-11-591 **Michelle Manes*** (mmanes@math.hawaii.edu), Department of Mathematics, 2565 McCarthy Mall, Keller 401A, Honolulu, HI 96822. *Dynamical Belyi Maps.*

We study the dynamical properties of two infinite families of PCF rational maps on $\mathbb{P}^1$ with exactly three ramification points. We describe these maps in three equivalent ways: as self-maps of $\mathbb{P}^1$, as combinatorial data, and as dessins d'enfants. We also describe ongoing work to study the arboreal Galois representations of these maps, extending recent work of Benedetto et al. The two projects are joint with (1) Bella Tobin and Gabbie Melamed, and (2) Jackie Anderson, Irene Bouw, Ozlem Ejder, Neslihan Girgin, Valentijn Karemaker. (Received February 20, 2018)

1139-11-595 **Ravi Ramakrishna*** (ravi@math.cornell.edu), Math Dept., Cornell University, Ithaca, NY 14853-4201. *Root Discriminant bounds in infinite towers number fields.* Preliminary report.

This talk will be a report on recent joint work in progress with Hajir and Maire on root discriminant bounds in towers of number fields. We will give examples of infinite totally real and totally complex towers of number fields, $\{K_n\}$, with new records on limsup $\mathrm{Disc}(K_n)^{1/[K_n:\mathbb{Q}]}$. (Received February 20, 2018)

1139-11-684 **tsz ho chan** (tchan@memphis.edu) and **máté wierdl*** (wierdlmate@gmail.com). *Random differences of arithmetic progressions in the primes.*

What kind of numbers can occur as differences of prime numbers? The twin prime conjecture says that there are infinitely many prime pairs p_1, p_2 so that the difference $p_1 - p_2$ is from the singleton $\{2\}$. Green, Tao and Ziegler prove that there are infinitely many prime pairs p_1, p_2 so that the difference $p_1 - p_2$ is a cube.

In this talk we are interested in possible difference sets for the primes which are randomly generated. The simplest example would be to generate this random set by repeatedly flipping a fair coin. But we will look at sets that are random versions of known sets of 0 density. For example, we get the set of "random squares" by taking the integer n into the random set with probability $\frac{1}{\sqrt{n}}$ or we get the set of "random cubes" by taking n into the random set with probability $\frac{1}{n^{2/3}}$.

We will discuss two generalizations: one, when we consider not the whole set of primes but positive density subsets of it, and two, when we look at not just differences between primes, but differences of three or longer term arithmetic progressions of primes.

As can be suspected, there are more questions than answers. (Received February 20, 2018)

12 ► Field theory and polynomials

1139-12-250 **Jan Minac*** (minac@uwo.ca), Western University, Department of Mathematics, Middlesex College, 1151 Richmond Street, London, Ontario N6A 5B7, Canada. *A Romantic Courtship of Massey Products, Koszul Algebras and Galois p-extensions.* Preliminary report.

Although neither Massey products nor the theory of Galois p-extensions and Koszul algebras may be considered young anymore, they have found new love together. Will this love blossom into a serious relationship? We shall discuss some relatively recent conjectures on the vanishing of Massey products in Galois cohomology, Koszulity properties of Galois cohomology, some progress in proving them, and their influence on the structure of maximal pro-p-quotients of absolute Galois groups.

This talk will include some joint work with P. Guillot, M. Palaisti, F. Pasini, C. Quadrelli, N. D. Tan, A. Topaz and O. Wittenberg. (Received February 12, 2018)

1139-12-622 **Daniele Bartoli** and **Ariane Masuda***, 300 Jay Street, Brooklyn, NY 11201, and **Luciane Quoos**. *Permutation polynomials over $\mathbb{F}_{q^2}$ from rational functions.* Preliminary report.

We discuss a method for constructing permutation polynomials over $\mathbb{F}_{q^2}$ by using rational functions that induce bijections either on the set μ_{q+1} of the $(q+1)$-th roots of unity or between μ_{q+1} and $\mathbb{F}_q \cup \{\infty\}$. (Received February 20, 2018)

13 ► Commutative rings and algebras

1139-13-74 **Alessandro De Stefani***, Department of Mathematics, University of Nebraska - Lincoln, NE 68588, and **Eloísa Grifo** and **Luis Núñez-Betancourt**. *Local cohomology of F-pure rings.*

We present some results concerning local cohomology modules of a local (or standard graded) F-finite and F-pure ring $(R, \mathfrak{m})$. More specifically, we provide certain ranges in which the Lyubeznik numbers of R vanish, and we give a formula to compute them in the case when R is standard graded. Finally, if we write R as a quotient of a regular ring S by an ideal I, we show that every associated prime of the local cohomology modules $\mathrm{H}^j_I(S)$ is compatible. This talk is based on joint work with E. Grifo and L. Núñez-Betancourt. (Received January 28, 2018)

1139-13-85 **Hans Schoutens*** (hschoutens@citytech.cuny.edu). *Ordinal length and local cohomology.*

The submodules in a Noetherian module are well-ordered for reverse inclusion, and the longest chain obtained this way is called the ordinal length of the module. I will show that this ordinal can be calculated via local cohomology. Conversely, by duality, we can also associate an ordinal length to any local cohomology group, thus obtaining a finitistic invariant measuring the local cohomology group. (Received January 31, 2018)

1139-13-87 **Saeed Nasseh***, Georgia Southern University, and **Sean Sather-Wagstaff**, **Ryo Takahashi** and **Keller VandeBogert**. *Applications of fiber product rings.* Preliminary report.

We investigate homological properties of non-trivial fiber products of local rings with a common residue field and discuss some applications. For instance, we show that the (uniform) Auslander condition is not preserved under localization. (Received January 31, 2018)

1139-13-147 **Jenny Kenkel*** (kenkel@math.utah.edu). *Local Cohomology of Thickenings.* Preliminary report.

Abstract: Let k be a field, and consider an $m \times n$ matrix X, whose entries are independent indeterminates over k. Let $R = k[X]$, and set I_n to be the ideal generated by the size n minors of X, and consider the residue class rings, R/I_n, known as determinantal rings. I will discuss local cohomology of the thickenings R/I_n^t in both characteristic 0 and p, and how an interesting calculation of such a cohomology module reduces to a calculation over a hypersurface. (Received February 06, 2018)

1139-13-168 **Michael DiPasquale*** (mdipasq@okstate.edu), OSU Mathematics Department, 401 Mathematical Sciences Building, Stillwater, OK 74078. *A homological approach to freeness of multi-arrangements.*

Given a multi-arrangement of hyperplanes, we present a co-chain complex derived from work of Brandt and Terao on k-formality whose exactness encodes freeness of the multi-arrangement. The cohomologies of this co-chain complex thus present obstructions to freeness of multi-arrangements. We use this criterion to give some new examples of the behavior of multi-arrangements in moduli, as well as a new family of examples which fails Orlik's conjecture. This builds on previous work with Francisco, Schweig, Mermin, and Wakefield. (Received February 07, 2018)

1139-13-219 **Mehdi Garrousian**, **Aron Simis** and **Stefan Tohaneanu***, University of Idaho, Department of Mathematics, Moscow, ID 83844. *A blowup algebra of hyperplane arrangements.*

We show that the Orlik-Terao algebra of a central arrangement of n hyperplanes is graded isomorphic to the special fiber of the ideal I generated by the $(n-1)-$fold products of the defining linear forms. This momentum is carried over to the Rees algebra (blowup) of I and it is shown that this algebra is of fiber-type and Cohen-Macaulay. It follows by a result of Simis-Vasconcelos that the special fiber of I is Cohen-Macaulay, thus giving another proof of a result by Proudfoot-Speyer about the Cohen-Macaulayness of the Orlik-Terao algebra. (Received February 12, 2018)

1139-13-223 **Robert M Walker*** (robmarsw@umich.edu), 530 East Church Street, 2070 East Hall, ANN ARBOR, MI 48109. *Hearing the Limiting Shape of a Hypersurface Configuration.* Preliminary report.

There is a body of work on limiting shapes of symbolic generic initial systems (by Mayes, and separately by Dumnicki, Szemberg, Szpond, and Tutaj-Gasinska). In particular, the latter four authors compute the limiting shape for ideals defining zero-dimensional star configurations in projective space. In this talk, we discuss work-in-progress anticipating how to generalize their computation to the case of ideals defining zero-dimensional configurations in projective space determined by hypersurfaces of a common fixed degree. Along the way, we draw connections to a 2015 investigation of select homological and asymptotic properties of hypersurface and matroidal configurations by Geramita, Harbourne, Migliore, and Nagel. (Received February 12, 2018)

1139-13-235 **Laura Ghezzi*** (lghezzi@citytech.cuny.edu). *Reduction numbers and multiplicity of the Sally module.*

We show how the reduction number of a primary ideal in a 2-dimensional Buchsbaum local ring can be bounded by the multiplicity of the Sally module and the Buchsbaum invariant of the ring. Our investigation led us to the study of several properties of the Sally module in general Noetherian rings. In ongoing work, we extend some of these properties to the Sally module of more general filtrations, with special focus on the normal filtration. This is joint work with S. Goto, J. Hong and W. Vasconcelos. (Received February 12, 2018)

1139-13-295 **Andrew R. Kustin*** (kustin@math.sc.edu), **Liana M. Sega** and **Adela Vraciu**. *Compressed local Artinian rings.*

We define a notion of compressed local Artinian ring that does not require the ring to contain a field. (Received February 14, 2018)

1139-13-341 **Eloísa Grifo*** (eloisa.grifo@virginia.edu), eloisa.grifo@virginia.edu. *Applying homological algebra to a problem on symbolic powers.* Preliminary report.

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 February 15, 2018)

1139-13-353 **Chloe I. Avery**, **Caitlyn Booms**, **Timothy M. Kostolansky** and **Susan Loepp***, 33 Stetson Ct., Williams College, Williamstown, MA 01267, and **Alex Semendinger**. *Completions of Noncatenary Local Domains.*

We first find necessary and sufficient conditions for a complete local ring to be the completion of a noncatenary local domain. This result can be used to find a large class of quasi-excellent local domains that are not excellent, as well as a large class of catenary domains that are not universally catenary. We then find necessary and sufficient conditions for a complete local ring to be the completion of a noncatenary local unique factorization domain. Finally, we use our second result to show that there is no bound on how noncatenary a unique factorization domain can be. (Received February 16, 2018)

1139-13-385 **Ezra Miller*** (ezra@math.duke.edu). *Data structures for real multiparameter persistence modules.*

Persistent homology with multiple real parameters is multigraded commutative algebra over polynomial rings with real exponents. For that context and beyond, a theory of modules over arbitrary posets is developed to define computationally feasible, topologically interpretable data structures, in terms of birth and death of homology classes. The noetherian hypothesis, which routinely fails in the presence of real exponents, is replaced in the general setting of modules over posets by a *finitely encoded* condition, defined combinatorially and developed algebraically. The finitely encoded hypothesis captures topological tameness of persistent homology, and poset-modules satisfying it can be specified by *fringe presentations* that reflect birth-and-death descriptions of persistent homology. The geometric and algebraic theory of modules over posets is further developed along classical lines over real-exponent semigroup rings, with complete theories of minimal primary and secondary decomposition, associated and attached faces, minimal generators and cogenerators, socles and tops, Matlis duality, and minimal fringe presentation. (Received February 17, 2018)

1139-13-416 **Sabine El Khoury*** (se24@aub.edu.lb) and **Andrew Kustin**. *The structure of Gorenstein-linear resolutions of Artinian algebras.*

Let $S = k[x_1, \ldots x_d]$ be the polynomial ring over a field k, and I a homogenous grade d Gorenstein linearly presented ideal generated by forms of degree n. Assume that $3 \leq d$ and $2 \leq n$. We give the structure of the minimal homogeneous resolution $\mathbf{B}$ of S/I by free S-modules, and describe explicitly the maps in terms of the coefficients of the Macaulay inverse system of I. This is a joint work with Andrew Kustin. (Received February 18, 2018)

1139-13-442 **Courtney R Gibbons***, 198 College Hill Road, Math Department, Hamilton College, Clinton, NY 13323, and **Robert Huben** and **Branden Stone**. *Recursive Strategy for Decomposing Betti Diagrams of Complete Intersections.*

We introduce a recursive decomposition algorithm for the Betti diagram of a complete intersection using the diagram of a smaller complete intersection. This alternative algorithm is the main tool that we use to investigate stability and compatibility of the Boij-Söderberg decompositions of related diagrams; indeed, when the biggest generating degree is sufficiently large, the alternative algorithm produces the Boij-Söderberg decomposition. (Received February 18, 2018)

1139-13-469 **Olgur Celikbas*** (olgur.celikbas@math.wvu.edu), West Virginia University, Department of Mathematics, Morgantown, WV 26506, and **Tokuji Araya** (araya@das.ous.ac.jp), Department of Applied Science, Faculty of Science, Okayama University of Science, Okayama, 700-0005, Japan. *Reducing Invariants and total reflexivity.* Preliminary report.

Throughout R is a commutative Noetherian local ring and R-modules are assumed to be finitely generated.

Recall a reflexive R-module M is called totally reflexive if $\mathrm{Ext}^i_R(M,R)=0=\mathrm{Ext}^i_R(M^*,R)$ for all $i\geq 1$, where $M^*=\mathrm{Hom}_R(M,R)$. The totally reflexive modules are precisely the nonzero modules of Gorenstein dimension zero. In 2006 Jorgensen and Şega proved the conditions defining total reflexivity are independent: they constructed a ring R, and a reflexive R-module M such that $\mathrm{Ext}^i_R(M,R)=0\neq\mathrm{Ext}^i_R(M^*,R)$ for all $i\geq 1$.

I will report on an ongoing joint work with Tokuji Araya. In view of the aforementioned result, we consider the problem of determining new conditions, under which the vanishing of $\mathrm{Ext}^i_R(M,R)$ forces M to be totally reflexive. Motivated by the definition of reducible complexity, a notion studied by Bergh, we introduce the reducing versions of standard homological dimensions.

In this talk we will raise some questions and discuss one of our results in this direction: if a module M has finite reducing Gorenstein dimension and $\mathrm{Ext}^i_R(M,R)=0$ for all $i\geq 1$, then M is totally reflexive. (Received February 19, 2018)

1139-13-485 **Rasoul Ahangari Maleki** and **Liana Şega*** (segal@umkc.edu). *The absolutely Koszul and Backelin-Roos properties for spaces of quadrics of small codimension.*

Let k be a field and let R be a quadratic standard graded k-algebra with $\dim_k R_2\leq 3$. We construct a graded surjective Golod homomorphism $\varphi\colon P\to R$ such that P is a complete intersection of codimension at most 3. Furthemore, we show that R is absolutely Koszul (that is, every finitely generated R-module has finite linearity defect) if and only if R is Koszul if and only if R is not a trivial fiber extension of a non-Koszul and non-Artinian quadratic algebra of embedding dimension 3. In particular, we recover earlier results on the Koszul property of Backelin, Conca and D'Alì. (Received February 19, 2018)

1139-13-487 **Lars Winther Christensen*** (lars.w.christensen@ttu.edu), **Oana Veliche** and **Jerzy Weyman**. *Linkage classes of grade* 3 *perfect ideals.* Preliminary report.

Let Q be a regular local ring and $I\subset Q$ a perfect ideal of grade 3. We prove that I is linked to a complete intersection or a Golod ideal. This means that understanding which grade 3 perfect ideals are *licci* (in the linkage class of a complete intersection) comes down to understanding the case of Golod ideals. In the talk I will relate this to our recent conjecture about the licci property of grade 3 perfect ideals. (Received February 19, 2018)

1139-13-505 **Courtney Gibbons**, **David A. Jorgensen*** (djorgens@uta.edu) and **Janet Striuli**. *On complete intersection dimension.* Preliminary report.

We give an alternate definition of finite complete intersection dimension for modules over commutative local rings. We show that many of the properties of modules having finite complete intersection dimension under the original definition (due to Avramov, Gasharov and Peeva) also hold for modules of finite complete intersection dimension under our alternate definition. We also exhibit some properties of the alternate definition not known for the original one. (Received February 19, 2018)

1139-13-525 **Lars Winther Christensen**, **Oana Veliche** and **Jerzy M Weyman***, Department of Mathematics, University of Connecticut, Storrs, CT 06269. *On the structure of almost complete intersections of codimension three.* Preliminary report.

We give an equivariant canonical form of almost complete intersection ideals of codimension three. (Received February 19, 2018)

1139-13-530 **Rebecca R.G.*** (rirebhuh@syr.edu), **Claudia Miller** and **Hamid 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 February 19, 2018)

1139-13-567 **Ela Celikbas*** (ela.celikbas@math.wvu.edu), **Olgur Celikbas**, **Shiro Goto** and **Naoki Taniguchi**. *Generalized Gorenstein Arf Rings.* Preliminary report.

In 1971, Lipman proved that, if $(R, \mathfrak{m})$ is a complete, saturated, one-dimensional commutative Noetherian local domain with an algebraically closed field of characteristic zero, then R has minimal multiplicity, i.e., the embedding dimension of R equals the multiplicity of R. In his proof, Lipman used the fact that such a ring R is an Arf ring, i.e., R satisfies a condition introduced and studied by Arf in 1949 pertaining to a certain classification of curve singularities. The defining condition of an Arf ring is easy to state: if R is as above, then R is Arf provided, whenever $0 \neq x \in \mathfrak{m}$ and $y/x,\ z/x \in \mathrm{Frac}(R)$ are integral over R, one has that $yz/x \in R$.

Goto and Kumashiro have recently introduced the notion of a generalized Gorenstein ring which is one of the generalizations of the Gorenstein property. A general Gorenstein ring is defined by a certain embedding of the ring into its canonical module. The class of generalized Gorenstein rings is a new class, strictly contained between the class of Cohen-Macaulay rings and that of Gorenstein rings.

In this talk we give a characterization of local rings that are both generalized Gorenstein and Arf. This is a joint work with Olgur Celikbas, Shiro Goto, and Naoki Taniguchi. (Received February 19, 2018)

1139-13-588 **Janet Page*** (jpage8@uic.edu). *Frobenius Complexity for Pairs.*

Given a commutative ring R of characteristic $p > 0$, its Frobenius complexity is a measure of the non-finite generation of its total Cartier algebra, which is the ring of all p^{-e}-linear maps on R and can be thought of as the ring of all potential Frobenius splittings. In this talk, I will review some prior results on Frobenius complexity and explain why it is useful to extend this notion to pairs. Further, I will discuss some new results for pairs which are a part of ongoing work. (Received February 20, 2018)

1139-13-607 **Victor Reiner** and **Anne V. Shepler*** (ashepler@unt.edu). *Invariant derivations and differential forms for reflection groups.*

Classical invariant theory of reflection groups operates from a straightforward maxim: The invariants of a set should exhibit the same algebraic structure as the original set. For example, a 1963 theorem of Louis Solomon exhibits the space of invariant differential forms as an exterior algebra in its own right. We use tools of Gutkin and Opdam on characters to extend Solomon's Theorem to mixed differential derivations. This work resolves some combinatorial conjectures motivated by W-Catalan combinatorics and correlates with Lie-theoretic conjectures and results of Bazlov, Broer, Joseph, Reeder, and Stembridge, and also Deconcini, Papi, and Procesi. (Received February 20, 2018)

1139-13-611 **Janet Striuli*** (jstriuli@fairfield.edu), Fairfield, CT 06825, and **Hamidreza Rahamati** and **Zheng Yang**. *Weak complete intersections and Poincare series.*

In this talk we will introduce the notion of weak complete intersection ideals. We will show that many formulas for Poincare series for fiber products over the maximal ideal also hold for those over weak intersection ideals. (Received February 20, 2018)

1139-13-614 **Haydee Lindo*** (08hml@williams.edu). *Trace Modules and Rigidity Conjectures.*

Given a commutative ring R and R-modules M and X, the module generated by the homomorphic images of M in X is the trace module of this pairing. I will speak on some recent developments in the theory of trace modules with applications to conjectures involving modules with no self-extensions. (Received February 20, 2018)

1139-13-619 **Patricia J Klein*** (triciajk@umich.edu), MI. *Conditions on Koszul cohomology guaranteeing finite length local cohomology.*

Let (R, m) be a local ring, I an m-primary ideal, and M a finitely-generated R-module. We will begin by giving background on the relationship between the length of M/IM, the multiplicity of I on M, and the length of the Koszul homology of a set of generators of I on M. There is a sense in which these values are all close if and only if enough of the local cohomology modules of I on M are finite length. We will describe this new test for finiteness of lengths of local cohomology modules. (Received February 20, 2018)

1139-13-676 **Mats Boij** and **Anthony Iarrobino*** (a.iarrobino@neu.edu), Mathematics Department, 567 Lake, Northeastern University, 360 Huntington Avenu, Boston, MA 02115, and **Leila Khatami** and **Bart Van Steirteghem**. *Equations of loci in tables of commuting Jordan types.* Preliminary report.

The Jordan type of a nilpotent matrix is the partition giving the sizes of the Jordan blocks in the normal Jordan form of the matrix. In this talk we discuss all partitions that have a fixed partition Q as the generic Jordan type in their nilpotent commutator. These partitions form at $(u - r) \times (r - 1)$ table $T(Q)$ when $Q = (u, u - r)$ with

$r \geq 2$. We report on ongoing joint work in which we study the equations of loci in $T(Q)$. (Received February 20, 2018)

1139-13-678 **Claudia Miller*** (clamille@syr.edu) and **Hamidreza Rahmati**. *Free resolutions of Artinian compressed algebras.*

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. 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 treat the noncompressed case and mention work in progress. (Received February 20, 2018)

14 ► Algebraic geometry

1139-14-32 **Uli Walther***, 150 N University Street, West Lafayette, IN 47907, and **Thomas Reichelt**. *GKZ-systems and mixed Hodge modules.* Preliminary report.

I will define GKZ-systems, and talk a little about their properties from the algebraic, analytic, and combinatorial point of view. Then I will discuss a theorem of Gelfand et al, and a sharpening by Mathias Schulze and myself, on the question which GKZ-systems arise as (D-module-)direct image of a natural D-module on a torus. In such cases, the GKZ-system can inherit a mixed Hodge module structure. I will then explain work with Thomas Reichelt that computes the weight filtration of this MHM structure on a class of GKZ-systems that comes up naturally in mirror symmetry. This complements work of Reichelt and Christian Sevenheck who computed the Hodge filtration, and supersedes computations of Batyrev who determined the weight filtration in a generic point. Very few of such explicitly computed structures seem to be known. (Received January 11, 2018)

1139-14-33 **Sándor J Kovács*** (skovacs@uw.edu). *A new approach to rational singularities.*

I will discuss a new point of view on rational singularities. This consists of two essential elements: replacing the use of resolutions of singularities with Macaulayfication (which is known to exist under very mild assumptions) and a Kempf-type criterion for rational singularities using these Macaulayfications. This new view-point allows the study of rational singularities in situations where resolution of singularities is not known to exist and it agrees with the traditional approach when resolutions do exist. In particular, this leads to new results in both zero and positive characteristic. (Received January 12, 2018)

1139-14-73 **Amnon Neeman***, Building 27, Australian National University, Canberra, ACT 2612, Australia. *Dualizing complexes - a conjectural formula.*

The definition of dualizing complexes, in algebraic geometry, goes way back to Grothendieck in the 1960s. The noncommutative version originated with Van den Bergh in 1997. We'll recall what's known about the existence of these things. We may also say a little about their significance.

Ten-year-old work by Avramov and Iyengar, followed more recently by a number of other articles by a number of authors, raises several intriguing questions. The one I will focus on is the following: in the commutative case Avramov and Iyengar provide a formula that produces dualizing complexes, but the proof that the formula works doesn't extend to the noncommutative setting.

Does the formula work in general? (Received January 28, 2018)

1139-14-89 **Bernard H. Teissier*** (bernard.teissier@imj-prg.fr), 73 Rue Claude Bernard, 75005 Paris, France. *Zero dimensional valuations on equicharacteristic noetherian local domains.*

A study of those valuations based, in the case where the domain is complete, on the relations between the elements of a minimal system of generators of the value semigroup or of the associated graded algebra.

The main idea is to present the ring as a quotient of a generalized power series ring instead of trying to present it "à la Kaplansky" as a subring of a generalized ring of Puiseux series.

The talk will emphasize the description of the valuation rings of Abhyankar valuations and the approximation of non-Abhyankar valuations by Abhyankar semivaluations. (Received February 01, 2018)

1139-14-127 **Klaus Altmann** and **Nathan Ilten*** (nilten@sfu.ca). *Fujita's Freeness Conjecture for Complexity-One T-Varieties.*

Fujita famously conjectured that for a d-dimensional smooth projective variety X with ample divisor H, $mH+K_X$ is basepoint free whenever $m \geq d+1$. I will discuss recent joint work with Klaus Altmann in which we show this conjecture is true whenever X admits an effective action by a torus of dimension $d-1$. (Received February 05, 2018)

1139-14-131 **Daniel Irving Bernstein*** (dibernst@ncsu.edu), Department of Mathematics, North Carolina State University, Box 8205, Raleigh, NC 27695, and **Greg Blekherman** and **Rainer Sinn**. *Typical and generic ranks in low-rank matrix completion.*

Given a matrix where only a subset of the entries are known, the low-rank matrix completion problem asks for the lowest possible rank that the completed matrix can have. For complex matrices with sufficiently generic known entries, the solution to the low-rank matrix completion problem only depends on the pattern of known entries and not the specific values observed. For real matrices, this is not the case. This talk will address some basic questions related to this phenomenon. (Received February 05, 2018)

1139-14-140 **Nham V Ngo*** (nvngo@ung.edu), University of North Georgia - Gainesville, Department of Mathematics, 3820 Mundy Mill Rd, Oakwood, GA 30566. *On geometric properties of G-saturation.*

Let G be a semisimple algebraic group defined over an algebraically closed field of characteristic 0 and P a parabolic subgroup of G. Let M be a P-module and V a P-stable closed subvariety of M. Suppose that V is a variety with nice structure such as normality or rational singularities. One of interesting questions is whether (or under what conditions) the G-saturation variety $G \cdot V = \{gv : g \in G, v \in V\}$ is so. In this talk, we present some results related to answering this question. As an application, we prove that nilpotent commuting varieties over 3×3 matrices have rational singularities. (Received February 06, 2018)

1139-14-160 **Dawei Chen*** (dawei.chen@bc.edu), Department of Mathematics, Boston College, Chestnut Hill, MA 02467. *Are affine invariant submanifolds affine?*

An abelian differential defines a flat metric such that the underlying Riemann surface can be realized as a plane polygon. Varying the shape of such polygons induces a GL(2,R)-action on the moduli space of abelian differentials. The corresponding GL(2,R)-orbit closures are called affine invariant submanifolds, where "affine" refers to the locally linear structure under the period coordinates. In this talk we study the amusing question whether affine invariant submanifolds are affine varieties in the sense of algebraic geometry. (Received February 07, 2018)

1139-14-177 **Paolo Aluffi*** (aluffi@math.fsu.edu), Tallahassee, FL. *Segre zeta functions.*

We define a power series associated with a choice of homogeneous polynomials, encoding Segre class information of corresponding subschemes of projective spaces. We prove that this is a rational function, with poles related to the degrees of the polynomials, and provide a partial description of the numerator of this function. We will also explain how to compute this 'Segre zeta function' as an integral over an associated convex body, at least in certain cases. The Segre zeta function has enumerative significance, and may be used to compute certain invariants of (possibly singular) spaces. (Received February 08, 2018)

1139-14-191 **Dori Bejleri*** (dbejleri@math.brown.edu) and **Kenneth Ascher** (kascher@mit.edu). *Stable pair compactifications of the moduli space of degree one del Pezzo surfaces via elliptic fibrations.*

A degree one del Pezzo surface is the blowup of $\mathbb{P}^2$ at 8 general points. By the classical Cayley-Bacharach Theorem, there is a unique 9th point whose blowup produces a rational elliptic surface with a section. Via this relationship, we construct a stable pair compactification of the moduli space of anti-canonically polarized degree one del Pezzo surfaces. (Received February 09, 2018)

1139-14-198 **Kelly A Jabbusch*** (jabbusch@umich.edu). *Visualizing toric vector bundles.*

Using Klaychko's characterization of toric vector bundles on a smooth complete toric variety we can relate to a toric vector bundle a parliament of polytopes, that is a collection of rational convex polytopes, which extends the corresponding theory of line bundles. Positivity properties, such as global generation and generation of jets can be be visualized in terms of convex properties of the corresponding polytopes. I will illustrate this correspondence and show how these criteria lead to proving and disproving connections between various notions of positivity. (Received February 10, 2018)

1139-14-199 **Isabel Vogt***, 77 Massachusetts Ave, MIT Dept. of Mathematics, Cambridge, MA 02139. *Interpolation problems for curves in projective space.*

In this talk we will discuss the following question: When does there exist a curve of degree d and genus g passing through n general points in $\mathbb{P}^r$? We will illustrate the general theory with concrete examples in low-dimensional projective spaces. (Received February 10, 2018)

1139-14-200 **Leslie C Wilson*** (les@math.hawaii.edu), Dept of Math, Univ of Hawaii, 2565 McCarthy Mall, Honolulu, HI 96822, and **Donal O'Shea**. *Exceptional rays and bilipschitz geometry of real surface singularities.*

It is known that ambient bilipschitz equivalence preserves tangent cones. This paper explores the behavior of the Nash cone and, in particular, exceptional rays under ambient bilipschitz equivalence for real surfaces in $\mathbf{R}^3$ with isolated singularity. (Received February 10, 2018)

1139-14-206 **David H Yang*** (dyang@math.harvard.edu). *Cohomology stabilization of Hom spaces and Manin's conjecture.*

We propose a cohomological stabilization conjecture for certain loci in spaces of maps from a fixed curve to a Fano variety. The sieving to obtain these loci is analogous to that needed in the classical Batyrev-Manin picture, and has been explored in work of Lehmann-Tanimoto. We show that a heuristic suggested by our conjecture recovers Peyre's constant, and provide some preliminary evidence toward its truth. (Received February 10, 2018)

1139-14-210 **Paolo Stellari*** (paolo.stellari@unimi.it), Dipartimento di Matematica "F. Enriques", Universita' degli Studi di Milano, Via Cesare Saldini 50, 20133 Milano, Italy. *Bridgeland stability for semiorthogonal decompositions, hyperkaehler manifolds and cubic fourfolds.*

We illustrate a new method to induce stability conditions on semiorthogonal decompositions and apply it to the Kuznetsov component of the derived category of cubic fourfolds. We use this to generalize results of Addington-Thomas about cubic fourfolds and to study the rich hyperkaehler geometry associated to these hypersurfaces. This is the content of joint works with Arend Bayer, Howard Nuer, Marti' Lahoz, Emanuele Macri' and Alex Perry. (Received February 11, 2018)

1139-14-232 **Tom Braden**, **June Huh**, **Jacob Matherne**, **Nicholas Proudfoot*** (njp@uoregon.edu) and **Botong Wang**. *Singular Hodge theory of matroids.* Preliminary report.

Given a hyperplane arrangement, one can use the intersection cohomology of a certain toric compactification of the complement to prove the top-heavy conjecture for the lattice of flats (Huh-Wang) and non-negativity of the Kazhdan-Lusztig polynomial (Elias-Proudfoot-Wakefield). In work in progress, the authors are constructing a combinatorial model for these intersection cohomology groups that should allow us to extend the results to arbitrary (non-realizable) matroids. (Received February 12, 2018)

1139-14-233 **Tom Braden*** (braden@math.umass.edu), **June Huh**, **Jacob Matherne**, **Nicholas Proudfoot** and **Botong Wang**. *Equivariant cohomology and intersection cohomology of a completion of a hyperplane arrangement.* Preliminary report.

Given a vector subspace $V \subset k^n$, its closure $Y(V)$ inside $(\mathbb{P}^1_k)^n$ has many properties reminiscent of Schubert varieties, but whereas the geometry of a Schubert variety is governed by the associated Coxeter-Weyl group, the geometry of $Y(V)$ is governed by the central hyperplane arrangement of coordinate hyperplanes in V. In particular $Y(V)$ has a stratification by affine spaces indexed by flats, and its local intersection cohomology is given by an analog of the Kazhdan-Lusztig polynomial defined by Elias, Proudfoot and Wakefield, in terms of the lattice of flats.

We consider a T-equivariant version of this story, where T is the one-dimensional torus acting on V by scalar multiplication. Although T is too small for standard GKM/moment graph techniques to apply, we are able to give a simple presentation for the equivariant cohomology $H^*_T(Y(V))$ and an inductive description of the equivariant intersection cohomology $IH^*_T(Y(V))$, in a spirit similar to the computations of T-equivariant IH of toric varieties and Schubert varieties using sheaves on fans and moment graphs. (Received February 12, 2018)

1139-14-243 **Zhuang He*** (he.zhu@husky.neu.edu), Department of Mathematics, Northeastern University, 360 Huntington Ave, Boston, MA 02115. *Mori Dream Spaces and blow-ups of weighted projective n-spaces.*

For every $n \geq 3$, we find a sufficient condition for some weighted projective n-spaces such that the blow-ups at the identity point are not Mori Dream Spaces. We show several infinite sequences of weighted projective n-spaces satisfying this condition, whose blow-ups are hence not Mori Dream Spaces. (Received February 12, 2018)

1139-14-258 **Chunyi Li** (c.li.25@warwick.ac.uk) and **Laura Pertusi*** (laura.pertusi@unimi.it), Dipartimento di Matematica Federigo Enriques, Università degli studi di Milano, Via Cesare Saldini 50, 20133 Milano, MI, Italy, and **Xiaolei Zhao** (x.zhao@northeastern.edu). *Rational curves of low degree on cubic fourfolds and stability conditions.*

In a recent work, Bayer, Lahoz, Macrì and Stellari constructed Bridgeland stability conditions on the Kuznetsov component of a cubic fourfold, which is an admissible K3 subcategory of the derived category of coherent sheaves. As a consequence, it is possible to address the problem of studying moduli spaces of stable objects in this K3 category. The aim of this talk is to describe the Fano variety of lines on a cubic fourfold and the hyperkähler eightfold, constructed by Lehn, Lehn, Sorger and van Straten from twisted cubic curves on a cubic fourfold non containing a plane, as moduli spaces of Bridgeland stable objects in the Kuznetsov component. Then, we discuss some applications concerning the categorical version of Torelli Theorem for cubic fourfolds, the relation between the period point of the Fano variety with that of the LLSvS eightfold, and the derived Torelli Theorem for cubic fourfolds. This is a joint work with Chunyi Li and Xiaolei Zhao. (Received February 13, 2018)

1139-14-284 **Qile Chen*** (qile.chen@bc.edu), Department of Mathematics, Maloney Hall, Fifth Floor, Boston College, Chestnut Hill, MA 02467. *Witten's top Chern classes via logarithmic compactification.*

Witten's top Chern class was constructed previously by Fan-Jarvis-Ruan and Chang-Li-Li. The authors proved that it can be represented by a Chow cycle supported on a proper locus inside a non-proper moduli space. In this talk, I will introduce a new approach aiming at a proper moduli space carrying a perfect obstruction theory whose associated virtual class is Witten's top Chern class. Our method also provides compactified moduli spaces for many interesting cases of Gauged linear sigma model introduced by Fan-Jarvis-Ruan.

This is a joint work in progress with Felix Janda and Yongbin Ruan. (Received February 14, 2018)

1139-14-285 **Daniel Matei*** (dmatei@imar.ro), Institute of Mathematics "Simion Stoilow", P.O. Box 1-764, 014700 Bucharest, Romania. *Aomoto-Betti numbers of matroids and finite geometries.*

The Aomoto complex associated to a matroid is defined by its Orlik-Solomon algebra with multiplication by a degree one form as differential. Any set of points in a projective geometry over a field defines a representable matroid. We discuss the Betti numbers of the Aomoto complex for finite geometries. (Received February 14, 2018)

1139-14-290 **Frank Gounelas***, Mathematisches Institut, Unter den Linden 6, 10099 Berlin, Germany. *Measures of irrationality of the Fano scheme of lines of a cubic threefold.*

In this talk I will recall definitions and basic properties of various invariants associated to an arbitrary projective variety, that aim to measure how far it is from being rational, rationally connected or uniruled respectively. In the second part of the talk I will discuss recent work with Kouvidakis computing these invariants for the Fano scheme of lines of a cubic threefold, which is a general type surface classically studied by Fano, Clemens-Griffiths and others. (Received February 14, 2018)

1139-14-294 **Colby Long*** (long.1579@mbi.osu.edu) and **Laura Kubatko**. *Identifiability of Species Phylogenies Under a Modified Coalescent.*

Coalescent models of evolution account for incomplete lineage sorting by specifying a species tree parameter which determines a distribution on gene trees. Each gene tree gives a DNA site pattern probability distribution and the site pattern probability distribution from the coalescent model is obtained by integrating over all possible gene trees. Using rank conditions on certain flattening matrices, it has been shown that the unrooted topology of the species tree parameter of the multispecies coalescent is generically identifiable from DNA site pattern frequencies. Moreover, a statistically consistent reconstruction method called SVDQuartets has been developed to recover this parameter. In this talk, we describe a modified multispecies coalescent model that allows for different effective population sizes and violations of the molecular clock. We show that the unrooted topology of the species tree for these models is generically identifiable and that SVDQuartets is still a statistically consistent method for inferring this parameter. (Received February 14, 2018)

1139-14-326 **Sara Jamshidi*** (sxj937@psu.edu) and **Jason Morton**. *A distributed, asynchronous Buchberger's algorithm.*

We present a distributed version of Buchberger's algorithm for faster computation of a Groebner basis. It differs from prior work in two key ways: (1) the method is entirely asynchronous and (2) there is no limitation on the number of threads in use. We present the algorithmic design, discuss the trade-offs and compute some examples. (Received February 15, 2018)

1139-14-348 **Brian Anderson Hepler*** (hepler.b@husky.neu.edu), 374 Washington Street, Cambridge, MA 02139. *Deformation Formulas for Parametrizable Hypersurfaces.*
We investigate one-parameter deformations of functions on affine space which define parametrizable hypersurfaces. With the assumption of isolated polar activity at the origin, we are able to completely express the Lê numbers of the special fiber in terms of the Lê numbers of the generic fiber and the characteristic polar multiplicities of the multiple-point complex, a perverse sheaf naturally associated to any parameterized hyper surface. (Received February 16, 2018)

1139-14-360 **Richard Rimanyi*** (rimanyi@email.unc.edu). *On Chern-Schwartz-MacPherson and motivic Chern classes of singularities.*
We will review a new approach to cohomological and K-theoretic characteristic classes of singularities. This new point of view is inspired by a quantum algebraic notion called 'stable envelope' introduced by Maulik and Okounkov. As a result, the characteristic classes named in the title are now computable for a wide range of quiver orbits and contact singularities. (Received February 16, 2018)

1139-14-366 **Antonella Grassi*** (grassi@math.upenn.edu), Philadelphia, PA 19104. *Noether-Lefschetz locus on singular varieties and applications.*
The classical Noether-Lefschetz theorem says that any curve in a very general surface X in $\mathbb{P}^3$ of degree $d \geq 4$ is a restriction of a surface in the ambient space, in particular the Picard number of X is 1. The Noether-Lefschetz locus is the locus of the degree $d \geq 4$ surfaces in $\mathbb{P}^3$ whose Picard number is greater than 1. I will discuss generalizations to singular ambient spaces, properties of the components of maximal codimension in the Noether-Lefschetz locus and applications to the Hodge conjecture for very general hypersurfaces in toric varieties. (Based on work with Bruzzo and Lopez) (Received February 16, 2018)

1139-14-372 **Mark Spivakovsky*** (mark.spivakovsky@math.univ-toulouse.fr). *Key polynomials in simple extensions of valued fields and the local uniformization problem in arbitrary characteristic.* Preliminary report.
Key polynomials and local uniformization.

Let $i : K- > L$ be a simple extension of valued fields. v is the valuation of L and its restriction to K. Key polynom. for i were introduced by MacLane when $v|_K$ is a discrete valuation. Simple extensions of valued fields with arbitrary (K, v) was studied by Vaquie and others. With Decaup, Mahboub and Novacoski we simplified our theory of key polynomials. We will give the simplified presentation of the theory. Resol. of sing. is the problem of constructing, for an alg. var. X (and for a quasi-excellent noetherian scheme), a non-sing. alg. var. (resp. scheme) X' and a birat. proper morphism $X' \to X$. The local version of the problem is stated in terms of valuations. Let (R, M, k) be a local quasi-excellent domain and R_ν a valuation ring containing R birat. to R. We want to construct a reg. loc. ring R' essentially of finite type over R such that $R \subset R' \subset R_\nu$. Existence of R' is the Loc. Unif Th. it was proved by Zariski when $char\ k = 0$ and is an open problem when $char\ k = p > 0$. We will give our definition of key polyn. and discuss their properties. We will proceed to the applications to the problem of Loc. Unif in char.> 0 (Received February 16, 2018)

1139-14-393 **Patricio Gallardo*** (pgallardocandela@wustl.edu), **K. Devleming** and **K. Ascher**. *On plane curves, double covers and their degenerations.*
We discuss different compactifications of the moduli space of smooth plane curves, explicit descriptions of the singular objects they parametrize, and applications for understanding the degenerations of double covers branching along them. This is joint work with K. Ascher and K. Devleming. (Received February 17, 2018)

1139-14-397 **Laura Escobar*** (lescobar@illinois.edu), **Megumi Harada** and **Kristin Shaw**. *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 February 17, 2018)

1139-14-406 **Rahul Singh*** (rahul.sharpeye@gmail.com). *The Conormal Variety of a Schubert variety.*
Let X, Y be compact homogeneous spaces for a semi-simple group G, and let $\mathcal{O}$ be an orbit under the diagonal action of G on $X \times Y$. We study the conormal variety N^* of $\mathcal{O}$. Suppose first that Y is a cominuscule Grassmannian. We show that for certain orbits $\mathcal{O}$, the conormal variety is a Schubert variety associated to the loop group of G. Further, we construct a vector bundle on a Bott-Samelson variety resolving the singularities of

N^*. In type A, this allows us to identify the equations defining N^* as a subvariety of the cotangent bundle of $X \times Y$. These results suggest some natural conjectures and proof strategies for the equations of N^* for general G and Y, which we discuss. (Received February 17, 2018)

1139-14-435 **Xiping Zhang*** (xzhang@math.fsu.edu), 1327 High Road, Apt T1, Tallhassee, FL 32304. *Chern Classes and Local Euler Obstruction of generic Determinantal Varieties.*

The (generic) determinantal variety is the projective variety consisting of m by n matrices with kernel dimension $\geq k$, which arises naturally from many aspects. In this talk I will give formulas of the local Euler obstruction functions, the sectional Euler characteristics and algorithms for the Chern-Mather/Chern-Schwartz-MacPherson classes of determinantal varieties.

The Formulas and algorithms are based on calculations of degrees of certain Chern classes of the universal bundles over Grassmannians. For low dimensions I use Macaulay2 to exhibit some examples, and formulate a conjecture concerning the symmetry and positivity of the Chern classes. (Received February 18, 2018)

1139-14-440 **Kiumars Kaveh*** (kaveh@pitt.edu), 301 Thackeray Hall, Department of Mathematics, University of Pittsburgh, Pittsburgh, PA 15260, and **Christopher Manon**, Lexington, KY. *Toric vector bundles and buildings.*

Klyachko famously classified (T-linearized) vector bundles on a toric variety by certain data of filtrations associated to the rays in the fan. We give an interpretation of Klyachko's data as a "piecewise linear map" and make a connection with the notion of "building". This leads us to a generalization of Klyachko's classification to principal G-bundles on toric varieties for semisimple groups G other than GL(n). (Received February 18, 2018)

1139-14-459 **Jonathan Esole*** (mboyoesole@gmail.com), Northeastern University, Department of Mathematics, 360 Huntington Avenue, Boston, MA 02115. *Slicing and Flopping: The Geometry of SO(4) Models.*

I will explain how the geometric engineering of SO(4) models in F-theory and its relation to elliptic fibrations with Mordell-Weil groups Z/2 and the Atiyah's flop. (Received February 18, 2018)

1139-14-470 **Ata Firat Pir*** (atafirat@math.tamu.edu). *Irrational Toric Varieties.*

Toric varieties form an important class of algebraic varieties that are among the simplest objects in algebraic geometry. In classical theory normal toric varieties are given by rational fans in $\mathbb{R}^n$. Motivated by applications, we construct a theory of irrational toric varieties associated to arbitrary fans in $\mathbb{R}^n$. These are $\mathbb{R}^n$-equivariant cell complexes dual to the fan and generalize the nonnegative part of a classical toric variety. Among the pleasing parallels with the classical theory is that the space of degenerations of a projective irrational toric variety is homeomorphic to the secondary polytope of a point configuration. (Received February 19, 2018)

1139-14-471 **Angela Gibney*** (angela.gibney@gmail.com), Department of Mathematics Rutgers University, Hill Center - Busch Campus, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019, and **Prakash Belkale** (belkale@email.unc.edu), Department of Mathematics, 120 E Cameron Avenue, CB #3250, 329 Phillips Hall, Chapel Hill, NC 27599. *On finite generation of the section ring of the determinant line bundle.*

I will discuss joint work, with Prakash Belkale, where we show the section ring for the pair (Bun, D) is finitely generated, for D the determinant of cohomology line bundle on the stack $Bun = Bun_{SL(r)}(C)$ parameterizing principal $SL(r)$-bundles on a singular stable curve C. I'll define these things, put the result into some historical perspective, and give two applications. (Received February 19, 2018)

1139-14-491 **Anne Pichon***, Campus de Luminy, Case 907, 13288 Marseille, France, and **Walter D Neumann**, **Helge Pedersen** and **Filip Misev**. *Which surface singularities are Lipschitz normally embedded?* Preliminary report.

We will present two large classes of surface singularities which are Lipschitz normally embedded. The first one is the class of minimal surface singularities: any minimal surface singularity is Lipschitz normally embedded, and they are the only rational surface singularities with this property. I will explain how this result is closely related with the resolution of singularities. This result is a joint work with Walter Neumann and Helge Pedersen. The second class of examples is among superisolated singularities. This result is a joint work with Filip Misev. (Received February 19, 2018)

1139-14-492 **Klim Efremenko**, **J.M. Landsberg** and **Hal Schenck*** (hschenck@iastate.edu), Iowa State Mathematics, 411 Morrill Road, Ames, IA 50011, and **Jerzy Weyman**. *Permanental ideals and complexity theory.*

The minimal free resolution of the Jacobian ideals of the determinant polynomial were computed by Lascoux, and it is an active area of research to understand the Jacobian ideals of the permanent. As a step in this direction we compute several new cases and completely determine the linear strand of the minimal free resolutions of the ideals generated by sub-permanents. Our motivation is to lay the groundwork for the use of commutative algebra in algebraic complexity theory, building on the use of Hilbert functions in work of Gupta-Kamath-Kayal-Saptharishi. We compute several such Hilbert functions relevant for complexity theory. (Received February 20, 2018)

1139-14-501 **Izzet Coskun**, Dept. of MSCS, Univ. of Illinois at Chicago, 322 Science and Engineering Offices (M/C 249), 851 S. Morgan St., Chicago, IL 60607-7045, **Howard Jacob Nuer*** (hnuer@uic.edu), Dept. of MSCS, Univ. of Illinois at Chicago, 322 Science and Engineering Offices (M/C 249), 851 S. Morgan St., Chicago, IL 60607-7045, and **Kota Yoshioka**. *Brill-Noether theory and global generation for sheaves on K3 surfaces.*

In the study of moduli spaces of sheaves, two natural questions arise: 1) does the generic sheaf in a moduli space have the expected cohomology (i.e. at most one nonzero cohomology group)? and 2) in the case of positive Euler characteristic, is the generic sheaf in the moduli space globally generated? When the first question has a positive answer, we say the given moduli space satisfies the "Weak Brill-Noether theorem." Using the theory of Bridgeland stability conditions and Bayer-Macrì's classification of walls on K3 surfaces, we discuss the progress of an ongoing project aimed at answering these two questions for stables sheaves on K3 surfaces of Picard rank 1. To illustrate our methods, we will discuss in detail how to cleanly and quickly obtain a complete classification in ranks 1 and 2 of those moduli spaces of stable sheaves which satisfy weak Brill-Noether and global generation, respectively. This is joint work with Izzet Coskun and Kota Yoshioka. (Received February 19, 2018)

1139-14-518 **Andreas P. Braun**, **Cody Long**, **Liam McAllister**, **Michael Stillman** and **Benjamin Sung*** (b.sung@northeastern.edu). *Computing sheaf cohomology on Calabi-Yau hypersurfaces in toric varieties and D-brane instantons.*

Sheaf cohomology on Calabi-Yau varieties serves as a key bridge between geometry and string theory. In particular, the sheaf cohomology of divisors on a Calabi-Yau threefold yields information about the zero mode spectrum of wrapped ED3 branes and hence the non-perturbative superpotential, which has direct applications for moduli stabilization and axion inflation. Although there are methods to perform such computations (Eisenbud-Mustata-Stillman), these fail for many large examples. I will present a new technique and explicit formulas for these computations using combinatorial properties of the ambient toric variety. (Received February 19, 2018)

1139-14-532 **Carlos Amendola**, **Nathan Bliss**, **Isaac Burke**, **Courtney R. Gibbons**, **Martin Helmer**, **Serkan Hosten**, **Evan D. Nash** and **Jose Israel Rodriguez***, Department of Statistics, George Herbert Jones Laboratory, 5747 S. Ellis, Chicago, IL 60637, and **Daniel Smolkin**. *The Maximum Likelihood Degree of Toric Varieties.*

The maximum likelihood degree is the number of complex critical points of the likelihood function on a projective variety. A wide class of such varieties is provided by hierarchical log-linear models and graphical models, a subclass of toric varieties. We will show how to compute the maximum likelihood degree of these models and exhibit examples. (Received February 19, 2018)

1139-14-548 **Antoni K Rangachev*** (rangachev@math.uchicago.edu), Department of Mathematics, University of Chicago, 5734 S University Ave, Chicago, IL 60637. *Deficient conormal singularities and local volumes.*

In this talk I will introduce a class of singularities that generalizes the class of smoothable singularities: these are all singularities that admit deformations to singularities with deficient conormal spaces. I will discuss how this new class arises from problems in differential equisingularity and how it relates to the local volume of a line bundle. If time permits, I will discuss which known classes of singularities have deficient conormal spaces. (Received February 19, 2018)

1139-14-590 **Javier Gonzalez-Anaya** (jga@math.ubc.ca), **Jose Gonzalez*** (jose.gonzalez@ucr.edu) and **Kalle Karu** (karu@math.ubc.ca). *On the Cox rings of some blown up toric surfaces.*

We present combinatorial sufficient conditions for the finite and non-finite generation of the Cox ring of the blowup at a general point of a toric surface of Picard number one. This generalizes work of Goto-Nishida-Watanabe, Kurano-Nishida and Srinivasan. We also discuss generalizations to higher dimensions and to toric surfaces with Picard number two. This problem has applications to deciding the noetherianity of symbolic algebras and has also been applied to decide other instances of non-finite generation of Cox rings. This talk is based on joint work with Javier Gonzalez-Anaya and Kalle Karu. (Received February 20, 2018)

1139-14-631 **Peter F Stiller*** (stiller@math.tamu.edu), Department of Mathematics MS 3368, Texas A&M University, College Station, TX 77843-3368. *Splines and Vector Bundles on Projective Spaces with Relationships to Hyperplane/Hypersurface Arrangements.* Preliminary report.

In this talk we discuss a number of connections between certain local and global problems in approximation theory, related to spaces of splines of various degrees and orders of smoothness, and certain vector bundles/reflexive sheaves on complex projective spaces. For semi-algebraic splines the results depend heavily on global properties of the associated arrangement of hypersurfaces used to define the space of splines. We also give some results that link theorems on the vanishing of the higher cohomology of those vector bundles to formulas for the dimension of spline spaces and discuss a possible connection with semi-stability as it applies to vector bundles and reflexive sheaves on projective spaces. (Received February 20, 2018)

1139-14-643 **Georgy Scholten** and **Cynthia Vinzant*** (clvinzan@ncsu.edu). *Semi-inverted linear spaces.*

The image of a linear space under inversion of some coordinates is an affine rational variety whose structure is governed by an underlying hyperplane arrangement. The image of a real linear space is a hyperbolic variety, meaning that there is a family of linear spaces all of whose intersections with it are real. Over the past ten years, the case of inverting all coordinates has appeared in connections with hyperplane arrangements, statistics, and linear programming. I will review some of these connections and talk about the nice real and combinatorial structure of this generalization. (Received February 20, 2018)

1139-14-646 **Robin Walters*** (rwalters@northeastern.edu), 360 Huntington Ave., Boston, MA 02115. *The Bernstein-Sato polynomial of a Weyl arrangement.*

The Bernstein-Sato polynomial, or b-function, is an important invariant in singularity theory, which is difficult to compute in general. It is related to eigenvalues of Milnor monodromy, log canonical threshold, and poles of Zeta functions. We describe a few different results towards computing the b-function of an arrangement ζ of fixed hyperplanes of a Weyl group. In 1989, Eric Opdam computed the b-function of a related polynomial, and we use his result to produce a lower bound for the b-function of ζ. We use duality of some D-modules to show that the roots of this b-function of ζ are symmetric about -1. Finally, we use results about jumping coefficients together with Kashiwara's proof that the roots of a b-function are rational in order to prove an upper bound for the b-function of ζ and give a conjectured formula. This is a joint work with Asilata Bapat. (Received February 20, 2018)

1139-14-663 **Mahir Bilen Can*** (mahirbilencan@gmail.com), 6823 St. Charles Ave., Department of Mathematics, Tulane University, New Orleans, LA 70118, and **Reuven Hodges**. *Levi spherical Schubert varieties and intersection theory.* Preliminary report.

By Poincaré duality, the class of a Schubert variety is identified with an invariant differential form on a flag variety. In this talk we present our recent progress on the geometry of Schubert varieties which are invariant under a spherical translation action of a Levi subgroup. In particular, we show that if a semisimple algebraic group G has no G_2 factor, then any smooth Schubert variety X is a spherical L-variety, where L is the Levi factor of the parabolic subgroup that stabilizes X. If time permits, we will present various combinatorial results on the orbits of L in X. (Received February 20, 2018)

1139-14-702 **Julianna Tymoczko***, Department of Mathematics and Statistics, Smith College, Northampton, MA 01063. *Affine Schubert calculus and Hessenberg varieties.*

Given a linear operator, its “eigenflags” can be thought of as the set of flags fixed by the linear operator. Hessenberg varieties are a family of subvarieties of the flag variety that generalize this idea, namely the flags that a linear operator shifts in a restricted way. The affine Grassmannian is an infinite-dimensional analogue of the Grassmannian. Both Hessenberg varieties and affine Grassmannians have a kind of Schubert decomposition, and both decompositions can be described by similar linear algebra and combinatorics. We show explicit ways to construct affine Schubert cells as pieces of Hessenberg varieties, thus realizing affine Schubert calculus as a special case of Hessenberg Schubert calculus.

This is joint work with Linda Chen. (Received February 21, 2018)

15 ► Linear and multilinear algebra; matrix theory

1139-15-38 **Christino Tamon***, Department of Computer Science, Clarkson University, 8 Clarkson Avenue, Potsdam, NY 13699-5815. *Is quantum state transfer monogamous?*

Given a graph with adjacency matrix A, if a continuous-time quantum walk matrix exp(-itA) sends the characteristic vector of a vertex to the characteristic vector of another vertex, we say perfect state transfer occurs between the two vertices. We consider the possibility for a vertex to be involved in perfect state transfer with two other distinct vertices. In this talk, we survey what is known about this question and describe some recent observations. (Received January 15, 2018)

1139-15-527 **Lek-Heng Lim** and **Jose Israel Rodriguez***, George Herbert Jones Laboratory, 5747 S. Ellis Ave, Chicago, IL 60637. *Factoring graphs, matrices, and polynomials as tensor products.*

The tensor or Kronecker product of two matrices is well-known. The tensor product of two graphs is one whose adjacency matrix is given by the tensor product of the adjacency matrices of the respective graphs. The tensor product of two (univariate) polynomials is one whose companion matrix is given by the tensor product of the companion matrices of the respective polynomials. These tensor products are category-theoretic products in the respective categories. We discuss how graphs, matrices, and polynomials may be factored into irreducible factors with respect to these tensor products. We use the Newton–Girard formulas and homotopy continuation to find the decomposition. This is joint work with Lek-Heng Lim. (Received February 19, 2018)

16 ► Associative rings and algebras

1139-16-48 **Nicolas Guay*** (nguay@ualberta.ca), **Vidas Regelskis** (vidasrr@gmail.com) and **Curtis Wendlandt** (cwendlan@ualberta.ca). *Twisted Yangians for symmetric pairs of types B, C and D.*

I will introduce twisted Yangians associated to symmetric pairs of types B, C and D which are similar to those of type A introduced by G. Olshanski over twenty-five years ago and which have been quite well studied. Whereas Yangians are Hopf algebras and important examples of quantum groups, twisted Yangians are very interesting families of co-ideal subalgebras of Yangians. After a brief discussion of a number of their properties, I will present classification results for their irreducible finite dimensional modules. This is joint work with Vidas Regelskis and Curtis Wendlandt. (Received January 21, 2018)

1139-16-151 **Thomas Brüstle*** (thomas.brustle@usherbrooke.ca) and **Hipolito Treffinger** (hjtc1@leicester.ac.uk). *Wall and chamber structure and maximal green sequences.*

We study the wall and chamber structure of an algebra A as defined by Bridgeland as part of the scattering diagram of A. It turns out that the simplicial complex of tau-rigid pairs of A can be embedded into the wall and chamber structure. As a consequence, we show that Bridgeland's D-generic paths describe maximal green sequences in module categories. (Received February 07, 2018)

1139-16-190 **Alexander H Sistko*** (alexander-sistko@uiowa.edu), 14 MacLean Hall, Iowa City, IA 52242-1419, and **Miodrag C Iovanov**. *Maximal Subalgebras of Finite-Dimensional Algebras with Applications.*

We present classification theorems for maximal subalgebras of finite-dimensional algebras over a field. For important classes of algebras (ex. basic over an algebraically closed field), this gives us nice presentations of (maximal) subalgebras. Trivial extensions and separable extensions arise naturally in the classification, allowing us to relate representation-theoretic properties of an algebra to those of its subalgebras via induction and restriction. We discuss applications of our classification to the study of finite-dimensional algebras, extensions between them, and automorphisms of algebras. (Received February 09, 2018)

1139-16-216 **Frauke M. Bleher***, University of Iowa, Department of Mathematics, 14 MLH, Iowa City, IA 52242. *Module theoretic aspects of Iwasawa theory.* Preliminary report.

This talk is about joint work with Ted Chinburg, Ralph Greenberg, Mahesh Kakde, Romyar Sharifi and Martin Taylor about higher codimension Iwasawa theory. Suppose R is a commutative Noetherian domain and M is a finitely generated R-module. The Chern classes of M can be used to describe the support of M as an R-module. If M is torsion and has trivial support in codimension 1, then its first Chern class is trivial and one says M is pseudo-null. In this talk I will focus on a purely module theoretic result which relates the maximal pseudo-null submodules of quotient modules of the top exterior power of M to the maximal pseudo-null submodules of quotient modules of R. I will then indicate how this leads to a result on second Chern classes of Iwasawa modules. (Received February 11, 2018)

1139-16-239 **Alexandru Chirvasitu*** (achirvas@buffalo.edu), Mathematics Department, SUNY at Buffalo, Buffalo, NY 14260. *Homogeneous spaces for compact quantum groups.*

In non-commutative geometry cosemisimple Hopf algebras are treated analogous to the algebras $\mathcal{O}(G)$ of regular functions on linearly reductive affine algebraic groups G. In this context, a homogeneous space of the "quantum group" attached to a Hopf algebra H would be a coideal subalgebra of A. Similarly, a quantum subgroup would be a quotient Hopf algebra $H \to C$.

Classically, the quotient stack of an algebraic group G by a closed subgroup N is an affine scheme precisely when $\mathcal{O}(G)$ is faithfully flat over the coideal subalgebra $\mathcal{O}(G/N)$ consisting of functions constant along the cosets of N. For this reason, faithful flatness is the technical condition that encapsulates the vague notion that homogeneous spaces are "well behaved".

For Hopf algebras H equipped with enough structure to render them analogous to function algebras on *compact* quantum groups it turns out that inclusions of right coideal $*$-subalgebras are automatically faithfully flat. In view of the previous paragraph, this confirms the intuition that quotients of semisimple affine algebraic groups by semisimple closed subgroups are affine schemes. (Received February 12, 2018)

1139-16-282 **Bach Nguyen*** (bnguy38@lsu.edu), **Kurt Trampel** and **Milen Yakimov**.
Discriminants of quantum groups at root of unity.

The notion of discriminant is an important tool in number theory, algebraic geometry and noncommutative algebra. However, discriminants are difficult to compute in concrete situations. This has been done for few noncommutative algebras, relying on direct calculations. We will present a formula for the discriminants of all quantized coordinate rings of simple algebraic groups at roots of unity. It is derived from a general method for computing noncommutative discriminants that relies on representation theory and Poisson geometry. (Received February 14, 2018)

1139-16-355 **Emily Barnard*** (e.barnard@northeastern.edu), **Andrew Carroll** and **Shijie Zhu**.
Cover relations in the Lattice of Torsion Classes.

Let Λ be a finite-dimensional associative algebra. The torsion classes of mod Λ form a lattice under containment, denoted by tors Λ. In this talk, we characterize the cover relations in tors Λ by certain indecomposable modules which we call *minimal extending modules.* (Received February 16, 2018)

1139-16-387 **Chelsea Walton*** (notlaw@temple.edu), Philadelphia, PA 19122. *Semisimple Hopf actions on path algebras of quivers.* Preliminary report.

In the talk, I will discuss recent work on actions of semisimple Hopf algebras on path algebras of quivers, which is joint work with Pavel Etingof and Ryan Kinser. The title and abstract are subject to change. (Received February 17, 2018)

1139-16-390 **Karin Erdmann** and **Xingting Wang*** (xingting@templ.edu), Department of Mathematics, Wachman Hall (038-16), 1805 N. Broad Street, Philadelphia, PA 19122, and **Oeyvind Solberg**. *Cohomology of some Hopf algebras in positive characteristic.* Preliminary report.

Let p be a prime, and k be a field of characteristic p. We investigate the algebra structure and the structure of the cohomology ring for the connected Hopf algebras of dimension p^3, which appear in the classification obtained in [V.C. Nguyen, L.-H. Wang and X.-T. Wang, Classification of connected Hopf algebras of dimension p^3, J. Algebra 424 (2015), 473-505]. The list consists of 23 algebras together with two infinite families. We identify the Morita type of the algebra, and in almost all cases this is sufficient to clarify the structure of the cohomology ring. This is a joint work of Karin Erdmann and Oeyvind Solberg. (Received February 17, 2018)

1139-16-392 **Chelesa Walton** and **Xingting Wang*** (xingting@temple.edu), Department of Mathematics, Wachman Hall (038-16), 1805 N. Broad Street, Philadelphia, PA 19122-6094, 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 February 17, 2018)

1139-16-395 **Ellen Kirkman*** (kirkman@wfu.edu), Box 7388 Wake Forest University, Winston-Salem, NC 27109, and **Luigi Ferraro**, **W. Frank Moore** and **Robert Won**. *Examples of Reflection Hopf Algebras.* Preliminary report.

The Shephard-Todd-Chevalley Theorem states that when a finite group G acts linearly on a commutative polynomial ring $A = k[x_1, \ldots, x_n]$ over a field k of characteristic zero, the invariant subring A^G is a commutative polynomial ring if and only if G is generated by reflections. More generally, let H be a semisimple Hopf algebra that acts on an Artin-Schelter regular algebra A so that A is an H-module algebra, the grading on A is preserved, and the action of H on A is inner faithful. When A^H is Artin-Schelter regular, we call H a reflection Hopf algebra for A. We present examples of such pairs (A,H), for two and three-dimensional AS regular algebras A, and the Hopf algebras $H = \mathcal{A}_{4m}$ and $H = \mathcal{B}_{4m}$ defined by A. Masuoka, the algebras $H = H_{2n^2}$ defined by D. Pansera, and some of the 16-dimensional Hopf algebras H classified by Y. Kashina. (Received February 17, 2018)

1139-16-413 **Kyungyong Lee**, **Li Li**, **Matthew Mills** and **Ralf Schiffler*** (schiffler@math.uconn.edu), 345 Mansfield Road, Storrs, CT 06269, and **Alexandra Seceleanu**. *A characterization of the finite-tame-wild trichotomy for acyclic quivers.* Preliminary report.

We give a new characterization of the finite–tame–wild trichotomy for acyclic quivers in terms of an algebraic variety $X(Q)$, called the frieze variety, associated to the quiver Q. The frieze variety is defined in an elementary recursive way by constructing a set of points in affine space. From a more conceptual viewpoint, the coordinates of these points are specializations of cluster variables in the cluster algebra associated to the quiver.

We show that an acyclic quiver Q is representation finite, tame, or wild, respectively, if and only if $\dim X(Q) = 0, 1$, or ≥ 2, respectively. (Received February 17, 2018)

1139-16-418 **Emre Sen*** (sen.e@husky.neu.edu). *Determinants of Graded Cartan matrices of Nakayama algebras.* Preliminary report.

We give a new algorithm to describe periodic modules over cyclic Nakayama algebras by Δ-filtrations introduced at [S]. Then we apply it to Cartan matrices associated to those algebras and show that two nonisomorphic cyclic Nakayama algebras of infinite global dimension cannot have the same determinant of their graded Cartan matrices even with different gradings.

[S] The φ-dim of cyclic Nakayama algebras, Sen. E. preprint (Received February 18, 2018)

1139-16-500 **Yorck Sommerhäuser*** (sommerh@mun.ca), Memorial University of Newfoundland, Department of Mathematics and Statistics, St. John's, NL A1C 5S7, Canada. *Extensions of Yetter-Drinfel'd Hopf Algebras I.* Preliminary report.

The theory of extensions of Hopf algebras carries over to Hopf algebras in categories, and therefore in particular to Yetter-Drinfel'd Hopf algebras, without essential modifications. However, there are important examples of Yetter-Drinfel'd Hopf algebras that do not fit into this framework that arises via direct generalization, because in these examples, the so-called cleaving map is not a morphism in the category. We will present a generalized concept of extensions that encompasses also these examples. The talk is based on joint work with Yevgenia Kashina, who will give the following talk and explain which cohomological data are necessary to describe these generalized extensions. (Received February 19, 2018)

1139-16-526 **Kiyoshi Igusa**, **Kent Orr**, **Gordana Todorov** and **Jerzy M Weyman***, Department of Mathematics, University of Connecticut, Storrs, CT 06269. *Homology of Picture Groups of type D_n.* Preliminary report.

We calculate the homology of picture groups of type D_n using the model of certain cluster tilted algebras. The calculation is parallel to the earlier calculations for type A_n. (Received February 19, 2018)

1139-16-544 **Yevgenia Kashina***, Department of Mathematical Sciences, DePaul University, Chicago, IL. *Extensions of Yetter-Drinfel'd Hopf Algebras II.* Preliminary report.

Extensions of Hopf algebras can be described by four structure elements: an action, a corresponding cocycle, a coaction, and a corresponding dual cocycle. For Yetter-Drinfel'd Hopf algebras, there is a generalized concept of extensions that was discussed in the previous talk. To describe this setting, two new structure elements are necessary: a so-called deviation map and a codeviation map. In this talk, we will explain what these are and how they can be used to build extensions in the generalized sense just mentioned. The talk is based on joint work with Yorck Sommerhäuser. (Received February 19, 2018)

1139-16-563 **Zajj B Daugherty*** (zdaugherty@gmail.com), New York, NY. *The affine signed Brauer algebra.*

The affine signed Brauer algebra arises in the study of the representation of the periplectic Lie super algebra via translation functors, analogous to the role of the degenerate affine Hecke algebras in studying representations of the general linear group. In this talk, we will explore its presentation as a diagram algebra, its natural action on tensor space, and other combinatorial structure. This is joint work with Martina Balagovic, Inna Entova-Aizenbud, Iva Halacheva, Johanna Hennig, Mee Seong Im, Gail Letzter, Emily Norton, Vera Serganova, and Catharina Stroppel. (Received February 19, 2018)

1139-16-604 **Anne V. Shepler*** (ashepler@unt.edu) and **Sarah Witherspoon**. *Twisted tensor products.*

Many noncommutative algebras manifest as twisted tensor products, for example, Ore algebras, semi-direct product algebras, Weyl algebras, Sridharan algebras, and Koszul pairs. We will build resolutions for the twisted tensor product of two algebras by weaving together existing resolutions of the algebra. The Chevalley-Eilenberg resolution for universal enveloping algebras arises as a special case. (Received February 20, 2018)

1139-16-670 **Miodrag C Iovanov*** (miodrag-iovanov@uiowa.edu), 14 MacLean Hall, Iowa City, IA 52242. *The tame-wild dichotomy for infinite dimensional algebras and the Brauer-Thrall 3 conjectures.*

The tame-wild dichotomy is a fundamental result in the representation theory of fi nite dimensional algebras, due to Drozd. For in finite dimensional algebras and coalgebras, it is an open question (conjectured true) whether the tame-wild dichotomy for f.d. representations still holds. We settle this conjecture in the positive in its full generality. The key part of the approach is proving new representation theoretic characterizations for when the Ext quiver of the category of finite dimensional representations of an arbitrary algebra A is locally finite: this is so exactly when for every dimension vector d, the representations of A of dimension vector d are all contained in a finite subcategory (a category of modules over a finite dimensional quotient algebra). We also show that tame/not wild are local in the sense of noncommutative localization: a category of comodules is tame/not wild if and only if every "fi nite" localization is so. As applications of the methods, we obtain a proof for another conjecture in representation theory called the "Brauer-Thrall 3 conjecture", also raised by Simson, for the class of all wild algebras: over such algebras, there are indecomposable representations of arbitrarily large (infi nite) dimension. (Received February 20, 2018)

1139-16-675 **Karl Schmidt*** (karls@uoregon.edu). *Based quantum cluster algebras.* Preliminary report.

Cluster algebras were introduced by Fomin and Zelevinsky in "an attempt to create an algebraic framework for dual canonical bases". In this talk, we attempt to meaningfully marry the notion of a $U_q(\mathfrak{g})$-module with a specified basis (e.g. dual canonical) and the notion of a quantum cluster algebra. We investigate braided tensor products of such *based quantum cluster algebras*. In particular, we produce a compatible anti-linear anti-involution and basis in the tensor product, then initiate the search for compatible quantum cluster algebra structures. Explicit quantum cluster structures are exhibited in some cases. (Received February 20, 2018)

1139-16-696 **Siddharth Venkatesh***, 12 Cambridge Terrace, Cambridge, MA 02140. *Algebra in the Verlinde Category.*

In this talk, I will describe the construction of the Verlinde category and show some properties of commutative algebras in the category. I will also describe a construction of Lie algebras in this category and discuss their representation theory. (Received February 20, 2018)

17 ► Nonassociative rings and algebras

1139-17-70 **Ben D Johnson*** (ben.johnson12@okstate.edu), Oklahoma State University, 401 Mathematical Sciences Building, Stillwater, OK 74078, and **Eric N Sommers** (esommers@math.umass.edu), Department of Mathematics and Statistics, University of Massachusetts Amherst, 710 N. Pleasant St., Amherst, MA 01003. *Equations for some nilpotent varieties.*

Given a simple complex Lie algebra, we want to understand the ideals defining its nilpotent varieties, which are the closures of its nilpotent orbits. It is a classic result of Kostant that the principal nilpotent variety is the nilpotent cone, whose defining ideal is generated by a complete set of fundamental invariants. A minimal generating set for the ideal of the subregular nilpotent variety was found by Broer by studying line bundles on the cotangent bundle of the flag variety. In this talk, based on joint work with Eric Sommers, we extend this result to find a minimal generating set for the ideal corresponding to any Richardson orbit induced from a parabolic subalgebra generated by orthogonal short simple roots. (Received January 27, 2018)

1139-17-172 **Van Nguyen**, **Idun Reiten**, **Gordana Todorov** and **Shijie Zhu*** (zhu.shi@husky.neu.edu), 360 Huntington Ave, 567 Lake Hall, Mathematics Department, Boston, MA 02115. *Dominant dimension and tilting modules.*

We study which algebras have tilting modules that are both generated and cogenerated by projective-injective modules. Crawley-Boevey and Sauter have shown that Auslander algebras have such tilting modules; and for algebras of global dimension 2, Auslander algebras are classified by the existence of such tilting modules. We show that the existence of such a tilting module is equivalent to the algebra having dominant dimension at least 2, independent of its global dimension. In general such a tilting module is not necessarily cotilting. Here, we show that the algebras which have a tilting-cotilting module generated-cogenerated by projective-injective modules are precisely 1-Auslander-Gorenstein algebras. We also study the global dimension of its endomorphism algebra, and discuss a connection with the Finitistic Dimension Conjecture. (Received February 07, 2018)

18 ► Category theory; homological algebra

1139-18-253 **John M Zhang*** (jmzhang@math.ucla.edu). *An introduction to derivators.*

We introduce the theory of derivators, which can be seen as an extension of traditional derived categories. We discuss how, using the framework of derivators, we can expand on a traditional result of Happel on derived equivalences of certain quivers as well as some implications of this derivator-esque result. (Received February 13, 2018)

1139-18-267 **Robert Laugwitz*** (robert.laugwitz@rutgers.edu) and **You Qi**. *Categorification of cyclotomic rings at non-prime roots of unity.* Preliminary report.

M. Khovanov categorified the cyclotomic ring O_n for a prime $n = p$ using the stable category of a truncated polynomial Hopf algebra. This work is closely related to the theory of p-complexes, that is, vector spaces with a differential that does not square to zero, but its p-th power is zero. Using algebras with such differentials, the quantum group at prime roots of unity has been categorified by Khovanov–Qi, Elias–Qi. In this talk, a construction of a triangulated monoidal category categorifying cyclotomic integers that does not require the restriction of n being a prime is discussed. (Received February 13, 2018)

1139-18-268 **Xiuhua Luo*** (xiuhualuo@ntu.edu.cn), 2600 Greenwood Ter Apt G211, Boca Raton, FL 33431, and **Pu Zhang**. *Separated monic representations* $\mathbf{I}$: *Gorenstein-projective modules.*

For a finite acyclic quiver Q, an ideal I of a path algebra kQ generated by monomial relations, and a finite-dimensional k-algebra A, we introduce the separated monic representations of a bound quiver (Q, I) over A. They differ from the monic representations. The category $\mathrm{smon}(Q, I, A)$ of the separated monic representations of (Q, I) over A coincides with the category $\mathrm{mon}(Q, I, A)$ of the monic representations if and only if $I = 0$ and each vertex of Q is the ending vertex of at most one arrow. We give properties of the structural maps of separated monic representations, and prove that smon(Q, I, A) is a resolving subcategory of rep(Q, I, A). Let $\Lambda := A \otimes_k kQ/I$. By the equivalence rep$(Q, I, A) \cong \Lambda$-mod of categories, the main result claims that a Λ-module is Gorenstein-projective if and only if it is in smon(Q, I, A) and has a local A-Gorenstein-projective property (G). As consequences, the separated monic Λ-modules are exactly the projective Λ-modules if and only if A is semi-simple; and they are exactly the Gorenstein-projective Λ-modules if and only if A is self-injective, and if and only if smon(Q, I, A) is a Frobenius category. (Received February 13, 2018)

1139-18-276 **Peder Thompson*** (peder.thompson@ttu.edu), Lubbock, TX , and **Lars Winther Christensen** (lars.w.christensen@ttu.edu). *Pure-minimal chain complexes.*

The notion of minimality for chain complexes (of modules over a ring) is useful in the study of many homological invariants, including computing projective or injective dimension. A chain complex is *minimal* if every self homotopy equivalence is an isomorphism; this encompasses other standard ways of thinking about minimal complexes of projective or injective modules. However, minimal complexes of flat modules are not as well-behaved; for instance, minimal flat resolutions need not be unique nor detect flat dimension. To address this, we introduce the notion of a *pure-minimal* chain complex. We show that pure-minimality coincides with the usual notion of minimality in standard settings, while providing a more useful notion of minimality for complexes of flat modules. (Received February 13, 2018)

1139-18-280 **Zhengwei Liu*** (zhengweiliu@fas.harvard.edu), 17 Oxford Street, Cambridge, MA 02138. *A new program on quantum subgroups.*

The A, D, E Dynkin diagrams capture the underlining symmetry of classical Lie theory. They also appeared as the quivers of subgroups and modules of quantum SU(2). We can study classical Lie theory using quantum SU(2). We introduce a new program that our group at Harvard is developing: higher mathematics over quantum SU(n). (Received February 13, 2018)

1139-18-289 **Pavel Etingof*** (etingof@math.mit.edu) and **Victor Ostrik** (vostrik@uoregon.edu). *On semisimplification of tensor categories.*

We develop the theory of semisimplifications of tensor categories defined by Barrett and Westbury. By definition, the semisimplification of a tensor category is its quotient by the tensor ideal of negligible morphisms, i.e., morphisms f such that $\mathrm{Tr}(fg) = 0$ for any morphism g in the opposite direction. In particular, we compute the semisimplification of the category of representations of a finite group in characteristic p in terms of representations of the normalizer of its p-Sylow subgroup. This allows us to compute the semisimplification of the representation category of the symmetric group S_{n+p} in characteristic p, where $n = 0, ..., p-1$, and of the abelian envelope of the Deligne category, $\mathrm{Rep}^{\mathrm{ab}} S_t$. We also compute the semisimplification of the category of representations of the Kac-De Concini quantum group of the Borel subalgebra of $\mathfrak{sl}_2$. Finally, we study tensor functors between Verlinde categories of semisimple algebraic groups arising from the semisimplification construction, and objects of finite type in categories of modular representations of finite groups (i.e., objects generating a fusion category in the semisimplification). (Received February 14, 2018)

1139-18-303 **Alexei Davydov*** (davydov@ohio.edu), Department of Mathematics, Ohio University, Athens, OH 45701, and **Dmitri Nikshych**. *Purely braided module categories.* Preliminary report.

Motivated by extension theory of braided fusion categories we examine module categories over a braided category C which could appear as components of braided extension of C. We call such module categories purely braided. They are distinguished by a condition natural from the point of view of the theory of module categories. (Received February 14, 2018)

1139-18-321 **Brian D. Boe**, **Jonathan R. Kujawa** and **Daniel K. Nakano*** (nakano@uga.edu). *Support varieties and tensor ideals for quantum groups.*

Let $\mathfrak{g}$ be a complex simple Lie algebra and let $U_\zeta(\mathfrak{g})$ be the corresponding Lusztig $\mathbb{Z}[q, q^{-1}]$-form of the quantized enveloping algebra specialized to an ℓth root of unity. Moreover, let mod$(U_\zeta(\mathfrak{g}))$ be the braided monoidal category of finite-dimensional modules for $U_\zeta(\mathfrak{g})$. In this talk I will discuss various questions involving support varieties for quantum groups, In this process I will show how to classify the thick tensor ideals of mod$(U_\zeta(\mathfrak{g}))$ to resolve some of these questions. With these results one can then compute the prime spectrum of the stable module category associated to mod$(U_\zeta(\mathfrak{g}))$ as defined by Balmer. (Received February 15, 2018)

1139-18-578 **Andrew B Maurer***, University of Georgia, Athens, GA 30605. *On the Finite Generation of Relative Cohomology for Classical Lie Superalgebras.*

A Lie superalgebra is a $\mathbb{Z}/(2)$-graded algebra which generalizes the notion of a Lie algebra. In contrast to Lie algebras, Lie superalgebras may have cohomology in infinitely many degrees. This means cohomology rings for Lie superalgebras may carry geometrically meaningful information, as in the case of finite group cohomology [Quillen 1971].

In fact, ordinary cohomology of Lie superalgebras tends to have Krull dimension 0 [Fuks-Leites], and as such we restrict attention to relative cohomology. The speaker will present a theorem stating that, in the case of cohomology of a classical Lie superalgebra relative to a purely even subsuperalgebra, this ring has finite Krull dimension. The proof involves a spectral sequence argument, inspired by [Hochschild-Serre 1953].

Finite generation ensures the existence of a relative support variety theory in this special case. The talk will conclude with a look at some first properties of this support variety theory. (Received February 19, 2018)

1139-18-586 **Siu-Hung Ng*** (`rng@math.lsu.edu`), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *A new family of braided quasi-Hopf algebras and their representation categories.*

The construction of twisted quantum doubles of finite groups G was motivated by holomorphic orbifold in conformal field theory. In this talk, we present a generalized construction of braided quasi-Hopf algebras $D^\omega(G, A)$ from a central subgroup A and a 3-cocycle ω of G. The modularity of their representation categories is equivalent to the nondegeneracy of some bicharacter induced on A. We particularly consider some finite groups with a unique involution as examples. This talk is based on some joint works with Geoffrey Mason. (Received February 20, 2018)

1139-18-608 **Ivan Angiono** and **Cesar Galindo*** (`cn.galindo1116@uniandes.edu.co`), Bogota. *Pointed finite tensor categories over abelian groups.*

In this talk, we will give a characterization of finite pointed tensor categories obtained as de-equivariantization of finite-dimensional pointed Hopf algebras over abelian groups only in terms of the (cohomology class of the) associator of the pointed part. As an application, we will prove that every coradically graded pointed finite braided tensor category is a de-equivariantization of a finite-dimensional pointed Hopf algebra over an abelian group. This talk is base on joint work with Iván Angiono. (Received February 20, 2018)

1139-18-694 **Henry Tucker*** (`hjtucker@ucsd.edu`), UC San Diego. *Reconstructing Kac quasi-Hopf algebras for group-theoretical fusion categories via cleft extensions.* Preliminary report.

A fusion category with all objects having integer dimension is realized by representations of a semisimple quasi-Hopf algebra. Group-theoretical fusion categories are an important example; these are fusion categories that may be obtained from finite groups and their cohomology. We consider examples of group-theoretical fusion categories given by the representations of a Kac quasi-Hopf algebra, which is equivalent to the given category fitting in a certain exact sequence of fusion categories. We construct these quasi-Hopf algebras as cleft extensions of Hopf algebras by cocommutative quasi-Hopf algebras. We see in our family of examples that these cleft extensions correspond to elements of Masuoka's OpExt' cohomology group. (Received February 20, 2018)

20 ► *Group theory and generalizations*

1139-20-30 **John Hutchens*** (`hutchensjd@wssu.edu`) and **N Schwartz**. *Involutions of G_2 over fields.*

Let C be an octonion algebra, then $\mathrm{Aut}(C)$ is a group of type G_2. We identify the quaternion subalgebras of C that correspond to conjugacy classes of involutions of $\mathrm{Aut}(C)$ over fields of characteristic not 2. Further, we establish a characterization of automorphisms of order 2 and their fixed point groups over fields of characteristic 2 by identifying corresponding four dimensional subalgebras of C. (Received January 09, 2018)

1139-20-65 **Christopher M Drupieski*** (`c.drupieski@depaul.edu`) and **Jonathan R Kujawa**. *Cohomology and support varieties for unipotent supergroup schemes.*

An affine supergroup scheme is a representable functor from the category of commutative superalgebras to the category of groups. Put another way, an affine supergroup scheme is a (affine) group scheme object in the category of $\mathbb{Z}/2$-graded vector spaces. The category of *finite* supergroup schemes is equivalent to the category of finite-dimensional cocommutative Hopf superalgebras. In this talk, I will discuss progress to date in trying to understand the cohomology of finite supergroup schemes. In particular, I will discuss recent joint work with

Jonathan Kujawa in which we describe the cohomology spectrum for some unipotent finite supergroup schemes. (Received January 25, 2018)

1139-20-71 **Keivan Mallahi-Karai*** (k.mallahikarai@jacobs-university.de), Campus Ring I, 28759 Bremen, Bremen, Germany, **Mohammad Bardestani** (mohammad.bardestani@gmail.com), Centre for Mathematical Sciences, University of Cambridge, Wilberforce Road, Cambridge, CB3 0WB, United Kingdom, and **Hadi Salmasian** (hadi.salmasian@uottawa.ca), 585 King Edward Ave., Ottawa, Ontario K1N 6N5, Canada. *Kirillov's orbit method and the polynomiality of the essential dimension of p-groups.*

Let G be a finite group. The faithful dimension of G is defined to be the smallest possible dimension for a faithful complex representation of G. Aside from its intrinsic interest, the problem of determining the faithful dimension of finite groups is intimately related to the notion of essential dimension, introduced by Buhler and Reichstein.

In this paper, we will use Kirillov's orbit method to address this problem for groups parameterized by a prime parameter p (e.g., Heisenberg groups over finite fields with p elements) and study the question of the dependence of the faithful dimension on p. As it will be shown, in general, this function is always a piecewise polynomial along certain "number-theoretically defined" sets, while, in some specific cases, it is given by a uniform polynomial in p. (Received January 27, 2018)

1139-20-116 **John Rhodes** and **Anne Schilling*** (anne@math.ucdavis.edu). *Unified theory for finite Markov chains.*

We provide a unified framework to compute the stationary distribution of any finite irreducible Markov chain or equivalently of any irreducible random walk on a finite semigroup S. Our methods use geometric finite semigroup theory via the Karnofsky–Rhodes and the McCammond expansions of finite semigroups with specified generators; this does not involve any linear algebra. The original Tsetlin library is obtained by applying the expansions to $P(n)$, the set of all subsets of an n element set. Our set-up generalizes previous groundbreaking work involving left-regular bands by Brown and Diaconis, extensions to $\mathcal{R}$-trivial semigroups by Ayyer, Steinberg, Thiéry and the second author, and important recent work by Chung and Graham. (Received February 04, 2018)

1139-20-125 **Jonathan Gryak*** (gryakj@med.umich.edu), **Robert M. Haralick** and **Delaram Kahrobaei**. *Solving the Conjugacy Decision Problem via Machine Learning.*

Machine learning and pattern recognition techniques have been successfully applied to algorithmic problems in free groups. In this talk, we seek to extend these techniques to finitely presented non-free groups, with a particular emphasis on polycyclic and metabelian groups that are of interest to non-commutative cryptography. As a prototypical example, we utilize supervised learning methods to construct classifiers that can solve the conjugacy decision problem, i.e., determine whether or not a pair of elements from a specified group are conjugate. The accuracies of classifiers created using decision trees, random forests, and N-tuple neural network models are evaluated for several non-free groups. The very high accuracy of these classifiers suggests an underlying mathematical relationship with respect to conjugacy in the tested groups. (Received February 05, 2018)

1139-20-148 **Vladimir Shpilrain*** (shpil@groups.sci.ccny.cuny.edu). *Complexity of the subgroup membership problem in SL(2,Z).*

We discuss computational complexity of the subgroup membership problem for some special subgroups of $SL_2(Z)$. (Received February 06, 2018)

1139-20-170 **Tuval Foguel*** (tfoguel@adelphi.edu), Department of Math and CS, Science Building, Room 416, One South Avenue, Garden City, NY 11530. *Partition Numbers of Finite Solvable Groups.*

A group partition is a group cover in which the elements have trivial pairwise intersection. Here we define the partition number of a group - the minimal number of subgroups necessary to form a partition - and examine some of its properties, including its relation to the covering number for solvable groups. Also, the role of GAP in this work is briefly discussed. (Received February 07, 2018)

1139-20-278 **Reuven Hodges***, Mathematics Department, 360 Huntington Ave., Boston, MA 02115, and **Venkatramani Lakshmibai**. *A classification of spherical Schubert varieties in the Grassmannian.*

Let L_w be the largest Levi subgroup of GL_N which acts stably by left multiplication on a Schubert variety $X(w)$ in the Grassmannian $G(d, N)$. We say that $X(w)$ is a spherical Schubert variety if $X(w)$ is a spherical variety for the action of L_w. In earlier work, V. Lakshmibai and I have given a combinatorial description of the decomposition of the homogeneous coordinate ring of $X(w)$ into irreducible L_w-modules for the induced action of L_w. In fact, our decomposition results hold for any Levi subgroup of GL_N contained in L_w. We classify those decompositions that are multiplicity-free. This can be applied towards giving a complete classification of the spherical Schubert varieties. Additionally, we may enumerate all spherical Schubert varieties for a given Levi subgroup of GL_N. I will conclude by discussing some results on orbits in spherical Schubert varieties. (Received February 13, 2018)

1139-20-287 **Peter A Brooksbank*** (pbrooksb@bucknell.edu), 1 Dent Drive, Lewisburg, PA 17837. *Geometric properties of involutions in classical groups.*

The equivalence of a finite group acting flag-transitively on abstract regular polytopes and the group being generated by certain sequences of involutions is well known. It is a connection that opens the possibility of constructing new polytopes by purely group-theoretic means. In this talk I will recall some geometric properties of involutions in classical groups and propose that these properties can often be exploited to decide whether such groups arise as automorphism groups of abstract regular polytopes. (Received February 14, 2018)

1139-20-315 **Gareth Tracey*** (g.m.tracey@bath.ac.uk). *Left 3-Engel elements in groups.*

It is still an open question as to whether a left 3-Engel element of a group G is always contained in the Hirsch-Plotkin radical of G. In this talk we define these elements, discuss their motivation (which comes from the Burnside problems), and present some new and recent results. (Received February 15, 2018)

1139-20-330 **George J McNinch*** (george.mcninch@tufts.edu), Department of Mathematics, Tufts University, 503 Boston Ave, Medford, MA 02155. *Centralizers of nilpotent elements.*

Suppose that G is a connected and reductive algebraic group over a local field K. Write A for the ring of integers of K, and k for the residue field of A. Consider a parahoric group scheme P; thus P is a smooth and affine group scheme over A whose generic fiber P_K identifies with G.

In the talk, we will discuss comparison between on the one hand, the orbits of $G(K)$ on K-rational nilpotent elements, and on the other hand, the $P(k)$ orbits on the k-rational nilpotent elements for the reductive quotient of the special fiber P_k. We will try to emphasize the role of centralizers in this comparison. (Received February 15, 2018)

1139-20-339 **Albert Garreta*** (garreta.a@gmail.com). *The Diophantine problem of some solvable groups.*

The Diophantine problem in a group G, denoted $DP(G)$, consists in algorithmically determining if a given system of equations in G has a solution or not. In this talk we will talk about this and related problems in some families of solvable groups (including nilpotent and metabelian groups). The main result I will present states that, for these groups, $DP(G)$ always reduces to $DP(\mathcal{O})$, where $\mathcal{O}$ is the ring of integers of some global field. The latter is an open problem in number theory, and it is conjectured to be undecidable. We will also provide examples where $DP(G)$ actually reduces to $DP(\mathbb{Z})$, which is known to be undecidable due to Hilbert's 10th problem.

This is joint work with Alexei Miasnikov, and Denis Ovchinnikov. (Received February 15, 2018)

1139-20-352 **Elsayed Ahmed** (eahmed1@mail.usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 E Fowler ave, CMC 342, Tampa, FL 33620, and **Dmytro Savchuk*** (savchuk@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 E Fowler ave, CMC 342, Tampa, FL 33620. *Endomorphisms of regular rooted trees induced by the action of polynomials on the ring $\mathbb{Z}_d$ of d-adic integers.*

We show that every polynomial in $\mathbb{Z}[x]$ defines an endomorphism of the d-ary rooted tree induced by its action on the ring $\mathbb{Z}_d$ of d-adic integers. The sections of this endomorphism also turn out to be induced by polynomials in $\mathbb{Z}[x]$ of the same degree. In the case of permutational polynomials acting on $\mathbb{Z}_d$ by bijections the induced endomorphisms are automorphisms of the tree. In the case of $\mathbb{Z}_2$ such polynomials were completely characterized by Rivest. As our main application we utilize the result of Rivest to derive the condition on the coefficients of a permutational polynomial $f(x) \in \mathbb{Z}[x]$ that is necessary and sufficient for f to induce a level transitive automorphism of the binary tree, which is equivalent to the ergodicity of the action of $f(x)$ on $\mathbb{Z}_2$ with respect to the normalized Haar measure. (Received February 16, 2018)

1139-20-354 **Riccardo Aragona**, **Marco Calderini**, **Antonio Tortora** and **Maria Tota*** (mtota@unisa.it), DipMat - Università di Salerno, Via Giovanni Paolo II, 132, 84084 Fisciano, SA, Italy. *On the primitivity of PRESENT and other lightweight ciphers.*

We provide two sufficient conditions to guarantee that the round functions of a translation based cipher generate a primitive group. Furthermore, under the same hypotheses, and assuming that a round of the cipher is *strongly* proper and consists of m-bit S-Boxes, with $m = 3, 4$ or 5, we prove that such a group is the alternating group. As an immediate consequence, we deduce that the round functions of some lightweight translation based ciphers, such as the PRESENT cipher, generate the alternating group. (Received February 16, 2018)

1139-20-391 **Emanuele Rodaro***, Politecnico di Milano, Piazza Leonardo da Vinci, 32, 20133 Milano, Italy. *On some algorithmic problems in automaton (semi)groups.*

In this talk we are going to survey some recent results regarding algorithmic problems in automaton (semi)groups. As an intermediate concept between automaton semigroups and automaton groups, we introduce automaton-inverse semigroups, which are generated by partial and invertible automata. We show that there is an automaton-inverse semigroup and, thus, an automaton semigroup with a PSPACE-complete word problem. We also show that there is an automaton group for which the word problem with a single rational constraint is PSPACE-complete. Finally, we survey some undecidability results regarding the freeness of an automaton (semi)group. First, we show that it is undecidable to check whether the group generated by a given invertible automaton has a positive relation, i.e., a relation $w = 1$ such that w only contains positive generators. Besides its obvious relation with the freeness of the group, the absence of positive relations is equivalent to the dynamical property that all (directed positive) orbital graphs centered at non-singular points are acyclic. Then, we show that checking whether the semigroup generated by an automaton group (the semigroup generated by considering only the positive generators) is free is also an undecidable problem. (Received February 17, 2018)

1139-20-399 **Marialaura Noce*** (mnoce@unisa.it). *Engel elements in fractal groups.*

An element g of a given group G is a left Engel element if for every $x \in G$ there exists an integer $n = n(g, x) \geq 1$ such that $[x, g, \overset{n}{\ldots}, g] = 1$. The set of such elements is denoted by $L(G)$. We prove that $L(G) = 1$ for a certain class of fractal groups. This includes the Basilica group, the Brunner Sidki Vieira group, and the GGS group with constant defining vector. The approach relies on comparing the action of G on its first level stabilizer H with the action of G/H on the abelianization of H.

This is joint work with G. Fernández-Alcober and A. Garreta. (Received February 17, 2018)

1139-20-403 **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 February 17, 2018)

1139-20-407 **Mark Kleiner*** (mkleiner@syr.edu), Department of Mathematics, Syracuse University, Syracuse, NY 13244. *Preprojective Quiver of a Coxeter Group.* Preliminary report.

Certain results on representations of quivers have analogs in the structure theory of general Coxeter groups. A fixed Coxeter element c turns the Coxeter graph into an acyclic quiver, the c-quiver. A positive root is c-preprojective if a positive power of c takes it to a negative root. A Coxeter group is finite if and only if every positive root is c-preprojective. The graded c-preprojective quiver is an enlargement of the c-quiver. The construction is analogous to, but different from, that of the graded preprojective algebra of a general quiver. The c-preprojective roots are explicitly described in terms of the graded paths in the c-preprojective quiver. (Received February 17, 2018)

1139-20-410 **Carmine Monetta*** (cmonetta@unisa.it), DipMat, via Giovanni Paolo II, 132, 84084 Fisciano, Salerno, Italy, and **Antonio Tortora** (antortora@unisa.it). *A solution of the conjugacy search problem for supersoluble groups.*

In cryptography key exchange methods are usually based on one-way functions, that is functions which are easy to compute but whose inverses are difficult to determine.

There are several ways in which group theory can be used to construct one-way functions. For example, in 1999, I. Anshel, M. Anshel and D. Goldfeld introduced a key exchange protocol whose security relies in part on the Conjugacy Search Problem (CSP): *given two conjugate elements u and v of a group G, find an element x in G such that $u^x = v$.*

In 2004, B. Eick and D. Kahrobaei considered polycyclic groups as platform groups for this method. However, not every class of polycyclic groups is useful as a basis for their cryptosystem. In fact, for finitely generated nilpotent groups CSP can be solved by efficient methods.

This suggested to analyze in detail the cryptosystem for the class of supersoluble groups, which contains all finitely generated nilpotent groups. The aim of this talk is to give a solution of CSP for supersoluble groups, which extends the algorithm for finitely generated nilpotent groups due to C. Sims. (Received February 17, 2018)

1139-20-414 **Susan Hermiller*** (hermiller@unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588, and **Zoran Sunic** (zoran.sunic@hofstra.edu), Department of Mathematics, Hofstra University, Hempstead, NY 11549. *No positive cone in a free product is regular.*

We show that there exists no left order on the free product of two nontrivial, finitely generated, left-orderable groups such that the corresponding positive cone is represented by a regular language. Since there are orders on free groups of rank at least two with positive cone languages that are context-free (in fact, 1-counter languages), our result provides a bound on the language complexity of positive cones in free products that is the best possible within the Chomsky hierarchy. It also provides a strengthening of a result by Cristóbal Rivas which states that the positive cone in a free product of nontrivial, finitely generated, left-orderable groups cannot be finitely generated as a semigroup. As another illustration of our method, we show that the language of all geodesics (with respect to the natural generating set) that represent positive elements in a graph product of groups defined by a graph of diameter at least 3 cannot be regular. (Received February 18, 2018)

1139-20-425 **Keivan Mallahi-Karai*** (k.mallahikarai@jacobs-university.de), Campus Ring I, 28759 Bremen, Germany. *Random free semigroups in solvable groups.*

Let G be a finitely generated solvable subgroup of $GL_n(\mathbb{C})$ with a connected Zariski closure, and let μ be a probability measure on G whose support generates G as a semigroup. By a theorem of Rosenblatt, if G is not virtually nilpotent then it contains a non-abelian free semigroup. We will prove a probabilistic generalization of this result, namely, that under some necessary assumptions on the underlying measure μ, if $(X_n)_{n\geq 1}$ and $(Y_n)_{n\geq 1}$ are independent μ-random walks on G, then the pair (X_n, Y_n) generates a non-abelian free semigroup with probability approaching 1 as $n \to \infty$. (Received February 18, 2018)

1139-20-448 **Andrzej Zuk*** (zuk@math.jussieu.fr). *Spectra of automata.*

We present spectral computations related to automata groups and semi-groups. (Received February 18, 2018)

1139-20-547 **Antonio Tortora*** (antortora@unisa.it), Dipartimento di Matematica, Università di Salerno, 84084 Fisciano, Salerno, Italy. *Engel elements in the first Grigorchuk group.*

Let G be a group. An element $g \in G$ is called a left Engel element if for any $x \in G$ there exists a positive integer $n = n(g, x)$ such that $[x,_n g] = 1$, where the commutator $[x,_n g]$ is defined inductively by the rules

$$[x,_1 g] = x^{-1}x^g \quad \text{and, for } n \geq 2, \quad [x,_n g] = [[x,_{n-1} g], g].$$

Similarly, g is a right Engel element if the variable x appears on the right. If n can be chosen independently of x, then g is called a left or right bounded Engel element, respectively.

In [1], Bartholdi provides a *partial* algorithm giving a criterion for an element to be left Engel when $G = \Gamma$ is the first Grigorchuk group. As an application the algorithm allows to determine all left Engel elements of Γ. The aim of this talk is to describe the sets of all right Engel, left bounded Engel and right bounded Engel elements of Γ.

This is a joint work with G. A. Fernández-Alcober and M. Noce.

References

[1] L. Bartholdi, *Algorithmic decidability of Engel's property for automaton groups*, Computer science–theory and applications, 29—40, Lecture Notes in Comput. Sci., 9691, Springer, 2016.

(Received February 19, 2018)

1139-20-583 **Jacob P. Matherne*** (matherne@math.umass.edu). *Derived geometric Satake equivalence, Springer correspondence, and small representations.*

A recurring theme in geometric representation theory is the ability to describe representations in terms of the topology of certain spaces. Two major theorems in this area are the geometric Satake equivalence and the Springer correspondence, which state:

(1) For G a semisimple algebraic group, we can realize $\mathrm{Rep}(G)$ using intersection cohomology of the affine Grassmannian for the Langlands dual group.

(2) For W a Weyl group, we can realize $\text{Rep}(W)$ using intersection cohomology of the nilpotent cone.

In the late 90s, M. Reeder computed the Weyl group action on the zero weight space of the irreducible representations of G, thereby relating $\text{Rep}(G)$ to $\text{Rep}(W)$. More recently, P. Achar, A. Henderson, and S. Riche established a functorial relationship between the two phenomena above. In my talk, I will review this story and discuss a result which extends their functorial relationship to the setting of mixed, derived categories. (Received February 20, 2018)

1139-20-621 **Reuven Hodges*** (hodges.r@husky.neu.edu) and **Venkatramani Lakshmibai**. *Levi subgroup actions on Schubert varieties in the Grassmannian.*

Let L be a Levi subgroup of the general linear group $GL_N(\mathbb{C})$ which acts stably by left multiplication on a Schubert variety $X(w)$ in the Grassmannian. We provide a combinatorial description of the decomposition of the homogeneous coordinate ring of $X(w)$ (for the Plucker embedding) into irreducible L-modules for the induced action. This is then used to classify all $X(w)$ whose homogeneous coordinate rings have a multiplicity free decomposition into irreducible L-modules in the case where L is the maximal Levi subgroup which acts on $X(w)$. When L is not maximal we give sufficient conditions for the decomposition to be multiplicity free. (Received February 20, 2018)

1139-20-624 **Peter Webb***, School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *Cohomological properties of cohomological Mackey functors.* Preliminary report.

Cohomological Mackey functors have dominant dimension 2 (when they are not semisimple) and so have a tilting module generated and cogenerated by the projective-injective objects, as considered recently by Nguyen-Reiten-Todorov-Zhu. We describe aspects of the torsion pair determined by this tilting module and the techniques used to compute it. (Received February 20, 2018)

1139-20-629 **David Carroll**, **Benjamin Francisco** and **Zoran Šunić*** (zoran.sunic@hofstra.edu), Department of Mathematics, 306 Roosevelt Hall, Hofstra University, Hempstead, NY 11549. *Deciding if a right-angled Artin group is free-by-free is an NP-complete problem.* Preliminary report.

We show that deciding if a right-angled Artin group is free-by-free is an NP-complete problem. The work is based on an earlier result by Susan Hermiller and the third author stating that the right-angled Artin group $A\Gamma$ defined by the graph Γ is free-by-free if and only if Γ is 2-breakable (a graph Γ is 2-brekable if there exists an independent set D of vertices in Γ such that every cycle in Γ contains as least two vertices from D). We reduce the 3SAT Problem to the problem of deciding if a given graph is 2-breakable (in fact, k-breakable, for any fixed $k \geq 1$). Once it is shown that the problem is NP-complete, it is not difficult to show that it stays NP-complete even if we restrict it to right-angled Artin groups defined by planar graphs. Note that the more special problem of deciding if a right-angled Artin group is free-by-infinite-cyclic has a very simple answer. Namely, it follows easily from known results that the following three statements are equivalent. (1) $A\Gamma$ is free-by-infinite-cyclic. (2) Γ is a forest. (3) $A\Gamma$ embeds in the right angled group defined by the path of length 3. (Received February 20, 2018)

1139-20-655 **Talia Fernos*** (t_fernos@uncg.edu), Greensboro. *Groups and CAT(0) Cube Complexes.*

CAT(0) cube complexes have interesting interconnections between geometry, analysis, and algebra. In this talk, we discuss a variety of aspects of groups acting on CAT(0) cube complexes. In particular, we will discuss the word and conjugacy problems for groups acting geometrically on CAT(0) cube complexes. (Received February 20, 2018)

1139-20-669 **Gilbert Baumslag**, **Benjamin Fine*** (fine@mail.fairfield.edu), **A Moldenhauer** and **Gerhard Rosenberger**. *Secure Passwords Using Combinatorial Group Theory.*

We describe a password security system based on free groupsd. We then prove that it is provabkly secure. (Received February 20, 2018)

22 ► Topological groups, Lie groups

1139-22-44 **Alfred G Noel*** (alfred.noel@umb.edu), 100 Morrissey Boulevard, Boston, MA 02125, and **Steven Jackson**, **Todor Milev** and **Thomas Folz-Donahue**. *Tau Signatures and Characters of Weyl Groups.* Preliminary report.

Let $G_{\mathbb{R}}$ be the set of real points of a complex reductive Lie group and $\hat{G}_\lambda$, its classes of irreducible character with infinitesimal integral regular character, λ. In this case, each cell of representations is associated to a special nilpotent orbit. This helps organize the corresponding set of irreducible Harish-Chandra modules. The goal of this talk is to describe algorithms for identifying the special nilpotent orbit attached to a cell in terms of descent sets appearing in the cell. (Received January 18, 2018)

1139-22-54 **Peter Crooks*** (peter.crooks@math.uni-hannover.de), Institute of Differential Geometry, Gottfried Wilhelm Leibniz University Hannover, Welfengarten 1, 30167 Hannover, Germany, and **Hiraku Abe**. *Slodowy slices and Hessenberg varieties.*

Toda systems and related algebraic integrable systems have been studied at the interface of algebraic geometry, holomorphic symplectic geometry, and representation theory. One instance of this involves fixing a complex semisimple algebraic group G with Borel subgroup B, in which setting Kostant studied the Toda system on the coadjoint B-orbit of a regular nilpotent element.

I will discuss embeddings of Kostant's Toda system into integrable systems on two larger varieties. The first of these varieties will be a holomorphic symplectic variety constructed via Slodowy slices, while the second will be a certain well-studied family of Hessenberg varieties. If time permits, I will discuss some implications of the two embeddings.

This represents previous work with S. Rayan and ongoing work with H. Abe. (Received January 24, 2018)

1139-22-97 **Peter Crooks*** (peter.crooks@math.uni-hannover.de), Institute of Differential Geometry, Gottfried Wilhelm Leibniz University Hannover, 30167 Hannover, Germany, and **Steven Rayan**, University of Saskatchewan. *Abstract integrable systems in a Lie-theoretic setting.*

A *completely integrable system* on a given $2n$-dimensional symplectic manifold X is usually defined to be the following data: a collection $f_1, \dots, f_s$ of functions on X, such that $s = n$, the f_i Poisson-commute in pairs, and $df_1 \wedge \cdots \wedge df_s$ is non-vanishing on an open dense subset of X. A mild generalization is the notion of a *non-commutative integrable system* (NCI system), in which s is allowed to exceed n and only certain f_i are required to Poisson-commute with all functions in the collection. Some recent work of Fernandes, Laurent-Gengoux, and Vanhaecke proposes a foliation-theoretic version of an NCI system in the smooth category, called an *abstract non-commutative integrable system* (ANCI system).

I will discuss joint work with S. Rayan concerning ANCI systems in the holomorphic category. Particular attention will be paid to a canonical ANCI system on each hyperkähler manifold of the form $G \times S_{\text{reg}}$, where G is a connected complex semisimple Lie group and S_{reg} is a regular Slodowy slice in the Lie algebra of G. If time permits, I will describe recent work with H. Abe on a leaf-wise compactification of $G \times S_{\text{reg}}$. (Received February 03, 2018)

1139-22-409 **Kayue Daniel Wong*** (kayue.wong@cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853, and **Dan Barbasch** (barbasch@math.cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853. *Admissible modules and normality of classical nilpotent orbits.*

In the case of complex classical groups, we study $(\mathfrak{g}, K)$-modules with the property that their K-structure matches the structure of regular functions on the Zariski closures of nilpotent orbits.

In particular, we give a description on the decomposition of the ring of regular functions of the orbit closures into irreducible, algebraic modules. This verifies the conditions on the normality of such varieties given by Kraft and Procesi. (Received February 17, 2018)

1139-22-697 **Oscar S Kivinen*** (okivinen@ucdavis.edu). *Springer theory for symmetric spaces in type A.*

Recently, Chen-Vilonen-Xue, Lusztig-Yun and Shoji-Yang considered a generalization of Springer theory to symmetric spaces in type A. I will discuss the combinatorics of the block decomposition of the category of equivariant perverse sheaves on cone of nilpotent symmetric matrices and explain some applications to cohomology of Hessenberg varieties. (Received February 21, 2018)

28 ► Measure and integration

1139-28-21 **Matthew Badger*** (matthew.badger@uconn.edu). *Traveling along Hölder curves.*

I will report on an extension of Peter Jones' traveling salesman construction, which provides a sufficient condition for a set in Euclidean space 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 is joint work with Lisa Naples and Vyron Vellis. (Received December 13, 2017)

1139-28-98 **Aimee S. A. Johnson*** (aimee@swarthmore.edu), Department of Mathematics and Statistics, 500 College Ave., Swarthmore, PA 19081, and **David M McClendon**, Department of Mathematics ASC 2021, Big Rapids, MI 49307. *Speedups of $\mathbb{Z}^d$-odometers.* Preliminary report.

A speedup of a dynamical system (X, T) is another system (X, T^p) where $p : X \to \{1, 2, 3 \dots\}$. A fundamental question about speedups concerns the relationship between the original system and the speedup. In the measure-theoretical case, Arnoux, Ornstein, and Weiss showed there does not need to be any relationship: given any two ergodic systems, one can be sped up to be isomorphic to the other. On the other hand, in the topological setting, Ash proved that given two Cantor minimal systems, whether or not one can be sped up to be conjugate to the other depends on the dimension groups of the systems. In fact, in recent work by Alvin, Ash, and Ormes, they show that any bounded speedup of an odometer must be an odometer that is conjugate to the original.

Speedups have been generalized to $\mathbb{Z}^d$ actions by Johnson and McClendon and they have shown that the measure-theoretical case remains the same. In this talk we discuss the generalization of the Alvin, Ash, and Ormes result to $\mathbb{Z}^d$ actions, starting with a description of a $\mathbb{Z}^d$-odometer and discussing the similarities and differences to the $d = 1$ case. (Received February 03, 2018)

1139-28-161 **Guy C. David***, Department of Mathematical Sciences, Ball State University, Muncie, IN 47306, and **Kyle Kinneberg**. *Bi-Lipschitz behavior of Lipschitz mappings between metric spaces.*

We will survey some old and recent results and counterexamples on the problem of finding bi-Lipschitz behavior in arbitrary Lipschitz mappings between given metric spaces. We will then discuss new results (joint with Kyle Kinneberg) concerning the situation between PI spaces and Carnot groups. These address some questions of Semmes. (Received February 07, 2018)

1139-28-227 **Jeremy T Tyson***, Department of Mathematics, 1409 West Green St, Urbana, IL 61801. *Geometric measure theory in the Heisenberg group.*

I will survey some recent results in geometric measure theory in the sub-Riemannian Heisenberg group, including Marstrand-type projection theorems and preliminary work related to Falconer's distance set problem. This talk is based on prior work with Zoltan Balogh, Estibalitz Durand Cartagena, Katrin Faessler and Pertti Mattila, and ongoing work with Fernando Roman Garcia. (Received February 12, 2018)

1139-28-236 **Silvia Ghinassi*** (ghinassi@math.stonybrook.edu). *Sufficient conditions for $C^{1,\alpha}$ parametrization and rectifiability.*

We provide sufficient conditions for a set or measure in $\mathbb{R}^n$ to be $C^{1,\alpha}$ d-rectifiable, with $\alpha \in [0, 1]$. The conditions use a Bishop-Jones type square function and all statements are quantitative in that the $C^{1,\alpha}$ constants depend on such a function. Key tools for the proof come from Guy David and Tatiana Toro's parametrization of Reifenberg flat sets (with holes) in the Hölder and Lipschitz categories. (Received February 12, 2018)

1139-28-238 **Silvia Ghinassi*** (ghinassi@math.stonybrook.edu). *Sufficient conditions for $C^{1,\alpha}$ parametrization.*

We provide sufficient conditions for a set in $\mathbb{R}^n$ to be parametrized by a $C^{1,\alpha}$ curve, with $\alpha \in [0, 1]$. The conditions involve an appropriate notion of "flatness" and boundedness of a Bishop-Jones type square function; all statements are quantitative in that the $C^{1,\alpha}$ constants depend on such a function. Key tools for the proof come from Guy David and Tatiana Toro's parametrization of Reifenberg flat sets (with holes) in the Hölder and Lipschitz categories. The results can be applied to obtain sufficient conditions for $C^{1,\alpha}$ d-rectifiability for sets and measures in $\mathbb{R}^n$. (Received February 21, 2018)

1139-28-296 **Bobby Wilson*** (bobbylwilson@gmail.com), 77 Massachusetts Avenue, Room 2-171, Cambridge, MA 02139. *Arbitrarily Slowly Decaying Favard Length.*

In this talk, we will discuss the concept of quantifying the visibility of a planar set and its relation to planar geometry. We will present the classical theorem of Besicovitch characterizing regularity of planar sets by the properties of their orthogonal projections which can be extrapolated to a characterization based on what is known as Favard length. This will be followed by an exploration of a similar characterization using approximations of sets in place of the original sets we want to study. (Received February 14, 2018)

1139-28-396 **Sean Li*** (sean.li@uconn.edu). *Traveling salesman and singular integrals.*

In 1977, Calderon proved that the Cauchy transform is bounded as a singular integral operator on the L_2 space of Lipschitz graphs in the complex plane. This subsequently sparked much work on singular integral operators on subsets of Euclidean space. Due to the deep works of David, Jones, Semmes, and many others, it is now known that the boundedness of singular integrals of certain odd kernels is intricately linked to a rectifiability structure of the underlying sets.

The 1-rectifiability of sets in the Heisenberg group has an almost tight characterization via an analyst's traveling salesman theorem which measures deviations of the set from "horizontal lines". We use this to study the connection between singular integrals and rectifiability for 1-dimensional subsets of the Heisenberg group where we find a similar connection to the Euclidean case. However, the kernels studied turn out to be positive and even, in stark contrast with the Euclidean setting. We also describe a recent 1-sided extension of the traveling salesman theorem to general Carnot groups.

Based on multiple joint works with V. Chousionis, R. Schul, and S. Zimmerman. (Received February 17, 2018)

1139-28-680 **Alan Chang**, **Marianna Csornyei*** (csornyei@math.uchicago.edu), **Kornelia Hera** and **Tamas Keleti**. *Small unions of affine subspaces and skeletons via Baire category.*

Our aim is to find the minimal Hausdorff dimension of the union of scaled and/or rotated copies of the k-skeleton of a fixed polytope centered at the points of a given set. For many of these problems, we show that a typical arrangement in the sense of Baire category gives minimal Hausdorff dimension. (Received February 20, 2018)

30 ► Functions of a complex variable

1139-30-17 **Hrant Hakobyan** and **Wenbo Li*** (liwenbomaths@gmail.com). *Quasisymmetric Embeddings of Slit Sierpiński Carpets into the Plane.*

The study of quasiconformal geometry of fractal metric spaces has received much attention recently. In particular, the metric spaces homeomorphic to the classical Sierpiński carpet, also known as metric carpets, were studies partly because of problems arising in geometric group theory.

A mapping between metric spaces is called quasisymmetric if it distorts relative distances and sizes of sets by a bounded amount. One of the most important questions in the theory is the problem of quasisymmetrically embedding a metric space into an Euclidean space. In this talk we will define a class of spaces called slit Sierpiński carpets and will completely characterize those slit Sierpiński carpets which can be embedded quasisymetrically into the plane. The main tools are classical and transboundary modulus of families of curves. (Received February 12, 2018)

1139-30-226 **Vyron Vellis*** (vyron.vellis@uconn.edu), 341 Mansfield Road U1009, Storrs, CT 06269-1009. *Quasisymmetric and bi-Lipschitz extensions on Euclidean spaces.*

One of the oldest problems in Geometric Analysis is the extension problem: if $E \subset \mathbb{R}^n$ and $f : E \to \mathbb{R}^n$ is a quasisymmetric (resp. bi-Lipschitz) embedding, when is it possible to extend f to a quasisymmetric (resp. bi-Lipschitz) self homeomorphism of $\mathbb{R}^n$? For $n = 1$ we give a complete answer while for $n = 2$ we generalize previous Schoenflies extension results of Beurling, Ahlfors and Tukia to uniform domains with relatively connected boundary. For $n \geq 3$ we show that any quasisymmetric (resp. bi-Lipschitz) map$f : E \to \mathbb{R}^n$ of a totally disconnected set $E \subset \mathbb{R}^n$ with bounded geometry can be extended to a quasisymmetric (resp. bi-Lipschitz) self homeomorphism of $\mathbb{R}^{n+1}$. (Received February 16, 2018)

1139-30-400 **Mario Bonk*** (mbonk@math.ucla.edu). *Quasisymmetric rigidity of Sierpiński carpets.*

Every quasisymmetric self-homeomorphism of a standard square carpet S_p, $p \geq 3$ odd, is an isometry. In my talk I will outline a proof of this fact. It uses quasisymmetric uniformization, rigidity results for Schottky maps, and the dynamics of Lattès maps. This is joint work with Sergei Merenkov. (Received February 17, 2018)

1139-30-432 **Marie A. Snipes*** (snipesm@kenyon.edu). *Harmonic measure distribution functions for a class of multiply-connected symmetrical slit domains.*

The harmonic measure distribution function $h : (0, \infty) \to \mathbb{R}$ of a domain Ω in the complex plane with basepoint $z_0 \in \Omega$ relates the behavior of a Brownian particle in Ω starting at z_0 to the geometry of the domain. For simply connected domains, the harmonic measure distribution function can often be explicitly computed by making use of conformal mapping techniques.

In this talk we give an explicit construction of the harmonic measure distribution functions for multiply connected "slit domains" that consist of the complex plane with a finite number of colinear slits deleted. The method of construction is based on the theory of the Schottky-Klein prime function, as recently developed by Crowdy and collaborators including Marshall and Green. This is joint work with Darren Crowdy, Chris Green, and Lesley Ward. (Received February 18, 2018)

32 ► Several complex variables and analytic spaces

1139-32-69 **Takuro Abe*** (abe@imi.kyushu-u.ac.jp), Motooka 744, Nishi-Ku, Fukuoka, Fukuoka 8190395, Japan. *Generators of logarithmic derivation modules of hyperplane arrangements.*

Logarithmic derivation modules are one of the most important objects to study in of hyperplane arrangements and hypersurfaces. In particular, the freeness of them have been intensively studied. But in general they are not free. By Dimca and Sticlaru, the near freeness of plane curves and cubic surfaces are introduced, which is close to the freeness from the viewpoint of the number of generators. We study several properties of free and nearly free curves from algebro-geometric points of view, and consider the higher dimensional version of them. This talk contains a joint work with Alex Dimca. (Received January 27, 2018)

1139-32-319 **Loredana Lanzani***, Department of Mathematics, Syracuse University, Syracuse, NY 13224, and **Elias M. Stein**. *Harmonic analysis techniques in several complex variables.* Preliminary report.

I will give a survey of recent joint work with E. M. Stein (Princeton U.) concerning the analysis of a family of singular integral operators in complex Euclidean space for domains with minimal boundary regularity. In contrast with the situation in real Euclidean space, here we must require that the integral kernel be a holomorphic (analytic) function of the output variable. I will present positive results (boundedness in Lebesgue space) for the Szego projection and for a family of Cauchy-like singular integrals. I will then give counterexamples (unboundedness) that indicate the optimality of our assumptions. (Received February 15, 2018)

1139-32-327 **Edward Bierstone*** (bierston@math.toronto.edu), University of Toronto, Department of Mathematics, 40 St. George Street, Toronto, Ontario M5S2E4, Canada. *Geometry of quasianalytic classes.*

Quasianalytic classes are classes of infinitely differentiable functions that enjoy the analytic continuation property of holomorphic functions. They are the objects of classical studies in real analysis (e.g., the Denjoy-Carleman theorem), and the last 20 years have seen the development of remarkable relationships with algebraic geometry (resolution of singularities) and model theory (o-minimal structures). I will talk about these developments, recent results on the solutions of quasianalytic equations, and open problems. (Received February 15, 2018)

33 ► Special functions

1139-33-78 **Alex Kasman*** (kasmana@cofc.edu), Department of Mathematics, 66 George Street, Charleston, SC 29424. *Recent Results on the Bispectrality of Integrable Systems.*

We say that a function of the (scalar or vector) variables x and z is *bispectral* if there is an operator in x having it as an eigenfunction with z-dependent eigenvalue *and* an operator in z having it as an eigenfunction with x-dependent eigenvalue. Since there is nothing in this definition to suggest a connection to dynamical systems, it is somewhat mysterious that bispectrality arises in the study of the duality of integrable particle systems in two seemingly unrelated ways. In the case of classical integrable systems duality is manifested in the bispectrality of the Baker-Akhiezer function of the Lax operator and for their quantized versions it is the dual Hamiltonians that share a bispectral eigenfunction. I have been seeking to understand this phenomenon since it was first identified in the case of the self-dual Calogero-Moser system. This talk will list open problems in this program and summarize the progress, including a surprising counter-example recently discovered in an attempt to extend it to the Toda Lattice. (Received January 29, 2018)

1139-33-422 **Robert Milson*** (robert.milson@gmail.com), Department of Mathematics & Statistics, Dalhousie University, Halifax, NS B3L4B6, Canada. *Toward the classification of Exceptional Orthogonal Polynomials: a progress report.*

Exceptional Orthogonal Polynomials are orthogonal polynomial familie s that arise as solutions for second-order eigenvalue problems. They generalize the classical families of Hermite, Laguerre, and Jacobi in that they allow for polynomial sequences with a finite number of missing degrees. The fundamental technique for constructing such objects is the Darboux transformation, which "dresses" a classical operators to obtain orthogonal polynomials with a finite number of exceptional degrees. Thanks to a foundational theorem that asserts that all exceptional orthogonal polynomials arise in precisely this fashion, it is now possible to envisage a complete classification of exceptional orthogonal operators and their attendant operators. In my talk I will describe the essential components of this programme and highlight the technical challenges that must be overcome en route to classification. (Received February 18, 2018)

1139-33-577 **Emma Previato***, Department of Mathematics and Statistics, Boston University, Boston, MA 02215. *The Kleinian sigma function: Algebraic and transcendental aspects.*

Klein extended the definition of the (genus-one) Weierstrass sigma function to hyperelliptic curves and curves of genus three. H.F. Baker developed an in-depth theory of PDEs satisfied by the hyperelliptic sigma function, which plays a key role in recent work on integrable hierarchies (KdV-type, e.g.). Beginning in the 1990s, this theory of Kleinian sigma functions was revisited, originally by V.M. Buchstaber, V.Z. Enolskii and D.V. Leykin, much extended in scope, eventually to be developed for "telescopic" curves (a condition on the Weierstrass semigroup at a point). In work with J. Komeda and S. Matsutani, we went beyond the telescopic case. This talk will explain our construction and display formulas connecting it with classical special functions, together with questions and current projects. The focus is on applications to integrable dynamics. (Received February 19, 2018)

34 ► Ordinary differential equations

1139-34-53 **Maya Chhetri**, **Lakshmi Sankar**, **Ratnasingham Shivaji** and **Byungjae Son*** (gm5431@wayne.edu), 1150 Faculty/Administration Building, 656 W. Kirby, Detroit, MI 48202. *An existence result for superlinear semipositone p-Laplacian systems on the exterior of a ball.*

We study the existence of positive radial solutions to the problem

$$\begin{cases} -\Delta_p u = \lambda K_1(|x|)f(v) & \text{in } \Omega_e, \\ -\Delta_p v = \lambda K_2(|x|)g(u) & \text{in } \Omega_e, \\ \quad u = v = 0 & \text{if } |x| = r_0, \\ \quad u(x) \to 0, v(x) \to 0 & \text{as } |x| \to \infty, \end{cases}$$

where $\Delta_p w := \operatorname{div}(|\nabla w|^{p-2}\nabla w)$, $1 < p < n$, λ is a positive parameter, $r_0 > 0$ and $\Omega_e := \{x \in \mathbb{R}^n | \ |x| > r_0\}$. Here $K_i : [r_0, \infty) \to (0, \infty)$, $i = 1, 2$ are continuous functions such that $\lim_{r\to\infty} K_i(r) = 0$, and $f, g : [0, \infty) \to \mathbb{R}$ are continuous functions which are negative at the origin and have a superlinear growth at infinity. We establish the existence of a positive radial solution for small values of λ via degree theory and rescaling arguments. (Received January 23, 2018)

1139-34-158 **K.D. Chu**, **D.D. Hai** and **Ratnasingham Shivaji*** (r_shivaj@uncg.edu). *Uniqueness of positive radial solutions for infinite semipositone p-Laplacian problems in exterior domains.*

We prove uniqueness and asymptotic behavior of positive radial solutions to the p-Laplacian problem

$$\begin{cases} -\Delta_p u = \lambda K(|x|)f(u) \text{ in } |x| > r_0, \\ u = 0 \text{ on } |x| = r_0, \quad u(x) \to 0 \text{ as } |x| \to \infty. \end{cases}$$

where $\Omega = \{x \in \mathbb{R}^N : |x| > r_0 > 0\}, N > 2, \ f : (0, \infty) \to \mathbb{R}$ is continuous, $f(u) \sim u^q$ at ∞ for some $q \in [0, p-1)$ with possible infinite semipositone structure at 0, and λ is a large parameter (Received February 07, 2018)

1139-34-620 **Vardayani Ratti*** (vardayani.ratti@dartmouth.edu), 27 N Main Stret, 314 Kemeny Hall, Hanover, NH 03755, and **Peter G. Kevan** and **Hermann J. Eberl**. *A mathematical approach to study loss of honeybee colonies infested with varroa destructor and deadly viruses.*

Honeybee (*Apis mellifera*) colonies continue to experience high annual losses that remain poorly explained. Among the many stressors that were proposed, parasitic varroa mites have been identified as one of the main culprits. These mites, in addition to being harmful to the bees themselves, are also the vector for several bee viruses.In this project, we study a mathematical model for the honeybees-*varroa destructor*-virus complex. We study this model with a combination of analytical and numerical techniques. We find that the bee colony is never able to fight off mites. We also find that depending on parameters, in a colony that is not treated with varroacides mites can establish themselves leading to colonies with slightly reduced number of bees; if some of these mites carry the virus, however, the colony might fail suddenly after several years without a noticeable sign of stress leading up to the failure. The immediate cause of failure is that at the end of Fall colonies are not strong enough to survive the Winter in viable numbers. We investigate the effect of the initial disease infestation on collapse time, and how varroacide treatment affects longterm behavior. We find that to control the virus epidemic, the mites as disease vector should be controlled. (Received February 20, 2018)

35 ► Partial differential equations

1139-35-6 **Benoit Pausader*** (benoit_pausader@brown.edu). *Hyperbolic nonlinear Schrodinger equation.*

We study some properties of the liner and nonlinear hyperbolic Schrodinger equation. This is joint work with B. Dodson, J. Marzuola and D. Spirn. (Received September 10, 2017)

1139-35-12 **Nathaniel Stambaugh*** (stambaughn@wit.edu) and **Mark Semon**. *Symmetry and Solutions to the Helmholtz equation inside an equilateral triangle.*

Solutions to the Helmholtz equation within an equilateral triangle which solve either the Dirichlet or Neumann problem are investigated. This is done by introducing a pair of differential operators, derived from symmetry considerations, which demonstrate interesting relationships among these solutions. One of these operators preserves the boundary condition while generating an orthogonal solution and the other leads to a bijection between solutions of the Dirichlet and Neumann problems. (Received November 02, 2017)

1139-35-13 **Paul M. N. Feehan*** (paul.feehan@math.rutgers.edu), Department of Mathematics, Hill Center for Mathematical Sciences, 110 Frelinghuysen Road, Piscataway, NJ 08854. *Lojasiewicz-Simon gradient inequalities and convergence of weak gradient flows to weak limits.*

Development and application of the Lojasiewicz-Simon gradient inequality was pioneered by Leon Simon in his analysis of global existence and convergence of gradient flows defined by certain analytic functions on Banach spaces arising in geometric analysis. This paradigm has been successfully used to prove global existence and convergence for all time of Yang-Mills and harmonic map gradient flows near smooth critical points that are local minima of the energy functions. We shall describe a new proof of the Lojasiewicz gradient inequality for an analytic function on Euclidean space and a Lojasiewicz-Simon gradient inequality for weak gradient flows that may be used to prove convergence for weak limits allowing for energy bubbling for the conformally invariant Yang-Mills energy function in dimension four and the harmonic map energy function in dimension two. (Received November 04, 2017)

1139-35-22 **Matthew Badger*** (matthew.badger@uconn.edu). *Two-phase free boundary problem for harmonic measure with Hölder data.*

I will report on joint work with Max Engelstein and Tatiana Toro. We continue the study of non-variational two-phase free boundary problems for harmonic measure. Previously, in separate and joint works, we showed that under appropriate a priori topological conditions on a pair of complementary domains $\Omega^{\pm} \subset \mathbb{R}^n$, if the Radon-Nikodym derivative of harmonic measure of one domain with respect to the harmonic measure of the other domain has α-Hölder continuous logarithm, then the common boundary of the domains splits into a regular set and a singular set: the regular set is an $(n-1)$-dimensional $C^{1,\alpha}$ submanifold and the singular set is closed and has Hausdorff and Minkowski dimension at most $n-3$. In new work, we use a Weiss-type monotonicity formula and an epiperimetric inequality for homogeneous harmonic functions to obtain refined information about the singular set. In particular, we establish uniqueness of blowups and $C^{1,\beta}$ rectifiability of the singular set. (Received December 15, 2017)

1139-35-27 **Luca Capogna**, Department of Mathematical Sciences, 100 Institute Road, Worcester, MA 01609, and **Xiaodan Zhou*** (xzhou3@wpi.edu), Department of Mathematical Sciences, 100 Institute Road, Worcester, MA 01609. *Strong Comparison Principle for $p-$harmonic functions in Carnot-Caratheodory spaces.*

We extend Bony's propagation of support argument to C^1 solutions of the non-homogeneous sub-elliptic $p-$Laplacian associated to a system of smooth vector fields satisfying Hörmander's finite rank condition. As a consequence, we prove a strong maximum principle and strong comparison principle that generalize results of Tolksdorf. This is joint work with Luca Capogna. (Received January 08, 2018)

1139-35-34 **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 January 13, 2018)

1139-35-36 **Stefanos Aretakis***, 55 Belfountain Dr, Whitby, ONTARIO L1R 0C4, Canada. *Asymptotics and scattering for the wave equation on black holes.*

We will present results regarding asymptotics for solutions to the wave equation on extremal and sub-extremal black holes. These results are motivated by the black hole stability problem and the strong cosmic censorship. We will also present various applications for the backwards scattering problem on black holes. (Received January 14, 2018)

1139-35-39 **Kazuo Yamazaki***, 1017 Hylan Hall, Department of Mathematics, University of Rochester, Rochester, NY 14627. *A few examples on the property of the noise in PDE of fluid mechanics.*

In this talk I will discuss a few examples of situations in which the noise permits some results for the randomly forced PDE in fluid mechanics for which there is no counterpart in the deterministic case.

In particular, it is well-known that for a deterministic system of nonlinear PDE in fluid mechanics, lack of diffusion makes it difficult, impossible actually to the best of my knowledge, for anybody to obtain a global well-posedness result with small initial data. As an example, I will describe how the Hall-MHD system forced by Levy noise with no velocity dissipation still allows a global well-posedness result with small initial data.

Secondly, it is well-known that Kelvin's conservation of circulation holds for the Euler equations but not the Navier-Stokes equations. Similarly it may be shown that the damped Euler equations has an exponential decay (in time) of the circulation but the identity no longer holds for the damped Navier-Stokes equations. Nevertheless, using stochastic Lagrangian formulation, it can be shown that these properties continue to hold even in the dissipative case "on average" (i.e. through expectation). Similar results are obtained for the Boussinesq system, Leray-alpha MHD system, micripolar and magneto-micropolar fluid systems as well. (Received January 15, 2018)

1139-35-45 **Olivier Lafitte***, 99 avenue J.B. Clement, 93430 Villetaneuse, France, **Mark Williams** (williams@unc.edu), Chapel Hill, NC 27199, and **kevin zumbrun** (kzumbrun@indiana.edu), 861 East Third Street, Bloomington, IN 47401. *Stability study of a system of PDEs: the Evans function near turning points.*

We describe some ODE tools for studying the stability of a steady-state (or a travelling wave solution) of hyperbolic systems, such as the Zeldovich-Von Neumann-Doring system for detonation waves (ZND).
Such systems are of the form

$$\partial_t U + \nabla.F(U) = -k\Psi(U'')U_m \begin{pmatrix} 0 \\ K(U'') \end{pmatrix} \tag{1}$$

where $U = \begin{pmatrix} U' \\ U'' \end{pmatrix}$ belongs to $C^1(\mathbb{R}^{d+1}, \mathbb{R}^m)$, $U' \in C^1(\mathbb{R}^{d+1}, \mathbb{R}^{m-d})$. For example, for the ZND system, U_1, U_2, U_3 are the components of the velocity, U_4, U_5, U_6 are respectively the specific volume, the entropy and the mass fraction of the reactant.
The linear stability of a steady-state solution $U_0(x_1)$ on $x_1 \geq x_1^*$ satisfying $\lim_{x_1 \to +\infty} = U_0$ is studied through the Evans function. Its calculation relies on finding bounded solutions of

$$h\frac{d\theta}{dx} = M(x_1, \zeta, h)\theta$$

The case$M(x_1, \zeta, 0)$ has a turning point at $x_1^0 > x_1^*$ and the case where $M(+\infty, \zeta, 0)$ has a turning point are studied through model problems, respectively an Airy function problem and a Bessel function problem. (Received January 19, 2018)

1139-35-46 **Luca Spolaor*** (lspolaor@princeton.edu). *Logarithmic Epiperimetric inequality and the regularity of the free-boundary.*

In this talk I will introduce a new Logarithmic Epiperimetric inequality and show how the regularity of the free-boundary can be deduced from it in many problems, such as the Obstacle, Thin-Obstacle and Alt-Caffarelli problems. If time permits, I will give an idea of how the inequality is proved. These are joint works with Maria Colombo, Max Engelstein and Bozhidar Velichkov. (Received January 19, 2018)

1139-35-50 **Tariel Kiguradze** (tkigurad@fit.edu) and **Noha Aljaber*** (naljaber2013@my.fit.edu), 150 W. University Blvd, Melbourne, FL 32901. *Periodic Problems for Higher Order Linear Hyperbolic Equations.*

For the equation

$$u^{(\mathbf{m})} = \sum_{\boldsymbol{\alpha}<\mathbf{m}} p_{\boldsymbol{\alpha}}(x)u^{(\boldsymbol{\alpha})} + q(x) \tag{1}$$

consider the periodic

$$u(x+\boldsymbol{\omega}_j) = u(x) \quad (j=1,\dots,n) \tag{2}$$

and the initial-periodic

$$\begin{aligned} u^{(\mathbf{k}_j)}(x_1,\dots,x_{j-1},0,x_{j+1},\dots,x_n) = \varphi_{jk_j}(\hat{x}_j) \quad (k_j=0,\dots,m_j-1; j=1,\dots,n_0),& \\ u(x+\boldsymbol{\omega}_j)=u(x) \quad (j=n_0+1,\dots,n)& \end{aligned} \tag{3}$$

conditions. Here $n\geq 2$, $\mathbf{m}=(m_1,\dots,m_n)$, $x=(x_1,\dots,x_n)$, $\boldsymbol{\omega}=(\omega_1,\dots,\omega_n)$,

$$\boldsymbol{\omega}_j=(0,\dots,\omega_j,\dots,0), \quad \mathbf{k}_j=(0,\dots,k_j,\dots,0), \ \ \hat{x}_j=(x_1,\dots,x_{j-1},x_{j+1},\dots,x_n)$$

$$\boldsymbol{\alpha}<\mathbf{m} \Leftrightarrow \alpha_j\leq m_j \ (j=1,\dots,n), \quad \boldsymbol{\alpha}\neq\mathbf{m}.$$

For problems $(1),(2)$ and $(1),(3)$ there are established:

(i) Necessary and sufficient conditions of well-posedness;

(ii)Optimal conditions of solvability and unique solvability in ill-posed (conditionally well-posed) cases. (Received January 23, 2018)

1139-35-51 **John Gemmer**, **Gary Moon** and **Sarah Raynor*** (raynorsg@wfu.edu). *Behavior of Solutions to an Elliptic Free Boundary Problem near a Neumann Fixed Boundary.*

We explore regularity properties of solutions to a two-phase elliptic free boundary problem near a Neumann fixed boundary in two dimensions. Consider a function u, defined variationally, which is harmonic where it is not zero and satisfies a gradient jump condition weakly along the free boundary $\partial\{u>0\}$. Our main result is that u is Lipschitz continuous up to the Neumann fixed boundary. Additionally, we prove various basic properties of such a minimizer near a portion of the fixed boundary on which $\partial_\nu u=0$ weakly. We also provide numerics that indicate the way in which the free and fixed boundaries interact and justify the convergence of those numerics. (Received January 23, 2018)

1139-35-52 **Ariel Barton*** (aeb019@uark.edu). *Extrapolation of well posedness for higher order elliptic systems with rough coefficients.*

We establish well posedness of certain boundary value problems for higher order equations in the divergence form $\nabla^m\cdot A\nabla^m u=\nabla^m\cdot\dot{H}$, where m is a positive integer and where $\dot{H}$ and A are given functions.

Specifically, we will establish well posedness for problems with boundary data in Besov spaces $\dot{B}^{p,p}_s$, $p\leq 1$, given well posedness for appropriate values of s and $p>1$. We work with smoothness parameter s between 0 and 1; this allows us to consider inhomogeneous differential equations, that is, $\nabla^m\cdot A\nabla^m u=\nabla^m\cdot\dot{F}$ rather than $\nabla^m\cdot A\nabla^m u=0$.

Combined with results of Maz'ya, I. Mitrea, M. Mitrea, and Shaposhnikova, this allows us to establish new well posedness results for higher order operators whose coefficients are in or close to the space VMO, for the biharmonic operator, and for fourth-order operators close to the biharmonic operator. (Received January 23, 2018)

1139-35-58 **Robert Stephen Cantrell**, **Chris Cosner*** (gcc@math.miami.edu) and **Xiao Yu**. *Dynamics of populations with individual variation in dispersal on bounded domains.*

Most classical models for the movement of organisms assume that all individuals have the same patterns and rates of movement, but there is empirical evidence that movement rates and patterns may vary among individuals. One way to capture variation in dispersal is to allow individuals to switch between two distinct dispersal modes. We consider models for populations with logistic-type local population dynamics whose members can switch between two different nonzero rates of diffusion. The resulting reaction-diffusion systems can be cooperative at some population densities and competitive at others. We analyze the dynamics of such systems on bounded regions. (Traveling waves and spread rates have been studied by others for similar models in the context of biological invasions.) The analytic methods include ideas and results from reaction-diffusion theory, semi-dynamical systems, and bifurcation/continuation theory (Received January 24, 2018)

1139-35-66 **Michael E. Taylor*** (met@math.unc.edu), Mathematics Dept., University of North Carolina, Chapel Hill, NC 27599. *Multidimensional Toeplitz operators with discontinuous symbols.*

We treat a class of Toeplitz operators with discontinuous symbols, stimulated by classical work of R. Douglas and H. Widom. We extend the notion of a locally sectorial symbol from the setting of scalar Toeplitz operators on the circle to systems, acting on vector valued functions on a class of multidimensional domains with minimal smoothness, known as uniformly rectifiable domains, and establish Fredholm properties in this expanded setting. (Received January 25, 2018)

1139-35-75 **Shuang Miao** and **Sohrab M. Shahshahani*** (sohrab@math.umass.edu). *Tidal energy in Newtonian two-body motion.*

Based on an essential linear analysis by Christodoulou, we study the tidal energy for the motion of two gravitating incompressible fluid balls with free boundaries. The orbital energy is defined as the mechanical energy of the center of mass of the two bodies. When the fluids are replaced by point masses, according to the classical analysis of Kepler and Newton, the conic curve describing the trajectories of the bodies is a hyperbola when the orbital energy is positive and an ellipse when the orbital energy is negative. If the point masses are initially very far, then the orbital energy, which is conserved in the case of point masses, is positive corresponding to hyperbolic motion. However, in the motion of fluid balls the orbital energy is no longer conserved, as part of the conserved energy is used in deforming the boundaries of the bodies. This energy is called the tidal energy. If the tidal energy becomes larger than the total energy during the evolution, the orbital energy must change its sign, signaling a qualitative change in the orbit of the bodies. We will show that under appropriate conditions on the initial configuration this change of sign occurs. (Received January 28, 2018)

1139-35-76 **Ko-shin Chen**, **Cyrill Muratov** and **Xiaodong Yan*** (xiaodong.yan@uconn.edu), 341 Mansfield Road, Storrs, CT 06029. *Layer solutions for a one-dimenional nonlocal model of Ginzburg-Landau type.*

We study a nonlocal model of Ginzburg-Landau type that gives rise to an equation involving a mixture of the Laplacian and half-Laplacian. Our focus is on one-dimensional transition layer profiles that connect the two distinct homogeneous phases. We first introduce a renormalized one-dimensional energy that is free from a logarithmic divergence due to the failure of the Gagliardo norm to be finite on smooth profiles that asymptote to different limits at infinity. We then prove existence, uniqueness, monotonicity and regularity of minimizers in a suitable class. Lastly, we consider the singular limit in which the coefficient in front of the Laplacian vanishes and prove convergence of the obtained minimizer to the solutions of the fractional Allen-Cahn equation. (Received February 19, 2018)

1139-35-80 **Blair Davey*** (bdavey@ccny.cuny.edu) and **Jenn-Nan Wang**. *Recent progress on Landis' conjecture.*

In the late 1960s, E.M. Landis made the following conjecture: If u and V are bounded functions, and u is a solution to $\Delta u = Vu$ in $\mathbb{R}^n$ that decays like $|u(x)| \leq c\exp(-C|x|^{1+})$, then u must be identically zero. In 1992, V. Z. Meshkov disproved this conjecture by constructing bounded functions $u, V : \mathbb{R}^2 \to \mathbb{C}$ that solve $\Delta u = Vu$ in $\mathbb{R}^2$ and satisfy $|u(x)| \leq c\exp(-C|x|^{4/3})$. The result of Meshkov was accompanied by qualitative unique continuation estimates for solutions in $\mathbb{R}^n$. In 2005, J. Bourgain and C. Kenig quantified Meshkov's unique continuation estimates. These results, and the generalizations that followed, have led to a fairly complete understanding of the complex-valued setting. However, there are reasons to believe that Landis' conjecture may be true in the real-valued setting. We will discuss recent progress towards resolving the real-valued version of Landis' conjecture in the plane. (Received January 30, 2018)

1139-35-91 **Xinliang An*** (xinliang.an@utoronto.ca), 40 St George Street, Room 6290, Toronto, Ontario M5S 2E4, Canada. *On the Geometric and Analytic Properties of the "First Singularities" in Gravitational Collapse.*

In this talk, we will present several results on singularity formation in general relativity. Mathematical properties of "first singularities" will be discussed. (Received February 01, 2018)

1139-35-92 **Xinliang An*** (xinliang.an@utoronto.ca), 40 St George Street, Room 6290, Toronto, Ontario M5S 2E4, Canada. *Signature for Decay Rates and Trapped Surface Formation.*

In this talk, we will prove trapped surface formation in the weak-field regime. A systematical approach with only signature for decay rates will be presented. (Received February 01, 2018)

1139-35-93 **Markus Kunze*** (mkunze@mi.uni-koeln.de), Weyertal 86-90, 50931 Köln, Germany. *Higher regularity of the 'transverse' fields in the relativistic Vlasov-Maxwell system.*

It is shown that for the 'transverse' electric and magnetic fields (according to the Glassey-Strauss representation formula) one in fact has a uniform bound in $L^{2+\delta}$ for some $\delta > 0$. (Received February 01, 2018)

1139-35-94 **Sam G. Krupa*** (skrupa@math.utexas.edu) and **Alexis F. Vasseur**. *Proving Uniqueness of Solutions for Burgers Equation Entropic for a Single Entropy, with Eye Towards Systems Case.*

For hyperbolic systems of conservation laws, uniqueness of solutions is still largely open. We aim to expand the theory of uniqueness for systems of conservation laws. One difficulty is that many systems have only one entropy. This contrasts with scalar conservation laws, where many entropies exist. It took until 1994 to show that one entropy is enough to ensure uniqueness of solutions for the scalar conservation laws (Panov). This single entropy result was proven again by De Lellis, Otto and Westdickenberg in 2004. These two proofs both rely on the special connection between Hamilton–Jacobi equations and scalar conservation laws in one space dimension. However, this special connection does not extend to systems. In our new work, we prove the single entropy result for scalar conservation laws without using Hamilton–Jacobi. Our proof lays out new techniques that are promising for showing uniqueness of solutions in the systems case. This is joint work with A. Vasseur. (Received February 01, 2018)

1139-35-95 **Thomas Backing** and **Donatella Danielli*** (danielli@math.purdue.edu), Department of Mathematics, 150 N University St, West Lafayette, IN 47907, and **Rohit Jain**. *Regularity Results for a Penalized Boundary Obstacle Problem.*

In this talk we will discuss a two-penalty boundary obstacle problem of interest in thermics and fluid dynamics. Specifically, our goal is to establish existence, uniqueness and optimal regularity of the solutions, as well as structural properties of the free boundary. The study hinges on the monotone character of a perturbed frequency function of Almgren's type, and the analysis of the associated blow-ups. (Received February 02, 2018)

1139-35-96 **Wenxiong Chen*** (wchen@yu.edu), 2495 Amsterdam Av., New York, NY 10033, and **Congming Li** and **Shijie Qi**. *A Hopf lemma and regularity for the fractional p-Laplacians.*

In this talk, we will present our recent results on the fractional p-Laplacian.

One is a Hopf type lemma which states that, on a domain Ω with smooth boundary, if

$$\begin{cases} (-\Delta)^s_p u(x) \geq 0 \text{ and } u(x) > 0 & x \in \Omega \\ u(x) = 0 & x \in \partial\Omega, \end{cases}$$

then

$$\lim_{x \to \partial\Omega} \frac{u(x)}{dist^s(x, \partial\Omega)} \geq c_o > 0.$$

The other is concerning the regularity of $(-\Delta)^s_p u(x)$. We prove that if $u(x)$ is smooth and if

$$p > \frac{3}{2-s}.$$

Then $(-\Delta)^s_p u(x)$ is in C^1.

We also show that the above condition is sharp in the sense that if it is violated, then there are counter examples of smooth functions u for which $(-\Delta)^s_p u(x)$ is not in C^1. (Received February 02, 2018)

1139-35-103 **Santosh Bhattarai***, Trocaire College, 360 Choate Ave, Buffalo, NY 14220. *Normalized solutions for some fractional Schrödinger equations.*

We prove existence of solutions with prescribed mass for some fractional nonlinear Schrödinger equations. Our approach involves characterizing these solutions as minimizers for a constrained variational problem. To establish the relative compactness of minimizing sequences via concentrated compactness, we show that the minimum value of the objective functional depends strictly subadditively on the values of the constraint functionals. We also discuss the orbital stability of the associated standing waves. (Received February 03, 2018)

1139-35-107 **Cakoni Fioralba***, 440 Hill Center - Busch Campus, 110 Frelinghuysen Road, Piscataway, NJ 08854. *Eigenvalue Problems is Inverse Scattering Theory.*

Spectral properties of operators associated with scattering phenomena carry essential information about the scattering media. The theory of scattering resonances is a rich and beautiful part of scattering theory, and although the notion of resonances is intrinsically dynamical, an elegant mathematical formulation comes from considering them as the poles of meromorphic extension of the scattering operator. These scattering poles capture the physical information by identifying the rate of oscillations with the real part of a pole and the rate of decay with its imaginary part. On the other hand, the transmission eigenvalue problem, is inherent to the scattering phenomena for the inhomogeneous media, and hence it plays an important role in understanding the corresponding inverse problem. Transmission eigenvalues are related to those wave numbers for which one is able to construct an incident field that does not scatterer by a given media. We will discuss some new results on the transmission eigenvalue problem at the level of partial differential equations as well as its profound relation with the scattering operator. (Received February 04, 2018)

1139-35-118 **Shijun Zheng*** (szheng@georgiasouthern.edu), Department of Mathematical Science, Georgia Southern University, Statesboro, GA 30460, and **Christopher Leonard**. *Sharp condition on stability for rotational NLSE in 3D.*

I will discuss our recent work concerning finding a criterion that determines the regimes for stability and instability for mass-critical nonlinear Schödinger equation with rotation in three dimensions. The technical challenges come from the symmetry breaking between the rotational term and anisotropic trapping potential, where the angular moment of a particle is not conserved in time. The analysis involves a virial type identity that requires careful estimation along with an application of certain comparison theorem. This is joint work with Christopher Leonard. (Received February 05, 2018)

1139-35-119 **Murat Akman** (murat.akman@uconn.edu), **John Lewis*** (johnl@uky.edu) and **Andrew Vogel** (alvogel@syracuse.edu). *Note on an Eigenvalue Problem.* Preliminary report.

We consider solutions $v > 0$ to certain nonlinear PDE of p Laplace type $(1 < p < \infty)$ in the cone, $K(\alpha) = \{x = (x_1, \dots, x_n) : x_1 > \alpha|x|\} \subset \mathcal{R}^n$ with continuous boundary value zero on $\partial K(\alpha)$ when $\alpha \in [-1, 1)$. It turns out that v is of the form,

$$v(x) = v(r, \theta) = r^{\lambda} f(\theta), \lambda > 0,$$

provided either $\alpha \neq -1$ or $\alpha = -1$ and $p > n - 1$. Here r, θ are spherical coordinates : $x_1 = r\cos\theta, r = |x|, 0 \leq \theta \leq \pi$. During the first part of our talk we discuss what is known about the relationship between α and λ for a fixed $p > 1$ and our attempts to solve a related eigenvalue problem for a nonlinear first order differential equation when $\alpha = -1$ and $p > n - 1$. During the second part of the talk we sketch a finesse type argument which shows for $\alpha = -1$ and $p > n - 1$ that $\lambda = 1 - (n - 1)/p$. Time permitting we discuss applications of this result. (Received February 05, 2018)

1139-35-123 **Ngoc Do*** (dothanhngocctsp@math.arizona.edu), dothanhngocctsp@math.arizona.edu, and **Leonid Kunyansky**. *Inverse source problem for the wave equation with reduced data: an explicit solution.*

The inverse source problem for the standard wave equation is a mathematical foundation for several promising emerging modalities of medical imaging. I will concentrate on the theoretical and algorithmic aspects of this problem. Of special interest here are theoretically exact inversion formulas, explicitly expressing solution of the problem in terms of the measured data. Practically all such formulas require data to be taken on a surface completely surrounding the object under investigation, which, in many cases, cannot be done in practice. The alternative approach we present yields explicit, theoretically exact reconstruction from data measured on an open surface. This is the first result of this kind. Numerical simulations illustrating the work of the method will be also presented. (Received February 05, 2018)

1139-35-129 **Pierre Germain**, **Benjamin Harrop-Griffiths*** (benjamin.harrop-griffiths@cims.nyu.edu) and **Jeremy L. Marzuola**. *Degenerate dispersive equations.*

We discuss recent work on some quasilinear toy models for degenerate dispersion. In particular, we prove the existence of solutions using a novel change of variables reminiscent of the classical hodograph transformation. This is joint work with Pierre Germain and Jeremy Marzuola. (Received February 05, 2018)

1139-35-136 **Yuji Kodama*** (kodama.1@osu.edu), Department of Mathematics, 231 West 18th Ave, Columbus, OH 43210. *Generalized hypergeometric functions and integrable hydrodynamic type equations.*

I begin to present a brief introduction of the Aomoto-Gelfand generalized hypergeometric (AGHG) functions and their confluences by means of the action of the centralizers of regular elements. The confluence then implies that the AGHG functions are now defined in a degenerate cell of the Grassmannian. I will then construct integrable hydrodynamic type systems defined on such cells. This is a joint work with Boris Konopelchenko. (Received February 05, 2018)

1139-35-141 **Hongjie Dong*** (hongjie_dong@brown.edu), 182 George Street, Providence, RI 02912, and **Zongyuan Li**. *The oblique derivative problem in Lipschitz domains.*

We prove the W^2_p estimate for the oblique derivative problem of nondivergence form elliptic equations with VMO coefficients in Lipscthiz domains with locally small Lipschitz constant. This improves an earlier result by G. Lieberman, where the domains are required to be in $C^{1,\alpha}$ for $\alpha > 1 - 1/p$. (Received February 06, 2018)

1139-35-149 **Yakov Shlapentokh-Rothman***, Fine Hall, Washington Road, Princeton, NJ 08544. *The asymptotically self-similar regime for the Einstein vacuum equations.*

We will dynamically construct singular solutions to the Einstein vacuum equations which are asymptotically self-similar in that successive rescalings around the singularity converge to a self-similar solution. Connections both to Christodoulou's bounded variation solutions of the spherically symmetric Einstein-scalar field system and to the ambient metric construction of Fefferman and Graham will be elaborated on. This is joint work with Igor Rodnianski. (Received February 06, 2018)

1139-35-156 **Mutlu Akar*** (makar@yildiz.edu.tr), YTU College of Arts and Sciences, Mathematics Department, Davutpasa Campus, Esenler, 34210 Istanbul, Turkey, and **Adem Cengiz Cevikel** (acevikel@yildiz.edu.tr), YTU College of Education, Department of Mathematics Education, Davutpasa Campus, Esenler, 34210 Istanbul, Turkey. *Bright and Dark Soliton Solutions for the KP Equation.*

In this paper, by using a solitary wave ansatz in the form of $sech^p$ and $tanh^p$ functions, we obtain the exact bright and dark soliton solutions for the KP equation, respectively. it is always useful and desirable to construct exact analytical solutions especially soliton-type envelope for the understanding of most nonlinear physical phenomena. The physical parameters in the soliton solutions are obtained as functions of the dependent coefficients. (Received February 07, 2018)

1139-35-157 **Adem Cengiz Cevikel*** (acevikel@yildiz.edu.tr), YTU College of Education, Department of Mathematics Education, Davutpasa Campus, Esenler, 34210 Istanbul, Turkey, and **Mutlu Akar** (makar@yildiz.edu.tr), YTU College of Arts and Sciences, Mathematics Department, Davutpasa Campus, Esenler, 34210 Istanbul, Turkey. *Periodic and Solitary Wave Solutions for the Nonlinear Evolution Equations.*

In this paper, we present a functional variable method for finding periodic wave and solitary wave solutions of nonlinear evolution equations in mathematical physics and engineering sciences. The proposed technique is tested on the some nonlinear equations. The method is straightforward and concise, and it can also be applied to other nonlinear evolution equations in applied mathematics. (Received February 07, 2018)

1139-35-171 **Yang Yang*** (yangy5@msu.edu), 220 Trowbridge Rd, East Lansing, MI 48824. *On a coupled physics inverse problem in electro-seismic imaging.*

Electro-seismic imaging is a geophysical imaging modality where electromagnetic wave is used to induce seismic wave in porous media. The mathematical model was derived by S. Pride in 1994 as a coupled system of the Maxwell's equations and the Biot's equations. In this talk, we will discuss a coupled physics inverse problem arising in electro-seismic imaging. The problem consists of retrieval of source data in the Biot's equations and inversion of the Maxwell's equations from the internal measurement. We will describe a time reversal approach to reconstruct the source data, and then prove that some parameters in the Maxwell's equations can be uniquely and stably determined from such data. This is based on joint work with Jie Chen, Yixian Gao and Peijun Li. (Received February 07, 2018)

1139-35-180 **Francis J Chung***, fj.chung@uky.edu. *Partial data results for unbounded potentials.*

The inverse problem for the Schrödinger operator $(\Delta + q)$ is well studied for the case of $q \in L^\infty$, even in the partial data case, when boundary data is available only on a subset of the boundary. For less regular potentials q, however, much less is known. In this talk I will give a brief introduction to this problem, and describe a recent result, in joint work with Leo Tzou, where we prove a partial data result for the Schrödinger inverse problem with $q \in L^{n/2}$, which is the critical regularity for the strong unique continuation property to hold. (Received February 08, 2018)

1139-35-181 **Roman Shvydkoy***, 851 S morgan st, m/c 249, chicago, IL 60607, and **Eitan Tadmor**. *Topological models of collective behavior: local interactions imply alignment.* Preliminary report.

In this talk we will introduce a new alignment model based on Cucker-Smale agent based system, which has only natural local interactions yet exhibits the phenomenon of alignment. We also describe regularity results and new challenges these models pose for global wellposedness of fractional parabolic equations. (Received February 08, 2018)

1139-35-184 **Jared Speck*** (jspeck@math.mit.edu), Massachusetts Institute of Technology, 77 Massachusetts Ave, Bldg. 2 Rm. 265, Cambridge, MA 02139-4307. *Singularity Formation in General Relativity.*

I will discuss some new results, joint with I. Rodnianski, on the formation of singularities in initially regular solutions to Einstein's equations without symmetry assumptions. Specifically, we showed that for an open subset of the data falling under the scope of Hawking's incompleteness theorem, the geodesic incompleteness coincides with curvature blowup. Compared to our previous works in this vein, our analytical framework is more robust and in particular is not based on approximate monotonicity identities. This allows us to treat initial data exhibiting moderate spatial anisotropy, thus going beyond the regime of nearly spatially isotropic data that we treated in earlier works. Our approach applies to open sets of data for the Einstein-vacuum equations in high spatial dimensions and to the Einstein-scalar field system in any number of spatial dimensions. From an analytic perspective, the main theorems are stable blowup results for quasilinear systems of elliptic-hyperbolic PDEs. I will provide an overview of these results and explain how they are tied to some of the main themes of investigation by the mathematical general relativity community. I will also discuss intriguing connections to other problems concerning stable singularity formation. (Received February 08, 2018)

1139-35-195 **Ping Liu** and **Junping Shi*** (jxshix@wm.edu), Department of mathematics, College of William and Mary, Williamsburg, VA 23187. *Bifurcation of positive solutions to scalar reaction–diffusion equations with nonlinear boundary condition.*

The bifurcation of non-trivial steady state solutions of a scalar reaction–diffusion equation with nonlinear boundary conditions is considered using several new abstract bifurcation theorems. The existence and sta-bility of positive steady state solutions are proved using a unified approach. The general results are applied to a Laplace equation with nonlinear boundary condition and bistable nonlinearity, and an elliptic equation with superlinear nonlinearity and sublinear boundary conditions. (Received February 10, 2018)

1139-35-202 **Joseph Feneuil*** (jfeneuil@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *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 February 10, 2018)

1139-35-211 **Zihui Zhao***, zhaozh@uw.edu. *Elliptic measures and geometric properties of the domains.*
Elliptic measure is an analogue of the harmonic measure and it allows us to represent the solution to a Dirichlet problem by integrating the boundary function. The study of the relationship between the elliptic measure ω and the surface measure σ of the boundary, in particular under various geometric assumptions of the domain, goes back to 100 years ago. In this talk we focus on the converse question: Assume that $\sigma \ll \omega$, in a qualitative or quantitative sense, what conclusions can we draw about the geometric properties of the domain? (Received February 11, 2018)

1139-35-220 **Agnid Banerjee**, **Mariana Smit Vega Garcia*** (marianag@uw.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+a} regular slit is H^{k+a} at the slit, for $k \geq 2$. In the case $k = 1$, we show that the quotient is in H^{1+a} if the slit is assumed to be space-time $C^{1,a}$ 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.

This is joint work with A. Banerjee and A. Zeller. (Received February 12, 2018)

1139-35-222 **Murat Akman**, **Jasun Gong**, **Jay Hineman**, **John Lewis** and **Andrew Vogel*** (alvogel@syr.edu), 215 Carnegie, Syracuse, NY 13244. *The Brunn-Minkowski inequality and a Minkowski problem for nonlinear capacity.* Preliminary report.

This talk will focus on the Minkowski problem for classes of equations similar to and including the p-Laplace equations for $1 < p < n$. The minimization problem that leads to the solution will be described along with a discussion of why the minimizing set has nonempty interior for the full range $1 < p < n$. We will also discuss the Brunn-Minkowski inequality which leads to uniqueness arguments for the Minkowski problem (Received February 12, 2018)

1139-35-241 **Benjamin Dodson** and **Jason Murphy***, Department of Mathematics and Statistics, Missouri University of Science and Technology, Rolla, MO 65409. *Scattering below the ground state threshold for nonlinear Schrödinger equations.*

We discuss scattering below the ground state threshold for nonlinear Schrödinger equations. In joint work with B. Dodson, we have found simple proofs of results obtained previously by Duyckaerts, Holmer, Roudenko (and others). In particular, by using suitable virial/Morawetz estimates and scattering criteria, we are able to avoid the use of concentration-compactness. (Received February 12, 2018)

1139-35-248 **Leonardo Abbrescia** (abbresci@msu.edu) and **Willie W.-Y. Wong*** (wongwwy@math.msu.edu). *Global large data solutions of the membrane equation.* Preliminary report.

The membrane equation, aka the time-like minimal/extremal surface equation, exhibits extraordinary null structure, a feature that has been used to demonstrate its small-data global wellposedness in all dimensions by Brendle and separately Lindblad. Recently the null structure has been further exploited by Wang and Wei to construct large-data, semi-global, dispersive solutions in the two- and three-spatial-dimensional case, using a modification of Christodoulou's short-pulse method; notably their construction allows the solutions to have a finite-time past singularity. In this talk we will present a very recent result constructing large, open families of global (both in the future and past time directions) solutions, in all spatial dimensions except for two. The solutions we construct are neither close to stationary nor dispersive. Our construction relies on perturbations around a geometric large-data ansatz, with the novelty where the solutions to the perturbation equations do not exhibit classical scattering behavior. (Received February 12, 2018)

1139-35-256 **Michael Liam McNulty*** (mmcnulty@math.ucr.edu), 900 University Ave, Surge 202, Riverside, CA 92521. *Development of Singularities of the Skyrme Model.*

The Skyrme model is a geometric field theory and a quasilinear modification of the Nonlinear Sigma Model (Wave Maps). In this talk, we study the development of singularities for the equivariant Skyrme Model, in the strong-field limit, where the restoration of scale invariance allows us to look for self-similar blow-up behavior. After introducing the Skyrme Model and reviewing what's known about formation of singularities in equivariant Wave Maps, we prove the existence of smooth self-similar solutions to the $5+1$-dimensional Skyrme Model in the strong-field limit, and use that to conclude that the solution to the corresponding Cauchy problem blows up in finite time, starting from a particular class of everywhere smooth initial data. (Received February 13, 2018)

1139-35-260 **Katharine Ott*** (kott@bates.edu). *The mixed boundary value problem in Lipschitz domains.*

In this talk I will report on recent progress on well-posedness of the mixed boundary value problem for elliptic equations and systems of equations in Lipschitz domains. (Received February 13, 2018)

1139-35-269 **David Jerison*** (jerison@math.mit.edu), Room 2-272, Department of Mathematics, MIT, Cambridge, MA 02139. *Localization of eigenfunctions via an effective potential.*

We discuss joint work with Douglas Arnold, Guy David, Marcel Filoche and Svitlana Mayboroda. Consider the Neumann boundary value problem for the operator

$$L\,u = -\mathrm{div}(A\nabla u) + V u$$

on a Lipschitz domain Ω and, more generally, on a manifold with or without boundary. The eigenfunctions of L are often localized, as a result of disorder of the potential V, the matrix of coefficients A, irregularities of the boundary, or all of the above. In earlier work, Filoche and Mayboroda introduced the function u solving $Lu = 1$, and showed numerically that it strongly reflects this localization. Here, we deepen the connection between the eigenfunctions and this *landscape* function u by proving that its reciprocal $1/u$ acts as an *effective potential*. The effective potential governs the exponential decay of the eigenfunctions of the system and delivers information on the distribution of eigenvalues near the bottom of the spectrum. (Received February 13, 2018)

1139-35-271 **David Jerison*** (jerison@math.mit.edu), Room 2-272, Department of Mathematics, MIT, Cambridge, MA 02139. *The two-hyperplane conjecture.* Preliminary report.

I will introduce a conjecture that I call the *Two Hyperplane Conjecture*, saying that an isoperimetric surface that divides a convex body in half by volume is trapped between parallel hyperplanes. This is related in spirit to the *Hyperplane Conjecture* of Kannan, Lovász and Simonovits in theoretical computer science, which says that the area of such an isoperimetric surface is comparable (by a universal constant independent of dimension) to the area of some hyperplane dividing the convex body in half. Their conjecture is closely related to several famous unsolved problems in high dimensional convex geometry. But unlike the hyperplane conjecture, the two-hyperplane conjecture has significance even in low dimensions.

I will relate the conjecture to qualitative and quantitative connectivity properties and regularity of area-minimizing surfaces, free boundaries and level sets of eigenfunctions. The main theme of the talk is that the level sets of least energy solutions to scalar variational problems should be as simple as possible, (Received February 13, 2018)

1139-35-272 **Katharine Ott*** (kott@bates.edu) and **R Brown**. *Estimates for Brascamp-Lieb forms in weighted L^p spaces.*

We discuss a family of Brascamp-Lieb forms in L^p-spaces with power weights. One such form arises in the $\bar{\partial}$ approach to the scattering theory for the Davey-Stewartson II equation. (Received February 13, 2018)

1139-35-283 **Veronica Ciocanel***, ciocanel.1@mbi.osu.edu, and **Bjorn Sandstede**. *Wave Propagation in Models of mRNA transport.*

In many organisms, messenger RNA (mRNA) must accumulate at the egg cell periphery to ensure healthy development. The transport of these particles is not well understood, but is thought to depend on diffusion, bidirectional movement and anchoring mechanisms. We investigate these proposed mechanisms using linear and nonlinear PDE models and analysis, informed by numerical parameter estimation. Our results yield spreading Gaussian solutions for mRNA concentrations. We predict that accounting for the microtubule cytoskeleton in these transport models through spatially-dependent switching rates may be key in better understanding time and spatial scales of intracellular transport. (Received February 14, 2018)

1139-35-297 **Jesenko Vukadinovic*** (jesenko.vukadinovic@csi.cuny.edu), 365 Fifth Avenue, PhD Program in Mathematics, New York, NY 10016. *Diffusion enhancement by Hamiltonian flows with hyperbolic equilibrium points.*

This is an extension of author's work on diffusion enhancement by closed flows with Hamiltonians that allow only elliptic equilibrium points to closed flows with Hamiltonians that allow for hyperbolic equilibrium points. Averaging along stream lines allows for quantizing of the 2D advection-diffusion equation to 1D Schrodinger equations with purely imaginary potentials. When hyperbolic points are present, the quantized problem is phrased on a Reeb graph with certain gluing conditions on the separatrix vertices. The work is closely related to Freidlin-Wentzell theory of randomly perturbed Hamiltonian systems, however the approach is deterministic rather than stochastic, and offers some new insights into the relationship between kinematic properties of the flow and diffusion enhancement. (Received February 14, 2018)

1139-35-306 **Donatella Danielli**, **Arshak Petrosyan** and **Camelia Pop*** (capop@umn.edu). *Obstacle problems for nonlocal operators.*

We prove existence, uniqueness, and regularity of viscosity solutions to the stationary and evolution obstacle problems defined by a class of nonlocal operators that are not stable-like and may have supercritical drift. We give sufficient conditions on the coefficients of the operator to obtain Hölder and Lipschitz continuous solutions. The class of nonlocal operators that we consider include non-Gaussian asset price models widely used in mathematical finance, such as Variance Gamma Processes and Regular Lévy Processes of Exponential type. In this context, the viscosity solutions that we analyze coincide with the prices of perpetual and finite expiry American options. (Received February 14, 2018)

1139-35-310 **Monika Pichler*** (pichler.mo@husky.neu.edu). *An inverse problem for Maxwell's equations with Lipschitz parameters.*

We consider an inverse boundary value problem for the time-harmonic Maxwell equations, which aims to recover the electromagnetic material properties of a body from measurements on the boundary. We show that a Lipschitz continuous conductivity, electric permittivity, and magnetic permeability are uniquely determined by knowledge of all tangential electric and magnetic fields on the boundary of the body at a fixed frequency. (Received February 15, 2018)

1139-35-320 **Rupert Frank** and **Gang Zhou*** (`gzhou@math.binghamton.edu`). *the effective equations for polaron, derivation and dynamics.*

Polaron theory is a model of an electron in a crystal lattice. It is studied in the framework of nonequilibrium statistic mechanics. There are two different mathematical models: H. Frohlich proposed a quantum model in 1937; L. Landau and S. I. Pekar proposed a system of nonlinear PDEs in 1948. In this talk I will present a proof that these two models are equivalent to certain orders, and some results about the dynamics. These are joint works with Rupert Frank. (Received February 15, 2018)

1139-35-325 **Agnid Banerjee** and **Nicola Garofalo***, nicola.garofalo@unipd.it. *Space-time strong unique continuation for nonlocal parabolic equations.*

In two visionary papers in 1938 and 1949 Marcel Riesz introduced the fractional powers of the Laplacian in Euclidean and Lorentzian space, developed the calculus of these nonlocal operators and studied the Dirichlet and Cauchy problems for respectively the fractional Laplacian and the wave equation. He also mentioned, but did not include in his study, the fractional heat equation.

In this talk I will present a new result on the strong unique continuation property, backward in time, for zero-order perturbations of the nonlocal heat equation: $(D_t - \Delta)^s u = Vu$ for $0 < s < 1$. To prove the main result we develop the regularity theory of the extension problem for the nonlocal equation. With such theory in hands we establish a basic monotonicity result for an adjusted frequency function.

This is joint work with Agnid Banerjee. (Received February 15, 2018)

1139-35-328 **Benjamin Dodson**, **Jonas Luhrmann*** (`luehrmann@math.jhu.edu`) and **Dana Mendelson**. *Probabilistic local well-posedness and scattering for the 4D cubic NLS.*

We consider the Cauchy problem for the cubic nonlinear Schrodinger equation (NLS) in four space dimensions. It is known that for initial data at energy regularity, the solutions exist globally in time and scatter. However, the problem is ill-posed for initial data at super-critical regularity, i.e. for regularities below the energy regularity.

In this talk we study the super-critical data regime for this Cauchy problem from a probabilistic point of view, using a randomization procedure that is based on a unit-scale decomposition of frequency space. In the first part of the talk we will explain how the problem of establishing almost sure local existence for the cubic NLS for such random data has some features in common with proving local existence for a derivative NLS equation. Our method is inspired by the local smoothing estimates and functional frameworks from the Schroedinger maps literature. If time permits, we will also present some (conditional) almost sure scattering results. (Received February 15, 2018)

1139-35-329 **Daniela De Silva*** (`desilva@math.columbia.edu`), 2990 Broadway, New York, NY 10027, and **Ovidiu Savin**. *Quasi Harnack inequality.*

In this talk we discuss some extensions of the classical Krylov-Safonov Harnack inequality and give several applications in very different settings such as discrete difference equations, nonlocal equations, homogenization and the quasi-minimal surfaces of Almgren. (Received February 15, 2018)

1139-35-335 **Bruno Poggi*** (`poggi008@umn.edu`), 206 Church Street SE, 505 Vincent Hall, Minneapolis, MN 55455, and **Svitlana Mayboroda** (`svitlana@math.umn.edu`), 206 Church Street SE, 223 Vincent Hall, Minneapolis, MN 55455. *Exponential decay estimates for fundamental solutions of Schrödinger-type operators.*

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 February 15, 2018)

1139-35-338 **Maya Chhetri*** (maya@uncg.edu), Department of Math & Stat, Petty 125, Greensboro, NC 27402, and **Pavel Drabek** and **R. Shivaji**. *Positive solutions for a class of singular problems on exterior domains.*

This talk is concerned with some recent results on positive solutions for a class of elliptic boundary value problems on the exterior of a connected bounded domain. In particular, under appropriate conditions on the weight function, we will discuss existence, uniqueness and multiplicity of positive solutions when the reaction term is positone and sublinear at infinity. (Received February 15, 2018)

1139-35-340 **Jeff Calder*** (jcalder@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *The weighted p-Laplacian and semi-supervised learning.*

Semi-supervised learning refers to machine learning algorithms that make use of both labeled data and unlabeled data for learning tasks. Examples include large scale nonparametric regression and classification problems, such as predicting voting preferences of social media users, or classifying medical images. In this talk, we will present some new results on continuum limits for graph-based semi-supervised learning in the limit of infinite unlabeled data and finite labeled data. We show that the continuum limits correspond to solving a weighted p-Laplace equation in the viscosity sense and are non-degenerate only when p>d. (Received February 15, 2018)

1139-35-363 **Maarten de Hoop**, **Gunther Uhlmann** and **Yiran Wang*** (wangy257@math.washington.edu). *Nonlinear responses from the interaction of two progressing waves at an interface.*

For scalar semilinear wave equations, we analyze the interaction of two (distorted) plane waves at an interface between media of different nonlinear properties. We show that new waves are generated from the nonlinear interactions, which might be responsible for the observed nonlinear effects in applications. Also, we show that the incident waves and the nonlinear responses determine the location of the interface and some information of the nonlinear properties of the media. In particular, for the case of a jump discontinuity at the interface, we can determine the magnitude of the jump. (Received February 16, 2018)

1139-35-364 **Jessica Lin*** (jessica.lin@mcgill.ca) and **Andrej Zlatos**. *Stochastic Homogenization for Reaction-Diffusion Equations.*

I will present several results concerning stochastic homogenization for reaction-diffusion equations. We consider heterogeneous reaction-diffusion equations with random nonlinear reaction terms. Under certain hypotheses on the environment, we show that the typical large-time, large-scale behavior of solutions is governed by a deterministic front propagation. The front propagation is identified by the level set of a deterministic Hamilton-Jacobi equation. This talk is based on a series of joint works with Andrej Zlatos. (Received February 16, 2018)

1139-35-373 **Shiferaw Berhanu*** (berhanu@temple.edu). *Unique continuation for CR mappings.*

Let $F : M \to M^{'}$ be a continuous CR mapping (the components of F are CR functions) that vanishes to infinite order at some point $p \in M$. We will present some sufficient conditions on the CR manifolds M and $M^{'}$ that guarantee that F vanishes identically. (Received February 16, 2018)

1139-35-377 **Sean R McCurdy*** (serimcc@uw.edu), Seattle, WA. *A tale of two approaches.* Preliminary report.

This talk will investigate the application of two different techniques, one developed by Naber and Valtorta and one developed by Edelen and Engelstein, to the investigation of the fine structure of solutions to a two-phase free boundary problem. Both approaches rely upon the exploitation of monotonicity formulae to build inductively-refined covers. This talk will focus on their relative strengths and differences.

The context of application will build upon work by Toro, Badger, and Engelstein, on two-sided free boundary problems with geometric conditions on the free boundary (two-sided NTA domains) and mild regularity on the Radon-Nikodym derivative of the harmonic measures from each side. Surprisingly, this context allows us to prove Minkowski dimension bounds on the strata of the critical set of such solutions across the free boundary. (Received February 16, 2018)

1139-35-379 **Wen-Xiu Ma*** (mawx@cas.usf.edu), 4202 E Fowler Avenue, Department of Mathematics and Statistics, University of South Florida, Tampa, FL 33620. *Riemann Hilbert problems of soliton equations.*

The talk aims to discuss a kind of Riemann-Hilbert problems on the real axis for soliton equations, based on their matrix spectral problems. Specific Riemann-Hilbert problems, whose jump matrices are the identity matrix, are solved to generate soliton solutions. An illustrative example is a multicomponent system of modified KdV equations associated with an arbitrary order matrix spectral problem. (Received February 16, 2018)

1139-35-382 **Quoc-Hung Nguyen** and **Phuc Cong Nguyen*** (pcnguyen@math.lsu.edu).
Muckenhoupt–Wheeden type bounds in quasilinear measure datum problems and their applications.

Weighted Muckenhoupt–Wheeden type bounds are obtained for gradients of solutions to a class of quasilinear elliptic equations with measure data. Such results are obtained globally over C^1 or sufficiently flat domains in $\mathbb{R}^n$. The principal operator here is modeled after the p-Laplacian, where for the first time singular case $\frac{3n-2}{2n-1} < p \le 2 - \frac{1}{n}$ is considered. Those bounds lead to useful compactness criteria for solution sets of quasilinear elliptic equations with measure data. As an application, sharp existence results and sharp bounds on the size of removable singular sets are deduced for a quasilinear Riccati type equation having a gradient source term with linear or super-linear power growth. This talk is based on joint work with Quoc-Hung Nguyen. (Received February 18, 2018)

1139-35-401 **Benjamin Fehrman*** (fehrman@mis.mpg.de), Inselstr. 22, 04103 Leipzig, Saxony, Germany. *A Liouville theorem for stationary and ergodic ensembles of parabolic systems.*

We will discuss a first-order Liouville theorem for random ensembles of uniformly parabolic systems under the qualitative assumptions of stationarity and ergodicity. In particular, the analysis will yield a quantitative homogenization estimate in terms of the sublinear growth of a canonical extended corrector. The sublinearity of the corrector provides the starting point for a Campanato iteration. We will use this iteration to establish, almost surely, an intrinsic large-scale $C^{1,\alpha}$-regularity estimate for caloric functions, from which the Liouville theorem follows. (Received February 17, 2018)

1139-35-402 **Stephen B Robinson*** (sbr@wfu.edu) and **Mauricio Rivas**. *Characterizing Steklov-Robin Eigencurves.*

This paper is motivated by the study of eigencurves associated with boundary value problems such as

$$\begin{aligned} -\Delta u(x) &= \mu\, m_0(x)\, u(x) \quad \text{for } x \in \Omega \\ \frac{\partial u}{\partial \nu}(x) \;+\; c(x)\, u(x) &= \lambda\, b_0(x)\, u(x) \quad \text{for } x \in \partial\Omega, \end{aligned}$$

where c, b_0, m_0 are given functions in appropriate L^p-spaces on a smooth bounded region Ω in $\mathbb{R}^N$, and λ, μ are real eigenparameters. Here, m_0 is assumed to be strictly positive, b_0 may be sign-changing, and ν denotes the outward normal vector. The weak formulation of this problem leads to an analysis of abstract eigencurve problems associated with triples (a, b, m) of continuous symmetric bilinear forms on a real Hilbert space V.

Our main result generalizes the geometric characterization of eigencurves given for *Sturm-Liouville* problems proved by Binding and Volkmer . We also expand on the issues regarding continuity, differentiability, and asymptotics of eigencurves. (Received February 17, 2018)

1139-35-433 **D Kinzebulatov*** (damir.kinzebulatov@mat.ulaval.ca), Quebec City, QC , Canada, and **Yu. A Semenov** (semenov.yu.a@gmail.com), Toronto, ON , Canada. *$W^{1,p}$ regularity of solutions to Kolmogorov equation with Gilbarg-Serrin matrix.*

In $\mathbb{R}^d$, $d \ge 3$, consider the divergence and the non-divergence form operators

$$-\Delta - \nabla \cdot (a - I) \cdot \nabla + b \cdot \nabla, \tag{i}$$

$$-\Delta - (a - I) \cdot \nabla^2 + b \cdot \nabla, \tag{ii}$$

where the second order perturbations are given by the matrix

$$a - I = c|x|^{-2} x \otimes x, \quad c > -1.$$

The vector field $b : \mathbb{R}^d \to \mathbb{R}^d$ is form-bounded with the form-bound $\delta > 0$ (this includes a sub-critical class $[L^d + L^\infty]^d$, as well as vector fields having critical-order singularities). We characterize quantitative dependence on c and δ of the $L^q \to W^{1,qd/(d-2)}$ regularity of the resolvents of the operator realizations of (i), (ii) in L^q, $q \ge 2 \vee (d-2)$ as (minus) generators of positivity preserving L^∞ contraction C_0 semigroups. (Received February 18, 2018)

1139-35-449 **Matthew Novack*** (mnovack@math.utexas.edu) and **Alexis Vasseur**. *Global Classical Solutions to the 3D Quasi-Geostrophic System.*

We show the existence of global in time classical solutions to the 3D quasi-geostrophic system with Ekman pumping for any smooth initial value (possibly large). This system couples an inviscid transport equation in $\mathbb{R}^3_+$ with an equation on the boundary satisfied by the trace. The proof combines the De Giorgi regularization effect on the boundary $z = 0$ –similar to the so called surface quasi-geostrophic equation– with Beale-Kato-Majda techniques to propagate regularity for $z > 0$. A bootstrapping argument combining potential theory and Littlewood-Paley techniques is used to strengthen the regularization effect on the trace up to the Besov space $\mathring{B}^1_{\infty,\infty}$. (Received February 18, 2018)

1139-35-453 **Peter Constantin** and **Theodore D Drivas***, tdrivas@math.princeton.edu, and **Huy Q Nguyen** and **Federico Pasqualotto**. *Global Regularity for 1D Viscous Compressible Fluid Models with Degenerate Viscosity.*

We will discuss a class of one-dimensional compressible Navier-Stokes type equations in which the viscosity depends on the density and vanishes with the density. We prove large data global regularity for a class of models covering viscous shallow water equations. Another result proves a conjecture of Peter Constantin on singularity formation for a model describing slender axisymmetric fluid jets. The proofs of these results rely on a new equation for an 'active potential' in the momentum equation. (Received February 18, 2018)

1139-35-454 **Benjamin Palacios*** (benja.palacios32@gmail.com). *Reconstruction for Thermoacoustic Tomography in attenuating acoustic media.*

The Time Reversal (TR) method is a well-known technique employed for reconstruction of initial sources on inverse problems involving acoustic wave propagation, such as the inverse Thermoacoustic Tomography problem, where the data is acquired on the boundary of a given domain. In the case of smooth and variable sound speed, G.Uhlmann and P. Stefanov developed a modification of TR that leads to an iterative reconstruction formula in the form of a Neumann series for optimal observation times. It's been observed that when acoustic attenuation is considered, the straightforward extension of the TR method fails to converge, unless the attenuation coefficients are assumed to be sufficiently small. In this talk, I will present a new version of the Time Reversal method that allows us to obtain a reconstruction formula for the inverse problem of Thermoacoustic Tomography, in the presence of ultrasound attenuation modeled by an integro-differential operator. (Received February 18, 2018)

1139-35-455 **Jose Luis Luna Garcia*** (jlwwc@mail.missouri.edu), 202 Math Sciences Building, 810 E. Rollins Street, Columbia, MO 65211, Columbia, MO 65211, and **Steve Hofmann**, **Svitlana Mayboroda**, **Simon Bortz** and **Bruno Poggi**. *Solvability of Elliptic Equations with Lower Order Terms.* Preliminary report.

We adress issues of solvability of boundary value problems in the upper half space $\mathbb{R}^{n+1}$ for elliptic operators of the form

$$Lu := -\mathrm{div}(A\nabla u) + \mathrm{div}(b_1 u) + b_2 \cdot \nabla u + Vu, \tag{1}$$

where the coefficients are independent of the 'vertical' variable $t := x_{n+1}$, A is a bounded uniformly elliptic matrix, $b_1, b_2 \in L^n(\mathbb{R}^n)^{n+1}$ and $V \in L^{n/2}(\mathbb{R}^n)$ with the additional assumption that the quantities

$$\|b_i\|_{L^n(\mathbb{R}^n)}, \|V\|_{L^{n/2}(\mathbb{R}^n)} \tag{2}$$

are small enough (in particular to guarantee the coercivity of the associated bilinear form). (Received February 18, 2018)

1139-35-456 **M. N. Nkashama*** (nkashama@math.uab.edu), Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294-1170, and **N. Mavinga** (mavinga@swarthmore.edu), Department of Mathematics and Statistics, Swarthmore College, Swarthmore, PA 19081. *Bifurcation from infinity and multiplicity of solutions for nonlinear diffusion equations with nonlinear boundary conditions.* Preliminary report.

We shall present bifurcation from infinity and multiplicity results for solutions of nonlinear second order elliptic partial differential equations with nonlinear boundary conditions with weights, including the so-called Steklov type problems. Oscillatory behavior of the bifurcation branches will also be discussed. The proofs are based on degree theory arguments, continuation methods and bifurcation from infinity techniques with the use of some recent results in geometric analysis. (Received February 18, 2018)

1139-35-467 **Nestor D Guillen*** (nguillen@math.umass.edu), Amherst, MA. *Coupling Levy measures and comparison principles for viscosity solutions.*

We prove a new comparison result for viscosity solutions of 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 using an optimal transport plan between Levy measures, the resulting coupling them being used in a doubling of variables argument. (Received February 18, 2018)

1139-35-468 **Yernat Assylbekov*** (y.assylbekov@northeastern.edu) and **Ting Zhou**. *Inverse problems for the nonlinear time-harmonic Maxwell equations in Kerr-type media.*

We consider inverse boundary value problems of electromagnetism in a nonlinear Kerr medium, which is one of the most common nonlinearities appearing in physics and engineering. We show the unique determination of the electromagnetic material parameters and the nonlinear susceptibility parameters of the medium by making electromagnetic measurements on the boundary. (Received February 19, 2018)

1139-35-474 **Tristan Buckmaster*** (buckmaster@math.princeton.edu). *Nonuniqueness of weak solutions to the Navier-Stokes equations.*

For initial datum of finite kinetic energy Leray has proven in 1934 that there exists at least one global in time finite energy weak solution of the 3D Navier-Stokes equations. In this talk, I will discuss recent joint work with Vlad Vicol in which we prove that weak solutions of the 3D Navier-Stokes equations are not unique in the class of weak solutions with finite kinetic energy. (Received February 19, 2018)

1139-35-484 **Cristian E Gutierrez*** (gutierre@temple.edu), Department of Mathematics, Temple University, Philadelphia, PA 19122, and **Ahmad Sabra**, Faculty of Mathematics, Informatics, and Mech, University of Warsaw. *On the existence of dichromatic single element lenses.*

Due to dispersion, light with different wavelengths, or colors, is refracted at different angles. So when white light is refracted by a lens, in general, each color comes to a focus at a different distance from the objective. Using fixed point theorems and solving a system of functional differential equations, we determine when is mathematically possible to design a lens made of a single homogeneous material so that it refracts light superposition of two colors into a desired fixed final direction. Two problems are solved: one is when light emanates in a parallel beam and the other is when light emanates from a point source. https://arxiv.org/abs/1801.07223 (Received February 19, 2018)

1139-35-488 **Yuanwei Qi*** (yuanwei.qi@ucf.edu), Department of Mathematics, Unvesity of Central Florida, 4000 Central Floirda BLVD, Orlando, FL 32816, **Xinfu Chen** (xinfu@pitt.edu), Department of Mathematics, University of Pittsburgh, Pittsburgh, PA 15260, and **Guirong Liu** (lgr5791@sxu.edu.cn), School of Mathematics, lgr5791@sxu.edu.cn, Taiyuan, Shanxi , Peoples Rep of China. *The Existence of Minimum Speed to Non-KPP systems.*

In this talk, I shall present some recent results on traveling waves of Non-KPP isothermal diffusion systems. In particualr, it is proved by author and his collaboators that there exists a minimum speed of traveling wave, settling a long time open problem. (Received February 19, 2018)

1139-35-490 **E. L. Compaan*** (compaan@mit.edu). *Low Regularity Global Existence for the Periodic Zakharov System.*

In this talk, we present a low-regularity global existence result for the periodic Zakharov system. This is a dispersive model for the motion of ionized plasma. Its dynamics have been extensively studied, and existence of solutions is in known for data in the Sobolev space $H^{\frac{1}{2}} \times L^2$. We present a global existence result which holds for even rougher data, in a class of Fourier Lebesgue spaces. It is obtained by combining the high-low decomposition method of Bourgain with an almost-conserved energy result of Kishimoto. Combining these two tools allows us to obtain a low-regularity result which was out of reach of either method alone. (Received February 19, 2018)

1139-35-495 **Jiuyi Zhu***, Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Doubling inequality and nodal sets for solutions of bi-Laplace equations.* Preliminary report.

We investigate the doubling inequality and nodal sets for the solutions of bi-Laplace equations. A polynomial upper bound for the nodal sets is obtained based on the recent development of nodal sets for Laplace eigenfunctions by Logunov. We show two types of doubling inequalities for the solutions of bi-Laplace equations. As a consequence, the rate of vanishing is given for the solutions. (Received February 19, 2018)

1139-35-498 **Tuomo Kuusi*** (tuomo.kuusi@oulu.fi), Oulu, Finland. *Numerical methods in stochastic homogenization.*

We introduce a new method for computing solutions of elliptic equations with random rapidly oscillating coefficients. This is a joint work with S. Armstrong, A. Hannukainen and J.-C. Mourrat. (Received February 19, 2018)

1139-35-516 **Pieter Blue*** (pblue@ed.ac.uk), Maxwell Institue & School of Mathematics, University of Edinburgh, Edinburgh, EH9 3FD, United Kingdom. *Decay for fields outside black holes.* Preliminary report.

The stability of Kerr black holes is one of the major open problems in mathematical relativity. If a two-tensor satisifies the linearised Einstein equation with the linearisation taken around a Kerr black hole, then it has been known since the early 1970s that the extreme components of the curvature must satisfy the Teukolsky equation. Breakthroughs in the last year by Ma and by Dafermos-Holzegel-Rodnianski have proven for the first time that there are uniformly bounded energies for this equation. This talk will present a method to reprove this result using differential operators instead of Fourier techniques. (Received February 19, 2018)

1139-35-521 **Walton Green**, **Shitao Liu*** (liul@clemson.edu) and **Mishko Mitkovski**. *A harmonic analysis proof of the boundary observability inequality for the visco-elastic equation.*

We give a harmonic analysis proof of the Neumann boundary observability inequality for the wave equation and visco-elastic equation in an arbitrary space dimension. The proof extends the classical moment method and gives simple, explicit constants. (Received February 19, 2018)

1139-35-524 **Mauricio Alexander Rivas*** (marivas@uncg.edu), Department of Mathematics & Statistics, 116 Petty Building, PO Box 26170, Greensboro, NC 27402. *Spectral characterization of surfaces in shape recognition problems.* Preliminary report.

This talk defines certain spectral characterizations of a shapes (or surfaces) in N-dimensional Euclidean space using the harmonic Steklov eigenfunctions of the region whose boundary is the surface to be characterized. The approach is intrinsic and provides for a Hilbert-like geometric approach to deformable shape classification or pose invariant segmentation. The Hilbert-like inner-product is shown to be associated with solution operators of certain harmonic equations. We discuss the robustness of the characterizations to local topology changes of the surface. (Received February 19, 2018)

1139-35-528 **William Feldman*** (feldman@math.uchicago.edu). *Continuity properties for boundary data homogenization problems.*

I will discuss the continuity, or lack thereof, of the effective boundary condition for boundary data homogenization problems in periodic media. For both divergence and non-divergence form problems continuity (generically) requires linearity of the PDE operator. Based on joint works with I. Kim and Y. Zhang. (Received February 19, 2018)

1139-35-537 **Haitian Yue*** (haityue@gmail.com), 9J Brandywine, Amherst, MA 01002. *Well-posedness for the cubic NLS on tori.*

The cubic nonlinear Schrödinger equation (NLS) is energy-critical ($s_c = 1$) with respect to the scaling symmetry, where s_c is the scaling critical regularity. The initial value problem (IVP) of cubic NLS is scaling invariant in the Sobolev norm H^1 of scaling critical regularity. First this talk introduce the deterministic global well-posedness result of cubic NLS on 4d-torus (T^4) in the critical regime (with H^1 initial data). Second we consider the cubic NLS in the super-critical regime (with H^s data, $s < 1$). A probabilistic approach is applied to obtain an "almost sure" well-posedness result for the cubic NLS on tori ($T^d, d \geq 3$). (Received February 19, 2018)

1139-35-541 **Sedar Ngoma*** (ngoma@geneseo.edu), SUNY Geneseo, 1 college Circle, 323 South Hall, Geneseo, NY 14454. *A fixed point method for a time-dependent inverse diffusion coefficient problem for a parabolic partial differential equation.*

We investigate an inverse diffusion coefficient problem for a parabolic partial differential equation with an integral constraint. We establish the existence and uniqueness of solutions using fixed point theory. We develop and implement an algorithm to approximate solutions of the inverse problem by means of the finite element method in space and the implicit Euler method in time. We calculate the error and report the rates of convergence which we estimate by the linear regression. These rates are consistent with the standard parabolic error estimates. The numerical results we present show the accuracy of our scheme. (Received February 19, 2018)

1139-35-549 **Leandro Lichtenfelz**, **Gerard Misiolek** and **Stephen C. Preston*** (stephen.preston@brooklyn.cuny.edu). *Axisymmetric ideal fluids on Riemannian 3-manifolds.*

In 3-dimensional Euclidean space, there are three symmetries one can impose to reduce the Euler equations to a manageable system: translational symmetry (which decouples into 2-D Euler and a transported third component); rotational symmetry (to get the axisymmetric equations with swirl); and a "screw" symmetry which combines both. However all these situations are either too simple (due to decoupling) or too complicated (due to singular behavior on the axis and nonconstant coefficients).

In this talk we will present the analogue of axisymmetric fluid flows on Riemannian 3-manifolds, in particular the eight Thurston geometries that have the most symmetries. Some of these geometries even have stagnation-point solutions which reduce to one-dimensional PDEs that are simpler than those appearing in the axisymmetric case. As one example, the reduced equation on $SL_2(\mathbb{R})$ becomes the system

$$\Delta f_t + \{f, \Delta f\} - \{f, g\} = 0, \;\; g_t + \{f, g\} = 0$$

for a stream function f and swirl g on $\mathbb{R}^2$, which is analogous to the 2D Boussinesq equation. (Received February 19, 2018)

1139-35-552 **Jill Pipher*** (jill_pipher@brown.edu), Box 1917, 151 Thayer St., Dept of Mathematics, Brown University, Providence, RI 02912, and **Martin Dindos**. *Boundary value problems for elliptic complex coefficient divergence form operators.*

Let $L = \mathrm{div} A\nabla$ be a second order elliptic operator, where A is a matrix of bounded measurable complex-valued functions. The concept of *p-ellipticity*, introduced by Cialdea and Mazya, and further refined by Carbonaro and Dragičević, allows us to prove higher integrabilty and regularity of solutions, via a Moser iteration argument. We then consider Dirichlet, regularity, and perturbation theory for p-elliptic operators. (Received February 19, 2018)

1139-35-558 **Benjamin Seeger*** (bseeger@math.uchicago.edu), University of Chicago, Department of Mathematics, 5734 S. University Avenue, Chicago, IL 60615. *Homogenization of pathwise Hamilton-Jacobi equations.*

I will present qualitative and quantitative homogenization results for pathwise Hamilton-Jacobi equations with “rough” multiplicative driving signals. When there is only one such signal and the Hamiltonian is convex, the equation, as well as equations with smooth approximating paths, homogenize. In the multi-signal setting, I will give examples to show that homogenization may or may not take place. (Received February 19, 2018)

1139-35-574 **Emma Previato***, Department of Mathematics and Statistics, Boston University, Boston, MA 02215. *NLS as an infinite dimensional ACI.* Preliminary report.

P.Deift, F. Lund and E. Trubowitz gave a continuous Hamiltonian model for the non-linear Schrödinger equation and other integrable PDEs (Comm. Math. Phys. 1980) and we adapted their identities to construct a finite-dimensional, algebraically completely integrable (ACI) Hamiltonian system which provides algebro-geometric solutions to sine-Gordon, as Abelian functions over a curve C (Phys. D 1986). Motivated by recent work by T. Kappeler and P. Topalov on differentials over curves of infinite genus, with applications to solving the focusing NLS (J. Diff. Geom. 2017), we adapt the ACI model to curves of infinite genus and their Abelian functions. In principle, these functions should give solutions to both defocusing and focusing cases, but technical conditions for convergence need to be verified. (Received February 19, 2018)

1139-35-580 **David Shirokoff*** (david.g.shirokoff@njit.edu) and **Mahdi Bandegi**. *Conic programming of a variational inequality for self-assembly.*

We examine the problem of minimizing a class of non-local, non-convex functionals, that arise from large systems of pairwise interacting particles. Although finding and verifying local minima to these functionals is relatively straightforward, computing and verifying global minima is much more difficult. Global minima are important as they characterize the most likely observable states for the associated particle systems (interacting in the presence of thermal noise). We discuss how minimizing the energy functionals can be viewed as testing whether an associated bilinear form is co-positive. We then examine sufficient conditions for global optimality obtained through a convex relaxation of the cone of co-positive functionals. The sufficient conditions are (i) often sharp; and (ii) provide an optimal decomposition of the functional (into the sum of a convex and non-negative functional) that can be used to characterize the emerging shapes of self-assembled structures. (Received February 19, 2018)

1139-35-581 **Emanuel 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 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 $\mathcal{C}_\epsilon := \{x_n > \epsilon|x'|\}$, $x' = (x_1, \ldots, x_{n-1})$. Tangential touch for the Laplacian is well-understood and the more general case in two dimensions is joint work with Minne. This talk focuses on the problem in higher dimensions. (Received February 19, 2018)

1139-35-594 **Changfeng Gui** and **Amir Moradifam*** (amirm@ucr.edu). *The Sphere Covering Inequality and Its Applications.*

We show that the total area of two distinct Gaussian curvature 1 surfaces with the same conformal factor on the boundary, which are also conformal to the Euclidean unit disk, must be at least 4π. In other words, the areas of these surfaces must cover the whole unit sphere after a proper rearrangement. We refer to this lower bound of total areas as the Sphere Covering Inequality. This inequality and it's generalizations are applied to a number of open problems related to Moser-Trudinger type inequalities, mean field equations and Onsager vortices, etc, and yield optimal results. In particular we confirm the best constant of a Moser-Truidinger type inequality conjectured by A. Chang and P. Yang in 1987. This is a joint work Changfeng Gui. (Received February 20, 2018)

1139-35-603 **Andrew Lorent*** (alorent@gmail.com), Cincinnati, OH 45219, and **Guanying Peng** (pgy218@gmail.com), AZ. *Null Lagrangian Measures in planes, compensated compactness and conservation laws.*

Compensated compactness is an important tool for solving non-linear PDE. In particular existence theorems for hyperbolic conservation laws. At their heart - compensated compactness proofs come down to showing a particular class of measures (call Null Lagrangian measures) supported on submanifolds in matrix space are actually Dirac measures. A general necessary and sufficient characterization of the conditions under which this is true is unknown even for subspaces in Matrix space, we present results in this direction answering the question in lower dimensions. As an application of the methods, we answer a question of Kircheim, Muller, Sverak and apply our results reformation of the proof of a classic result by DiPerna. This is joint work with Guanying Peng of the University of Arizona. (Received February 20, 2018)

1139-35-612 **B. Dodson**, **A. Lawrie** and **D. Mendelson***, dana@math.uchicago.edu, and **J. Murphy**. *Energy subcritical nonlinear wave equations in the non-radial setting.*

In this talk we'll describe joint work with B. Dodson, A. Lawrie and J. Murphy on the energy subcritical radial cubic wave equation. We prove that all solutions scatter as long as the critical norm of the evolution stays bounded using techniques inspired by the work of Kenig and Merle and Duyckaerts, Kenig, and Merle. We'll focus on the new methods we introduced to treat the energy subcritical case in the non-radial setting. (Received February 20, 2018)

1139-35-615 **B. Dodson**, **J. Luhrmann** and **D. Mendelson*** (dana@math.uchicago.edu), dana@math.uchicago.edu. *Probabilistic wellposedness and scattering results for wave and Schrodinger equations on Euclidean space.*

We will discuss recent progress on the probabilistic local well-posedness of the nonlinear Schrodinger equation. The main ingredient in our proof is the introduction of a functional framework for the study of the associated forced cubic nonlinear Schrödinger equation, which is inspired by certain function spaces used in the study of the Schrödinger maps problem, and is based on Strichartz spaces as well as variants of local smoothing, inhomogeneous local smoothing, and maximal function spaces. We will also discuss certain probabilistic scattering results for nonlinear Schrodinger and wave equations. (Received February 20, 2018)

1139-35-618 **Juraj Foldes*** (foldes@virginia.edu), **Nathan Glatt-Holtz**, **Geordie Richards** and **Jared Whitehead**. *Stochastic variational problems and applications to fluid dynamics.*

Stochastic Boussinesq system is a model for buoyancy driven convection with random exterior fluctuations. As in the deterministic systems, also in random setting it is important to understand equilibria and their stability properties. In particular if there is just one statistical equilibrium, it is asymptotically stable and globally attractive, and therefore the existence of multiple steady states is closely connected to their stability. In turn, stability of statistical equilibria lead to constraint variational problems with random potentials, and consequently to random eigenvalue problems. We will rigorously analyze minimizers of random functionals and show that the small stochastic forcing stabilizes the system, compared to the deterministic one, and large stochastic forcing destabilizes Boussinesq system. (Received February 20, 2018)

1139-35-637 **Benoit Pausader***, Mathematics department, Brown University, Providence, RI 02912. *On the Einstein equation with massive scalar field.*

We consider perturbations of the Minkowski space for the Einstein equation in the presence of a massive scalar field. This leads to studying quasilinear dispersive systems consisting of wave and Klein-Gordon-type equations. We prove a small-data/global existence result, even when the initial data have a fairly slow fall-off at infinity. This is a joint work with A. Ionescu. (Received February 20, 2018)

1139-35-638 **Jasun Gong*** (jgong7@fordham.edu), 441 E. Fordham Road, John Mulcahy Hall, Fordham University, Bronx, NY 10458, and **Murat Akman**, **Jay Hineman**, **John Lewis** and **Andrew Vogel**. *A Brunn-Minkowski inequality for nonlinear capacity.* Preliminary report.

In this work we study associated capacities to degenerate elliptic PDEs in divergence form, i.e.

$$\operatorname{div}[\mathbf{A}\nabla u(x))] \;=\; 0$$

with suitable structural assumptions on $\mathbf{A} : \mathbb{R}^n \to \mathbb{R}^n$ that include the p-Laplacian $\mathbf{A}(\mathbf{v}) = \|\mathbf{v}\|^{p-2}\mathbf{v}$ as an example. Our main result is a Brunn-Minkowski inequality for such capacities:

$$[\mathrm{Cap}_{\mathcal{A}}(\lambda E_1 + (1-\lambda)E_2)]^{\frac{1}{(n-p)}} \geq \lambda\,[\mathrm{Cap}_{\mathcal{A}}(E_1)]^{\frac{1}{(n-p)}} + (1-\lambda)\,[\mathrm{Cap}_{\mathcal{A}}(E_2)]^{\frac{1}{(n-p)}}$$

where $1 < p < n$ and $0 < \lambda < 1$, and where E_1, E_2 are convex compact sets with positive $\mathcal{A}$-capacity. Moreover, if equality holds in the above inequality for some E_1 and E_2, then with further regularity assumptions on $\mathcal{A}$, we show that E_1 and E_2 must be homothetic. (Received February 20, 2018)

1139-35-641 **Jacob Bedrosssian***, jacob@cscamm.umd.edu, and **Michele Coti Zelati** and **Vlad Vicol**. *Vortex axisymmetrization, inviscid damping, and vorticity depletion in the linearized 2D Euler equations.*

Coherent vortices are often observed to persist for long times in turbulent 2D flows even at very high Reynolds numbers and are observed in experiments and computer simulations to potentially be asymptotically stable in a weak sense for the 2D Euler equations. We consider the incompressible 2D Euler equations linearized around a radially symmetric, strictly monotone decreasing vorticity distribution. For sufficiently regular data, we prove the inviscid damping of the θ-dependent radial and angular velocity fields with the optimal rates. We moreover prove that the vorticity weakly converges back to radial symmetry as a phenomenon known as vortex axisymmetrization in the physics literature, and characterize the dynamics in higher Sobolev spaces. Furthermore, we prove that the θ-dependent angular Fourier modes in the vorticity are ejected from the origin as time goes to infinity, resulting in faster inviscid damping rates than those possible with passive scalar evolution. This non-local effect is called vorticity depletion; our work appears to be the first to find it relevant for the dynamics of vortices. Joint work with Michele Coti Zelati and Vlad Vicol. (Received February 20, 2018)

1139-35-649 **Gustavo Hoepfner***, Rod. Washington Luis, km 235, Sao Carlos, Sao Paulo 13565-905, Brazil, and **Paulo Liboni**, **Dorina Mitrea**, **Irina Mitrea** and **Marius Mitrea**. *Multi-Layers operators on rough domains and boundary value problems.*

In this talk I will discuss Calderón-Zygmund theory results for multi-layer potential operators associated with homogeneous constant coefficient higher order systems in uniformly rectifiable domains in $\mathbb{R}^n$ and applications to Fredholm theory for boundary value problems.

This is a joint work with P. Liboni (UEL-Brazil), D. Mitrea (Univ. Missouri), I. Mitrea (Temple Univ.) and M. Mitrea (Univ. Missouri). (Received February 20, 2018)

1139-35-661 **Mimi Dai*** (mdai@uic.edu). *Well-posedness problems for the magneto-hydrodynamics systems.*

We will talk about some recent results on the well-posedness problems in Sobolev spaces for the magneto-hydrodynamics with and without Hall effect, i.e., the Hall MHD and classical MHD models. One of the purposes of the work is to search the optimal Sobolev space of well-posedness for the two models. Another purpose is to understand the nonlinear Hall term $\nabla \times ((\nabla \times b) \times b)$ in the Hall MHD, which appears more singular than $u \cdot \nabla u$ in the NSE, but with special geometry. (Received February 20, 2018)

1139-35-674 **Dat T Cao***, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, and **Luan T Hoang**, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409. *Asymptotic expansions for decaying solutions of Navier-Stokes equations.*

We investigate the long-time behavior of solutions to the three-dimensional Navier-Stokes equations with periodic boundary conditions. We show that if the force has an asymptotic expansion, as time goes to infinity, with respect to certain families of decaying functions in Sobolev-Gevrey space, then any weak solution admits an asymptotic expansion of the same type. In particular, we establish the expansions in terms of power decaying functions and the log or log(log) decaying ones. This is a joint work with Luan Hoang (Texas Tech University). (Received February 20, 2018)

1139-35-688 **Diego Cordoba** and **Javier Gomez-Serrano***, jg27@math.princeton.edu, and **Andrej Zlatos**. *Stability shift for the Muskat problem.*

The Muskat problem models the evolution of incompressible fluids of different nature in porous media. It is known that if the denser fluid is below the lighter fluid, the system is stable, and unstable otherwise. In this talk we will show the existence of solutions that transition between stable and unstable regimes several times, without breaking down. Joint work with Diego Cordoba and Andrej Zlatos. (Received February 20, 2018)

1139-35-698 **Trevor M Leslie*** (tlesli2@uic.edu). *Weak and Strong Solutions to the Forced Fractional Euler Alignment System.*

We consider a hydrodynamic model of self-organized evolution of agents, with singular interaction kernel $\phi(x) = 1/|x|^{1+\alpha}$, $\alpha \in (0,2)$, in the presence of an additional external force. Well-posedness results are available for this system in classical regularity spaces. We define a notion of solutions in larger function spaces—both in L^∞ and $W^{1,\infty}$, and prove the existence and uniqueness of such solutions. We also discuss various properties (i.e., energy equality, fast alignment and flocking in the forceless case) of more regular solutions, and under what additional assumptions, if any, these properties are enjoyed by the weaker solutions that we define. (Received February 21, 2018)

1139-35-699 **Mimi Dai*** (mdai@uic.edu) and **Alexey Cheskidov**. *Determining modes for the Navier-Stokes equation.*

In this talk we review classical results on determining modes for fluid equations and present a slightly different approach where we start with a time-dependent determining wavenumber defined for each individual trajectory and then study its dependence on the force. While in some cases this wavenumber has a uniform upper bound, it may blow up when the equation is supercritical. A bound on the determining wavenumber provides determining modes, which in some sense measure the number of degrees of freedom of the flow, or resolution needed to describe a solution. For the 3D Navier-Stokes equations, we obtain a uniform bound on the time average of this wavenumber, which we estimate in terms of the Kolmogorov dissipation number and Grashof constant. (Received February 21, 2018)

1139-35-703 **Alexandru D. Ionescu***, Department of Mathematics, Washington Rd., Princeton, NJ 08540, and **Benoit Pausader**. *On the global regularity of certain quasilinear evolution models.*

I will discuss some recent work on the problem of global regularity of a class of physical evolution equations. I will mostly focus on two-speed evolution problems, such as the Einstein-Klein-Gordon system of General Relativity. This is joint work with Benoit Pausader. (Received February 21, 2018)

37 ► Dynamical systems and ergodic theory

1139-37-40 **John R. Doyle*** (jdoyle@latech.edu), Department of Mathematics and Statistics, Louisiana Tech University, Ruston, LA 71272, and **Bjorn Poonen** (poonen@math.mit.edu), Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA 02139. *Dynamical modular curves and uniform boundedness of preperiodic points.*

Morton and Silverman's uniform boundedness conjecture (UBC) for preperiodic points of rational maps, originally stated over number fields, has a natural analogue over function fields. We will discuss a recent proof of the function field UBC for the unicritical family $f_c(z) = z^d + c$ with $d \geq 2$, which involves giving lower bounds on the gonalities of (the geometric components of) the associated dynamical modular curves. Finally, we will discuss how, for the unicritical family over number fields, these gonality bounds reduce the UBC for preperiodic points to the UBC for periodic points. (Received January 16, 2018)

1139-37-60 **Joseph M Rosenblatt*** (joserose@iupui.edu), Department of Mathematical Sciences, IUPUI, 402 N. Blackford Street, Indianapolis, IN 46202. *Error distortion rates in quantization via orbits.* Preliminary report.

We consider the rates of approximation by orbits generated by IID, number theoretic, or dynamical models. These rates relate to non-parametric statistics in the case of IID models, Diophantine approximation in the case of number theoretic models, and hitting shrinking targets in the case of dynamical models. (Received January 24, 2018)

1139-37-68 **Ethan Akin*** (ethanakin@earthlink.net), Mathematics Department, The City College of New York, 137 Street and Convent Avenue, New York, NY 10031. *Solving the Iterated Prisoner's Dilemma the Smale way.*

In 1980, Smale introduced a geometric approach to formulating strategy for the IPD. Using these methods, we describe how to deal with an n-person version of the IPD. (Received January 26, 2018)

1139-37-81 **Vitaly Bergelson*** (vitaly@math.ohio-state.edu), Department of Mathematics, Ohio State University, 231 West 18th Avenue, Columbus, OH 43210. *Ergodic Ramsey Theory: Some Classical Problems and Recent Advancements.*

We will start with formulating some classical results of Ramsey theory and analyzing their dynamical underpinning. We will move then to the discussion of the main principles of Ergodic Ramsey theory and survey some of the developments which were triggered by Furstenberg's ergodic proof of Szemeredi's theorem on arithmetic progressions. We will conclude with formulating and discussing some of the natural open problems which link dynamics, combinatorics and number theory. (Received January 31, 2018)

1139-37-86 **Anh Ngoc Le*** (anhle@math.northwestern.edu), 2033 Sheridan Road, Evanston, IL 60208. *Nilsequences and multiple correlations along subsequences.*

Let (X, μ, T) be a measure preserving system and f a bounded function on X. The sequence $a(n) = \int f \cdot T^n f \dots T^{kn} f d\mu$ is called a multiple correlation sequence. By the works of Bergelson, Host, Kra and Leibman, a multiple correlation sequence can be decomposed into a sum of a nilsequence (a sequence defined by evaluating a continuous function along an orbit in a nilsystem) and a nullsequence (a sequence that is zero in uniform density). In this talk, we present a refinement of that result by showing the nullsequence is null along primes, along integer polynomials and Hardy field sequence $[n^c]$. (Received January 31, 2018)

1139-37-102 **Sebastian Donoso**, **Ahn Lee**, **Joel Moriera** and **Wenbo Sun*** (sun.1991@osu.edu), 281 W. Lane Ave., Columbus, OH 43210. *Quantitative recurrence theorem and solution counting problem.*

Let $p_1, \dots, p_d$ be linear functions. In ergodic theory, the quantitative recurrence theorem studies the lower bound for the measure of the set $A \cap T^{p_1(n)} A \cap \dots \cap T^{p_d(n)} A$ over a large set of return time n. Let $p(x_1, \dots, x_n)$ be a linear function with n variables. In combinatorics, the solution counting problem studies the number of solutions for the equation $p(x_1, \dots, x_n) = 0$ for $x_1, \dots, x_n$ lying in a given subset of integers. In this talk, I will talk about recent advances for these topics, and discuss the connection between these two questions. This is joint work with Sebastian Donoso, Anh Lee and Joel Moreira. (Received February 03, 2018)

1139-37-104 **V Bergelson** and **D Robertson*** (robertso@math.utah.edu). *IP sets and weakly mixing groups.* Preliminary report.

By an example of Straus, there are positive density sets of integers no shift of which contain a sequence and all its finite sums. We prove that positive density subsets of minimally almost periodic amenable groups contain highly structured sets that do contain a sequence together with all its finite products. (Received February 12, 2018)

1139-37-106 **Stefanos Orfanos**, **Ayşe Şahin*** (ayse.sahin@wright.edu) and **Ilie Ugarcovici**. *Classifying general odometers: spectrum, geometric group theory, and orbit equivalence.* Preliminary report.

We discuss odometer actions of semi-direct product groups of the form $G = \mathbb{Z}^d \rtimes_A \mathbb{Z}$ with $A \in GL_d(\mathbb{Z})$. We discuss their classification in terms of the geometry of the underlying subgroups, their spectrum, and their continuous topological orbit equivalence class. (Received February 04, 2018)

1139-37-110 **Andreas Koutsogiannis*** (koutsogiannis.1@osu.edu), 100 Math Tower, 231 West 18th Avenue, Columbus, OH 43210. *Pointwise multiple averages for sublinear functions.*

In this talk we will study the pointwise convergence of multiple ergodic averages with iterates of different growth sublinear functions in a measure preserving system, where we assume no commutativity on the transformations.

The class of interest properly contains important subclasses of Hardy field functions of order 0 and of Fejér functions. The case where the fastest function is linear will presented as well, and we will provide, in all the cases, an explicit formula of the limit function. This is a joint work with S. Donoso and W. Sun. (Received February 04, 2018)

1139-37-112 **Jan Kiwi** and **Hongming Nie***, Department of Mathematics, Indiana University, Bloomington, IN 47405. *Indeterminacy Loci of Iterate Maps.*

The moduli spaces of complex rational maps admit natural GIT compactifications. But the iterate maps on the moduli spaces do not extend continuously to maps on the GIT compactifications. In this talk, we will give a complete description of the indeterminacy loci of the extensions. (Received February 04, 2018)

1139-37-117 **Marc Carnovale*** (carnovale.2@osu.edu), 231 West 18th Ave, Columbus, Oh 43210, Columbus, OH 43210. *Gowers-Host-Kra norms and Euclidean harmonic analysis.*

As the field of additive combinatorics has matured it has seen a number of striking applications both within combinatorial number theory and without. In this talk we will survey some developments at the interface between Euclidean harmonic analysis and the fine arithmetic properties of functions controlled by the Gowers-Host-Kra norms and related data. (Received February 05, 2018)

1139-37-132 **Mrinal K Roychowdhury*** (mrinal.roychowdhury@utrgv.edu), 1201 West University Drive, Edinburg, TX 78539. *Quantization for Probability Distributions.*

Quantization for a probability distribution refers to the idea of estimating a given probability by a discrete probability supported by a set with finite number of points. It has broad applications in signal processing and data compression. It is also closely connected with data mining. In my talk, I will try to give an overview of optimal quantization for different probability distributions. (Received February 05, 2018)

1139-37-133 **Dmitry Kleinbock***, Department of Mathematics, Brandeis University, Waltham, MA 02454, and **Nick Wadleigh**, Mathematics Department, Technion - Israel Institute of Technology, 32000 Haifa, Israel. *Dynamics and combinatorics of improving Dirichlet's Theorem on Diophantine approximation.*

For a non-increasing function ψ, say that a real number x belongs to the ψ-*Dirichlet* set $D(\psi)$ if the system

$$\begin{cases} |qx-p| < \psi(t) \\ |q| < t \end{cases}$$

has a nontrivial integer solution (p,q) for all large enough t. The choice $\psi_1(t) = 1/t$ corresponds to the classical Dirichlet's Theorem which states that every x is in $D(\psi_1)$. In the 1960s Davenport and Schmidt showed that for any $c < 1$ the set $D(c\psi_1)$ has Lebesgue measure zero, and in fact elements of this set were explicitly identified using continued fractions. We extend their work to similarly describe sets $D(\psi)$ for arbitrary ψ, and then use dynamics of the Gauss map to find a criterion for ψ-Dirichlet sets to have zero or full Lebesgue measure. (Received February 05, 2018)

1139-37-175 **Steven J Miller*** (sjm1@williams.edu), Williams College, Williamstown, MA 01267. *Benford's Law and the 3x+1 Problem, or: Why the IRS cares about Discrete Dynamical Systems.*

Many systems exhibit a digit bias. For example, the first digit (base 10) of the Fibonacci numbers or of 2^n equals 1 about 30% of the time; the IRS uses this digit bias to detect fraudulent corporate tax returns. This phenomenon, known as Benford's Law, was first noticed by observing which pages of log tables were most worn from age – it's a good thing there were no calculators 100 years ago! The first digit of values of L-functions near the critical line also exhibit this bias, as do the first digit of iterates in the $3x + 1$ problem (provided the base B is not a power of two). After discussing the general theory and describing some applications of Benford's law to fraud detection, we discuss the proof for a large class of systems. For the $3x + 1$ problem the key ingredient is the rate of equidistribution of $n \log_B 2 \bmod 1$, which comes from the irrationality measure of $\log_B 2$. This work is joint with Alex Kontorovich. (Received February 08, 2018)

1139-37-225 **W. Patrick Hooper*** (whooper@ccny.cuny.edu), City College Dept. of Mathematics, 160 Convent Ave, New York, NY 10031. *Pseudo-Anosovs and Cylinders on the Polygonal Parabola.*

I'll describe some results about the dynamics of hyperbolic affine automorphisms of a particular highly symmetric infinite area translation surface built out of polygonal parabolas. In particular, I will describe mixing-type formula and distribution results for cylinders pushed around by a hyperbolic automorphism.

I'll emphasize the main idea of the proofs of these results rather than the results themselves. First, the cylinders introduce a discretization of the space, and areas of intersecting cylinders is very much related to their intersection numbers. Second, we show that for this special surface, intersection numbers can be computed through an integral formula. Our main results follow then from understanding the asymptotics of certain integrals. (Received February 12, 2018)

1139-37-265 **Benjamin Hutz***, Saint Louis University, Saint Louis, MO , and **Michael Stoll**, Universitat Bayreuth, Bayreuth, Germany. *Smallest representatives of $SL(2,\mathbb{Z})$-orbits of binary forms and endomorphisms of $\mathbb{P}^1$.*

We develop an algorithm that determines, for a given squarefree binary form F with real coefficients, a smallest representative of its orbit under $SL(2,\mathbb{Z})$, either with respect to the Euclidean norm of the coefficient vector or with respect to the global height. This is based on earlier work of Cremona and Stoll. We then generalize our approach so that it also applies to the problem of finding a representative of smallest height in the $SL(2,\mathbb{Z})$-orbit of an endomorphism of the projective line. Having a small model of such an endomorphism is useful for various computations. (Received February 13, 2018)

1139-37-279 **Thomas Silverman*** (thomas_silverman@brown.edu). *A non-archimedean λ-lemma and J-stability.*

In a celebrated paper published in 1983, R. Mañé, P. Sad, and D. Sullivan prove a result about holomorphic families of injections called the λ-Lemma with impressive applications to the complex dynamics of families of one-variable rational functions. In this talk, I will discuss a framework for studying the dynamics of families of one-variable rational functions parametrized by Berkovich spaces over a complete non-archimedean field and a suitable non-archimedean analogue of the λ-Lemma. I will also explain how this can be used to prove the equivalence of two stability conditions in non-archimedean dynamics. (Received February 13, 2018)

1139-37-316 **Ren Yi***, 151 Thayer Street, Providence, RI 02912, **Ian Alevy** (ian_alevy@brown.edu), 170 Hope room 113, Providence, RI 02912, and **Richard Kenyon** (rkenyon@math.brown.edu), 151 Thayer Street, Providence, RI 02912. *Self-Induced Rectangle Exchange Maps.*

A domain exchange map (DEM) is a dynamical system of piecewise translation defined on a smooth Jordan domain. We explain how to use cut-and-project sets to construct minimal DEMs on any smooth Jordan domain. Specializing in the case when the domain is a unit square, we construct an infinitely family of rectangle exchange maps (REMs). We show that these REMs are self-induced. Moreover, certain REMs in this family can be composed to create new REMs called multi-stage REMs. The renormalization scheme of the multi-stage REMs will be discussed in this talk. This is joint work with Ian Alevy and Richard Kenyon. (Received February 15, 2018)

1139-37-336 **Diana Davis*** (dianajdavis@gmail.com), 500 College Avenue, Swarthmore, PA 19081, and **Samuel Lelièvre**, Laboratoire de mathématique d'Orsay, UMR 8628 CNRS / Université Paris-Sud, Bâtiment 307, campus Orsay-vallée, 91405 Orsay cedex, France. *Periodic paths on the pentagon.*

Periodic billiard paths on regular polygons are beautiful to look at, and have an elegant mathematical structure related to continued fractions. I'll remind you what happens on the familiar square, and then delve into our recent work on the regular pentagon, with lots of pictures. (Received February 15, 2018)

1139-37-356 **Luen-Chau Li*** (luenli@math.psu.edu), Department of Mathematics, Pennsylvania State University, University Park, PA 16802. *Integrable isospectral flows on infinite periodic band matrices.*

The periodic Kostant-Toda flow was introduced by K. Ben Abdeljelil on general complex simple Lie algebras. When the Lie algebra is $mathfrak\mathfrak{sl}(n,\mathbb{C})$, this turns out to be a special case of the flows considered by van Moerbeke and Mumford. In this talk, we will begin by discussing the resolution of the conjecture of Ben Abdeljelil for $\mathfrak{sl}(n,\mathbb{C})$ where the band matrices have upper bandwidth equal to 1 with 1's on the first superdiagonal. Then we will discuss recent progress in understanding the case where the upper bandwidth is general. (Received February 16, 2018)

1139-37-376 **Sarah C. Koch*** (kochsc@umich.edu). *The Thurston operator: looking for geometry in the algebra.*

Associated to every postcritically finite rational map f is a holomorphic endomorphism $\sigma_f : \mathcal{T} \to \mathcal{T}$ of a certain Teichmüller space. William Thurston proved that σ_f has a unique fixed point. The derivative of σ_f at the fixed point is called the *Thurston operator* associated to f. We explicitly compute the characteristic polynomial of the Thurston operator in the case where f is a quadratic polynomial with periodic critical point, and we study the coefficients; these coefficients are all algebraic, and in fact, they are rather mysterious rational functions of the postcritical points of f. (Received February 16, 2018)

1139-37-380 **Mattias Jonsson*** (mattiasj@umich.edu), Mathematics, University of Michigan, Ann Arbor, MI 48109-1043. *On dynamical height functions for rational maps.*

Consider a rational selfmap f of a projective variety defined over a the field $\overline{\mathbf{Q}}$ of algebraic numbers. A fundamental invariant of f is the first dynamical degree δ_f , measuring the asymptotic degree growth of f^n as $n \to \infty$. In many instances, one expects there to be a nonnegative (but not identically zero) dynamical height function $\hat{h}_f$ on $X(\overline{\mathbf{Q}})$ satisfying the invariance relation $\hat{h}_f \circ f = \delta_f \hat{h}_f$. I will discuss some instances when this is known. (Received February 16, 2018)

1139-37-381 **S Eigen*** (s.eigen@northeastern.edu), 360 Huntington Ave, Boston, MA 02115, and **A Hajian** and **V Prasad**. *SWW Sequences and the Infinite Measure Preserving Random Walk.*

We demonstrate the power and simplicity of *sww* (special weakly wandering) sequences and use them to obtain the first explicit *eww* (exhaustive weakly wandering) sequence for the infinite measure preserving random walk transformation. Applications are given for tilings of the integers (Received February 16, 2018)

1139-37-386 **Alessandro Arsie** and **Paolo Lorenzoni*** (paolo.lorenzoni@unimib.it). *Bi-Flat F-manifolds, complex reflection groups and integrable systems of conservation laws.*

We extend some of the results proved for scalar equations in, to the case of systems of integrable conservation laws. In particular, for such systems we prove that the eigenvalues of a matrix obtained from the quasilinear part of the system are invariants under Miura transformations and we show 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, we study the corresponding integrable deformations up to order 2 in the deformation parameter. 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. It turns out that a part two values of the parameter all deformations of order one are Miura-trivial, while all those of order two are essentially parameterized by two arbitrary functions of single variables (the Riemann invariants) both in the bi-Hamiltonian and in the non-Hamiltonian case. In the two remaining cases, due to the existence of non-trivial first order deformations, there is an additional functional parameter. (Received February 17, 2018)

1139-37-394 **Kenneth Jacobs*** (ken@northwestern.edu). *A New 'Height' in Arithmetic Dynamics.*

In this talk, I will describe the construction of a new 'height' function on the moduli space $\mathcal{M}_d$ of rational maps over a global field. The construction is based on work of Rumely on the minimal resultant of a rational map over a non-Archimedean field, as well as generalizations of this work to maps over $\mathbb{C}$. This 'height' is known to be a Weil height in special cases, and we'll discuss progress on proving that it is (comparable to) a Weil height in general. (Received February 17, 2018)

1139-37-431 **Maxim Arnold**, **Dmitry Fuchs**, **Ivan Izmestiev** and **Sergei Tabachnikov*** (tabachni@math.psu.edu). *A family of dynamical systems on ideal polygons.* Preliminary report.

Two labeled ideal polygons in the hyperbolic plane are said to make angle α if i-th side of the first polygon makes angle α with i-th side of the second one for all i. This defines a 1-parameter family of discrete dynamical systems on the moduli space of isometry equivalence classes of ideal polygons. I shall discuss complete integrability of these systems and related topics, including continuous limits. (Received February 18, 2018)

1139-37-445 **Anton Lukyanenko*** (alukyane@gmu.edu) and **Joseph Vandehey**. *Ergodicity of Iwasawa continued fractions.* Preliminary report.

Rational Carnot groups retain sufficient similarity to the real numbers to study analogs of number-theoretic constructions. In particular, $\mathbb{R}^n$ and certain H-type Carnot groups admit a continued fraction algorithm that is related to both Diophantine properties of the space and the geometry of an associated hyperbolic space. We use the latter to study the dynamical properties of the Gauss map associated to these *Iwasawa continued fractions*, proving ergodicity in the geometrically complete case, which includes multiple variants of real continued fractions as well as new variants of complex continued fractions and Heisenberg continued fractions. (Received February 18, 2018)

1139-37-457 **Vladimir Dragovic*** (vladimir.dragovic@utdallas.edu), 800 West Campbell Road, FO 35, Richardson, TX 75080. *Billiards within ellipsoids and extremal polynomials.*

A comprehensive study of periodic trajectories of the billiards within ellipsoids in d-dimensional space is presented. The novelty of the approach is based on a relationship established between the periodic billiard trajectories and the extremal polynomials on a systems of d intervals on the real line. The case study of trajectories of small periods T, $d \leq T \leq 2d$ is given. The talk is based on a joint work with M. Radnovic. (Received February 18, 2018)

1139-37-478 **Laura DeMarco**, **Holly Krieger*** (hkrieger@dpmms.cam.ac.uk) and **Hexi Ye**. *Bounds on dynamical height pairings.* Preliminary report.

I will discuss current work joint with DeMarco and Ye on lower bounds for dynamical height pairings. Time- and progress-permitting, I will explain how these bounds can be used to produce uniform upper bounds on the size of the intersection of the preperiodic points of two distinct quadratic polynomials. (Received February 19, 2018)

1139-37-481 **Munther Dahleh*** (dahleh@mit.edu). *Learning for control: the role of model approximation.*

Robust control theory highlighted the importance of quantifying model uncertainty for the design of feedback control strategies that achieve a provable level of performance. The robustness paradigm motivated work on 'robust learning' to address the question of how well model uncertainty can be characterized from data. The quality and convergence rate of model approximation from data imposes a fundamental limit on the rate of adaptation of the underlying control/decision strategy. In particular, for some model classes, sample complexity results impose significant limitations on such adaptation rates.

The characterization of the relationship between learning and model uncertainty hinges on having a tractable theory for model approximation. While this is available in the case of LTI systems, such theory is lacking for more general stochastic models. In this talk, I will present some partial results for learning classes of stochastic systems, namely, jump linear systems and Hidden Markov Models. A key question for such models is the unraveling of the underlying model structure from data. I will discuss how spectral methods can be used for this purpose.

This work is in collaboration with Tuhin Sarkar and Mardavij Roozbehani. (Received February 19, 2018)

1139-37-554 **Trevor Hyde*** (tghyde@umich.edu) and **Michael E. Zieve**. *Finite automata and the dynamics of several rational functions.*

Let M be a monoid generated by finitely many rational functions under composition. I will discuss several ways in which the dynamics of M leads naturally to finite automata, including a recent generalization of the dynamical Mordell-Lang conjecture. This is joint work with Mike Zieve. (Received February 19, 2018)

1139-37-561 **Annalisa M Calini*** (calinia@cofc.edu) and **Gloria Marí-Beffa**. *Integrable evolution of twisted polygons in centro-affine $\mathbb{R}^n$.* Preliminary report.

The so-called $m/m+1$ Adler-Gel'fand-Dikii (AGD) flows can be realized as local evolutions of curves in real projective spaces. Marí-Beffa and Wang (Nonlinearity, 2013) introduced a discretization of the AGD flows realizing local evolutions of twisted polygons in $\mathbb{RP}^m$ and used the geometric group to define a pair of Hamiltonian structures. In their article, they left open the question of compatibility of such structures, and its implications on integrability. We prove that the two Hamiltonian structures are indeed compatible by lifting them to a pair of pre-symplectic forms on the space of arc length parametrized twisted polygons in centro-affine $\mathbb{R}^{m+1}$. The simplicity of the expressions of the pre-symplectic forms makes checking compatibility a relatively easy task. We also study their kernels and possible integrable systems associated to the pair. (Received February 19, 2018)

1139-37-576 **Florian Karl Richter*** (richter.109@osu.edu). *The dichotomy between structure and randomness in multiplicative number theory.*

We will begin the talk by discussing a dichotomy theorem in multiplicative number theory which asserts that any multiplicative function (that satisfies certain minor regularity conditions) is either an almost periodic function or a pseudo-random function. Then we will explore how this phenomenon extends to other classical objects in number theory. In particular, we will discuss the combinatorial and dynamical properties of level sets of multiplicative functions which includes a structure theorem that allows us to derive new results in ergodic theory and in additive combinatorics. (Received February 19, 2018)

1139-37-616 **Michael E Zieve*** (zieve@umich.edu). *Dynamics of noncommuting endomorphisms.* Preliminary report.

I will present some preliminary results and examples involving the dynamics of multiple noncommuting endomorphisms of an affine or projective space. These suggest that several results about dynamics of a single map will likely have 'nice' generalizations to the setting of multiple maps, once we become comfortable with what the right notion of 'nice' should be. (Received February 20, 2018)

1139-37-644 **Cesar E. Silva*** (csilva@williams.edu). *On rank-one infinite measure-preserving examples and extensions of properties of the Chacon transformation.* Preliminary report.

We will discuss infinite measure-preserving rank-one transformations, including topological models, and weak mixing type properties for a family of Chacon transformations. Some is joint work with I. Loh, with I. Loh and B. Athiwaratkun, and J. Gaebler, A. Kastner, X. Xu, and Z. Zhou. (Received February 20, 2018)

39 ► Difference and functional equations

1139-39-155 **Y Kostrov***, kostrovy@mville.edu, and **Z Kudlak** and **P Vernon**. *On a First Order Rational System of Difference Equations with Non-Constant Coefficients.* Preliminary report.

We investigate the boundedness character of nonnegative solutions of the following nonautonomous rational system

$$\begin{cases} x_{n+1} = \frac{\alpha_n+\gamma_n x_n}{\beta_n x_n + y_n} \\ \\ y_{n+1} = \frac{a_n+b_n x_n+c_n y_n}{A_n+B_n x_n+C_n y_n} \end{cases} \quad \text{for } n = 0, 1, \ldots$$

with coefficients that are nonnegative sequences and initial conditions which are non- negative real numbers, such that the denominators are always positive. We present several theorems which establish the limiting behaviors of special cases of the system when the coefficients are periodic, or bounded above and below by positive constants. (Received February 07, 2018)

1139-39-317 **Sarah G Van Beaver*** (svanbeaver@uri.edu), University of Rhode Island, Kingston, RI 02881. *Global Dynamics and Bifurcations of Two Second Order Exponential Difference Equations.* Preliminary report.

We investigate the global behavior of two difference equations with exponential nonlinearities

$$x_{n+1} = be^{-cx_n} + px_{n-1}, \quad n = 0, 1, \ldots$$

where the parameters b, c are positive real numbers and $p \in (0, 1)$ and

$$x_{n+1} = a + bx_{n-1}e^{-x_n}, \quad n = 0, 1, \ldots$$

where the parameters a, b are positive numbers. The the initial conditions x_{-1}, x_0 are arbitrary nonnegative numbers. The two equations are well known mathematical models in biology which behavior was studied by other authors and resulted in partial global dynamics behavior. In this paper, we complete the results of other authors and give the global dynamics of both equations. In order to obtain our results we will prove several results on global attractivity and boundedness and unboundedness for general second order difference equations

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

which are of interest on their own. (Received February 15, 2018)

1139-39-437 **Elliott J. Bertrand***, Department of Mathematics, University of Rhode Island, 5 Lippitt Road, Kingston, RI 02881, and **Mustafa R.S. Kulenovic**. *Higher-Order Generalizations of the Beverton-Holt Equation.*

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

$$x_{n+1} = \frac{af(x_n, x_{n-1}, \ldots, x_{n+1-k})}{1 + f(x_n, x_{n-1}, \ldots, x_{n+1-k})}, \quad n = 0, 1, \ldots, \quad k \geq 2,$$

where f is a function nondecreasing in all arguments, the parameter a is a positive constant, and the initial conditions $x_0, x_{-1}, \ldots, x_{1-k}$ are arbitrary nonnegative numbers in the domain of f. We will discuss several examples of such equations and present some general theory. In particular, when $k = 2$, we will investigate the local and global dynamics in the event f is a certain type of linear or quadratic polynomial, and we explore the existence problem of period-two solutions. Further, we will analyze the global dynamics of the class of difference equations for which $f(x, x, \ldots, x)$ is chosen to be a concave function. (Received February 18, 2018)

1139-39-523 **Toufik Khyat*** (toufik.khyat@trincoll.edu). *Global Dynamics for competitive Maps in the Plane.*

In this paper I provide some possible scenarios for general discrete competitive dynamical systems in the plane. My work is focused on a class of second order difference equations of the form:

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

where the function $f(x, y)$ is decreasing in the variable x and increasing in the variable y. Furthermore, I illustrate my results with an application to the equation:

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

where the initial conditions x_{-1} and x_0 are arbitrary non-negative numbers and the parameters c, d, f >0. (Received February 19, 2018)

1139-39-557 **David T. McArdle*** (dmcardle@uconn.edu), 341 Mansfield Road, Storrs, CT 06269. *Global Dynamics of a Leslie Host-Parasite Model.*

We consider the system of difference equations

$$x_{n+1} = \frac{\alpha\, x_n}{1 + \beta\, y_n}, \quad y_{n+1} = \frac{\gamma\, x_n\, y_n}{x_n + \delta\, y_n}, \quad n = 0, 1, 2, \ldots,$$

where $\alpha, \beta, \gamma, \delta, x_0, y_0$ are positive real numbers. A boundedness and persistence result along with global attractivity results for various parameter regions are established. Numerical evidence of chaotic behavior is also presented for solutions of the system in select parameter regions. . (Received February 19, 2018)

1139-39-593 **Choonkil Park*** (baak@hanyang.ac.kr), Department of Mathematics, Hanyang University, Seoul, 04763, South Korea. *New additive functional inequalities and partial multipliers in Banach algebras.* Preliminary report.

In this talk, we solve the additive functional inequalities

$$\|f(x + y + z) - f(x + y) - f(z)\| \le \|s(f(x - y) + f(y - z) - f(x - z))\| \tag{1}$$

and

$$\|f(x - y) + f(y - z) - f(x - z)\| \le \|s(f(x + y - z) + f(x - y + z) - 2f(x))\|, \tag{2}$$

where s is a fixed nonzero complex number with $|s| < 1$.

Using the direct method, we prove the Hyers-Ulam stability of the additive functional inequalities (1) and (2) in complex Banach spaces. This is applied to investigate partial multipliers in Banach $*$-algebras, unital C^*-algebras, Lie C^*-algebras, JC^*-algebras and C^*-ternary algebras, associated with the additive functional inequalities (1) and (2). (Received February 20, 2018)

1139-39-625 **M. R.S. Kulenovic*** (mkulenovic@uri.edu), Lippitt Hall 202D, University of Rhode Island, Kingston, RI 02881, **Naida Mujic**, University of Sarajevo, Sarajevo, Bosnia-Herzegovina, and **Esmir Pilav**, University of Sarajevo, Sarajevo, Bosnia-Herzegovina. *Period-Doubling and Naimark-Sacker Bifurcations of Certain Second Order Quadratic Fractional Difference Equation.*

We investigate the Period-Doubling and Naimark-Sacker Bifurcations of the equilibrium of the difference equation

$$x_{n+1} = \frac{\gamma x_{n-1}^2 + \delta x_n}{Cx_{n-1}^2 + x_n}$$

where the parameters γ, δ, C are positive numbers and the initial conditions x_{-1} and x_0 are arbitrary nonnegative numbers such that $x_{-1} + x_0 > 0$. (Received February 20, 2018)

1139-39-626 **Chris Staniszewski*** (cstaniszewski@uri.edu), Kingston, RI , and **Mark Comerford** (mark_comerford@uri.edu), University of Rhode Island, Kingston, RI. *Non-autonomous iteration and univalent functions.*

In this presentation, we will see that every function of the well-studied Schlicht class is a limit function of a subsequence of iterates of a single non-autonomous sequence of polynomials, on one Fatou component for this sequence. (Received February 20, 2018)

1139-39-640 **James Marcotte*** (jamesmarcotte@uri.edu), Department of Mathematics, University of Rhode Island, 5 Lippitt Road, Kingston, RI 02881. *Systems of Difference Equations in $\mathbb{R}^n$ that are monotone in the order induced by a standard octant.* Preliminary report.

We establish a characterization for systems of difference equations in n-dimensional space that are monotone with respect to the order induced by a positive cone given by one standard octant. This result is applied to the study of global behavior of solutions to several systems in three-dimensional space. (Received February 20, 2018)

1139-39-673 **Ann Brett*** (ann.brett@jwu.edu), RI. *Symmetry Methods in the Solution of Difference Equations and Discrete Dynamical Systems.* Preliminary report.

In this talk we present an introduction to symmetry in the context of mathematics and an overview of symmetric methods used in the solution of difference equations and discrete dynamical systems. Preliminary work on some open problems will be discussed. (Received February 20, 2018)

41 ► Approximations and expansions

1139-41-192 **Vladyslav Babenko*** (babenko.vladislav@gmail.com), **Vira Babenko** and **Mariia Polischuk**. *Quadrature formulas for set-valued functions. Errors estimates. Optimization.*

We will consider various quadrature formulas for approximate integration of set-valued functions and give their error estimates. Several problems of optimization of such quadrature formulas will be considered as well. Besides, we will discuss possible generalizations of obtained results to the case of functions with values in L – spaces. (Received February 09, 2018)

1139-41-193 **Vira Babenko*** (vbabenko@ithaca.edu), **Vladyslav Babenko** and **Mariia Polischuk**. *Approximation of some classes of set-valued periodic functions by generalized trigonometric polynomials.*

In approximation theory, problems on finding the exact solutions of best, best linear and best one-sided approximation, on the classes of periodic functions by trigonometric polynomials for real-valued functions, are well-studied. The purpose of this work is to generalize some of the results to the case of set-valued functions and more general functions with values in L-spaces. (Received February 09, 2018)

1139-41-358 **Tatyana Sorokina*** (tsorokina@towson.edu), Towson University, 8000 York Rd, Towson, MD 21093, and **Min Ji** and **Liang Dong**. *Piecewise polynomial copulas.*

Copulas are a very powerful tool in modeling joint behavior of different sorts of risks. The word copula derives from the Latin noun *cupula*, which means "small cup". It captures the dependence structure among random variables, irrespective of their marginal distributions. This property makes copulas popular in recent years in the area of risk modeling for insurance and finance. There exists a copula for any joint distribution. We show that Bernstein-Bézier analysis is a useful tool for constructing piecewise polynomial copulas. First we apply Bernstein-Bézier techniques to reconstruct the linear B-spline copulas. Using the same techniques, we further construct a new class of differentiable biquadratic quasi-interpolating copulas that have continuous second order mixed derivatives. We test the performance of the empirical biquadratic quasi-interpolating copulas, and show that they perform better than the empirical linear B-spline copulas in nonparametric estimation of the copulas. (Received February 16, 2018)

1139-41-438 **Dmitry Batenkov***, Department of Mathematics, 2-336, Massachusetts Institute of Technology, Massachusetts Ave., 77, Cambridge, MA 02139, and **Laurent Demanet** and **Hrushikesh Mhaskar**. *Stability of some super-resolution problems.*

The problem of computational super-resolution asks to recover high-frequency features of an object from the noisy and band-limited samples of its Fourier transform. A core theoretical question is to quantify the possible bandwidth extension and the accuracy of the recovered frequency components.

In this work we assume that the object has a compact space/time extent in one dimension, while the low-pass window can have a super-exponentially decaying "soft" shape (such as a Gaussian). The super-resolution problem in this case is equivalent to a stable analytic continuation of an entire function of finite exponential type. We show that a weighted least-squares polynomial approximation with equispaced samples and a judiciously chosen number of terms allows one to have a super-resolution factor which scales logarithmically with the noise level, while the pointwise extrapolation error exhibits a Hölder-type continuity with an exponent derived from weighted potential theory. The algorithm is asymptotically minimax, in the sense that there is essentially no better algorithm yielding meaningfully lower error over the same smoothness class. (Received February 18, 2018)

42 ► Fourier analysis

1139-42-197 **Steve Hofmann*** (hofmanns@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Quantitative Rectifiability and absolute continuity of harmonic measure.*

We discuss recent progress in an ongoing program to characterize geometrically those open sets in Euclidean space, such that harmonic measure for the open set Ω is absolutely continuous, in a quantitative, scale invariant sense, with respect to surface measure on $\partial\Omega$. In part, this involves understanding the relationship between quantitative rectifiability of the boundary of Ω, and the boundary behavior of harmonic functions. (Received February 10, 2018)

1139-42-389 **Vasileios Chousionis*** (vasileios.chousionis@uconn.edu), Department of Mathematics, University of Connecticut, 341 Mansfield Road U1009, Storrs, CT 06269-3. *Singular integrals on $C^{1,\alpha}$ intrinsic graphs in the Heisenberg group.*

We study singular integral operators induced by 3-dimensional Calderón-Zygmund kernels in the Heisenberg group. We show that if such an operator is L^2 bounded on vertical planes, with uniform constants, then it is also L^2 bounded on all intrinsic graphs of compactly supported $C^{1,\alpha}$ functions over vertical planes. In particular our result applies to the singular integral associated to the horizontal gradient of the fundamental solution of the sub-Laplacian. We show that, as in the Euclidean setting, the L^2 boundedness of this operator is connected with the question of removability for Lipschitz harmonic functions. As a corollary of our result, we infer that the intrinsic graphs mentioned above are non-removable, providing the first known examples of non-removable sets with positive and locally finite 3-dimensional measure. Joint work with K. Fassler and T. Orponen. (Received February 17, 2018)

1139-42-439 **Galia Dafni*** (galia.dafni@concordia.ca), Department of Mathematics and Statistics, Concordia University, 1455 de Maisonneuve Blvd West, Montreal, Quebec H3G1M8, Canada, and **Tuomas Hytönen**, **Riikka Korte** and **Hong Yue**. *On the space JN_p.*

The space JN_p, $1 < p < \infty$, consists of functions satisfying a condition, weaker than bounded mean oscillation, originally introduced in the work of John and Nirenberg, who showed that such functions lie in weak L^p. While JN_p contains L^p, it was not known whether it was strictly larger. We show this is true by means of an example, but that surprisingly the two spaces coincide in the case of monotone functions in one dimension. We also characterize JN_p as the dual of a new space defined in terms of atomic decomposition. (Received February 18, 2018)

1139-42-550 **Dorina Mitrea*** (mitread@missouri.edu), University of Missouri, Department of Mathematics, Columbia, MO 65211. *Poisson integral representation formulas for elliptic systems in domains with Ahlfors regular boundaries.*

The Poisson integral representation formula is a basic result in the theory of elliptic PDE's, which allows one to express the solution of the Dirichlet problem for a given elliptic operator in terms of the boundary datum, via an integral involving the Poisson kernel associated with the domain in question.

In this talk I will present a very general result of this flavor, valid for weakly elliptic second-order systems L and domains with Ahlfors regular boundaries satisfying an additional nontangential path-accessibility. The Poisson kernel is written as the conormal derivative of the Green function for the transposed system $L^\top$. (Received February 19, 2018)

1139-42-551 **Marius Mitrea*** (mitream@missouri.edu), University of Missouri, Department of Mathematics, Columbia, MO 65211. *Fatou-Type Results for Elliptic Systems in Uniformly Rectifiable Domains.*

In this talk, I will be presenting a new approach for establishing quantitative Fatou-type theorems for null-solutions of an injectively elliptic first-order (homogeneous, constant complex coefficient) system of differential operators in an arbitrary uniformly rectifiable domain in the n-dimensional Euclidean space, assuming that the nontangential maximal operator is p-th power integrable (with respect to the Hausdorff measure) for some integrability exponent larger than $(n-1)/n$. Such a result has a wide range of applications, including the theory of Hardy spaces associated with injectively elliptic first-order systems in uniformly rectifiable domains. This new approach also yields Fatou-type results for the gradient of null-solutions of elliptic second-order systems in arbitrary uniformly rectifiable domains. (Received February 19, 2018)

44 ► Integral transforms, operational calculus

1139-44-165 **Leise Borg**, **Juergen Frikel**, **Jakob Jorgensen** and **Eric Todd Quinto*** (todd.quinto@tufts.edu), Department of Mathematics, Tufts University, 503 Boston Ave., Medford, MA 02155. *Full Characterization of Artifacts from Arbitrary Incomplete X-ray CT Data.*

We will describe our characterization of artifacts in limited data X-ray tomography reconstructions with arbitrary data. We also provide estimates of the strength of the added artifacts in some cases, and we illustrate our results using standard and non-standard limited data tomography problems with real and simulated data. The work is based on a microlocal analysis of the X-ray transform and backprojection, and it can be applied to a range of limited data problems.

We will provide sample reconstructions to illustrate our theorems. (Received February 07, 2018)

1139-44-606 **Eric L Grinberg*** (eric.grinberg@umb.edu), Department of Mathematics, UMass Boston, 100 Morrissey Blvd., Boston, MA 02125, and **Mehmet Orhon** (mo@unh.edu), Department of Mathematics, University of New Hanpshire, 33 Academic Way, Durham, NH 03824. *Counting Admissible Complexes for the X-Ray Transform over the two-element Field.* Preliminary report.

The X-Ray transform can model a CAT scanner and replacing euclidean space by a finite field allows detailed analysis of this transform. Admissible complexes are minimal sets of lines on which the restricted X-Ray transform is injective. Such complexes have been counted by brute force means in the past. Here we use a geometric-graph-theoretic characterization of admissible complexes to count them. One hopes that extensions to higher dimensions and larger fields are possible. In the projective variant this has been done by D.Feldman and E.Grinberg. (Received February 20, 2018)

47 ► Operator theory

1139-47-20 **Monika Winklmeier***, Carrera 1 No. 18A-10, Edificio H, Bogotá, 111711, Colombia. *Sharp bounds for the eigenvalues of the Kerr-Newman-Dirac angular operator.* Preliminary report.

The angular part of the Dirac equation in the Kerr-Newman metric is the block operator matrix

$$\mathcal{A} = \begin{pmatrix} -am\cos\theta & \frac{\mathrm{d}}{\mathrm{d}\theta} + \frac{\kappa}{\sin\theta} + am\cos\theta \\ \frac{\mathrm{d}}{\mathrm{d}\theta} + \frac{\kappa}{\sin\theta} + am\cos\theta & am\cos\theta \end{pmatrix}$$

which acts on functions in $L_2(0,\pi)^2$. Here $\kappa \in \mathbb{Z} + \frac{1}{2}$ and a, m and ω are real parameters. It can be shown that this operator has only point spectrum. To the best of our knowledge, analytic formulae for the eigenvalues are available only in special cases. I will show how the so-called second order spectrum allows us to find numerical approximations of the eigenvalues with guaranteed error bounds and I will compare the numerical values found my this method with those available in the literature.
(Received December 09, 2017)

1139-47-291 **Markus Schmidmeier*** (markusschmidmeier@gmail.com), Florida Atlantic University. *The boundary of irreducible components: T. Maeda's example.*

In his 1934 landmark paper *Subgroups of abelian groups,* G. Birkhoff locates the first occurrence of parametrized families of pairwise non-isomorphic subgroup embeddings. They arise when a group of type $\mathbb{Z}/(p^4) \oplus \mathbb{Z}/(p^2)$ is contained in one of type $\mathbb{Z}/(p^6) \oplus \mathbb{Z}/(p^4) \oplus \mathbb{Z}/(p^2)$.

In his recent paper titled *The boundaries of the sets of subspaces stable under a nilpotent linear transformation,* T. Maeda describes the corresponding situation for the Grassmannian of embeddings of invariant subspaces in a nilpotent linear operator. In my talk I plan to discuss his combinatorial description of the boundaries of tableau varieties as this refines related joint work of the presenter with J. Kosakowska. (Received February 14, 2018)

49 ► Calculus of variations and optimal control; optimization

1139-49-189 **Fengbo Hang*** (fengbo@cims.nyu.edu), 251 Mercer Street, New York, NY 10012, and **Paul C Yang**. *A perturbation approach for Paneitz energy on standard three sphere.*

We discuss a new proof of the sharp inequality for Paneitz operator on the standard three sphere, in the spirit of subcritical approximation for the classical Yamabe problem. To solve the perturbed problem, we use a symmetrization process which only works for extremal functions. This gives a new example of symmetrization for higher order variational problems. (Received February 09, 2018)

1139-49-361 **Muhammad Junaid Farooq***, 2 Metrotech Center, 10th FL, NYU Center for Cyber Security, Brooklyn, NY 11201, and **Quanyan Zhu**, 5 Metrotech Center, NYU Tandon School of Engineering, Brooklyn, NY 11201. *Adaptive and Resilient Revenue Maximizing Dynamic Resource Allocation and Pricing for Cloud-Enabled IoT Systems.*

Cloud computing is becoming an essential component in the emerging Internet of Things (IoT) paradigm. The available resources at the cloud such as computing nodes, storage, databases, etc. are often packaged in the form of virtual machines (VMs) to be used by remotely located IoT client applications for computational tasks. However, the cloud has a limited number of VMs available and hence, for massive IoT systems, the available resources must be efficiently utilized to increase productivity and subsequently maximize revenue of the CSP. IoT client applications generate requests with computational tasks at random times with random complexity to be processed by the cloud. The cloud service provider (CSP) has to decide whether to allocate a VM to a task at hand or to wait for a higher complexity task in the future. We propose a threshold-based mechanism to optimally decide the allocation and pricing of VMs to sequentially arriving requests in order to maximize the revenue of the CSP over a finite time horizon. Moreover, we develop an adaptive and resilient framework that can counter the effect of realtime changes in the number of available VMs at the cloud server, the frequency and nature of arriving tasks on the revenue of the CSP. (Received February 16, 2018)

1139-49-424 **Andrzej Ruszczynski*** (rusz@business.rutgers.edu), Rutgers University. *Risk-Averse Control of Partially Observable Markov Systems.*

We consider risk measurement in controlled partially observable Markov systems in discrete time. In such systems, part of the state vector is not observed, but affects the transition kernel and the costs. We introduce new concepts of risk filters and study their properties. We also introduce the concept of conditional stochastic time consistency. We derive the structure of risk filters enjoying this property and prove that they can be represented by a collection of law invariant risk measures on the space of function of the observable part of the state. We also derive the corresponding dynamic programming equations. Then we illustrate the results on a clinical trial problem and a machine deterioration problem. (Received February 18, 2018)

1139-49-650 **Ioannis Ch Paschalidis***, Dept. of Electrical & Computer Eng., Boston University, 8 Saint Mary's St, Boston, MA 02215, and **Ruidi Chen**. *Robust Regression under the Wasserstein Metric.*

We present a Distributionally Robust Optimization (DRO) approach to linear regression, where the closeness of probability distributions is measured by the Wasserstein metric. Training data contaminated with outliers skew the regression plane computed by least squares and lead to inaccurate predictions. Classical approaches remedy this problem by downweighting the contribution of atypical data points. In contrast, our DRO approach hedges against a family of distributions that are close to the empirical distribution. We show that the resulting formulation encompasses a class of models, including the regularized Least Absolute Deviation (LAD). We provide new insights into the regularization term and give guidance on the selection of the regularization coefficient from the standpoint of a confidence region. We establish two types of performance guarantees for the solution to our formulation under mild conditions. One is related to its out-of-sample behavior, and the other concerns the discrepancy between the estimated and true regression planes. We consider applications to outlier detection and through extensive numerical results demonstrate the superiority of our approach to various alternatives in terms of estimation accuracy and outlier detection rates. (Received February 20, 2018)

1139-49-692 **Michael C Caramanis*** (mcaraman@bu.edu), Department of Mechanical Engineering, 110 Cummington Mall, Boston, MA 02215, and **Selin Yanikara**, Boston University, 110 Cummington Mall, Boston, MA 02215. *Optimal Day Ahead Bidding of Forecast Error prone Renewable Generation.*

We consider a day-ahead market clearing process encompassing error prone wind generation forecasts. More specifically, we introduce an endogenous determination of additional reserve requirements that depend on the aggressiveness of wind generation bids measured in terms of the risk of falling short of delivering the generation level in the bid. Conventional and Wind generation along with Distributed Energy Resources (DERs) are co-optimized over a 24 hour day ahead cycle to meet energy balance and reserve requirements. Wind generation is paid for offering energy and is charged for the additional reserve that it imposes as a contingency planning measure when it offers energy forecasts associated with a large error. Optimal risk taking is determined and shown to depend on the combined supply of reserves by DERs and conventional generation. (Received February 20, 2018)

1139-49-707 **Mehdi Behroozi*** (m.behroozi@neu.edu), 334 Snell Engineering Center, 360 Huntington Avenue, Boston, MA 02115. *Data-Driven Robust Optimization in Routing Problems.*

Using Wasserstein metric in defining the ambiguity set in robust optimization allows us to circumvent common overestimation that arises when other procedures are used. In this paper, we consider a distributionally robust version of the Euclidean travelling salesman problem in which we compute the worst-case spatial distribution of demand against all distributions whose Wasserstein distance to an observed demand distribution is bounded from above. We compare the advantages of this method with other approaches for describing the region of uncertainty, such as taking convex combinations of observed demand vectors or imposing constraints on the moments of the spatial demand distribution. (Received February 21, 2018)

51 ► Geometry

1139-51-145 **Max Glick*** (glick.107@osu.edu). *The limit point of the pentagram map.*

The pentagram map is a discrete dynamical system defined on the space of polygons in the plane. In the first paper on the subject, R. Schwartz proved that the pentagram map produces from each convex polygon a sequence of successively smaller polygons that converge exponentially to a point. We investigate this limit point itself, giving an explicit description of its Cartesian coordinates as roots of certain degree 3 polynomials. (Received February 06, 2018)

1139-51-207 **Kyler Bryce Siegel*** (kylersiegel@gmail.com). *On Stein manifolds diffeomorphic to Euclidean space.* Preliminary report.

I will discuss work in progress which constructs exotic Stein manifolds (or equivalently Weinstein manifolds) which are diffeomorphic but not symplectomorphic to standard affine space. The main novelty is that these examples have vanishing symplectic cohomology, hence a new invariant is necessary. Recent previous work studied Stein manifolds with vanishing symplectic cohomology but nontrivial twisted or bulk deformed symplectic cohomology. However, these invariants require a nontrivial singular cohomology class and hence cannot be fruitfully applied to a contractible space. Instead, we introduce the idea of deforming symplectic cohomology by a Maurer-Cartan Reeb orbit. This idea is quite natural from the point of view of deformation theory but raises a number of tricky convergence issues. (Received February 11, 2018)

1139-51-221 **Sylvester D Eriksson-Bique*** (syerikss@gmail.com) and **Jasun Gong** (jgong7@fordham.edu). *Non-self similar carpets and sponges in higher dimensions and general metric spaces.* Preliminary report.

I will discuss ongoing work with Jasun Gong on giving a general framework to prove results similar to Tyson, McKay and Wildrick on the existence and explicit examples of non-selfsimilar subsets of Euclidean space supporting Poincare inequalities. Our work gives a single proof that works for a variety of carpet- and spongelike metric spaces in the plane and higher dimensions, and shows that many positive measure subsets with empty interior support $(1, p)$-Poincaré inequalities for $p > 1$. We suggest that such constructions could also give examples of subsets of the Heisenberg Group with empty interior satisfying Poincaré inequalities. Further they lead to interesting classification problems in the plane. The results lead to new examples but also give a new and rather short way of proving the results. (Received February 12, 2018)

1139-51-342 **DeJaneke Johnson*** (jdejaneke@yahoo.com), 4000 Cadillac St, New Orleans, LA 70122, New Orleans, LA 70122, and **Tianna M. Robinson** (tiannarobinson71401@gmail.com), **Majid H. Butler** (majidhbutler54@gmail.com), **Sandernisha D. Claiborne** (nisha.claiborne@gmail.com) and **Tomme A. Denney** (tomme.denney32@gmail.com). *Embeddings of H_4 Polytopes.*

The 600-cell (a regular H_4 polytope whose coordinates in 4 dimensions involve $\varphi = (1+\sqrt{5})/2$) is usually embedded in 8-dimensional space using a trick that changes the norms of vectors: if v is a vertex of the H_4 polytope with norm $\langle v,v\rangle = a + b\varphi$ $(a,b \in \mathbb{Z})$ then by redefining $\langle v,v\rangle = a$, the 120 vertices of the 600-cell are transformed into 120 of the 240 root vectors of the E_8 lattice.

This trick uses number theory, which we don't understand. But by reverting to geometry we increased the number of norm-changing maps, and in our lecture we show how these maps yield several new embeddings of H_4 polytopes in E_8.

We use these results to partition the 2160 norm 4 vectors of E_8 into five H_4 polytopes: two 600-cells (with 120 vertices each); two 120-cells (600 vertices each); and a rectified 600-cell with 720 vertices.

These embeddings also present a new way to view the 600-cell (and its dual): its ± 60 vertices and 25 24-cells form the 60 non-singular and 25 singular points of a 4-space over F_4. (Received February 21, 2018)

1139-51-417 **Chaya Norton*** (chaya.norton@concordia.ca), Department of Mathematics & Statistics, LB 901.18, 1400 de Maisonneuve Blvd W, Montreal, QC H3G 1M8, Canada. *Symplectic Geometry of the moduli space of Projective Structures.*

The moduli space of projective connections/structures on Riemann surfaces of genus g can be identified with the moduli space of quadratic differentials, and hence the total space of $T^*\mathcal{M}_g$, by choosing a base projective connection which varies holomorphically in moduli. The monodromy map from the moduli space of projective connections to the character variety of $PSL(2,\mathbb{C})$ representations of the fundamental group of the Riemann surface maps a holomorphic projective connection $u(z)$ to the monodromy group associated to the second order equation $\psi'' - u(z)\psi = 0$. In joint work with Bertola and Korotkin, we study the symplectic geometry induced via these maps and highlight the role played by the base projective connection. Using the homological symplectic structure, we characterize base projective connections which induce equivalent symplectic structure on the moduli space of projective connections and prove the equivalence of Bergman, Schottky, and Wringer projective connections. By an explicit computation we prove the monodromy map with with the base Bergman projective connection is a symplectomorphism from the moduli space of quadratic differentials with the homological symplectic structure to the character variety with the Goldman bracket. (Received February 18, 2018)

1139-51-559 **Elisheva Adina Gamse*** (eagamse@math.toronto.edu). *Vanishing theorems in the cohomology ring of the moduli space of parabolic vector bundles over a Riemann surface.*

Let Σ be a compact connected oriented 2-manifold of genus $g \geq 2$, and let p be a point on Σ. We define a space $S_g(t)$ consisting of certain irreducible representations of the fundamental group of $\Sigma \setminus p$, modulo conjugation by $SU(n)$. This space has interpretations in algebraic geometry, gauge theory and topological quantum field theory; in particular if Σ has a Kahler structure then $S_g(t)$ is the moduli space of parabolic vector bundles of rank n over Σ.

For $n = 2$, Weitsman considered a tautological line bundle on $S_g(t)$, and proved that the $2g^{th}$ power of its first Chern class vanishes, as conjectured by Newstead. In this talk I will present his proof and outline my extension of his work to $SU(n)$ and to $SO(2n+1)$. I will also explore the case where Σ has multiple marked points. (Received February 19, 2018)

52 ► *Convex and discrete geometry*

1139-52-24 **Barry Monson*** (bmonson@unb.ca) and **Egon Schulte**. *Symmetries of Universal Alternating Semiregular Polytopes.* Preliminary report.

Any abstract regular n-polytope R has a free extension U_R, a regular $(n+1)$-polytope whose n-faces are all isomorphic to R [Schulte, 1983]. Think of such R's as building blocks which we glue together face-to-face in the 'freest possible way'. The automorphism group of U_R is about as complicated as that of its building block R.

Recently we extended this construction by allowing two kinds of compatible building blocks P and Q. Since the facets of these regular n-polytopes are all isomorphic, we can fit copies of P and Q in alternating fashion around $(n-2)$-faces. Again doing this in the freest possible way we get the universal alternating semiregular $(n+1)$-polytope $U_{P,Q}$. We know a lot about its structure: for example, $U_{P,Q}$ covers any $(n+1)$-polytope (of arbitrary symmetry) whose facets alternate between any selection of quotients of P and Q. But when $P \not\simeq Q$ and we want to understand the regular covers of $U_{P,Q}$ itself, we run into confounding and unexpected difficulties. I will complain about this as time permits. (Received December 30, 2017)

1139-52-62 **Michal Adamaszek**, **Henry Adams*** (henry.adams@colostate.edu) and **Florian Frick**. *Connections between Čech complexes and the Carathéodory orbitope.*

Čech and Vietoris–Rips simplicial complexes are ways to "thicken" a metric space. For example, a Čeech complex is the nerve complex of all metric balls of a fixed radius. I will describe how the Čech complexes of the circle (which obtain the homotopy types of the circle, the 3-sphere, the 5-sphere, ... as the radius increases) are related to cyclic polytopes and to the Carathéodory orbitope (the convex hull of the trigonometric moment curve). However, many questions remain open. There are similar connections between the Vietoris–Rips complexes of the circle and the Barvinok–Novik orbitope, where even more questions remain. (Received February 17, 2018)

1139-52-88 **Jesus A. De Loera*** (deloera@math.ucdavis.edu), Dept. of Mathematics, University of California, One Shields Avenue, Davis, CA 95616. *Money problems and Affine Semigroups.*

Affine semigroups are the algebraic combinatorics analogues of convex polyhedral cones and appear convex geometry, algebraic geometry, and combinatorics. They can be written as $Sg(A) = \{b : b = Ax, x \in Z^n, x \geq 0\}$ and A is an integer $d \times n$ matrix. Of course if $d = 1$, A is just a list of coin values. Each such vector x is a {representation} of b in the semigroup $Sg(A)$ and, for $d = 1$, membership has a monetary meaning as a denomination one can make change for using the given coin values.

This talk is about two questions about the representations of the members of an affine semigroup in terms of its generators (i.e., the columns of A).

1) What is the set $Sg_{\geq k}(A)$ of all elements in the semigroup $Sg(A)$, that have {at least} k different representations?

2) For an element b of $Sg(A)$, what is its {sparsest} representation? I.e., one using the fewest possible generators.

Joint work with subsets of the following researchers: Iskander Aliev, Quentin Louveaux, Timm Oertel, Chris O'Neill, Fritz Eisenbrand, and Robert Weismantel. (Received February 01, 2018)

1139-52-100 **Alathea I. Jensen*** (alatheajensen@gmail.com). *Self-Polar Polytopes.* Preliminary report.

The only set which is equal to its own polar set is the unit ball, but there are many sets which are orthogonal transformations of their polar sets. We will investigate polytopes which are equal to their negative polar sets. These polytopes were first studied by Lovász as a means of establishing the chromatic number of distance graphs on spheres, and they can also be used to construct triangle-free graphs with arbitrarily high chromatic number. We will also investigate polytopes which are equal to other orthogonal transformations of their polar sets. We will discuss the existence, construction, and facial structure of self-polar polytopes, as well as the place of these polytopes within the broader set of self-dual polytopes. (Received February 03, 2018)

1139-52-134 **Wai Yeung Lam*** (lam@math.brown.edu). *Discrete holomorphic quadratic differentials.*

We introduce holomorphic quadratic differentials on graphs. They are the derivative of cross ratios analogous to the Schwarzian derivative. On one hand, they connect discrete harmonic functions, circle packings and Luo's vertex scaling in discrete complex analysis. On the other hand, they unify discrete minimal surfaces via a Weierstass representation formula.

They show up in dynamical systems like the bicycle transformation and the pentagram map. Particularly they play an important role in Miquel dynamics on circle patterns, which is related to Goncharov and Kenyon's integrable systems for dimer models. (Received February 05, 2018)

1139-52-137 **Valeriu Soltan*** (vsoltan@gmu.edu), 4400 University Drive, Fairfax, VA 22030. *Polarity and separation of convex cones.* Preliminary report.

Given a nonempty closed convex cone $C \subset \mathbb{R}^n$ and its (negative) polar cone C°, we prove that the set $\mathrm{rint} C \cap (-\mathrm{rint} C^\circ)$ is nonempty and find its dimension. Based on this assertion, we establish new results on separation of C and C° by hyperplanes. (Received February 06, 2018)

1139-52-208 **Egon Schulte** and **Asia Ivic Weiss***, weiss@mathstat.yorku.ca, Toronto, ON , Canada. *On hereditary polyhedra and polytopes.*

We review some results on hereditary polytopes, the polytopes that inherit all symmetries of its facets, and present some recent results on hereditary polyhedra. (Received February 11, 2018)

1139-52-215 **Alexey Garber*** (alexeygarber@gmail.com). *On a Helly-type question for central symmetry.*

The classical Carathéodory theorem in dimension 2 can be stated in the following way. If any 4 points of a finite set X are in convex position, then all points of X are in convex position. In this talk we will discuss a similar Helly-type question requireing certain restrictions on the symmetry of the convex set.

Assume that X is a set of points such that every k-subset of X lies on a boundary of centrally symmetric convex polygon, is it true that X must also be in a boundary of centrally symmetric convex polygon? It is easy to see that this is false for small k, but it may be true for sufficiently large k. We show that the statement is not true even when $k = 8$, but $k = 6$ is enough if X is a continuous closed curve.

This is a joint work with Edgardo Roldán-Pensado (Received February 11, 2018)

1139-52-224 **Alexey Garber*** (alexeygarber@gmail.com). *Measuring weighted cut-and-project sets.*

A cut-and-project set X in $\mathbb{R}^d$ can be constructed (in a simplest case) as a projection of points of a $(d+n)$-dimensional lattice Λ in a certain neighborhood, called *window* W, of n-dimensional space onto $\mathbb{R}^d$.

One of the ways to construct a measure μ_X associated with X is taking the Dirac comb associated with the set . In that case if the window of the cut and project set X is a projection of a fundamental cell of Λ, then the measure μ_X will be close to a uniform measure in a certain sense. This is almost

In this talk we will discuss how we can construct a measure associated with a cut-and-project set using a function supported by the window W. In particularly we will sketch proof that in case $d = n = 1$ any window and any continuous piecewise linear or twice differentiable function with bounded second derivative will define a measure close to a uniform measure. (Received February 12, 2018)

1139-52-277 **Deborah Oliveros*** (dolivero@matem.unam.mx), Instituto de Matematicas UNAM, CU. Coyoacan, 04510 Mexico, Queretaro, Mexico, and **Tibor Bisztriczky** (tbisztri@ucalgary.ca), Mathematics & Statistics, 612 Campus Place N.W, Calgary, AB T2N 1N4, Canada. *Bodies of constant width and Meissner n-polytopes.* Preliminary report.

In 1911 it appeared for the first time in a catalogue of mathematical models produced by Martin Schilling the first non-rotational body of constant width defined by E. Meissner. Such body consist in a series of modifications of the Reuleaux tetrahedron. In this talk, we will discuss some families of n-dimensional self-dual polytopes that may yield into examples of bodies of constant width in any dimension. (Received February 13, 2018)

1139-52-292 **Marjorie Wikler Senechal*** (senechal@smith.edu), Northampton, MA. *The versatile triacontahedron.* Preliminary report.

The rhombic triacontahedron is a polyhedral peacock: Catalan, zonohedral, multi-inscribable, multi-stellatable (in 358,833,072 ways!) But a space filler – parallelotope – it is not. Or is it? The question arises in modeling quasicrystal structures by soft-packed nested clusters. (Joint work with Jean Taylor, Erin Teich, Pablo Damasceno, and Yoav Kallus.) (Received February 14, 2018)

1139-52-371 **Ian M Alevy*** (ian_alevy@brown.edu), Division of Applied Mathematics, 182 George Street, Box F, Providence, RI 02912. *Regular Polygon Surfaces.*

A *regular polygon surface* M is a surface graph (Σ, Γ) together with a continuous map ψ from Σ into Euclidean 3-space which maps faces to regular polygons. When Σ is homeomorphic to the sphere, and the degree of every face of Γ is five, we prove that M can be realized as the boundary of a union of dodecahedra glued together along common facets. Under the same assumptions but when the faces of Γ have degree four or eight, we prove that M can be realized as the boundary of a union of cubes and octahedra glued together along common facets. We exhibit counterexamples showing the failure of both theorems for higher genus surfaces. (Received February 16, 2018)

1139-52-378 **Abigail Williams***, abigail.williams13@gmail.com. *Uniform polyhedra with nonplanar faces.*

In this talk, we will discuss a method for generating uniform polyhedra with nonplanar faces. Uniform polyhedra are vertex transitive under one of the symmetry groups of the regular polyhedra and, additionally, have regular polygons as faces. We consider polygons as connected edge sets without requiring a membrane spanning those edges. This allows us to examine polygons as being either planar or nonplanar. To define regularity of a nonplanar polygons, we exploit their relationship with prisms and antiprisms. This definition is the guiding principle of our method of generating uniform polyhedra with nonplanar faces. (Received February 16, 2018)

1139-52-388 **Bryan Gin-ge Chen*** (chb@physics.upenn.edu), Philadelphia, PA 19104, **D Zeb Rocklin**, Atlanta, GA 30332, and **Christian D Santangelo** and **Louis Theran**. *The static-geometric correspondence in the rigidity of polyhedral surfaces.* Preliminary report.

Motivated by questions arising from the study of origami-inspired mechanical metamaterials, we study the infinitesimal rigidity of infinite periodic polyhedral surfaces embedded in 3-space. We construct mappings between the infinitesimal isometric deformations of such a surface and the self stresses in another "block-and-hole swapped" surface, generalizing a theorem of Finbow, Ross, and Whiteley's on spherical polyhedra and results of Borcea and Streinu on Maxwell-Cremona liftings of periodic planar frameworks. We will explain how our results discretize the static-geometric correspondence in thin shell elasticity studied by structural engineers, and we will describe an analogy with Serre duality in the theory of Riemann surfaces. (Received February 17, 2018)

1139-52-461 **Karoly Bezdek*** (kbezdek@ucalgary.ca), Dept. of Math. and Stats., University of Calgary, Calgary, Alberta T2N 1N4, Canada, and **Zsolt Langi**, Budapest University of Technology, Budapest, Hungary. *Minimizing the mean projections of finite ρ-separable packings.*

A packing of translates of a convex body in the d-dimensional Euclidean space $\mathbb{E}^d$ is said to be totally separable if any two packing elements can be separated by a hyperplane of $\mathbb{E}^d$ disjoint from the interior of every packing element. We call the packing $\mathcal{P}$ of translates of a centrally symmetric convex body $\mathbf{C}$ in $\mathbb{E}^d$ a ρ-separable packing for given $\rho \geq 1$ if in every ball concentric to a packing element of $\mathcal{P}$ having radius ρ (measured in the norm generated by $\mathbf{C}$) the corresponding sub-packing of $\mathcal{P}$ is totally separable. The main result of this paper is the following theorem. Consider the convex hull $\mathbf{Q}$ of n non-overlapping translates of an arbitrary centrally symmetric convex body $\mathbf{C}$ forming a ρ-separable packing in $\mathbb{E}^d$ with n being sufficiently large for given $\rho \geq 1$. If $\mathbf{Q}$ has minimal mean i-dimensional projection for given i with $1 \leq i < d$, then the convex polytope $\mathbf{P}$ which is the convex hull of the centres of the packing elements is approximately a d-dimensional ball. This extends a theorem of K. Böröczky Jr. (1994) from translative packings to ρ-separable translative packings for $\rho \geq 1$. (Received February 18, 2018)

1139-52-493 **Daniel C. Cohen*** (cohen@math.lsu.edu). *Some representations of arrangement groups.*

I will exhibit representations of certain arrangement groups, fundamental groups of complements of complex hyperplane arrangements, and attempt to illustrate their utility. (Received February 19, 2018)

1139-52-514 **Pablo Soberón*** (p.soberonbravo@northeastern.edu), Northeastern University Mathematics Departmen, 360 Huntington Avenue, 567 Lake Hall, Boston, MA 02115. *Extending robust versions of Tverberg's theorem.*

During this talk we will discuss some variations of Tverberg's theorem which are resistant to changes. In particular, we will show how the probabilistic method can give variations of this result which behave like weak epsilon-nets for convex sets. (Received February 19, 2018)

1139-52-522 **Alexey Glazyrin*** (alexey.glazyrin@utrgv.edu), One West University Boulevard, BLHSB 2.520, Brownsville, TX 78520. *Covering with convex homothets.*

The talk is devoted to various problems on coverings with homothets of a given convex body. In particular, necessary conditions on the homothety coefficients are analyzed and their connections with illumination problems are established. Two new results on coverings by spheres will be also presented. (Received February 19, 2018)

1139-52-571 **David Rolnick*** (drolnick@mit.edu) and **Pablo Soberón**. *Algorithms for Tverberg's theorem via centerpoints.*

Tverberg's theorem describes when a point set may be partitioned into subsets such that the convex hulls intersect. We obtain algorithms for computing Tverberg partitions via approximated centerpoints. Our techniques apply to a wide range of convexity spaces, from the classic Euclidean setting to geodetic convexity in graphs (motivated by the partition conjecture). In the Euclidean setting, we present probabilistic algorithms that are weakly polynomial in the number of points and the dimension. For geodetic convexity in graphs, we obtain deterministic algorithms for cactus graphs and show that the general problem of finding the Radon number is NP-hard. (Received February 19, 2018)

1139-52-601 **Ciprian S Borcea** (borcea@rider.edu), Department of Mathematics, Rider University, Lawrenceville, NJ 08648, and **Ileana Streinu*** (istreinu@smith.edu), Computer Science Department, Smith College, Northampton, MA 01063. *Recognizing auxetic behavior.*

A material is said to exhibit auxetic behavior if it widens (rather than shrinks) laterally when stretched in some direction. This intuitive description can be formalized in purely geometric terms for periodic bar-and-joint frameworks. We discuss efficient methods for recognizing the existence of infinitesimal auxetic deformations. (Received February 20, 2018)

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1139-53-14 **Joseph Palmer*** (j.palmer@rutgers.edu), Hill Center - Mathematics Department, 110 Frelinghuysen Road, Piscataway, NJ 08854. *New constructions of semitoric integrable systems.*

A semitoric integrable system is a four-dimensional integrable system for which one of the integrals is assumed to have periodic Hamiltonian flow, corresponding to a circular symmetry of the system. Since their introduction by Pelayo and Vũ Ngọc semitoric integrable systems have been the subject of a large amount of research, but so far what has been missing is a broad collection of examples. In this talk we provide explicit examples of such systems and discuss techniques to construct semitoric systems in more general cases. Moreover, we examine examples of families of integrable systems depending on parameters which transition between being toric, semitoric, degenerate, and having hyperbolic singular points. Partially joint work with S. Hohloch and Y. Le Floch. (Received November 09, 2017)

1139-53-31 **David N Pham*** (dnpham@qcc.cuny.edu). *The Lie groupoid analogue of a symplectic Lie group.* Preliminary report.

A symplectic Lie group is a Lie group with a left-invariant symplectic form. Its Lie algebra structure is that of a quasi-Frobenius Lie algebra. In this talk, we identify the groupoid analogue of a symplectic Lie group. We call the aforementioned structure a *t-symplectic Lie groupoid*; the "*t*" is motivated by the fact that each target fiber of a *t*-symplectic Lie groupoid is a symplectic manifold. For a Lie groupoid $\mathcal{G} \rightrightarrows M$, we show that there is a one-to-one correspondence between quasi-Frobenius Lie algebroid structures on $A\mathcal{G}$ and *t*-symplectic Lie groupoid structures on $\mathcal{G} \rightrightarrows M$. (Received January 10, 2018)

1139-53-56 **Hong Van Le*** (hvle@math.cas.cz), Institute of Mathematics of CAS, Zitna 25, Praha, Czech Rep. *Frölicher-Nijenhuis bracket and derived invariants of Riemannian manifolds provided with a parallel form of even degree.*

Riemannian manifolds (M, g) provided with a parallel form of even degree are main examples of Riemannian manifolds with special holonomy, of Einstein manifolds and calibrated manifolds, and they play important role in higher dimensional gauge theory as well as in M-theory. In my talk I shall report on new methods of constructing invariants of Riemannian manifolds (M, g) provided with a parallel form of even degree, using the graded Lie algebra $\Omega(M, TM)$ of tangent valued differential forms with the Frölicher-Nijenhuis bracket, and exploiting various higher algebraic and geometric structures. The first part of my talk is based on my joint works with Kotaro Kawai and Lorenz Schwachhöfer (arXiv:1605.01508, accepted for AMPA, and arXiv:1703.05133); the second part is based on my joint work in progress with Domenico Fiorenza and Luca Vitagliano. (Received January 24, 2018)

1139-53-144 **Thomas Ivey*** (iveyt@cofc.edu) and **Spiro Karigiannis**. *Remarks on Twisted-Austere Submanifolds.* Preliminary report.

Austere submanifolds $M \subset \mathbb{R}^n$ are related to calibrated submanifolds in $\mathbb{C}^n$ since the conormal bundle N^*M becomes special Lagrangian (SL) when one identifies $\mathbb{C}^n$ with the cotangent bundle $T^*\mathbb{R}^n$. They were investigated by Bryant and by Dacjzer-Florit; the austere condition was also generalized to S^n by Karigiannis-Min-Oo, and to $\mathbb{C}P^n$ by Ionel-Ivey.

Conditions under which a *twisted* conormal bundle $N^*M + \alpha$, where the fiber is translated by a 1-form α, is SL were formulated by Karigiannis-Leung. We refer to submanifolds $M \subset \mathbb{R}^n$ with a 1-form satisfying these conditions as *twisted-austere* submanifolds, although the algebraic conditions involve both the second fundamental form of M and the covariant derivative of the (necessarily closed) 1-form α.

In this preliminary report I will review relevant classification results for austere submanifolds, and describe recent joint work with Karigiannis on classifying twisted-austere 3-folds. Our results imply that all such 3-folds are ruled, and we produce a class of examples which are cylinders over minimal surfaces. If time permits, I will also discuss deformations of SL submanifolds built over an austere base. (Received February 06, 2018)

1139-53-169 **Scott Robert Zimmerman*** (scott.zimmerman@uconn.edu), 341 Mansfield Rd, Storrs, CT 06269. *Applications of a change of variables for Lipschitz mappings into metric spaces.*

Consider a C^1 mapping $f : \mathbb{R}^k \to \mathbb{R}^n$, and suppose $Df(x_0)$ has rank j for $j \leq k \leq n$. It follows from the classical implicit function theorem that there is a C^1 diffeomorphism Φ in a neighborhood of x_0 so that the mapping $f \circ \Phi^{-1}$ fixes the first j coordinates in a neighborhood of $\Phi(x_0)$. This result extends easily to mappings $f : \mathbb{R}^k \to \ell^\infty$ whose coordinates are C^1 functions and hence, by way of the Kuratowski embedding and C^1-Lusin approximations, to any metric space valued Lipschitz mapping on $\mathbb{R}^k$. This was first introduced in a paper by Malekzadeh and Hajłasz. In this talk, I will present applications of this change of variables to BLD mappings, Sard-type results in metric spaces, and sub-Riemannian geometry. This covers joint work with Soheil Malekzadeh and with Piotr Hajłasz. (Received February 07, 2018)

1139-53-174 **Susan Tolman*** (tolman@illinois.edu). *Symplectic cohomological rigidity and toric degenerations.*

An open conjecture asserts that toric manifolds are cohomologically rigid, that is, two toric manifolds are diffeomorphic exactly if their cohomology rings are isomorphic. This conjecture has a symplectic generalization: toric manifolds are symplectomorphic exactly of there is an isomorphism of their cohomology rings that respects the cohomology classes of the symplectic forms. We prove this conjecture in several special cases, including toric manifolds whose cohomology ring is isomorphic to $H^*((S^2)^n)$. To prove this, we use toric degenerations to construct symplectomorphisms. Based on joint work with Milena Pabiniak. (Received February 08, 2018)

1139-53-183 **Eva Miranda*** (eva.miranda@upc.edu), Laboratory of Geometry and Dynamical Systems, Department of Mathematics, EPSEB-UPC, 08028 Barcelona, Spain. *Desingularizing singular symplectic structures.*

In this talk I will present a desingularization procedure (joint work with Victor Guillemin and Jonathan Weitsman) for singular symplectic structures which are symplectic away from a smooth hypersurface and meet some transversality requirements.

These singular symplectic structures appear modelling some problems in celestial mechanics (like the 3-body problem or the elliptic restricted 3-body problem) where the singularities are associated to the line at infinity or collision set.

The desingularization technique (deblogging) associates a family of symplectic structures to singular symplectic structures with even exponent (the so-called b^{2k}-symplectic structures) and a family of folded symplectic structures for odd exponent (b^{2k}-symplectic structures) and has good convergence properties.

Time permitting, I will explain some applications of this desingularization technique to these motivating problems in Celestial mechanics (including periodic orbits and KAM theory). (Received February 08, 2018)

1139-53-185 **Victor W Guillemin*** (vwg@math.mit.edu), Department of Mathematics 2-207, MIT, Cambridge, MA 02139, and **Alejandro Uribe** and **Zuoqin Wang**. *Superpositions of coherent states.*

I will discuss in this talk applications of symplectic techniques to problems in semi-classical analysis. I'll begin by giving examples of some of the basic objects in this subject: pseudo-differential operators, Fourier integral operators and Toeplitz operators of semi-classical type, and then describe a simple, fairly intuitive way that I and my collaborators, Alex Uribe and Zuoqin Wang, have discovered of describing the Schwartz kernels of these operators as "superpositions of coherent states" (Received February 09, 2018)

1139-53-188 **Anna Fino*** (annamaria.fino@unito.it), via Carlo Alberto 10, 10123 Torino, Italy. *G_2-structures and Ricci solitons.*

In this talk we present some general results about G_2-structures whose underlying Riemannian metric is Einstein, as well results on the existence of left invariant closed G_2 forms determining a Ricci soliton metric on nilpotent Lie groups. For closed G_2-structures, we will also show some results related to the Laplacian flow. (Received February 09, 2018)

1139-53-201 **Dan Cristofaro-Gardiner*** (dcristof@ucsc.edu), Mathematics Department, McHenry, Santa Cruz, CA, and **Richard Hind** and **Dusa McDuff**. *Symplectic embeddings in dimension greater than 4.*

I will describe joint work with Hind and McDuff exploring the higher dimensional ellipsoid embedding problem. For embeddings of four-dimensional ellipsoids, McDuff showed that embedded contact homology gives sharp obstructions; in higher dimensions, however, much less is known and new techniques are needed. We develop a "stabilization" procedure for building new obstructions from four-dimensional ones, and we show that in many cases the obstructions we get are optimal. (Received February 10, 2018)

1139-53-213 **Ustun Yildirim*** (ustun@mailbox.org). *On the Minimal Compactification of the Cayley Grassmannian.*

In 1967, Brown and Gray showed that an exceptional (r-fold) cross product exists only for r=2 in dimensions 3 and 7 and for r=3 in dimensions 4 and 8. Using these exceptional cross products, we can identify special subvarieties of Grassmann varieties in dimensions 7 and 8. They are called associative and Cayley Grassmannian respectively. These Grassmannians are of natural interest in calibrated geometry: The tangent spaces of calibrated submanifolds (absolutely volume minimizing submanifolds in their homology classes) lie in these Grassmannians.

Over complex numbers, these Grassmannians are not compact. In this talk, after I talk about the necessary background, I will explain some of the results I obtained on the minimal compactification of Cayley Grassmannian. (Received February 11, 2018)

1139-53-240 **Valentino Tosatti*** (tosatti@math.northwestern.edu), 2033 Sheridan Rd, Evanston, IL 60208-2730. *Metric limits of Calabi-Yau manifolds.*

Calabi-Yau manifolds are a class of compact complex manifolds that enjoys remarkable geometric properties, which makes them widely-studied objects in several areas of mathematics. Their defining feature are special Riemannian metrics which have vanishing Ricci curvature and are compatible with the complex structure (they are Kähler metrics). The existence of such Ricci-flat Kähler metrics was conjectured by Calabi and proved by Yau, hence their name. I will discuss the problem of understanding the behavior of degenerating families of Ricci-flat Kähler metrics on a Calabi-Yau manifold, and what their possible metric limits are. I will explain what we know in general about such metric limits, what techniques are used to approach these questions, and what applications these results have. (Received February 12, 2018)

1139-53-252 **Eckhard Meinrenken*** (mein@math.toronto.edu). *On the van Est map for Lie groupoids.* Preliminary report.

I will describe results from an article with David Li-Bland, giving a conceptual explanation of the van Est map for Lie groupoids, and recent generalizations obtained in work (in progress) with Jeff Pike. (Received February 12, 2018)

1139-53-308 **David Gu**, **Feng Luo** and **Tianqi Wu*** (tianqi@cims.nyu.edu). *Convergence of Discrete Conformal Geometry and Computation of Uniformization Maps.*

The classical uniformization theorem of Poincaré and Koebe states that any simply connected surface with a Riemannian metric is conformally diffeomorphic to the Riemann sphere, or the complex plane or the unit disk. Using the work by Gu-Luo-Sun-Wu on discrete conformal geometry for polyhedral surfaces, we provide an algorithm which computes the uniformization maps for Riemannian disks. (Received February 15, 2018)

1139-53-343 **Eduardo Gonzalez***, Mathematics Department, 100 William T. Morrissey Boulevard, UMASS, Boston, MA 02125, and **B Uribe**. *On symplectic manifolds with semi-free circle actions and isolated fixed points.* Preliminary report.

Let X be a symplectic (Kähler) manifold with a semi-free circle action and isolated fixed points. A result of Tolman and Weitsman shows that X has the same cohomology type of a product of projective lines. Using Seidel's representation in quantum cohomology, one can show that X has the same quantum cohomology of a product of projective lines. Moreover, X is equivariantly isomorphic to a product of projective lines, if the (complex) dimension of X is less or equal than 3. In this talk I will discuss further evidence supporting that this result should hold in all dimensions. This is joint work with B. Uribe. (Received February 16, 2018)

1139-53-350 **Ian Alexander Becket Strachan*** (ian.strachan@glasgow.ac.uk), School of Mathematics and Statistics, University of Glasgow, Glasgow, G12 8SQ, United Kingdom. *Darboux Coordinates for Gelfand-Dorfman-Balinski-Novikov Hamiltonian Strutures: from Novikov algebras to flat coordinates via cyclic quotient singularities.*

Linear Hamiltonian structures are, by the work of Gelfand and Dorfman, defined in terms of a so-called Novikov algebra. But by the fundamental result of Dubrovin and Novikov, these Hamiltonian structures are defined by a flat metric and hence there must exist a coordinate system which reduces the metric (defined by the Novikov algebra) to a constant, or Darboux, form. The coordinate transformation may also be considered as a (dispersionless) Muira transformation.

In the simplest case - studied by Balinski and Novikov - the algebra is commutative and the algebra reduces to a Frobenius algebra. In this case the transformation is just given by a quadratic change of variable.

By solving the associated Gauss-Manin equations in the general, non-commutative, case, the Darboux coordinates may be found in full generality. In this work, this construction is given and, in the case of a finite monodromy group, the Darboux coordinates are given by certain invariant polynomials (invariant under the action of a cyclic group). These are directly related to certain quotient spaces - cyclic quotient singularities. (Received February 16, 2018)

1139-53-412 **Rob Kusner*** (profkusner@gmail.com), 1435G Lederle GRT, Department of Mathematics & Statistics, University of Massachusetts, Amherst, MA 01003. *Geometry and stability of critical point-configurations in S^2 and critical links in S^3.* Preliminary report.

Consider N distinct points in the unit 2-sphere S^2. We study point-configurations which are critical for geometrically natural functions, especially for the *Coulomb energy*, or for the *injectivity radius.* (The latter is a *min*-function, so this means *critical for maximizing* the injectivity radius.) The "lift" under the Hopf map of such a critical N-configuration is an N-component Hopf link in the 3-sphere S^3 which is itself critical for the *Möbius energy*, or for (maximizing) the *thickness*, respectively, among all isotopic links in S^3. We investigate when optimality "downstairs" in S^2 implies optimality "upstairs" in S^3, and more generally discuss the extent to which the stability index or co-index of a critical N-configuration downstairs persists when we lift to a critical link upstairs. [A joint project with Wöden Kusner....] (Received February 17, 2018)

1139-53-482 **Sergey Grigorian*** (sergey.grigorian@utrgv.edu), 1201 W University Drive, Edinburg, TX 78539. *A heat flow of isometric G_2-structures.* Preliminary report.

Given a Riemannian metric g on a 7-dimensional manifold M that admits G_2-structures, the family of G_2-structures that are compatible with g is parametrized by sections of an $\mathbb{R}P^7$-bundle over M. A natural question is how to characterize the "best"G_2-structures within a given metric class. One way is to consider G_2-structures that minimize that L^2-norm of the torsion. This turns out to be equivalent to an energy functional on an associated octonion bundle and the critical points correspond to G_2-structures with divergence-free torsion. In this talk, we will consider properties of the gradient flow of this functional, and will show some estimates for quantities along the flow which give information regarding long-term existence. (Received February 19, 2018)

1139-53-555 **Gao Chen*** (gchen@ias.edu), Institute for Advanced Study, 1 Einstein Drive, Princeton, NJ 08540. *On G_2 manifolds with conic singularities.*

In this talk, I will present my recent work on the construction of manifolds with G_2 holonomy and conic singularities. I will discuss the rate of asymptotic convergence to the cone metric and other related topics. (Received February 19, 2018)

1139-53-562 **Sema Salur*** (sema.salur@rochester.edu), Department of Mathematics, University of Rochester, Rochester, NY 14627. *Geometric Structures on Manifolds with Special Holonomy and Applications.* Preliminary report.

Calibrated submanifolds of Calabi-Yau and G_2 manifolds are volume minimizing in their homology classes and their moduli spaces have many important applications in geometry, topology and physics. In this talk we give a report of recent research on the calibrations inside the manifolds with special holonomy. (Received February 19, 2018)

1139-53-564 **Emily Autumn Windes*** (ewindes@u.rochester.edu), 1181 S. Plymouth Ave., Rochester, NY 14611. *Killing Vector Fields on G_2 Manifolds.*

G_2 manifolds are 7-dimensional Riemannian manifolds with holonomy group Hol(g) contained in the exceptional Lie group G_2. They are Ricci-flat and almost compact. Even though we expect to have many of them, we still don't have an existence theorem which gives necessary and sufficient conditions under which a 7-manifold admits a G_2 metric. In this talk, I will report on my work related to Killing vector fields on G_2 manifolds as well as recent research on related problems. (Received February 19, 2018)

1139-53-565 **Jason Cantarella***, Boyd Graduate Research Center, Athens, GA 30606, and **Clayton Shonkwiler**. *Sampling and theory for random embedded spatial graphs, with applications to topologically complex polymers.* Preliminary report.

While many biopolymers and lab-created polymers are either linear or ring (circular) polymers, there are now many polymers with more complicated topologies, ranging from theta-curves and multitheta curves to much more complicated topologies such as the random networks found in collagen and other elastic materials such as rubber. However, the theory of random embedded spatial graphs is certainly not as well developed for these topological types as it is for linear and ring polymers.

Uehara has recently presented theoretical and sampling results on random spatial graphs with the topology of a multitheta curve. Here, we give some preliminary results on a generalization of her methods to arbitrary topologies which cover both sampling and (some) theory. (Received February 19, 2018)

1139-53-569 **Yu Zeng*** (yzeng15@ur.rochester.edu), Dept. of Mathematics, University of Rochester, Rochester, NY 14627. *The regularity of the minimizer of the K-energy.*

In this talk, we study constant scalar curvature equation (CSCK), a nonlinear fourth order elliptic equation, and its weak solutions on Kähler manifolds. We first define a notion of weak solution of CSCK for an L^∞ Kähler metric. The main result is to show that such a weak solution (with uniform L^∞ bound) is smooth. As an application, this answers in part a conjecture of Chen regarding the regularity of K-energy minimizers. The new technical ingredient is a $W^{2,2}$ regularity result for the Laplacian equation $\Delta_g u = f$ on Kähler manifolds, where the metric has only L^∞ coefficients. It is well-known that such a $W^{2,2}$ regularity ($W^{2,p}$ regularity for any $p > 1$) fails in general (except for dimension two) for uniform elliptic equations of the form $a^{ij}\partial^2_{ij}u = f$ for $a^{ij} \in L^\infty$, without certain smallness assumptions on the local oscillation of a^{ij}. We observe that the Kähler condition plays an essential role to obtain a $W^{2,2}$ regularity for elliptic equations with only L^∞ elliptic coefficients on compact manifolds. (Received February 19, 2018)

1139-53-572 **Jason Cantarella**, **Philipp Reiter** and **Clayton Shonkwiler*** (clay@shonkwiler.org), Colorado State University, Department of Mathematics, Campus Delivery 1874, Fort Collins, CO 80523. *A Natural Map from Random Walks to Equilateral Polygons in Any Dimension.*

There is a long history of modeling biopolymers by random walks. Such walks exhibit the same scaling behavior as polymers at the θ temperature, but modeling polymers with nontrivial topology presents additional challenges. Recently, the toric symplectic structure on equilateral polygons in 3-space has been exploited to give fast sampling algorithms and useful numerical integration techniques, giving the first provably correct method for simulating random walks with nontrivial topology.

Unfortunately, this structure is special to three dimensions: it's due to the equivalence of the 2-sphere and the complex projective line. Even in the plane, it is challenging to sample equilateral polygons. I will present a map from random walks to closed polygons in any dimension. Viewing the edges of an equilateral polygon as a point cloud on the sphere, the key idea is a proof that the closest closed polygon to an open chain is given by recentering the cloud at its geometric median and renormalizing. This gives a loop closure procedure which is a mathematically principled way to associate a unique closed loop (and knot type) to open chains like proteins. Since sampling points on the sphere is easy, this provides a way of generating large ensembles of closed equilateral polygons. (Received February 19, 2018)

1139-53-596 **Gaston Giribet*** (gg1043@nyu.edu), Center for Cosmology and Particle Physics, Physics Department, New York University, 726 Broadway av., New York City, NY 10003. *Q-curvature and generalization of Einstein equations.* Preliminary report.

Branson's Q-curvature is an important element in conformal geometry, which finds applications in spectral geometry, in the theory of higher order differential equations, and in theoretical physics. In my talk I will describe how Q-curvature naturally leads to generalizations of Einstein equations -and, consequently, of the notion of Einstein manifolds-. The Einstein-Hilbert variational problem associated to the Q-curvature can be thought of as defining a theory of gravity in space(times) of dimension grater than 4, which incorporates, apart from the Einstein tensor, higher-derivative modifications to the latter. This is closely related to the generalization of the Ricci flat spaces proposed by Lin and Yuan, which is canonically associated to the Q-curvature. I will explain how physics could help to gain intuition about the local meaning of the Q-curvature. (Received February 20, 2018)

1139-53-666 **Rebecca Glover***, rebecca.glover@stthomas.edu, and **Sema Salur**. *Lagrangian-type submanifolds of G_2 and $Spin(7)$ manifolds.*

The study of Lagrangian submanifolds has played a fundamental role in furthering the field of symplectic geometry. Lagrangian submanifolds reveal information about Hamiltonian mechanics, symplectic rigidity, and local invariants of symplectic manifolds. Further, a deeper understanding of Lagrangian submanifolds has provided insight towards establishing a correspondence between Calabi-Yau mirror pairs in Kontsevich's homological mirror symmetry via the Fukaya category. In this talk, we discuss the analogues for Lagrangian submanifolds in G_2 and Spin(7) geometry. We will discuss properties of these submanifolds as well as their deformation spaces. This is joint work with Sema Salur. (Received February 20, 2018)

54 ► General topology

1139-54-451 **Seungwon Kim** and **Maggie Miller*** (maggiem@math.princeton.edu). *RP^2 surgeries and trisections.* Preliminary report.

The Price twist is surgery on an RP^2 embedded in a 4-manifold with normal Euler number ± 2. I will discuss how to draw this surgery in trisection diagrams. (Received February 18, 2018)

1139-54-511 **Clement Ampadu*** (drampadu@hotmail.com), 31 Carrolton Rd, West Roxbury, MA 02132-6303. *An Almost Berinde Reich Mapping Theorem with Unique Fixed Point.* Preliminary report.

Inspired by the Berinde Weak Contraction [V. Berinde, Approximating fixed points of weak contractions using the Picard iteration, Nonlinear Anal. Forum 9 (1) (2004) 43–53] we introduced a generalization of it, for example see the references contained in [Seyma Cevik and Hasan Furkan, Some Fixed Point Theorems for Berinde-Type Contraction Mappings on Gp-Metric Spaces, Journal of Advances in Mathematics and Computer Science 25(3): 1-18, 2017; Article no.JAMCS.37129].

In this talk, we introduce (δ,1-3δ) weak Reich contraction, and show such mappings have a unique fixed point. An example is given to illustrate the main result. It should be noted that the Reich Mapping Theorem appeared in [S. Reich, Some remarks concerning contraction mappings, Canadian Mathematical Bulletin, 14 (1971), 121 - 124] (Received February 19, 2018)

1139-54-534 **Marla Williams*** (marla.williams@huskers.unl.edu). *Trisecting an S^2 bundle over $\mathbb{RP}^2$.* Preliminary report.

This talk will look at a construction for trisections (and trisection diagrams) of surface bundles over surfaces, with a particular focus on an S^2 bundle over $\mathbb{RP}^2$. For this example, the construction yields a known trisection diagram for spun $\mathbb{RP}^3$. (Received February 19, 2018)

1139-54-685 **NIckolas A Castro*** (ncastro@math.ucdavis.edu), Department of Mathematics, UC Davis, Davis, CA 95616. *Complicated Monodromies and Relative Trisections.* Preliminary report.

When a smooth, compact, connected, oriented 4-manifold is trisected relative to a non-empty boundary, the bounding 3-manifold inherits the structure of an open book decomposition. In joint work with Gay and Pinzón, an explicit algorithm was given to recover the (abstract) open book from a relative trisection diagram. In this talk, we will use this algorithm to understand the complexity of the monodromy of an induced open book decomposition with connected binding (i.e., a fibered knot). This gives rise to interesting questions regarding relatively trisected cobordisms and their induced open books. (Received February 20, 2018)

1139-54-704 **Vincent Longo***, Vlongo2@unl.edu. *Non-uniqueness of Prime Decompositions of Knotted Surfaces.*

Viro's unknot is an example of the connect sum of an unknotted projective plane with a nontrivial knotted surface that is equivalent to the same unknotted projective plane. In this talk, we will discuss the implications of this example and some results that try to generalize this construction. (Received February 21, 2018)

55 ► Algebraic topology

1139-55-49 **Luis Montejano*** (luismontej@gmail.com), Rancho Largo 211, 76230 Queretaro, Mexico, and **Frédéric Meunier**. *Variations of the Nerve Theorem.*

The Nerve theorem is a fundamental result in topological combinatorics. It has many applications, not only in combinatorics, but in category and homotopy theory and also in applied and computational topology. Roughly speaking, it relates the topological "complexity" of a simplicial complex to the topological "complexity" of the intersection complex of a "nice" cover of it. Stating the Nerve theorem with conditions on intersection seems to be somehow dictated by its very nature. It might thus come as a surprise that a Nerve theorem for unions also holds.

In this talk, we shall present the a theorem which interpolates between a version of the Nerve theorem with intersections and a version with unions. The case k=d is a classical version of the Nerve theorem. The case k=-1 is the same theorem, but with unions in place of intersection. (Received January 23, 2018)

1139-55-178 **Laurentiu G Maxim*** (maxim@math.wisc.edu). *Topology of very affine manifolds.*
I'll discuss joint work with Y. Liu and B. Wang on the topology of very affine manifolds. As main applications, I'll present finiteness properties of Alexander-type invariants of very affine manifolds, and their various topological consequences. (Received February 08, 2018)

1139-55-411 **Graham C. Denham** and **Alexander I. Suciu*** (a.suciu@northeastern.edu). *Abelian duality spaces.*
In joint work with Sergey Yuzvinsky, we introduced the notion of "abelian duality space." I will report here on recent progress in understanding the varied consequences of this topological property, and expanding its range of applicability in algebraic geometry, group theory, and combinatorics. (Received February 17, 2018)

1139-55-446 **Christin Bibby**, **Graham Denham** and **Eva-Maria Feichtner*** (emf@math.uni-bremen.de), Department of Mathematics, University of Bremen, Bibliothekstrasse 1, Bremen, Germany. *On a Leray model for Orlik-Solomon algebras.* Preliminary report.
I will present bits and pieces from an ongoing project with Christin Bibby and Graham Denham, the goal being a matroid version of an interpolation between Orlik-Solomon algebras and cohomology algebras of arrangement compactifications through a family of CDGAs. (Received February 18, 2018)

1139-55-633 **Yuri Berest*** (berest@math.cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853-4201. *Representation homology and Macdonald conjectures.*
In 1982, generalizing some earlier work of A. Selberg, F. Dyson, G. Andrews and others, I. G. Macdonald formulated several remarkable conjectures on the constant terms of certain Laurent polynomial expressions associated with root systems. These conjectures motivated a lot of interesting developments in representation theory, combinatorics and mathematical physics over the past 30 years, leading, in particular, to the discovery of Dunkl operators and Cherednik's theory of double affine Hecke algebras. In this talk, I will give a new *topological* interpretation of Macdonald's conjectures and discuss some natural generalizations. The existence of such generalizations answers a question posed by Macdonald in his original paper. (Received February 20, 2018)

57 ▶ Manifolds and cell complexes

1139-57-79 **Dale Koenig*** (dale.koenig@oist.jp). *Finding 3-manifolds in trisections of 4-manifolds.*
A trisection of a 4-manifold has a spine, a singular 3 dimensional subset that contains all the information needed to reconstruct the trisection. We define what it means for an embedded 3-manifold to lie almost entirely in the spine of a trisection of a 4-manifold. 3-manifolds with such embeddings can often be found directly from trisection diagrams. We will present several examples of such embeddings and how we can find them in diagrams. We will then outline the proof that every orientable closed 3-manifold M embeds almost in the spine of standard minimal genus trisections of $\#^n S^2 \tilde{\times} S^2$ for large enough n. (Received January 29, 2018)

1139-57-99 **Kenneth C Millett***, Department of Mathematics, UCSB, Santa Barbara, CA 93106. *Knots and Links in Proteins.*
Some proteins contain important topological structures: knots and slipknots as well as links if one includes cysteine bonds. As a consequence, the geometrical and topological character of these spatial structures is of interest to mathematicians as well as molecular biologists, biochemists and biophysicists. We will describe characterizations of knotting and slip knotting as well as linking within proteins. (Received February 03, 2018)

1139-57-167 **Nathaniel Bottman*** (nbottman@math.ias.edu). *Moduli spaces of quilted disks mapping to $\mathbb{CP}^1$ and $\mathbb{CP}^2$.* Preliminary report.
There is a monotone Lagrangian $\Lambda \subset (\mathbb{CP}^1)^- \times \mathbb{CP}^2$ coming from the action of S^1 on $\mathbb{CP}^2$ that rotates the last homogeneous coordinate. By work of Wehrheim and Woodward, we should expect that Λ induces a functor $F_\Lambda \colon \mathrm{Fuk}(\mathbb{CP}^1) \to \mathrm{Fuk}(\mathbb{CP}^2)$ between monotone Fukaya categories, which sends $L \subset \mathbb{CP}^1$ to a circle bundle over L and which is defined on the morphism level in terms of moduli spaces of quilted disks with one patch mapping to $\mathbb{CP}^1$ and one to $\mathbb{CP}^2$. I will explain how to classify these quilted disks, and describe some features of the compactified moduli spaces thereof. Time and circumstances permitting, I may talk about more general examples of quilted disks mapping to a toric manifold and its reduction by a Hamiltonian action. (Received February 07, 2018)

1139-57-186 **Ziva Myer*** (zmyer@math.duke.edu). *Product structures for Legendrian submanifolds with generating families.*

Algebraic invariants of Legendrian submanifolds in standard contact 1-jet spaces have been defined through a variety of techniques. I will discuss how I am using the Morse-theoretical technique of generating families to build such invariants. In particular, I have constructed a "two-to-one" product on generating family cohomology and I will discuss current work on different ways to extend this construction to A-infinity algebras and categories. If time permits, I will discuss conjectured relations of these constructions to others in the field. (Received February 09, 2018)

1139-57-229 **Eric J Rawdon*** (ericrawdon@gmail.com). *Average crossing number and writhe of knotted random polygons in confinement.*

Knots in nature typically are confined in some fashion. We explore how the average crossing number and writhe of random polygons behave under spherical confinement. In particular, we analyze how length, confinement radius, and knotting affect these two quantities. This is joint work with Yuanan Diao, Claus Ernst, and Uta Ziegler. (Received February 12, 2018)

1139-57-331 **Gabriel Islambouli*** (gfi8ps@virginia.edu). *Nielsen equivalence and isotopy classes of trisections.*

Let $S = \{s_1, ..., s_n\}$ and $T = \{t_1, ..., t_n\}$ be sets of generating systems of a group G. S and T are said to be Nielsen equivalent if there exist bases $X = \{x_1, ..., x_n\}$ and $Y = \{y_1, ..., y_n\}$ of the free group of rank n, F_n, and a surjection $\phi : F_n \to G$ so that $\phi(x_i) = s_i$ and $\phi(y_i) = t_i$.

Heegaard splittings give rise to two Nielsen classes of generators for the fundamental group and this fact has been used extensively to distinguish isotopy classes of Heegaard splittings. We show how to leverage this, together with Meir's spin construction, to produce a large class of 4-Manifolds which admit many isotopy classes of trisections. (Received February 15, 2018)

1139-57-351 **Paweł Goldstein**, **Piotr Hajłasz*** (hajlasz@pitt.edu) and **Pekka Pankka**. *Topologically nontrivial counterexamples to Sard's theorem.* Preliminary report.

We prove the following dichotomy: if $n = 2, 3$ and $f \in C^1(S^{n+1}, S^n)$ is not homotopic to a constant map, then there is an open set $\Omega \subset S^{n+1}$ such that $\operatorname{rank} Df = n$ on Ω and $f(\Omega)$ is dense in S^n, while for any $n \geq 4$, there is a map $f \in C^1(S^{n+1}, S^n)$ that is not homotopic to a constant map and such that $\operatorname{rank} Df < n$ everywhere. While the result deals with mappings between spheres, the motivation comes from the theory of mappings from Euclidean spaces into the Heisenberg groups H^n, because the rank of the derivative of such a mapping is bounded by n. In fact, our proofs are based on methods that have previously been applied to study Lipschitz homotopy groups of the Heisenberg groups. (Received February 16, 2018)

1139-57-357 **Michael Gekhtman*** (mgekhtma@nd.edu). *Dilogarithm identities in cluster algebras from Hamiltonian/Lagrangian point of view.*

I will discuss a Hamiltonian formalism for cluster mutations using canonical (Darboux) coordinates and piecewise-Hamiltonian flows with Euler dilogarithm playing the role of the Hamiltonian. The Rogers dilogarithm then appears naturally in the dual Lagrangian picture. I will show how the dilogarithm identity associated with a period of mutations in a cluster algebra arises from Hamiltonian/Lagrangian point of view. (Based on the joint paper with T. Nakanishi and D. Rupel.) (Received February 16, 2018)

1139-57-450 **Adam R Saltz*** (saltz.adam@gmail.com). *A Khovanov-theoretic invariant of bridge trisections.* Preliminary report.

We use a beefed-up version of Khovanov homology to assign an A-infinity algebra to a bridge trisection diagram. The chain homotopy type of the algebra is an invariant of the bridge trisection. We will discuss progress towards an isotopy class invariant and topological applications. (Received February 18, 2018)

1139-57-504 **David T Gay*** (dgay@uga.edu), Mathematics, University of Georgia, Athens, GA 30602. *Trisection diagrams for surgeries along embedded surfaces.* Preliminary report.

Given an embedded surface in a closed 4-manifold, removing a neighborhood of that surface and replacing it with some interesting object (perhaps diffeomorphic to what you removed) via an interesting gluing map produces a new and interesting 4-manifold. The Gluck twist operation is one example, which produces potential counterexamples to the smooth 4-dimensional Poincare conjecture. I'll discuss how to draw trisection diagrams of the resulting manifold given a trisected description of the original manifold and the embedded surface - at least I'll do this for some simple cases. (Received February 19, 2018)

1139-57-507 **Alexandra Kjuchukova*** (kjuchukova@wisc.edu), 480 Lincoln Dr, Madison, WI 53706, and **Patricia Cahn**. *Trisections of singular branched covers between four-manifolds.*

We consider branched covering maps $f : Y \to S^4$, where Y is a closed oriented four-manifold and the branching set of f is embedded in the four-sphere with a cone singularity. I will sketch a method to produce a trisection of Y from a singular triplane diagram of the pair (S^4, B). I will construct infinite family of three-fold covers $f_i : Y_i \to S^4$, branched along pairwise non-isotopic singularly embedded two-spheres. With the help of trisections, I will prove that, for each i in this construction, Y_i is diffeomorphic to $\mathbb{CP}^2$. Time-permitting, I will explain how a homotopy ribbon obstruction (for the knot describing the singularity type) arises in this setting. Joint work with Patricia Cahn. (Received February 19, 2018)

1139-57-513 **Catalina Betancourt** (catalina-betancourt@uiowa.edu), **Isabel K Darcy*** (idarcybiomath@gmail.com) and **Robert G Scharein** (rob@hypnagogic.net). *Persistent homology heatmaps of knots.*

We calculated the persistent homology of knots and compare their barcodes using heatmaps. (Received February 19, 2018)

1139-57-517 **Undine Leopold*** (undine.leopold@gmail.com) and **Thomas Tucker**. *Euclidean Symmetry of Closed Surfaces Immersed in 3-Space.* Preliminary report.

Given a finite group G of isometries of Euclidean 3-space E^3 and a closed surface S, an immersion $f : S \to E^3$ is in G-general position if $f(S)$ is invariant under G, points of S have disk neighborhoods whose images are in general position, and double curves on $f(S)$ are in general position with respect to any rotation axes or reflection planes of G. For such an immersion, there is an induced action of G on S whose generalized Riemann-Hurwitz equation (GRH), that is, orbifold S/G with branching information, satisfies certain natural restrictions. We classify which restricted GRH are realized by a G-general position immersion of S.

In this first talk, we review the classification for groups G consisting of orientation-preserving Euclidean isometries. Most restricted Riemann-Hurwitz equations can be realized with standard models in the orbifold E^3/G; the only difficulties occur when there is little branching or the Euler genus of S/G is small. We then consider the possibility of G containing orientation-reversing Euclidean isometries, giving the nine possibilities for G. (Received February 19, 2018)

1139-57-553 **R. Inanc Baykur***, University of Massachusetts Amherst, MA , and **Osamu Saeki**, Kyushu University, Japan. *Simplified broken Lefschetz fibrations and trisections.*

We will explain, and illustrate by quintessential examples, how to simplify generic maps on 4-manifolds to produce broken Lefschetz fibrations and trisections with simpler topologies. Joint work with Osamu Saeki. (Received February 19, 2018)

1139-57-568 **Trenton F Schirmer*** (trenton.schirmer@uga.edu). *Calculating the intersection form from a trisection diagram.* Preliminary report.

I will explain how to calculate the intersection form of a trisected 4-manifold using the triple of algebraic intersection matrices associated with any given diagram of the trisection, and discuss the extent to which this triple of intersection matrices can be simplified. This is joint work with Peter Feller, Michael Klug, and Drew Zemke. (Received February 19, 2018)

1139-57-579 **Michael R Klug*** (michael.r.klug@gmail.com). *Kernels of splitting homomorphisms and group trisections.*

After reviewing the notions of group trisections and splitting homomorphisms we investigate the structure of the kernel of such a map and prove that it is an infinitely generated free group. (Received February 19, 2018)

1139-57-582 **Jason Joseph***, jjoseph@math.uga.edu. *Quandle Invariants via Bridge Trisections.*

Quandles are algebraic structures whose axioms encode the Reidemeister moves. Every codimension two embedding has a fundamental quandle, and they have been used extensively to study knot theory. In this talk we will show how to calculate the fundamental quandle of a knotted surface directly from a bridge trisection diagram, and discuss some applications. (Received February 19, 2018)

1139-57-589 **Selman Akbulut***, Michigan State University, Dept of Mathematics, 619 Red Cedar Road C-335 Wells, East Lansing, MI 48824. *Complex G_2 Manifolds.* Preliminary report.

I will report on the joint work, in progress with Ustun Yildirim, in which we define the notion of complex G_2 manifold, and complexifying a G_2 manifold (M, φ), which is $M_{\mathbf{C}} := (T(M), J_\varphi)$, where J_φ is a complex structure associated to φ. From this, we can show that the deformation equations of a given associative submanifold $L^3 \subset M$ inside $M_{\mathbf{C}}$ becomes the Seiberg-Witten equations:

$$D_{\mathbf{A}}(x) = 0$$
$$*F_A = \sigma(x).$$

These equations were first introduced in 2007, by S. Akbulut and S. Salur. The first term is the Dirac equation $D_{\mathbf{A}} = \sum e^j \times \nabla_{e_j}$. By using the normal bundle $L \subset M$ as a spinor bundle one gets the Seiberg-Witten equations. To do this naturally, we split $TM = E^3 \oplus V^4$ by using a 2-frame field. Then any unit section of E gives an almost complex structure on V, from this we can split $V_{\mathbf{C}} = V^{1,0} \oplus V^{0,1}$. The above equations take place in the complex bundle $V^{1,0}$, which is no longer the normal bundle of $L \subset M$. To fix this we view these equations as deformations in the complexificaion $L \subset M_{\mathbf{C}}$. (Received February 20, 2018)

1139-57-613 **William E Olsen*** (`wolsen@uga.edu`). *Applications of Heegaard Floer theory to trisections of four-manifolds.* Preliminary report.

Heegaard Floer homology is a powerful tool for studying the topology of three- and four-manifolds. In this presentation, we will focus on the so-called 'mixed invariants' of closed four-manifolds as defined by Peter Ozsváth and Zoltán Szabó. We will give an outline of current work in progress on how one might hope to apply these invariants to the theory of trisections of four-manifolds. (Received February 20, 2018)

1139-57-659 **Alexander Zupan*** (`zupan@unl.edu`). *Diagrammatics of knotted surfaces.* Preliminary report.

Tri-plane diagrams are one of many ways to draw a picture representing a knotted surface in the 4-sphere. A more classical depiction of a knotted surface is a broken surface diagram, which is an immersed surface in 3-dimensional space with "crossing" data at double and triple points – both classical knot diagrams and classical broken surface diagrams are generic projections equipped with crossing information. I'll discuss a new method which converts a tri-plane diagram to a broken surface diagram, with relevant examples. (Received February 20, 2018)

1139-57-662 **Abigail Thompson*** (`thompson@math.ucdavis.edu`), Mathematics, UC Davis, Davis, CA 95616, and **Robion Kirby** (`kirby@math.ucdavis.edu`), Mathematics, UC Berkeley, Berkeley, CA 94720. *On the monodromy of a trisected 4-manifold part 1.* Preliminary report.

We examine how to obtain information about a 4-manifold by considering the induced monodromy on the associated 3-dimensional handlebodies. This is joint work with Rob Kirby. (Received February 20, 2018)

1139-57-665 **Robion Kirby*** (`kirby@math.berkeley.edu`), Mathematics, UC Berkeley, Berkeley, CA 94720, and **Abigail Thompson** (`thompson@math.ucdavis.edu`), Mathematics, UC Davis, Davis, CA 95616. *On the monodromy of a trisected 4-manifold part 2.* Preliminary report.

We examine how to obtain information about a 4-manifold by considering the induced monodromy on the associated 3-dimensional handlebodies; we look specifically at the case of adding a 0-framed 2-handle to a knot in the 3-sphere. This is joint work with Abby Thompson. (Received February 20, 2018)

1139-57-682 **Peter Lambert-Cole*** (`plc@math.gatech.edu`). *Bridge trisections in $\mathbb{CP}^2$.*

Given a surface S in a 4-manifold X, Meier and Zupan proved that S can be isotoped into bridge position relative to a trisection. This generalizes bridge position for knots in a 3-manifold. In this talk, I will give examples of algebraic curves in bridge position in $\mathbb{CP}^2$ and discuss how these surfaces can be understood in terms of their shadow diagrams onto a central torus. (Received February 20, 2018)

58 ► Global analysis, analysis on manifolds

1139-58-113 **Boris Khesin***, Department of Mathematics, University of Toronto, Toronto, ON M5S 2E4, Canada. *Beyond Arnold's geodesic framework of an ideal hydrodynamics I.*

In the talk we start discussing two ramifications of Arnold's group-theoretic approach to ideal hydrodynamics as the geodesic flow for a right-invariant metric on the group of volume-preserving diffeomorphisms. We show that problems of optimal mass transport are in a sense dual to the Euler hydrodynamics. By regarding volume-preserving diffeomorphisms as a subgroup of all diffeomorphisms, one can describe L^2 and H^1 versions of the Kantorovich-Wasserstein and Fisher-Rao metrics on the spaces of densities. In particular, the Hunter-Saxton equation naturally appears within this framework. Moreover, many equations of mathematical physics, such as fluids with moving boundary, have Lie groupoid, rather than Lie group, symmetries (this is a joint work with Anton Izosimov). (Received February 04, 2018)

1139-58-114 **Anton Izosimov***, Department of Mathematics, The University of Arizona, Tucson, AZ 85721. *Beyond Arnold's geodesic framework of an ideal hydrodynamics II.*

In the talk we continue the description of two ramifications of Arnold's group-theoretic approach to ideal hydrodynamics. Here we present an Arnold-like geodesic and Hamiltonian description for fluid flows with vortex sheets. It turns out that the corresponding dynamics is related to a certain groupoid of pairs of volume-preserving diffeomorphisms with common interface and equipped with a one-sided invariant metric (this is a joint work with Boris Khesin). (Received February 04, 2018)

1139-58-115 **Anton Izosimov*** (izosimov@math.arizona.edu), Department of Mathematics, The University of Arizona, Tucson, AZ 85721, and **Boris Khesin** (khesin@math.toronto.edu), Department of Mathematics, University of Toronto, Toronto, ON M5S 2E4, Canada.
Vortex sheets and diffeomorphism groupoids.

In 1966, V.Arnold suggested group-theoretic and Hamiltonian frameworks for an ideal hydrodynamics. According to his approach, the motion of an incompressible fluid on a Riemannian manifold is described as the geodesic flow of a right-invariant metric on the group of volume-preserving diffeomorphisms. In this talk we will review Arnold's picture and show how it can be extended to incorporate certain discontinuous fluid motions, known as vortex sheets. This is done by replacing groups and algebras in Arnold's approach by certain groupoids and algebroids. (Received February 04, 2018)

1139-58-163 **Luca Capogna*** (lcapogna@wpi.edu), Worcester Polytechnic Institute, Department of Mathematical Sciences, 100 Institute Road, Worcester, MA 01609. *Smooth boundary extensions of biholomorphisms and the Liouville theorem in sub-Riemannian manifolds.*

Starting from an original idea of Michael Cowling, we show how one can prove a celebrated result of Charles Fefferman, concerning the smooth boundary extensions of biholomorphisms between strictly pseudo convex domains, using quasiconformal mappings.

The proof is articulated in two steps: (1) prove that biholomorphisms extend to homeomorphisms between the boundaries, that are 1-quasiconformal with respect to the sub-Riemannian metrics arising from the corresponding Levi forms; (2) prove a sub-Riemannian Liouville theorem, i.e. every 1-quasiconformal map is a smooth diffeomorphism.

This talk is based on joint work with Giovanna Citti (Bologna), Enrico Le Donne (Jyvaskyla), and Alessandro Ottazzi (New South Wales). It involves techniques and ideas from several fields, including analysis in metric space, geometric measure theory and non linear PDE. (Received February 07, 2018)

1139-58-245 **Gerard Misiolek*** (gmisiole@nd.edu). *Fredholm properties of the L^2 exponential map in 2D and 3D hydrodynamics.*

Fredholm properties of the L^2 exponential map in 2D and 3D hydrodynamics. (Received February 12, 2018)

1139-58-420 **Janna Lierl*** (janna.lierl@uconn.edu), 341 Mansfield Road, Storrs, CT 06269, and **Karl-Theodor Sturm**. *Neumann heat flow and gradient flow for the entropy on non-convex domains.*

For large classes of non-convex subsets Y in $\mathbb{R}^n$ or in Riemannian manifolds (M, g) or in RCD-spaces (X, d, m) we prove that the gradient flow for the Boltzmann entropy on the restricted metric measure space (Y, d_Y, m_Y) exists – despite the fact that the entropy is not semiconvex – and coincides with the heat flow on Y with Neumann boundary conditions. (Received February 18, 2018)

1139-58-460 **Lisa Jeffrey*** (jeffrey@math.toronto.edu), BCIT, 40 St George St., Toronto, ON M5S 2E4, Canada. *Volume of reduced product.*

We give a formula for the symplectic volume of the reduced space of the product of coadjoint orbits.

(Joint work with Jia Ji) (Received February 18, 2018)

1139-58-503 **Dimiter Vassilev*** (vassilev@unm.edu), Department of Mathematics and Statistics, MSC01 1115 The University of New Mexico, Albuquerque, NM 87131. *Entropy in CR and quaternionic contact sub-Riemannian geometries.*

We will focus on some comparison results and show the monotonicity of an entropy like energy for the heat equation in the considered sub-Riemannian settings. (Received February 19, 2018)

1139-58-679 **P. Robert Kotiuga*** (prk@bu.edu), 8 Saint Mary's Street, Boston, MA 02215. *Nonlinear Conformally-invariant First-order Elliptic Systems in Three Dimensions: A variational perspective with and applications to geometric inverse problems.* Preliminary report.

The Laplace-Beltrami operator acting on middle degree forms of an even dimensional manifold is conformally invariant. In 2-D this relates to conformal invariance in complex analysis. In 4-D this relates to the conformal invariance of Maxwell's equations and Yang-Mills equations. Unfortunately, there's no "middle dimension" in odd dimensions, and no analogous conformally invariant geometric differential operators. However, they have a pair of middle dimensions and is particularly interesting in 4k-1 dimensions .

In this paper we develop a variational formulation of a conformally invariant 1^{st}-order elliptic system in 3-D which is necessarily nonlinear. It has a connection to:

- Arnold's work on the mean asymptotic linking number of a flow and its relation to the helicity of a flow.
- Freedman and He's use of the conformal modulus in bounding the mean asymptotic crossing number of a flow.
- Kotiuga's use of the Giroux correspondence in order to characterize the topology of near force-free magnetic fields.
- Adrian Nachman's use of minimal surface theory in the context of impedance tomography; an inverse problem where a Riemannian metric is determined within its conformal class.

(Received February 20, 2018)

60 ► *Probability theory and stochastic processes*

1139-60-57 **Yu Gu*** (yugu1105@gmail.com), Pittsburgh, PA 15232, and **Lenya Ryzhik** and **Ofer Zeitouni**. *The Edwards-Wilkinson limit for stochastic heat equation in high dimensions.*

We consider the heat equation with a random potential in dimensions three and higher, and show that the large scale random fluctuations are described by the Edwards-Wilkinson model with a homogenized diffusivity and variance. Based on joint work with Lenya Ryzhik and Ofer Zeitouni. (Received January 24, 2018)

1139-60-67 **Elena Kosygina***, **Atilla Yilmaz** and **Ofer Zeitouni**. *Homogenization of a class of one-dimensional non-convex viscous Hamilton-Jacobi equations with random potential.* Preliminary report.

We prove the homogenization of a class of one-dimensional viscous Hamilton-Jacobi equations with random Hamiltonians that are non-convex in the gradient variable. Due to the special form of the Hamiltonians, the solutions of these PDEs with linear initial conditions have representations involving exponential expectations of controlled Brownian motion in a random potential. The effective Hamiltonian is the asymptotic rate of growth of these exponential expectations as time goes to infinity and is explicit in terms of the tilted free energy of (uncontrolled) Brownian motion in a random potential. The proof involves large deviations, construction of correctors which lead to exponential martingales, and identification of asymptotically optimal policies. (Received February 19, 2018)

1139-60-154 **Jon Chaika** and **Arjun Krishnan*** (arjun.krishnan@rochester.edu). *Stationary coalescing walks on the lattice.* Preliminary report.

Consider a measurable dense family of semi-infinite nearest-neighbor paths on the integer lattice $\mathbb{Z}^d$. If the measure on the paths is translation invariant, we completely classify their collective behavior in $d = 2$ under mild assumptions. We use our theory to classify the behavior of semi-infinite geodesics in random translation invariant metrics on the lattice; it applies, in particular, to first- and last-passage percolation. (joint work with Jon Chaika) (Received February 07, 2018)

1139-60-176 **Jian Ding*** (dingjian@wharton.upenn.edu), Wharton School, University of Pennsylvania. *Random walk, random media and random geometry.*

This talk aims to present a glimpse on a small portion of some recent research on geometric aspects for random walks, Gaussian free fields, as well as random walks on random media. In particular, I will illustrate rich connections between (both the formulation and the solution of) the presented problems and percolation theory. During the talk, I will not focus on any particular research problem; rather, I will give a low-resolution description on the flavor of a number of facets on these research topics. This talk is based on works with/by many colleagues. (Received February 08, 2018)

1139-60-230 **Allan Sly***, Fine Hall, Department of Mathematics, Princeton University, Princeton, NJ, and **Riddhipratim Basu** and **Shirshendu Ganguly**. *Upper Tail Large Deviations in First Passage Percolation.*

For first passage percolation on Z^2 with i.i.d. bounded edge weights, we consider the upper tail large deviation; that is the rare event where the first passage time between two points at distance n, is macroscopically larger than typical. While the lower tail rate function was established by Kesten (1986) the upper tail had remained open. We show that under mild regularity assumption on the passage time distribution, the rate function for upper tail large deviation indeed exists. The proof is carried out by effectively dilating the large deviation environment to compare the upper tail probabilities for various values of n. The key new tool is to show that for each subsequential metric limit for the large deviation event, there is some scale in which the metric is locally well behaved almost everywhere. (Received February 12, 2018)

1139-60-254 **Anish Agarwal**, **Muhammad Amjad** and **Devavrat Shah*** (`devavrat@mit.edu`), 32 Vassar Street, 32-D670, Cambridge, MA 02139, and **Dennis Shen**. *Time Series Analysis via Matrix Estimation.*

We consider the task of interpolating and forecasting a time series in the presence of noise and missing data. As the main contribution of this work, we introduce an algorithm for this task that transforms the observed time-series into a matrix, utilizes the singular value thresholding algorithm from matrix estimation literature to recover missing time-series as well as de-noise observed time-series and then perform a simple linear regression to do forecasting. We argue that this method provides meaningful imputation and forecasting for a large class of models: finite sum of harmonics which approximate stationary processes, non-stationary sub-linear trends, linear time invariant systems and mixtures of all of these. Our method can be viewed as one which recovers the hidden state of dynamics based on its noisy observations, like that in a hidden Markov model (HMM), as long as the hidden dynamics obeys the above stated models. We demonstrate on synthetic and real-world datasets that our algorithm outperforms standard software packages in the presence of significant missing data and high levels of noise even when the software package is told what is the underlying model while ours is not. (Received February 13, 2018)

1139-60-255 **Jiaoyang Huang*** (`jiaoyang@math.harvard.edu`), 1 Oxford St Science Center, Math Department Room 425E, Cambridge, MA 02138. *Nonintersecting Random Walks and Gaussian Free Field.*

We study β analogues of the discrete nonintersecting random walks, which, in a special case, degenerates to the β-Dyson Brownian motion. We prove that, under mild conditions of the initial data, the fluctuations of the empirical particle density converge to the Gaussian free field. The central observation is that the fluctuations of multi-time linear statistics can be efficiently expressed in terms of the Jack generating function. As a consequence, a rich family of discrete Markov chains on Young diagrams defined by means of Jack symmetric polynomials converge to the Gaussian free field. (Received February 13, 2018)

1139-60-274 **Jing Dong***, 3022 Broadway, New York, NY 10027, Uris Hall 413, New York, NY 10027, and **Peter Glynn** and **Yi Zhu**. *A new approach to sequential stopping for stochastic simulation.*

In this work, we solve the sequential stopping problem for a class of simulation problems in which variance estimation is difficult. In particular, we establish the asymptotic validity of sequential stopping procedures for estimators constructed using the sectioning (replication) methods with a fixed number of sections. We also demonstrate how to apply this framework to important estimation and optimization problems. (Received February 13, 2018)

1139-60-322 **Sungwon Ahn*** (`sahn02@roosevelt.edu`), 905 Casey Ct 2, Schaumburg, IL 60173, and **Jonathon Peterson**. *Quenched central limit theorem rates of convergence for one-dimensional random walks in random environments.*

Unlike classical simple random walks, one-dimensional random walks in random environments (RWRE) are known to have a wide array of potential limiting distributions. Under certain assumptions, however, it is known that central limit theorem like limiting distributions hold for the walk under both the quenched and averaged measures. In this talk, we show certain polynomial rates of convergence for the quenched central limit theorems for both the hitting time and position of the RWRE. Joint work with Jonathon Peterson. (Received February 15, 2018)

1139-60-367 **Hung Nguyen*** (hnguye25@tulane.edu). *Anomalous diffusion and the Generalized Langevin Equation.*

The Generalized Langevin Equation is commonly used to describe the velocity of microparticles in viscoelastic fluids. Formally, the Generalized Langevin Equation (GLE) is written

$$m\ddot{x}(t) = -\gamma\dot{x}(t) - \Phi'(x(t)) - \int_{-\infty}^{t} K(t-s)\dot{x}(s)ds + F(t) + \sqrt{2\gamma}\dot{W}(t)$$

where $\Phi(x)$ is a non-linear potential well, $W(t)$ is a Brownian motion, and $F(t)$ is a stationary, mean zero and Gaussian process satisfying $E(F(t)F(s)) = K(t-s)$. Describing the long-term behavior of sub-diffusive GLEs in non-linear potentials is a long-standing open problem. We will look at recent advances in establishing existence and uniqueness of a stationary distribution for an infinite-dimensional Markov representation of the GLE. If time permits, we will also discuss asymptotic behaviors of the GLE in different limits, namely, the small-mass limit and the white noise limit. (Received February 16, 2018)

1139-60-423 **William A Massey*** (wmassey@princeton.edu), ORFE Department, Sherrerd Hall, Princeton University, Princeton, NJ 08544. *Static Profit Optimal Staffing of Dynamic Erlang-A Queues.* Preliminary report.

The Erlang-A queue is a Markovian multi-server queueing model with customer abandonment. It is inspired by telephone resource sharing problems for call center design. Moreover, it has applications to a similar set of resource problems found in healthcare management. The inspiration for our optimization problem comes from a multiple time scale staffing problem involving the management of nursing homes.

We use the theory of strong approximations as we simultaneously scale up the customer demand along with the service resource supply. We then obtain a functional strong law of large numbers result that gives us a limiting deterministic "fluid" limit for the Erlang-A queue. The result is a simple one-dimensional dynamical system that approximates the queueing mean behavior.

Assuming time varying customer demand, we can combine control theory and Lagrangian methods with fixed point equations to create a new algorithm that finds a fixed staffing size for the profit optimality of the Erlang-A fluid model. (Received February 18, 2018)

1139-60-428 **Evgeni S Dimitrov*** (edimitro@mit.edu), 550 Memorial Drive, Apt 2E, Cambridge, MA 02139. *Log-gases on a quadratic lattice via discrete loop equations and q-boxed plane partitions.*

I will discuss a general class of log-gas ensembles on a quadratic lattice. Under suitable scaling, the corresponding empirical measures satisfy a law of large numbers and their global fluctuations are Gaussian with a universal covariance that matches the one for continuous log-gases.

The general results find application in the asymptotic analysis of q-boxed plane partition models introduced by Borodin, Gorin and Rains. For these models, one can compute the law of large numbers for the height function and identify its global fluctuations on a fixed slice with a one-dimensional section of a pullback of the two-dimensional Gaussian free field.

The approach is based on a q-analogue of the Schwinger-Dyson (or loop) equations, which originate in the work of Nekrasov and his collaborators, and extends the methods developed by Borodin, Gorin and Guionnet to a quadratic lattice.

This is joint work with Alisa Knizel. (Received February 18, 2018)

1139-60-452 **Alexey Bufetov*** (alexey.bufetov@gmail.com), MA. *Gaussian Free Field in random tiling models.*

A Kenyon-Okounkov conjecture states that the fluctuations of the height function in random tiling models should converge to a Gaussian Free Field. We will discuss some particular cases where this convergence was proven. (Received February 18, 2018)

1139-60-499 **Maurice Duits***, duits@kth.se. *Random tilings with periodic weights and matrix orthogonal polynomials.*

In this talk we will discuss certain random tilings with periodic weightings, such as the two periodic Aztec diamond. Due to the periodicity new features may appear, such as a gas phase. In order to study the fine asymptotic structure, one would like to have a formula for the correlation kernel that is amenable for asymptotic analysis. In this talk, an approach will be discussed for finding such a formula in case one can reformulate the random tiling in terms of non-intersecting paths with periodic transition matrices. We then express the correlation kernel in terms of a double integral formula where the integrand is constructed out of matrix orthogonal polynomials. In special situations, in particular for the two periodic Aztec diamond, this formula can be simplified further leading to an expression that is tractable for asymptotic analysis. The talk is partly based on joint work with Arno Kuijlaars. (Received February 19, 2018)

1139-60-531 **Marek Biskup*** (`biskup@math.ucla.edu`) and **Yoshihiro Abe**. *Extremal processes for the local time of the simple random walk on trees and tori.* Preliminary report.

I will attempt to elucidate the present understanding of the various extremal processes associated with the local time of simple random walk at multiples of the cover time. In particularly, I will compere these with the corresponding processes for the two dimensional Gaussian Free Field (DGFF). As it turns out, for the random walk on homogeneous tree, the two processes are remarkably close: their distribution differs only by a constant multiplying a limit intensity measure. (This was mostly shown by Y.Abe with the cluster process being resolved in collaboration of his with the speaker.) For the random walk on tori, we can currently offer only some understanding of the intermediate level sets (the thick points) of the local time. Also these show remarkable resemblance to those of the DGFF. Based on work in progress with Y. Abe. (Received February 19, 2018)

1139-60-542 **Olivier Bernardi**, **Christophe Garban**, **Ewain Gwynne**, **Nina Holden*** (`ninah@mit.edu`), **Avelio Sepulveda** and **Xin Sun**. *Scaling limits for percolated random planar maps.*

The Schramm-Loewner evolution (SLE) is a family of random fractal curves, which is the proven or conjectured scaling limit of a variety of two-dimensional lattice models in statistical mechanics. Liouville quantum gravity (LQG) is a model for a random surface which is the proven or conjectured scaling limit of discrete surfaces known as random planar maps (RPM). We prove scaling limit results for percolation-decorated RPM to SLE-decorated LQG. (Received February 19, 2018)

1139-60-623 **Linan Chen*** (`linan.chen@mcgill.ca`), 805 Sherbrooke Street West, Burnside 1005, Burnside Hall 1005, Montreal, Quebec H3A0B9, Canada. *On the Exceptional Sets of Gaussian Free Fields in Any Dimension.*

The geometry of log-correlated Gaussian free fields (GFFs) has been extensively studied. For example, for the 2D GFF on a bounded planar domain (associated with the Laplace operator with the Dirichlet boundary condition), Hu, Miller and Peres (2010) studied the thick points, which, heuristically speaking, are locations where the GFF becomes "exceptionally" large, and they further determined the Hausdorff dimension of the set consisting of thick points. In this talk, we will explain how the study of such exceptional behaviors can be extended to a more general class of Gaussian random fields, for which we will continue using the terminology "GFFs". In particular, we adopt a sphere averaging regularization to treat polynomial-correlated GFFs in any dimension, and carry out an analysis of the "thick point" set analogous to the one in the log-correlated setting. Furthermore, we propose a general framework to study certain exceptional behaviors for both log-correlated and polynomial-correlated GFFs. Besides reproducing the classical results on thick point sets, this framework gives rise to new kinds of exceptional sets, the study of which leads to new information on the random geometry of the GFF. (Received February 20, 2018)

1139-60-639 **Yingdong Lu**, IBM Thomas J. Watson Research Center, 1101 Kitchawan Road, Yorktown Heights, NY 10598, **Mark S. Squillante***, IBM Thomas J. Watson Research Center, 1101 Kitchawan Road, Yorktown Heights, NY 10598, and **Chai Wah Wu**, IBM Thomas J. Watson Research Center, 1101 Kitchawan Road, Yorktown Heights, NY 10598. *On the Control of Density-Dependent Stochastic Population Processes with Time-Varying Behavior.*

The study of density-dependent stochastic population processes is important from a historical perspective as well as from the perspective of a number of existing and emerging applications today. In more recent applications of these processes, it can be especially important to include time-varying parameters for the rates that impact the density-dependent population structures and behaviors. Under a mean-field scaling, we show that such density-dependent stochastic population processes with time-varying behavior converge to a corresponding dynamical system. We analogously establish that the optimal control of such density-dependent stochastic population processes converges to the optimal control of the limiting dynamical system. An analysis of both the dynamical system and its optimal control renders various important mathematical properties of interest. (Received February 20, 2018)

1139-60-645 **Josh Reed*** (`jreed@stern.nyu.edu`), **Peter Lakner** and **Bert Zwart**. *A Dirichlet Process Characterization of Brownian Motion in a Wedge.*

Reflected Brownian motion (RBM) in a wedge is a 2-dimensional stochastic process Z whose state space in $\mathbb{R}^2$ is given in polar coordinates by $S = \{(r,\theta) : r \geq 0, 0 \leq \theta \leq \xi\}$ for some $0 < \xi < 2\pi$. Let $\alpha = (\theta_1 + \theta_2)/\xi$, where

$-\pi/2 < \theta_1, \theta_2 < \pi/2$ are the directions of reflection of Z off each of the two edges of the wedge as measured from the corresponding inward facing normal. We prove that in the case of $1 < \alpha < 2$, RBM in a wedge is a Dirichlet process. Specifically, its unique Doob-Meyer type decomposition is given by $Z = X + Y$, where X is a two-dimensional Brownian motion and Y is a continuous process of zero energy. Furthermore, we show that for $p > \alpha$, the strong p-variation of the sample paths of Y is finite on compact intervals, and, for $0 < p \leq \alpha$, the strong p-variation of Y is infinite on $[0, T]$ whenever Z has been started from the origin. We also show that on excursion intervals of Z away from the origin, (Z, Y) satisfies the standard Skorokhod problem for X. However, on the entire time horizon (Z, Y) does not satisfy the standard Skorokhod problem for X, but nevertheless we show that it satisfies the extended Skorkohod problem. (Received February 20, 2018)

1139-60-651 **Scott Sheffield***, 77 Massachusetts Avenue, Cambridge, MA 02139. *Random walks in random environments: a new approach.*

I will discuss some recent joint work with Ewain Gwynne and Jason Miller concerning the extension of "random walk in random environment" results to the setting of "scale free" environments, where classical techniques do not directly apply. I will also discuss applications of this theory to random walks on planar maps and to various discretizations of Liouville quantum gravity. (Received February 20, 2018)

1139-60-705 **David Gamarnik***, gamarnik@mit.edu, and **Ilias Zadik**. *Algorithms and Algorithmic Obstacles in High-Dimensional Regression.*

Many optimization problems arising in studying of random structures exhibit an apparent gap between the optimal values and the best values achievable by fast (polynomial time) algorithms. Through a combined effort of researchers it became apparent that a potential and in some cases a provable obstruction for designing algorithms bridging this gap is a phase transition in the geometry of nearly optimal solutions, in particular the presence of a certain Overlap Gap Property (OGP).

In this talk we discuss this geometrical concept in the context of sparse high dimensional linear regression problem. We show that, on the one hand, in the sampling regime where the known methods for this problem are effective, the space of solutions exhibits a nice monotonicity with respect to the proximity to the ground truth regression vector, no local optimums exist and, as a result, a very simple algorithm based on local improvement succeed with high probability in recovering the ground truth regression vector.

On the other hand, once the sampling number is in the regime where known methods fail, we show that the monotonicity is broken, and the model exhibits an OGP. (Received February 21, 2018)

62 ► Statistics

1139-62-63 **Anna Seigal*** (`seigal@berkeley.edu`) and **Guido Montúfar**. *Semialgebraic statistics of mixture models and restricted Boltzmann machines.*

We compare two statistical models of three binary random variables. One is a mixture model and the other is a product of mixtures model called a restricted Boltzmann machine. Although the two models we study look different from their parametrization, we show that they represent the same set of distributions on the interior of the probability simplex, and are equal up to closure. We give a semi-algebraic description of the model in terms of six binomial inequalities and obtain closed form expressions for the maximum likelihood estimates. (Received January 24, 2018)

1139-62-84 **Laura Kubatko*** (`kubatko.2@osu.edu`), **Julia Chifman** (`chifman@american.edu`) and **Jing Peng** (`peng.650@osu.edu`). *Coalescent-based Estimation of Speciation Times Using Site Pattern Frequencies.*

The advent of rapid and inexpensive sequencing technologies has necessitated the development of computationally efficient methods for analyzing sequence data for many genes simultaneously in a phylogenetic framework. The coalescent process is the most commonly used model for linking the underlying genealogies of individual genes with the global species-level phylogeny, but inference under the coalescent model is computationally daunting in the typical inference frameworks (e.g., the likelihood and Bayesian frameworks) due to the dimensionality of the space of both gene trees and species trees. In this talk, I consider the estimation of species tree branch lengths, and show that simple estimators for the branch lengths can be derived based on observed site pattern frequencies. Properties of these estimators, such as their asymptotic variances and large-sample distributions, will be examined, and performance of the estimators will be assessed using simulation. (Received January 31, 2018)

1139-62-275 **Elisa Perrone*** (eperrone@mit.edu), Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA 02138. *The geometry of discrete copulas.*

Copulas are functions which serve as a flexible tool for constructing diverse stochastic dependences among random vectors. The focus of this work is on studying discretized versions of copulas, namely *discrete copulas*, which are fascinating geometric objects of great importance for empirical modeling in the applied sciences. In particular, we here analyze mathematical features of discrete copulas, and define their geometry in terms of their related convex polytopes. First, we highlight fundamental connections between discrete copulas and generalizations of the Birkhoff polytope. Then, we present a geometric approach to describe families of discrete copulas with prescribed stochastic dependence properties through features of their associated polytopes. Finally, we discuss how our geometric findings could possibly open the door to constructing new statistical tests for copulas and smooth approximators of analytically unfeasible copulas.

Based on joint work with Liam Solus (KTH, Sweden) and Caroline Uhler (MIT, USA). (Received February 13, 2018)

1139-62-458 **Victor-Emmanuel Brunel*** (vebrunel@mit.edu). *The principal minor assignment problem and its application to learning determinantal point processes.*

The principal minor assignment (PMA) problem consists of finding all matrices with a prescribed list of principal minors, in given class. More precisely, if $\mathcal{A} \subseteq \mathbb{C}^{N\times N}$ is a class of matrices (e.g., real symmetric matrices, Hermitian matrices, etc.) and $(p_J)_{J\subseteq[N],J\neq\emptyset} \subseteq \mathbb{C}$, the PMA problem consists of finding all matrices $K \in \mathcal{A}$ with $det(K_J) = p_J$ for all $J \subseteq [N], J \neq \emptyset$. One part of this talk will be focused on solving the PMA at both a theoretical and a computational level. Namely, for some specific classes $\mathcal{A}$, we describe all the solutions to the PMA problem and we ask how to find one of them with as few queries of the prescribed list as possible.

This problem is closely related to that of identifiability and estimation of the parameters of discrete determinantal point processes, which have recently gained a lot of attention in the machine learning and statistics literature, as an alternative to Ising models. In this talk, we will review the definition of these processes and use the PMA problem in order to characterize the identifiability of their parameters and design algorithms to learn them in a statistical sense. (Received February 18, 2018)

1139-62-570 **Sonja Petrovic*** (sonja.petrovic@iit.edu), 10 West 32nd street, rm 208, Chicago, IL 60616. *An invitation to algebraic statistics: a brief overview.* Preliminary report.

Algebraic statistics focuses on mathematical aspects of statistical models, where algebraic, geometric and combinatorial insights can be useful to study behavior of statistical procedures. While the roots of algebraic ideas in statistics are quite old, modern algebraic statistics started two decades ago with two lines of work: construction of Markov bases for analysis of and exact tests for contingency tables and use of Gröbner bases for experimental design.

The field has expanded in both scope and tools in recent years and by now has touched upon all major topics in statistical inference. This session gives an overview of recent advances in the field, broadly defined. The goal of this talk is to introduce some of the classical problems and constructions that motivate many of the session's talks: algebra of parameter estimation, the problem of parameter identifiability, geometry of mixture models, and more. (Received February 19, 2018)

1139-62-681 **Ashleigh Thomas*** (althomas41@gmail.com), **Surabhi Beriwal** and **Ezra Miller**. *Multirank functions for comparing multiparameter persistence modules.*

Persistent homology extracts topological and geometric features from data and stores that information in persistence modules, which are covariant functors from posets to the category of vector spaces. To compare persistence modules and ultimately perform statistical analysis, we construct pseudometrics on the space of persistence modules based on information from module invariants. For example, for single-parameter persistence there are bottleneck and rank pseudometrics, which are based on two (equivalent) complete module invariants: the module's decomposition into a direct sum of indecomposables; and the rank function, which records the ranks of the module's structure morphisms.

We introduce multirank functions – extensions of the rank function – as invariants of multiparameter persistence modules and define multirank pseudometrics based on Robins and Turner's rank pseudometric. (Received February 20, 2018)

65 ► Numerical analysis

1139-65-42 **Sergiy Borodachov*** (sborodachov@towson.edu), 7800 York Rd., Towson, MD 21252.
Optimal recovery of three times differentiable functions on a convex polytope inscribed in a sphere.

We consider the problem of global recovery on the class $W^3(P)$ of three times differentiable functions which have uniformly bounded third order derivatives in any direction on a d-dimensional convex polytope P inscribed in a sphere and containing its circumcenter. The information $I(f)$ known about each function $f \in W^3(P)$ is given by its values and gradients at the vertices of P. The recovery error is measured in the uniform norm on P. We prove the optimality on the class $W^3(P)$ of a certain quasi-interpolating recovery method among all non-adaptive global recovery methods which use the information $I(f)$. This method was constructed earlier for the case of a d-dimensional simplex T in the work by the author and T.S. Sorokina in 2011, where its optimality was proved for an analogous class $W^2(T)$ of twice differentiable functions. (Received January 18, 2018)

1139-65-695 **Viktor Grigoryan*** (grigoryan@simmons.edu), Department of Mathematics and Statistics, Simmons College, 300 The Fenway, Boston, MA 02115. *Finite element simulation of wound healing.* Preliminary report.

We numerically investigate chemical biological and mechanical interplay contributing to wound healing and scar formation. The underlying equations in the mathematical model are of coupled reaction-diffusion type for the biological and chemical fields, and of visco-elastic type for the mechanical fields. The overall system is modeled by a finite-element method and the results are interpreted in the biological context. (Received February 20, 2018)

68 ► Computer science

1139-68-105 **Urmila Mahadev***, Soda Hall 635, Berkeley, CA 94720. *Classical Homomorphic Encryption for Quantum Circuits.*

We present a computationally secure classical homomorphic encryption scheme for quantum circuits. The scheme allows a classical server to blindly delegate a quantum computation to a quantum server; the server is able to run the computation without learning about the computation itself. We show that it is possible to construct such a scheme directly from quantum secure classical homomorphic encryption schemes with certain properties. Finally, we show that an existing classical homomorphic encryption scheme has the required properties, and can therefore be used to homomorphically evaluate quantum circuits. (Received February 03, 2018)

1139-68-139 **Emanuele Viola***, viola@ccs.neu.edu. *The complexity of distributions.*

We survey the complexity of sampling distributions by classical algorithms, including recent results. The focus is on lower bounds, such as showing that certain explicit distributions cannot be sampled by polynomial-size, constant-depth circuits. (Received February 06, 2018)

1139-68-182 **Kelsey Horan*** (khoran@gradcenter.cuny.edu), New York, NY, and **Jean-Charles Faugere**, **Delaram Kahrobaei**, **Marc Kaplan**, **Elham Kashefi** and **Ludovic Perret**.
Fast Quantum Algorithm for Solving Multivariate Quadratic Equations.

After the announcement for the transition to post-quantum secure cryptographic constructions by the US National Security Agency the cryptography community has been working towards developing and evaluating standards. Of particular interest is the calculation of the quantum bit security for many proposed post-quantum cryptosystems. This talk addresses the problem of solving a system of m boolean multivariate quadratic equations in n variables, the MQ2 problem – a problem that is central to evaluating the quantum security of many cryptosystems. A Las-Vegas quantum algorithm for solving the boolean multivariate quadratic problem, which requires in expectation the evaluation of $O(2^(0.462n))$ quantum gates, will be presented. (Received February 08, 2018)

1139-68-301 **Anand Natarajan*** (anandn@mit.edu) and **Thomas Vidick** (vidick@cms.caltech.edu).
Low-degree testing for quantum states.

For any integer $n \geq 2$ we construct a one-round two-player game G_n, with communication that scales polylogarithmically with n, having the following properties. First, there exists an entangled strategy that wins with probability 1 and in which the players perform generalized Pauli measurements on their respective share of an n-qudit maximally entangled state, with local dimension $q = \text{poly}\log(n)$. Second, any strategy that succeeds with probability at least $1-\varepsilon$ must be within distance $O((\log n)^c \varepsilon^{1/d})$, for universal constants $c, d \geq 1$, of the perfect strategy, up to local isometries. This is an exponential improvement on the size of any previously known game certifying $\Omega(n)$ qudits of entanglement with comparable robustness guarantees. The construction of the game G_n is based on the classical test for low-degree polynomials of Raz and Safra, which we extend to the quantum regime. We further obtain several consequences for complexity theory, most notably that it is QMA-hard, under randomized reductions, to approximate up to a constant factor the maximum acceptance probability of a multiround, multiplayer entangled game with poly $\log(n)$ bits of classical communication. (Received February 14, 2018)

1139-68-318 **Michael N Katehakis*** (mnk@rutgers.edu), 100 Rockafeller Road, Piscataway, NJ 08854, **Wesley Cowan** (c.wes.cowan@gmail.com), 100 Rockafeller Road, Piscataway, and **Daniel Pirutinsky**, 100 Rockafeller Road, Piscataway, NJ. *Reinforcement learning: connections between MDPs and MAB problems.* Preliminary report.

This talk considers a basic reinforcement learning model dealing with adaptively controlling an unknown Markov Decision Process (MDP), in order to maximize the long term expected average value. In this work, we consider a factored representation of the MDP problem that allows it to be decoupled into a set of individual MAB-problems on a state by state basis. In this way, we show sufficient conditions for efficiently extending classical MAB-type policies to corresponding MDP policies. These constructed MDP policies largely inherit the properties of their MAB-generators, allowing the simple construction of asymptotically optimal MDP policies. We additionally show the construction of a simple UCB-type MDP policy, dramatically simplifying an earlier proof of its optimality. Additional extensions to other MAB policies (e.g., Thompson Sampling) are discussed. (Received February 15, 2018)

1139-68-345 **Ashley Montanaro*** (ashley.montanaro@bristol.ac.uk). *Quantum states cannot be transmitted efficiently classically.*

In this talk I will show that any classical communication protocol that can approximately simulate the result of applying an arbitrary measurement (held by one party) to a quantum state of n qubits (held by another) must transmit at least 2^n bits, up to constant factors. The argument is based on a lower bound on the classical communication complexity of a distributed variant of the Fourier sampling problem. Two optimal quantum-classical separations follow as corollaries. First, a sampling problem which can be solved with one quantum query to the input, but which requires order-N classical queries for an input of size N. Second, a nonlocal task which can be solved using n Bell pairs, but for which any approximate classical solution must communicate 2^n bits, up to constant factors.

The talk will be based on the paper arXiv:1612.06546. (Received February 16, 2018)

1139-68-476 **Giovanni Di Crescenzo** (gdicrescenzo@vencorelabs.com), **Matluba Khodjaeva*** (mkhodjaeva@jjay.cuny.edu), **Delaram Kahrobaei** (dkahrobaei@gc.cuny.edu) and **Vladimir Shpilrain** (shpil@groups.sci.ccny.cuny.edu). *Computing Multiple Exponentiations in Discrete Log and RSA Groups: From Batch Verification to Batch Delegation.*

We consider the problem of a client efficiently, privately and securely delegating the computation of multiple group exponentiations to a computationally more powerful server (e.g. a cloud server). We provide the first practical and provable solutions to this batch delegation problem for groups commonly used in cryptography, based on discrete logarithm and RSA hardness assumptions. Previous results either solved delegation of a single group exponentiation with limited security properties, or verification of multiple group exponentiations in prime-order groups (not applicable to RSA) and under certain simplifying assumptions on the exponentiation values (not applicable to some discrete logarithm groups). Our results directly solve batch delegation of various algorithms in cryptosystems, including RSA encryption and Diffie-Hellman key agreement protocols. (Received February 19, 2018)

1139-68-519 **Alexander N Wood*** (awood@gradcenter.cuny.eud), The Graduate Center, CUNY, 365 Fifth Avenue, Room 4319, New York, NY 10016, and **Vladimir Shpilrain** (shpil@groups.sci.ccny.cuny.edu), **Ali Mostashari** (ali@lifenome.com), **Kayvan Najarian** (kayvan@med.umich.edu) and **Delaram Kahrobaei** (dkahrobaei@gc.cuny.edu). *Combinatorial Algebra and Fully Homomorphic Encryption for Implementation of Private Classification Algorithms.*

Fully homomorphic encryption (FHE) enables computation over encrypted data. However, implementation of FHE schemes requires balancing security, speed, homomorphic encoding of numeric values as ring elements. In this talk we discuss past approaches and challenges to implementing fully homomorphic encryption and decryption algorithms for medical classification. We present our methods and results for using private-key fully homomorphic encryption to implement Naive Bayes classification. (Received February 19, 2018)

1139-68-653 **Li Zhang*** (zhangli@us.ibm.com). *Multi-resource fair sharing for multiclass workflows.*
Computer jobs in Big Data systems such as the Cloud, commonly require resources of multiple dimensions, including, CPU, memory, network, etc. Multi-resource sharing for concurrent workflows necessitates a fairness criteria to allocate multiple resources to workflows with heterogeneous demands. Recently, this problem has attracted increasing attention and has been investigated by assuming that each workflow has a single class of jobs and that each class contains jobs of the same demand profile. The demand profile of a class represents the required multi-resources of a job. However, for typical applications in cloud computing and distributed data processing systems, a workflow usually needs to process multiple classes of jobs. Relying on the concept of slowdown, we characterize fairness for multi-resource sharing and address the scheduling of multi-class workflows. We optimize the mixture of different classes of jobs for a workflow as optimal operation points to achieve the least slowdown, and discuss desirable properties for these operation points. (Received February 20, 2018)

1139-68-664 **Mengdi Wang*** (mengdiw@princeton.edu), 302 Trinity Ct Apt 2, Princeton, NJ 08540.
Compressive Learning for Sequential Decision Process.
Model reduction has been a central problem in system management and data science. This talk presents a data-driven methodology for learning reduced-order representations of stochastic decision process. In particular, we develop a tractable method for state compression of Markov processes. The state compression method is able to " sketch" a black-box system from its empirical data, for which we provide both minimax statistical guarantees and scalable computational tools. We demonstrate applications of state compression in modeling taxi-trip data and clinical pathways. Furthermore, the state compression method applies to high-dimensional reinforcement learning and policy imitation. It helps decision makers take advantages of past experiences and significantly reduces the complexity of learning to perform a new task. (Received February 20, 2018)

70 ► Mechanics of particles and systems

1139-70-447 **Federico Bonetto**, School of Mathematics, 686 Cherry Street NW, Atlanta, GA 30332-0160, **Alissa Geisinger**, Auf der Morgenstelle 10, 72076 Tübingen, Germany, **Michael Loss***, School of Mathematics, 686 Cherry Street, Atlanta, GA 30332-0160, and **Tobias Ried**, Englerstrasse 2, 76131 Karlsruhe, Germany. *Entropy decay for the Kac master equation.*
The Kac master equation models the behavior of a large number of randomly colliding particles. Due to its simplicity it allows, without too much pain, to investigate a number of issues. E.g., Mark Kac, who invented this model in 1956, used it to give a simple derivation of the spatially inhomogeneous Boltzmann equation. One important issue is the rate of approach to equilibrium, which can be analyzed in various ways, using, e.g., the gap or the entropy. Explicit entropy estimates will be discussed for a Kac type master equation modeling the interaction of a finite system with a large but finite reservoir. (Received February 18, 2018)

76 ► Fluid mechanics

1139-76-9 **Thomas G. Fai*** (tfai@seas.harvard.edu), 29 Oxford St., Cambridge, MA 02138. *Active vesicle transport into Dendritic Spines.*
We use lubrication theory to model the fluid dynamics of vesicle transport into dendritic spines, which are micron-sized structures at which neuronal postsynapses are located. Dendritic spines are characterized by their thin necks and bulbous heads, and recent high-resolution 3D images show a fascinating variety of spine morphologies. Our model, which has been validated by 3D lattice Boltzmann simulations, reduces the dynamics of vesicle motion to two essential parameters representing the system geometry and elasticity and allows us to thoroughly explore phase space. Upon including competing molecular motor species that push and pull on vesicles, we observe multistability that we speculate neurons could exploit in order to control spine growth. The bifurcations of the resulting dynamical system illustrate the levers the cell may adjust in order to achieve different behaviors.
(Received October 24, 2017)

1139-76-298 **Gary S. Lapham*** (gary.lapham@mma.edu) and **John P. McHugh**. *Bessel Functions and Unbounded Wall Flow.*

Free surface waves in the presence of a non-uniform shear flow are treated. The shear flow of interest varies with both the transverse and vertical coordinates. Initial results treat a mean flow varying as a decaying exponential in the transverse coordinate. The domain is bounded on one side by a flat rigid vertical wall and is unbounded on the other side. The mean flows considered here are nonzero near the vertical wall and approach zero far from the wall. The flowfield is treated as inviscid but rotational. Linear solutions are obtained using a nonuniform coordinate transformation that converts the free surface boundary condition into a modified Bessel equation. Velocity components are expanded in modified Bessel functions of purely imaginary order. An eigenvalue problem is formulated for wavespeeds. Corresponding eigenvectors show a sequence of wave profiles of increasing complexity near the wall. The wave amplitude approaches zero far from the wall. (Received February 14, 2018)

1139-76-597 **Lucia Carichino*** (lcarichino@wpi.edu), **Giovanna Guidoboni** and **Marcela Szopos**. *Coupling PDEs and ODEs for blood flow simulations.*

Multiscale coupling of nonlinear distributed and lumped fluid flow models are often necessary when modeling complex biological vascular systems. When interested in studying in details a specific segment of the vasculature, usually, to reduce simulations costs, a distributed partial differential equations (PDEs) model is used to simulate the segment of interest, while the rest of the vasculature is approximated using a lumped ordinary differential equations (ODEs) model. We develop a novel technique based on operator splitting for the time discretization of coupled systems of Stokes equations and ODEs that: (i) allows nonlinearities to be solved in separate steps; (ii) ensures overall stability of the numerical scheme; (iii) gives flexibility in choosing the numerical method and discretization approach of each sub-step. The main novelty of this splitting approach is that it ensures that the energy of the semi-discrete problem mirrors the behavior of the energy of the fully coupled problem, providing unconditional stability. Moreover, the block structure of the proposed splitting scheme allows the scheme to be easily modified to be first or second-order in time, to account for different fluid rheologies, and to consider rigid or deformable domains. (Received February 20, 2018)

1139-76-599 **David G Ebin*** (ebin@math.sunysb.edu), Mathematics Department, Stony Brook University, Stony Brook, NY 11794-3651. *Motion with strong constraining force.*

We describe a general theory of motions with a strong constraining force. Let N be a Riemannian manifold and let M be a submanifold. Let V be a function on N for which M is a strict minimum. Assume that D^2V gives a positive definite bilinear form on vectors perpendicular to M. Then a geodesic in M can be approximated by a curve in N which would be a geodesic except that it is accelerated by $-\nabla V$. If V is multiplied by a large constant k, then the distance between the curves is like 1/k. Also the difference between the curves will be oscillatory with a frequency like $\sqrt{k}$. The above construction has several physical applications. We will first discuss the case of slightly compressible fluids. Their motion is shown to be close to incompressible motion and the difference comes from the equation of propagation of sound. Second case: For a fluid with free boundary and surface tension we show that the motion will be close to motion of a fluid with a fixed boundary is the surface tension constant is large. (Received February 20, 2018)

1139-76-632 **Aseel Farhat*** (af7py@virginia.edu) and **Zoran Grujić**. *Helical nature of turbulence and the regularity problem of the 3D Navier-Stokes equations.*

Direct numerical simulations showed that there is a high probability that velocity and vorticity vectors of the flow are nearly aligned in regions of high vorticity. We will show that that 3D NSE are regular under some appropriate local condition on the helicity in the the regions of intense vorticity. (Received February 20, 2018)

1139-76-672 **Robin Ming Chen**, **Sam Walsh** and **Miles H. Wheeler*** (miles.wheeler@univie.ac.at). *Spatial asymptotics for solitary waves in deep water.*

We consider the behavior near spatial infinity of a localized traveling wave on the surface of an infinitely deep fluid. In a variety of settings and under suitable decay assumptions, we show that the leading order term in these asymptotics is a dipole term. This has many implications for the wave, particularly in the simpler settings where the dipole moment in the expansion is given explicitly in terms of the kinetic energy. As an application, we provide detailed asymptotics for the waves with compactly supported vorticity constructed in [Shatah–Walsh–Zeng 2013]. (Received February 20, 2018)

78 ► Optics, electromagnetic theory

1139-78-347 **Volker Perlick*** (perlick@zarm.uni-bremen.de), **Claus Laemmerzahl** and **Alfredo Macias**. *On the polarisation of light in non-linear vacuum electrodynamics.*

We consider non-linear electrodynamical theories of the Plebański class (i.e., with a Lagrangian that depends only on the two Lorentz invariants F and G of the electromagnetic field) on an unspecified general-relativistic spacetime. It is known that for all these theories the light rays are null geodesics of two ("optical") Lorentzian metrics. Here we derive the general transport laws for the polarisation plane along the rays. The procedure is considerably more complicated than in the case of a linear theory because of frequency doubling (also known as generation of higher harmonics). The Born-Infeld and Heisenberg-Euler theories are treated as examples. (Received February 16, 2018)

1139-78-690 **De Leo Roberto**, **Gutierrez Cristian** and **Henok Mawi*** (henok.mawi@howard.edu), 2441 Sixth St. NW, Howard University, Dept. of Mathematics, ASB-B, Washington, DC 20059. *A constructive approach to the Far field Refractor Problem.*

The far field refractor problem in geometric optics is an inverse problem which deals with constructing a refracting surface that is capable of reshaping a light beam from a one point source with a given illumination intensity into a prescribed intensity distribution. The aim of this talk is to discuss its numerical solution. In particular, we will describe a numerical algorithm which was first used in the work of Caffarelli, Kochengin and Oliker, in relation to synthesis of reflector surfaces and show that a simplified version of this algorithm can be extended to obtain an approximate solution for the refractor problem with arbitrary precision. We further exhibit the convergence in finite steps of the method when the distribution density functions are bounded and mass balance conditions are met. (Received February 20, 2018)

81 ► Quantum theory

1139-81-29 **Matthias Lienert*** (m.lienert@rutgers.edu), Department of Mathematics, Rutgers University, Piscataway, NJ 08904. *Direct interaction along light cones at the quantum level.*

Here we explain the idea that direct interactions along light cones (not mediated by fields) can be implemented on the quantum level using multi-time wave functions. These are wave functions $\psi(x_1, ..., x_N)$ with N spacetime arguments $x_i = (t_i, \mathbf{x}_i)$ for N particles. Starting from the integral formulation of the non-relativistic Schrödinger equation, a covariant integral equation is derived as an novel tpye of evolution equation for ψ, and its mathematical structure is discussed. Moreover, we show that it correctly reduces to a Schrödinger equation with Coulomb potential if time delay effects are neglected. (Received January 09, 2018)

1139-81-153 **Shelby Kimmel***, Middlebury College, Middlebury, VT, and **Michael Jarret**, **Stacey Jeffery** and **Alvaro Piedrafita**. *Quantum Algorithms for Connectivity: Applications and Analysis.*

A large class of quantum algorithms are derived from linear algebraic objects called span programs. However, analyzing properties of span programs (which in turn gives us information about the performance of quantum algorithms) can be challenging. I will describe a tight characterization of a span program-based quantum algorithm for st-connectivity that has a wide variety of applications (Received February 09, 2018)

1139-81-218 **Zhengfeng Ji** and **Debbie Leung*** (wcleung@uwaterloo.ca), Dept of Combinatorics and Optimization, University of Waterloo, Waterloo, Ontario N2L3G1, Canada, and **Thomas Vidick**. *A nonlocal game that cannot be played optimally using a finite amount of entanglement.*

We introduce a three-player nonlocal game, with a finite number of classical questions and answers, such that the optimal success probability of 1 in the game can only be achieved in the limit of strategies using arbitrarily high-dimensional entangled states. Precisely, there exists a constant $0 < c \leq 1$ such that to succeed with probability $1 - \epsilon$ in the game it is necessary to use an entangled state of at least $\Omega(\epsilon^{-c})$ qubits, and it is sufficient to use a state of at most $O(\epsilon^{-1})$ qubits. The game is based on embezzlement of entanglement.

Nonlocal games are equivalent to Bell inequalities, where the questions become measurement settings, answers become measurement outcomes, and the success probability is related to special correlations in the measurement outcomes. (Received February 12, 2018)

1139-81-228 **Isaac Hyun Kim*** (isaac.kim.quantum@gmail.com), 382 Via Pueblo, Stanford, CA 94305.
Quantum Error Correction Dualities.

There are well-known equivalent conditions for quantum error correction. The equivalence can be viewed as a simple consequence of Sion's minimax theorem. Based on this observation, the quantum error correction conditions can be substantially generalized. I will discuss physical applications of these generalized conditions. (Received February 12, 2018)

1139-81-257 **Alastair Kay*** (alastair.kay@rhul.ac.uk). *Quantum cloning derived from Quantum walks.*

Discussions of continuous time quantum walks are often confined to considerations within the subspace of a single excitation, and concentrate on a single protocol: perfect state transfer. Here, we propose a new protocol, the generation of uniform superpositions, that could be useful as a standalone application in near-future quantum technologies. Moreover, we show that by extending beyond the single excitation subspace, this protocol can be used to great effect in simplifying other quantum protocols, such as optimal quantum cloning. (Received February 13, 2018)

1139-81-259 **Vu Hoang*** (duynguyenvu.hoang@utsa.edu), Department of Mathematics, University of Texas at San Antonio, One UTSA Circle, San Antonio, TX 78249. *Quantitative bounds versus weakly coupled states for some pseudorelativistic operators.*

In this talk I consider various quantum mechanical operators having the form (kinetic energy)+(potential energy). Having applications in solid state and relativistic physics in mind, the kinetic energy term is more general than usually assumed. I present a condition on the kinetic energy that guarantees the existence of bound states for arbitrarily weak attractive potentials. If the condition fails, weakly coupled bound states do not exist and we have a quantitative bound on the number of eigenvalues below the essential spectrum. I will present some applications to pseudorelativistic one-body and two-body operators. This is joint work with D. Hundertmark, J. Richter and S. Vugalter. (Received February 13, 2018)

1139-81-307 **Chris Chubb** and **Steven Flammia***, steven.flammia@sydney.edu.au. *Stat mech models for any stabilizer code and Pauli channel.* Preliminary report.

We give a broad generalization of the mapping, originally due to Dennis, Kitaev, Landahl and Preskill, between certain statistical mechanical models and quantum error correcting codes. We show how the mapping can be applied to arbitrary stabilizer or subsystem codes and for arbitrarily correlated Pauli noise models, including models of fault tolerance. When the code is topological and the noise correlations are local in space-time, the critical point in the stat mech model coincides with the threshold. Therefore any existing method (e.g. Monte Carlo) for finding phase transitions in stat mech models can be applied to find the threshold of any such code without having to compute the optimal decoding. Simultaneously, we show that this mapping also gives a general recipe for speeding up the optimal decoder by generalizing the tensor network approach of Bravyi, Suchara and Vargo. For $N = L^D$ qubits and T rounds of syndrome measurement, the optimal decoding can be computed in time $\exp\bigl[O(NT/X)\bigr]$, where $X = \max\{L, T\}$. Moreover, any efficient strategy for contracting tensor networks leads to an approximation of the optimal decoder that runs in polynomial time. (Received February 14, 2018)

1139-81-312 **Mark M. Wilde*** (mwilde@lsu.edu), 202 Nicholson Hall, Tower Drive, Baton Rouge, LA 70803. *Optimized quantum f-divergences and data processing.*

The quantum relative entropy is a measure of the distinguishability of two quantum states, and it is a unifying concept in quantum information theory: many information measures such as entropy, conditional entropy, mutual information, and entanglement measures can be realized from it. As such, there has been broad interest in generalizing the notion to further understand its most basic properties, one of which is the data processing inequality. The quantum f-divergence of Petz is one generalization of the quantum relative entropy, and it also leads to other relative entropies, such as the Petz–Rényi relative entropies. In this talk, I introduce the optimized quantum f-divergence as a related generalization of quantum relative entropy. I prove that it satisfies the data processing inequality, and the method of proof relies upon the operator Jensen inequality, similar to Petz's original approach. Interestingly, the sandwiched Rényi relative entropies are particular examples of the optimized f-divergence. Thus, one benefit of this result is that there is now a single, unified approach for establishing the data processing inequality for both the Petz–Rényi and sandwiched Rényi relative entropies, for the full range of parameters for which it is known to hold. (Received February 15, 2018)

1139-81-333 **Michael Nathanson*** (man6@stmarys-ca.edu). *Local state discrimination and transformation in multipartite systems.*

It is well-known that some sets of orthogonal multipartite quantum states cannot be perfectly distinguished using only local operations and classical communication (LOCC). This challenge can sometimes be overcome in the presence of additional shared entanglement. For instance, any maximally-entangled bipartite resource state enables quantum teleportation, which in turn allows any complete global measurement to be implemented.

We show an equivalence between the problems of local state discrimination and local state transformation; and demonstrate connections to algebraic structures used to understand multipartite entanglement. The result is a strong necessary condition for an entangled resource state to allow perfect state discrimination. This is based on recent papers with Bandyopadhyay and Halder. (Received February 15, 2018)

1139-81-368 **Kristan Temme***, 1101 Kitchawan Rd, Yorktown Heights, NY 10598, and **Sergey Bravyi** and **Jay M Gambetta**. *Simple tricks to squeeze more out of your noisy quantum device.*

Near-term applications of early quantum devices, such as quantum simulations, rely on accurate estimates of expectation values to become relevant. Decoherence and gate errors lead to wrong estimates of the expectation values of observables used to evaluate the noisy circuit. This problem has been, at least in theory, remedied with the advent of quantum error correction. However, the overhead that is needed to implement a fully fault-tolerant gate set with current codes and current devices seems prohibitively large. In turn, steady progress is made in improving the quality of the quantum hardware. This leads to the question: what computational tasks could be accomplished with only limited, or no error correction? We introduce two simple techniques for quantum error mitigation that increase the quality of short-depth quantum simulations. The first method, extrapolation to the zero noise limit, subsequently cancels powers of the noise perturbations by an application of Richardson's deferred approach to the limit. The second method cancels errors by resampling randomized circuits according to a quasi-probability distribution. The two schemes are presented and we will discuss their application to current experiments. (Received February 16, 2018)

1139-81-369 **Mary Beth Ruskai*** (ruskai@member.ams.org), 710 Wake Robin Dr., Shelburne, VT 05482. *Using local additivity to find examples of superadditivity of classical capacity of qubit channels.* Preliminary report.

The local additivity of minimal output entropy can be extended to local additivity of maximal relative entropy with respect to a fixed reference state. This can be exploited to test channels for superadditivity of Holevo capacity with numerical effort comparable to searching for the minimal output entropy. Local maxima which do not arise from product inputs play a key role. Moreover, evidence of superadditivity can be found even if the additivity violation itself is too small to be seen numerically.

A program for conducting such a search using 3-state qubit channels will be described. (Received February 16, 2018)

1139-81-375 **Sergey Bravyi*** (sbravyi@us.ibm.com), IBM Watson Research Center, Yorktown Heights, NY , and **David Gosset**. *Polynomial-time classical simulation of quantum ferromagnets.*

We consider a family of quantum spin systems which includes as special cases the ferromagnetic XY model and ferromagnetic Ising model on any graph, with or without a transverse magnetic field. We prove that the partition function of any model in this family can be efficiently approximated to a given relative error E using a classical randomized algorithm with runtime polynomial in 1/E, system size, and inverse temperature. As a consequence we obtain a polynomial time algorithm which approximates the free energy or ground energy to a given additive error. We first show how to approximate the partition function by the perfect matching sum of a finite graph with positive edge weights. Although the perfect matching sum is not known to be efficiently approximable in general, the graphs obtained by our method have a special structure which facilitates efficient approximation via a randomized algorithm due to Jerrum and Sinclair. (Received February 16, 2018)

1139-81-426 **James D Whitfield***, Dartmouth College, 6127 Wilder Laboratory, Hanover, NH 03755, and **Sahil Gulania**, University of Southern California. *Exploiting wave function symmetries in quantum simulation.* Preliminary report.

In order to advance the state of the art in quantum simulation, we must update standard approaches in electronic structure. Our particular interest here is exploiting symmetry of the wave function including both point group symmetries and space-spin symmetries. In our previous work, we analyzed how to project first and second quantizated wave functions into particular irreducible representation of the symmetry group being exploited. Presently, we return to this effort to consider how to construct the Hamiltonian within a single irreducible representation. The recent efforts of several other research teams help inform our research. However, their works have focused on specific aspects whereas we will build a general mathematical framework based on projection operators. The ultimate goal is creating black box quantum simulations by constructing the Hamiltonian only within a single irreducible representation and we will report on our recent progress in this direction. (Received February 18, 2018)

1139-81-434 **Ramis Movassagh*** (ramis@us.ibm.com), IBM Research (second floor), 75 Binney Street, Cambridge, MA 02142. *Applications of Free Probability Theory to Quantum Many-Body Systems.*

Suppose the eigenvalue distributions of two matrices M_1 and M_2 are known. What is the eigenvalue distribution of the sum $M_1 + M_2$? 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 examples of its powers for the qualitative understanding (often approximations) of physical quantities such as density of states, and gapped vs. gapless phases of quantum matter. 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. (Received February 18, 2018)

1139-81-475 **Christopher M van Bommel*** (cvanbomm@uwaterloo.ca). *Pretty Good State Transfer on Paths.*

We consider pretty good state transfer on a uniformly coupled chain of n particles with XY Hamiltonian, or equivalently, on an unweighted path of n vertices with respect to the adjacency matrix. It was previously observed that if pretty good state transfer occurrs between the end vertices of a path, then it occurrs between pairs of internal vertices if the two vertices are equidistant from the centre. However, it was not known if pretty good state transfer could occur between internal vertices without occurring between the end vertices. We determine an infinite family of paths where this occurs, and show it is the only such family, completely characterizing pretty good state transfer on paths. Includes joint work with Gabriel Coutinho and Krystal Guo. (Received February 19, 2018)

1139-81-502 **Fernando Brandao*** (fbrandao@caltech.edu), 423 S Oak Ave, Pasadena, CA 91107. *Localizable Mutual Information: Tensor Networks meets Dynamical Systems.*

In the talk I will discuss the problem of correlating two separated regions in a multipartite quantum state by making measurements in the region connecting the two. For pure states the concept of localizable entanglement describes this process. We will consider the problem for mixed states described by tensor networks, specifically matrix product density operators (MPDO). We define the "localizable mutual information" as the maximum mutual information attainable between two far-away regions by making measurements on the middle region connecting them.

The main result is a complete characterization of MPDOs with a diverging localizable mutual information length (meaning arbitrarily far apart systems can be made correlated by measuring the middle region). One considers a linear cocycle of a dynamical system given by the matrices defining the MPDO and their associated Lyapunov exponents. Then the localizable mutual information diverges if, and only if, the top Lyapunov exponent is unique.

Finally, we will connect the result with some challenging open questions in quantum many-body theory: finding a parent Hamiltonian for MPDOs and proving that the topological entanglement entropy truly signals topological order (i.e. that it is invariant under short-depth quantum circuits). (Received February 19, 2018)

1139-81-536 **Aram W. Harrow** and **Saeed Mehraban*** (mehraban@mit.edu), 32 Vassar Street, 32-G636, Cambridge, MA 02139. *Approximate unitary t-designs by short random quantum circuits using nearest-neighbor and long-range gates.*

We prove that poly$(t) \cdot n^{1/D}$-depth local random quantum circuits with two qudit nearest-neighbor gates on a D-dimensional lattice composed of n qudits are approximate t-designs in various measures. Previously, the best bound was poly(t) $\cdot\, n$ due to Brandão-Harrow-Horodecki (BHH)(arXiv: 1208.0692) for $D = 1$ and it was not known how to improve this to take advantage of better connectivity when $D > 1$. One consequence of our result is to confirm the conjecture of the Google Quantum AI group which asserts that $O(\sqrt{n})$-depth random circuits on n qubits laid out in a 2-D lattice have output which is "anti-concentrated", meaning roughly that its entropy is near maximal. Along with some conjectures in complexity theory, this would imply that the output of such circuits is hard to sample from classically. The proof is based on a previous construction of t-designs by BHH, an analysis of how approximate designs behave under composition, and an extension of the quasi-orthogonality of permutation operators developed by BHH. For random circuits with long-range gates, we use different methods to show that anti-concentration, and thus hardness of simulation happens at size $O(n \ln n)$. (Received February 19, 2018)

1139-81-592 **Shalev Ben-David*** (shalev@umd.edu), **Adam Bouland**, **Ankit Garg** and **Robin Kothari**. *Classical Lower Bounds from Quantum Upper Bounds.* Preliminary report.

We prove lower bounds on classical measures, such as the approximate degree of a Boolean function and the approximate rank of a Boolean matrix, using quantum arguments. We prove that these lower bounds using a quantum query algorithm for the combinatorial group testing problem.

We show that for any function f, the approximate degree of computing the OR of n copies of f is $\Theta(\sqrt{n})$ times the approximate degree of f. No such general result was known prior to our work, and even the lower bound for the OR of ANDs function was only resolved in 2013.

We then prove an analogous result in communication complexity, showing that the logarithm of the approximate rank (or more precisely, the approximate γ_2 norm) of $F : X \times Y \to \{0,1\}$ grows by a factor of $\tilde{\Theta}(\sqrt{n})$ when we take the OR of n copies of F. As a corollary, we give a new proof of Razborov's celebrated $\Omega(\sqrt{n})$ lower bound on the quantum communication complexity of the disjointness problem. (Received February 20, 2018)

1139-81-628 **John B. DeBrota*** (john.debrota001@umb.edu), **Christopher A. Fuchs** and **Blake C. Stacey**. *Symmetric Informationally Complete Measurements Identify the Essential Difference between Classical and Quantum.*

In this talk we describe a general procedure for associating a minimal informationally-complete quantum measurement (or MIC) and a set of post-measurement states with a probabilistic representation of quantum theory. Towards this, we make use of the idea that the Born Rule is a consistency criterion among subjectively assigned probabilities rather than a tool to *set* purely physically mandated probabilities. In our setting, the difference between quantum theory and classical statistical physics is the way their physical assumptions augment bare probability theory: Classical statistical physics corresponds to a trivial augmentation, while quantum theory makes crucial use of the Born Rule. We prove that the representation of the Born Rule obtained from a *symmetric* informationally-complete measurement (or SIC) minimizes the distinction between the two theories in at least two senses, one functional, the other geometric. Our results suggest that this representation supplies a natural vantage point from which to identify their essential differences, and, perhaps thereby, a set of physical postulates reflecting the quantum nature of the world. (Received February 20, 2018)

1139-81-701 **Jon Yard*** (jyard@uwaterloo.ca). *On the existence of symmetric quantum measurements.*

Optimal symmetric quantum measurements, known as SIC-POVMs (Symmetric Informationally Complete Positive Operator-Valued Measures), are currently proved to exist in only finitely many dimensions as orbits of finite Heisenberg groups. Surprisingly, these examples are always defined over explicit class fields of certain real quadratic fields. They possess combined Galois and generalized Clifford symmetries which, when better understood, may lead to a general existence proof in all dimensions. In this talk, I will discuss certain aspects of these symmetries in specific examples and in other prime dimensions. (Received February 21, 2018)

82 ► Statistical mechanics, structure of matter

1139-82-288 **Sylvia Serfaty***, serfaty@cims.nyu.edu. *LDP and CLT for Log and Coulomb Gases.*

We present a Large Deviation Principle for large systems of particles with logarithmic interactions in 1D and 2D, or more general inverse power (= Riesz) interactions, including Coulomb interactions. The LDP lies at next to leading order and is expressed in terms of the microscopic point processes or "empirical fields". In the case of the 1D and 2D logarithmic interactions, we also present a Central Limit Theorem for the fluctuations from the macroscopic distribution. All the results are valid for arbitrary values of the inverse temperature, and fairly general confining potentials. This is based on joint work with Thomas Leblé, and Florent Bekerman and Thomas Leblé. (Received February 14, 2018)

83 ► Relativity and gravitational theory

1139-83-28 **Sophia Jahns***, Mathematisches Institut, Auf der Morgenstelle 10, 72076 Tübingen, Germany. *Geometry and topology of the Kerr photon region in phase space.*

Light can circle a massive object (like a black hole or a neutron star) at a "fixed distance", or, more generally, circle the object without falling in or escaping to infinity. This phenomenon is called trapping of light and geometrically well-understood in static, asymptotically flat spacetimes. If we drop the requirement of staticity, similar behavior of light is known, but the set of trapped lightrays in the physical spacetime does not exhibit nice geometric properties. We therefore identify the set of trapped lightrays of any stationary spacetime as a subset of the (co-)tangent bundle and show that for the case of the subcritical ($\|a\| < M$) Kerr spacetime this set is a smooth 5-dimensional submanifold of the (co-)tangent bundle. We then characterize its topology as $\mathbb{S}^2 \times \mathbb{S}^1 \times \mathbb{R}^2$, using methods from algebraic topology. This is joint work with C. Cederbaum. (Received January 09, 2018)

1139-83-101 **P. P. Yu***, 501 Westminster Ave., Fulton, MO 65251. *Symplectic induction for the linking theory of shape dynamics.*

Largely motivated by the relational philosophy, a modification to classical canonical gravity known as shape dynamics has been recently developed by physicists with an eye towards quantization. Both Einstein's general relativity and shape dynamics appear as different gauge-fixings of the so-called linking theory. In this talk, symplectic induction is applied to give a natural geometric construction of the linking theory for shape dynamics. The extended phase space with the extended symmetry group $\mathbf{P}$ of point-wise conformal transformations on the space $\mathbf{M}$ of Riemannian metrics is shown to be a trivial vector bundle over the original phase space $T^*\mathbf{M}$ in general relativity. The gauge fixing conditions for shape dynamics are analyzed with the assistance of the geometrization of the Lichnerowicz-York equation lifted to the extended phase space. An alternative description is provided to show that the same geometry simply derives from the symplectic construction. (Received February 03, 2018)

1139-83-124 **Annegret Y. Burtscher*** (annegret.burtscher@rutgers.edu). *Static perfect fluids in general relativity.*

For reasonable equations of state, non-rotating stellar models are necessarily spherically symmetric, and are solutions to the Tolman–Oppenheimer–Volkoff equation. While global existence, uniqueness and even smoothness of these solutions is known since 1991, very little is still known about the geometry of these fluid solutions. In general, it is even difficult to determine whether the fluid is confined to a bounded region (with vacuum exterior) or extends to infinity. We will see that the asymptotic behavior largely depends on the prescribed equation of state and central density. In particular, solutions with linear and certain polytropic equations of state do not have finite extend and are not even asymptotically flat. We introduce new tools to describe their global geometry. This is joint work with Lars Andersson. (Received February 05, 2018)

1139-83-128 **Federico Pasqualotto***, fp2@princeton.edu. *Nonlinear stability for the Maxwell–Born–Infeld system on a Schwarzschild background.*

The Maxwell–Born–Infeld (MBI) theory is a hyperbolic system of PDEs which describes nonlinear electromagnetism. Due to its tensorial and quasilinear nature, this system can be seen as a nonlinear model problem to study the stability properties of solutions to the Einstein vacuum equations. In this talk, I will present a nonlinear stability result for the MBI system on a fixed Schwarzschild background, when the initial data are constrained to be small. A crucial element of the proof is the observation that some null components of the MBI field satisfy "good" Fackerell–Ipser equations, as in the linear Maxwell case. However, in the MBI case, these equations are coupled through cubic nonlinear right hand sides, which contain all components of the MBI field. In order to resolve the coupling, we prove high-order energy decay and, subsequently, pointwise decay for all the components of the MBI field. This is achieved through the application of several ideas developed in recent years, regarding the decay of linear fields. (Received February 05, 2018)

1139-83-159 **Jordan Keller*** (jordan_keller@fas.harvard.edu), **Mu-Tao Wang** and **Pei-Ken Hung**. *Linear Stability of Higher Dimensional Schwarzschild Black Holes.*

The Schwarzschild-Tangherlini black holes are higher-dimensional generalizations of the Schwarzschild spacetimes, comprising a static, spherically symmetric family of black hole solutions to higher-dimensional vacuum gravity. The physical relevance of such solutions is intimately related to their stability under gravitational perturbations. We present results on the linear stability of the Schwarzschild-Tangherlini black holes in dimensions four, five, and six, joint work with Pei-Ken Hung and Mu-Tao Wang. (Received February 07, 2018)

1139-83-196 **David Garfinkle*** (garfinkl@oakland.edu), Dept of Physics, Oakland University, Rochester, MI 48309. *Gravitational wave memory.*

Gravitational waves are detected by their stretching and squeezing of space. Even after the wave has passed, there is a residual stretch and squeeze, which is called gravitational wave memory. This talk will cover several aspects of memory including memory in the expanding universe, an electromagnetic analog of memory, simple models and simple estimates of memory, and gauge invariant treatment of memory. (Received February 10, 2018)

1139-83-262 **Erik Amorim*** (erik.amorim@math.rutgers.edu), Department of Mathematics, Rutgers University, Busch campus, Hill Center, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. *On the static spacetime of a point charge, assuming the Bopp-Lande-Thomas-Podolsky law of the electromagnetic vacuum.* Preliminary report.

The talk describes work in progress on the search for a static spacetime of a charged point particle whose electric field is coupled to spacetime structure via the energy-momentum-stress tensor of the Bopp-Lande-Thomas-Podolsky electromagnetic theory. Previous work by Cuzinatto et. al claims that the existence of an event horizon inevitably yields the Reissner-Weyl-Nordström spacetime. In our inquiry it is assumed that the singularity is naked, as is the case for the RWN solution of the conventional Einstein-Maxwell electromagnetism in which the mass and charge parameters have been chosen so as to correspond to the electron's properties. (Received February 19, 2018)

1139-83-309 **Shabnam Beheshti*** (s.beheshti@qmul.ac.uk), School of Mathematical Sciences, Queen Mary University of London, Mile End Road, London, E1 4NS, United Kingdom. *Viscous dynamics in cosmological fluids.* Preliminary report.

It is known that viscous effects lead to nontrivial dynamical behaviour in homogeneous cosmological models such as FLRW and Bianchi spacetimes. Recent progress in well-posedness of certain Einstein-Navier-Stokes systems motivates revisiting a model first proposed by Lichnerowicz in 1967. We investigate the role of dynamic velocity in a cosmological background, demonstrating that the additional degree of freedom afforded by the associated fluid index may play a geometric role in the evolution of the fluid. Open questions for the more general setting of conformal fluids are also discussed. (Received February 15, 2018)

1139-83-398 **Philippe G. LeFloch***, Laboratoire Jacques-Louis Lions, Centre National de la Recherche Scientifique, PARIS, France. *Nonlinear stability of self-gravitating massive fields.*

I will discuss the global evolution problem for self-gravitating massive matter in the context of Einstein's theory and, more generally, for the f(R)-modified theory of gravity. In collaboration with Yue Ma (Xi'an Jiaotong), by analyzing the Einstein equations in wave gauge coupled to Klein-Gordon equations, I have established that Minkowski spacetime is globally nonlinearly stable in presence of massive fields. This extends a fundamental work by Christodoulou and Klainerman in 1993, later revised by Lindblad and Rodnianski, who were concerned with the stability of vacuum spacetimes and massless fields. Blog address: http://philippelefloch.org (Received February 17, 2018)

1139-83-483 **Lydia R. Bieri*** (lbieri@umich.edu), University of Michigan, Department of Mathematics, Ann Arbor, MI 48109, and **David Garfinkle** and **Nicolas Yunes**. *Gravitational wave memory in LambdaCDM cosmology.*

Some of the most interesting solutions of the Einstein equations are spacetimes exhibiting gravitational radiation. A major breakthrough of General Relativity happened in 2015 with LIGO's first detection of gravitational waves. So far, most studies have been devoted to asymptotically flat systems, which applies perfectly to gravitational wave sources whose distance to the detector is small compared to the Hubble radius. However, some of the most powerful sources are at cosmological distances, and we have to study what happens in an expanding universe. In this talk, we investigate the geometric-analytic properties of various spacetimes with gravitational radiation, in particular of cosmological spacetimes. This is joint work with D. Garfinkle and N. Yunes. (Received February 19, 2018)

1139-83-658 **Moulik Kallupalam Balasubramanian*** (moulik@math.rutgers.edu), Rutgers University Mathematics Dept., Hill Center, Piscataway, NJ 08854. *General-relativistic hydrogenic atoms.* Preliminary report.

We identify the nucleus of a single-electron ion (hydrogenic atom) with the central singularity of a static, spherically symmetric electrovacuum spacetime. We consider spacetimes that are singular on a timelike line (representing the world line of the nucleus), every point of which is a conical singularity for the metric. One such spacetime is Hoffmann's, where the electromagnetic vacuum law is that of Born-Infeld. The single electron is treated as a test particle whose equation of motion is the one-body Dirac equation. We analyze the spectrum of the pertinent Hamiltonian and compare it to other models, such as the Dirac equation on Minkowski space with the Coulomb potential and the Dirac equation on naked Reissner-Nordstrom spacetime. (Received February 20, 2018)

90 ► Operations research, mathematical programming

1139-90-247 **David Simchi-Levi*** (dslevi@mit.edu), Professor of Engineering Systems, Institute for Data, Systems, and Society, 77 Massachusetts Avenue, Room E17-459 Cambrid, Cambridge, MA 02111, and **Will Ma**. *Online Resource Allocation with Applications to Revenue Management.*

Online resource allocation is a fundamental problem in OR and CS with applications such as offering products to customers, distributing jobs to candidates, assigning advertisers to ad slots, and matching drivers to passengers. These problems can be abstracted as follows: there are fixed resources, each of which can be sold at multiple known prices. These resources must be allocated on-the-fly, without assuming anything about future demand. In this talk we cover the CS and OR literature on the problem and in particular focus on two techniques: exploration and exploitation methods, as well as competitive analysis.

In the latter case, we review new algorithms that achieve tight competitive ratios under the integral or asymptotic settings. Our algorithms are simple, intuitive and robust and our competitive ratios are provably optimal, for every possible set of prices.

In the former case, we discuss an efficient and effective dynamic pricing algorithm, which builds upon the Thompson sampling algorithm used for multi-armed bandit problems by incorporating inventory constraints into the pricing decisions. The algorithm proves to have both strong theoretical performance guarantees as well as promising numerical performance results. (Received February 12, 2018)

1139-90-251 **Henry Lam*** (khl2114@columbia.edu), 500 W. 120th St., New York, NY 10027, and **Huajie Qian** (hq2157@columbia.edu), 500 W. 120th St., New York, NY 10027. *Parameter Calibration for Optimization under Uncertainty.*

Optimization formulations to handle decision-making under uncertainty often contain parameters needed to be calibrated from data. Examples include uncertainty set sizes in robust optimization, and Monte Carlo sample sizes in constraint sampling or scenario generation. We investigate strategies to select good parameter values based on data splitting and the validation of their performances in terms of feasibility and optimality. We analyze the effectiveness of these strategies in relation to the complexity of the optimization class and problem dimension. (Received February 12, 2018)

1139-90-266 **Jefferson Huang*** (jh2543@cornell.edu), School of ORIE, Cornell University, Ithaca, NY 14853. *Dynamic Scheduling and Maintenance of a Deteriorating Server.* Preliminary report.

Motivated by a quality control problem in semiconductor manufacturing, we consider a stochastic scheduling problem in the context of a multi-class queue with a single server whose service capacity deteriorates randomly over time. We show that the system may be unstable under a natural extension of the $c\mu$-rule, and provide a sufficient condition for this rule to be optimal. We also consider the problem of jointly deciding whether to perform service or preventive maintenance, for which we provide insights into the structure of optimal policies and heuristics. (Received February 13, 2018)

1139-90-304 **Eugene A Feinberg*** (eugene.feinberg@stonybrook.edu), Department of Applied Mathematics and Statist, Stony Brook University, Stony Brook, NY 11794-3600, **Pavlo O Kasyanov**, Institute for Applied System Analysis, National Technical University of Ukraine, "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine, and **Michael Z Zgurovsky**, National Technical University of Ukraine, "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine. *Continuity of solutions to minimax equations for decision making under uncertainty.*

This talk describes extensions of Berge's maximum theorem for possibly noncompact action sets and unbounded cost functions to minimax problems modeling decision making under uncertainty. The talk presents natural sufficient conditions for certain continuity properties of value functions and solution multifunctions. In particular, we introduce the notion of the A-lower semi-continuity of the multifunction that defines uncertainty sets. This notion is stronger than lower semi-continuity, but it coincides with lower semi-continuity in the following two classic cases: (i) the decision sets are defined by an upper semi-continuous compact-valued multifunction, and (ii) the uncertainty sets do not depend on actions of the decision maker. In general, A-lower semi-continuity of the multifunction, that defines uncertainty sets, cannot be relaxed to lower semi-continuity in the sufficient conditions for lower semi-continuity of the value function and for upper semi-continuity of the solution multifunction. (Received February 14, 2018)

1139-90-362 **Sanghamitra Dutta**, **Gauri Joshi**, **Soumyadip Ghosh*** (ghoshs@us.ibm.com), **Parijat Dube** and **Priya Nagpurkar**. *Slow and Stale Gradients Can Win the Race: Error-Runtime Trade-offs in Distributed SGD.*

Distributed Stochastic Gradient Descent (SGD) when run in a synchronous manner, suffers from delays in waiting for the slowest learners (stragglers). Asynchronous methods can alleviate stragglers, but cause gradient staleness that can adversely affect convergence. In this work we present the first theoretical characterization of the speed-up offered by asynchronous methods by analyzing the trade-off between the error in the trained model and the actual training runtime (wallclock time). The novelty in our work is that our runtime analysis considers random straggler delays, which helps us design and compare distributed SGD algorithms that strike a balance between stragglers and staleness. We also present a new convergence analysis of asynchronous SGD variants without bounded or exponential delay assumptions, and a novel learning rate schedule to compensate for gradient staleness. (Received February 16, 2018)

1139-90-634 **Fatma Selin Yanikara*** (yanikara@bu.edu), Boston, MA , and **Michael Caramanis** (mcaraman@bu.edu). *A Dynamic Programming Approach to Optimal Regulation Service Deployment of Electric Vehicles.*

Increasing penetration from volatile renewable energy resources impose reliability challenges on the power grid. Demand side resources such as flexible appliances and Electric Vehicles (EVs) carry significant potential in overcoming these challenges. Electric Vehicles can be put to dual use as distributed storage devices and participate in ancillary energy markets by offering regulation service reserves (RSR). As a part of RSR, EVs respond to grid signals broadcasted every 2-4 seconds and rapidly ramp up or down their consumption within a range defined by the real power and reserve quantities they bid in the day ahead market. However, keeping a certain level of signal tracking performance is required, which might be challenging due to battery storage and charging capacity constraints. Therefore, it is essential for an RSR participant to incorporate the cost associated with offering regulation service reserves in the decision of optimal market bid quantities. In this work, we apply a Dynamic Programming approach to identify the optimal regulation service deployment policy and estimate average signal tracking costs given the stochastic dynamics of the regulation signal. A novel approach is also applied to overcome the dimensionality and tractability issues of the Dynamic Program. (Received February 20, 2018)

1139-90-654 **Panagiotis Andrianesis*** (panosa@bu.edu), 15 Saint Mary's Street, Brookline, MA 02446, and **Ioannis Paschalidis**, **Michael Caramanis** and **Ruidi Chen**. *Data-driven marginal cost estimation in electricity markets using inverse optimization.*

In this work we consider the strategic bidding problem in the context of a day-ahead electricity market, where electricity suppliers submit linear non-decreasing supply functions for their as-bid marginal costs. Our aim is to infer the true cost parameters of these supply functions based on past observations of the market results, and some knowledge on the electricity generation unit technologies. We employ a data-driven estimation technique which combines inverse optimization with the theory of variational inequalities, and explore cases with the presence of noise in the data. (Received February 20, 2018)

1139-90-660 **Floske M. Spieksma*** (spieksma@math.leidenuniv.nl), Niels Bohrweg 1, 2311KL Leiden, Netherlands. *Monotonicity properties of the single server queue with abandonments and retrials by coupling.*

We study a single server queue with impatient customers that can retry, if they renege. Each customer has a static joining rule that determines whether the customer enters the system upon arrival. We are interested in the structural properties of the value function of the system, as a function of the joining rule. The derivation of structural properties cannot be done using standard mathematical tools, since the analysis is hindered due to the fact that the system is not uniformisable. We present a general coupling method that overcomes the limitations of standard techniques and allows for the derivation of structural properties.

This is joint work with Dwi Ertiningsih and Sandjai Bhulai. (Received February 20, 2018)

91 ► Game theory, economics, social and behavioral sciences

1139-91-204 **Feng Fu*** (fufeng@gmail.com) and **Xingru Chen**. *Evolutionary game theory with applications to public health problems.* Preliminary report.

Evolutionary game theory has become a general approach to studying a wide range of biological and social problems. In particular, it has proved useful in understanding human strategic behavior in social dilemma situations where people can cooperate for the common good. Notably, the tragedy of the commons can also arise as a result of free-riding in the important context of public health problems, such as vaccine compliance and antibiotics overuse. Understanding them through the lens of evolutionary game theory is a new promising direction. (Received February 10, 2018)

92 ► Biology and other natural sciences

1139-92-41 **Xiaolin Wang*** (xiaolinwang@seas.harvard.edu) and **Silas Alben**. *Dynamics and Locomotion of Flexible Foils in a Frictional Environment.*

Over the past few decades, oscillating flexible foils have been used to study the physics of organismal propulsion in different fluid environments. In this work, we extend this idea to a study of flexible foils in a frictional environment. This model can be applied to study the snake locomotion as well as other locomotor systems when the Coulomb friction is valid. When the foil is oscillated by heaving at one end but is not free to locomote, the dynamics change from periodic to non-periodic and chaotic as the heaving amplitude increases or the bending rigidity decreases. Resonant peaks are damped and shifted by friction and large heaving amplitudes, leading to bistable states. When the foil is free to locomote, the horizontal motion smoothes the resonant behaviours. For moderate frictional coefficients, steady but slow locomotion is obtained. For large transverse friction and small tangential friction corresponding to wheeled snake robots, faster locomotion is obtained. Travelling wave motions arise spontaneously, and scaling laws are obtained for the moving speed and input power. These scalings are consistent with a boundary layer form of the solutions near the foil's leading edge. (Received January 18, 2018)

1139-92-77 **Alex Kasman*** (kasmana@cofc.edu), 66 George Street, Department of Mathematics, Charleston, SC 29424. *On the Duplexing of DNA's Genetic and Geometric Codes.*

This talk will mathematically investigate the relationship between two naturally arising "codes". One is the famous genetic code which associates protein chains to DNA sequences. The other, in which the three-dimensional geometry of a DNA molecule is determined by its DNA sequence, was only discovered much more recently. Two different methods will be used to determine how well-duplexed these codes are with each other. (Received January 29, 2018)

1139-92-135 **Min Wu*** (mwu2@wpi.edu), Stratton Hall, 100 Institute Rd, Worcester, MA 01609, and **Madhav Mani**. *A mechanism for the proliferative control of tissue mechanics in the absence of growth.*

During the development of a multicellular organism, cells coordinate their activities to generate mechanical forces, which in turn drive tissue deformation and eventually define the shape of the adult tissue. Broadly speaking, it is recognized that mechanical forces can be generated through differential growth and the activity of the cytoskeleton. Based on quantitative analyses of live imaging of the Drosophila dorsal thorax, we suggest a novel mechanism that can generate contractile forces within the plane of an epithelia - via cell proliferation in the absence of growth. Utilizing force inference techniques, we demonstrate that it is not the gradient of junction tension but the divergence of junction-tension associated stresses that induces the area constriction of the proliferating tissue. Using the vertex model simulations, we show that the local averaged stresses can be roughly elevated by a fold of mechanism is robust to disordered cell shapes and the division anisotropy, but can be dominated by growth. In competition with growth, we identify the parameter regime where this mechanism is effective and suggest experiments to test this new mechanism. (Received February 05, 2018)

1139-92-173 **Erica Flapan*** (eflapan@pomona.edu), **Adam He** and **Helen Wong**. *A new model of protein knot folding.* Preliminary report.

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 describe a new model of knot folding that could explain the formation of all currently known protein knot types and predict knot types that might be identified in the future. Our model is motivated by computer simulations of Virnau and coworkers for the $+6_1$-knotted DehI protein which implicate a loop flipping mechanism that results in the simultaneous threading of two loops. We analyze fingerprint data from crystal structures of protein knots as evidence that particular protein knots fold according to specific configurations from our model. (Received February 08, 2018)

1139-92-179 **Jose N Onuchic*** (jonuchic@rice.edu), Center for Theoretical Biological Physics, Department of Physics and Astronomy, Rice University, 6100 Main Street- MS-61, Houston, TX 77005-182. *A Predictive Model for Chromatin Folding.*

In vivo, the human genome folds into a characteristic ensemble of 3D structures. The mechanism driving the folding process remains unknown. A theoretical model for chromatin (minimal chromatin model) that explains the folding of interphase chromosomes and generates chromosome conformations consistent with experimental data will be presented. The energy landscape of the model was derived by using the maximum entropy principle and relies on two experimentally derived inputs: a classification of loci into chromatin types and a catalog of the positions of chromatin loops. First, we trained our energy function using the Hi-C contact map of chromosome 10 from human GM12878 lymphoblastoid cells. Then, we used the model to perform molecular dynamics simulations producing an ensemble of 3D structures for all GM12878 autosomes. Finally, we used these 3D structures to generate contact maps. We found that simulated contact maps closely agree with experimental results for all GM12878 autosomes. The ensemble of structures exhibited unknotted chromosomes, phase separation of chromatin types, and a tendency for open chromatin to lie at the periphery of chromosome territories. Finally we discuss how to extract the chromatin types from ChIP-Seq information.

* Supported by the NSF (Received February 08, 2018)

1139-92-209 **Andrea Arnold*** (anarnold@wpi.edu). *Time-Varying Parameter Estimation for Biological Systems.*

Many applications in the life sciences involve unknown system parameters that must be estimated using little to no prior information. In addition, these parameters may be time-varying and possibly subject to structural characteristics such as periodicity. We show how nonlinear Bayesian filtering techniques can be employed to estimate time-varying parameters, while naturally providing a measure of uncertainty in the estimation. Results are demonstrated using data from several biological applications. (Received February 11, 2018)

1139-92-217 **Eduardo D Sontag*** (eduardo.sontag@gmail.com), 360 Huntington Ave, Boston, MA 02115. *Detection of exponential rate of growth of antigen challenges by incoherent feedforward loops, and implications for immune/tumor modeling.*

Since the early 1990s, many authors have independently suggested that self/nonself recognition by the immune system might be modulated by the rates of change of antigen challenges. This talk discusses an extremely simple and purely conceptual mathematical model that allows dynamic discrimination of immune challenges. The main component of the model is a motif which is ubiquitous in systems biology, the incoherent feedforward loop, which endows the system with the capability to estimate exponential growth exponents, a prediction which is consistent with experimental work showing that exponentially increasing antigen stimulation is a determinant of immune reactivity. Combined with a bistable system and a simple feedback repression mechanism, an interesting phenomenon emerges as a tumor growth rate increases: elimination, tolerance (tumor growth), again elimination, and finally a second zone of tolerance (tumor escape). This prediction from our model is analogous to the "two-zone tumor tolerance" phenomenon experimentally validated since the mid 1970s. Moreover, we provide a plausible biological instantiation of our circuit using combinations of regulatory and effector T cells. (Received February 11, 2018)

1139-92-286 **Patricia FN Faisca*** (pffaisca@fc.ul.pt), Department of Physics, BioISI Institute, Campo Grande Ed. C8, Lisboa, Portugal, **Miguel A Soler**, Scuola Internazionale Superiore di Studi, Avanzati, Trieste, Italy, and **Antonio Rey**, Facultad de Ciencias Químicas, Departamento de Química Física I, Madrid, Spain. *Effects of steric confinement in the folding of knotted proteins.*

The chaperonin complex GroEL–GroES is able to accelerate the folding process of knotted proteins considerably. However, the folding mechanism inside the chaperonin cage is elusive. We used a combination of lattice and off-lattice Monte Carlo simulations of simple Gō models to study the effect of physical confinement and local flexibility on the folding process of protein model systems embedding a trefoil knot in their native structure. This study predicts that steric confinement plays a specific role in the folding of knotted proteins by increasing the knotting probability for very high degrees of confinement. This effect is observed for protein MJ0366 even above the melting temperature for confinement sizes compatible with the size of the GroEL/GroES chaperonin cage. An enhanced local flexibility produces the same qualitative effects on the folding process. In particular, we observe that knotting probability increases up to 40% in the transition state of protein MJ0366 when flexibility is enhanced. This is underlined by a structural change in the transition state, which becomes devoid of helical content. No relation between the knotting mechanism and flexibility was found in the context of the off-lattice model adopted in this work. (Received February 14, 2018)

1139-92-293 **Samuel A Isaacson***, Department of Mathematics and Statistics, 111 Cummington Mall, Boston, MA 02215. *Bimolecular reactions in the cell membrane exhibit switch-like behavior with respect to diffusivity and molecular reach.*

Many T cell receptors have long, unstructured cytoplasmic tails that contain tyrosine sites. These sites can serve as regulators of receptor activation when phosphorylated or dephosphorylated, while also serving as docking sites for cytosolic enzymes. We develop a particle-based stochastic reaction-diffusion model to study the combined diffusion of individual receptors within the cell membrane, and chemical reactions between proteins bound to receptor tails. The model suggests a switch-like behavior in the dependence of the fraction of activated receptors on both receptor diffusivity, and on the molecular reach at which two receptor tails can interact. A simplified, analytically solvable model is developed to approximate the more complicated multi-particle system, and used to illustrate how the switch-like behavior appears. (Received February 14, 2018)

1139-92-324 **Peter R Kramer*** (kramep@rpi.edu), Dept Mathematical Sciences, 110 8th Street, Rensselaer Polytechnic Institute, Troy, NY 12180, and **Abhishek Choudhary** and **Joe Klobusicky**. *Stochastic Spatial Models for Molecular Motors on Parallel Microtubule Networks.* Preliminary report.

Switched drift-diffusion models will be presented for the dynamics of a system of a cargo particle with one or two cooperative molecular motors attaching and detaching from a parallel network of microtubules. The dynamical equations include stochastic fluctuations in the spatial configuration of the motors and cargo, which affect the attachment and detachment processes. Models are developed and analyzed, neglecting steric effects, for both the case of closely spaced microtubules and widely spaced microtubules, with the latter involving a small target first passage time calculation for the effective attachment rate. These models relate parameters and functions governing the motor-cargo dynamics and the microtubule geometry to the effective transport rate of the cargo along the microtubule. (Received February 15, 2018)

1139-92-332 **Nessy Tania*** (ntania@smith.edu), 44 College Lane, Clark Science Center, Smith College, Northampton, MA 01063. *Mathematical Modeling and Analyses of Interspike-Intervals of Spontaneous Activity in Afferent Neurons of the Zebrafish Lateral Line.*

Without stimuli, hair cells spontaneously release neurotransmitter leading to spontaneous generation of action potentials (spikes) in innervating afferent neurons. We will discuss properties of the distribution of interspike-intervals (ISI) from spontaneous spiking data recorded from the lateral line of zebrafish. Additionally, successive ISIs in the lateral line recordings tended to have positive serial correlation, i.e., successive ISI pairs were either short/short or long/long. This pattern contrasts previous findings from the auditory system where ISIs tended to have negative serial correlation due to the effects of synaptic depletion. Overall, our analyses provide evidence of how physiological similarities and differences between synapses and innervation patterns in the auditory, vestibular, and lateral line systems can lead to variations in spontaneous activity. This work is jointly pursued with Josef Trapani (Amherst College, Biological Sciences) and the following undergraduate students: Sangmin Song, Ji Ah Lee, Varun Iyengar and Ilya Kiselev. (Received February 15, 2018)

1139-92-344 **Fabrizio Benedetti**, **Dusan Racko**, **Julien Dorier**, **Dimos Goundaroulis** and **Andrzej Stasiak***, Center for Integrative Genomics, University of Lausanne, Lausanne, Switzerland. *Mechanisms of chromatin unknotting.*

Chromosomes undergo repeated structural transitions between highly compact form during cell divisions and a decondensed form during interphase i.e. between cell divisions. During interphase genes are expressed and DNA is replicated. Studies of the scaling behaviour of chromatin fibres concluded that interphase chromosomes are not at topological equilibrium and thus are unknotted (1). This contrasts with the natural expectation that long and crowded chromatin fibres should reach highly knotted state in the presence of DNA topoisomerases permitting DNA-DNA passages. One of possible explanations for the paucity of chromatin knots is that regular chromatin fibres may not permit topoisomerase-mediated passages (2). It is also possible that chromatin knots do form (3), but are actively removed by specialized biological mechanisms. Our Brownian dynamics simulations show that chromatin loop extrusion, known to be involved in organizing interphase chromosomes (4), provides very efficient mean of chromatin unknotting. 1. E. Lieberman-Aiden et al., Science 326, 289-293 (2009). 2. J. Dorier, A. Stasiak, Nucleic acids research 37, 6316-6322 (2009). 3. J. T. Siebert et al., Polymers 9, 317 (2017). 4. A. L. Sanborn et al., Proc Natl Acad Sci U S A 112, E6456-6465 (2015). (Received February 16, 2018)

1139-92-465 **Tetsuo Deguchi*** (deguchi@phys.ocha.ac.jp), Ochanomizu University, 2-1-1 Ohtsuka, Bunkyo-ku, Tokyo, 112-8610, and **Erica Uehara**, Ochanomizu University, 2-1-1 Ohtsuka, Bunkyo-ku, Tokyo, 112-8610. *Knotting probability of self-avoiding polygons under a topological constraint: A sum rule derived from the factorization property.*

We define the knotting probability of a knot K by the probability for a random polygon (RP) or self-avoiding polygon (SAP) of N segments having the knot type K. We investigate it for the SAP consisting of hard cylindrical segments of unit length and radius r_{ex}. Here we remark that the cylindrical SAP gives a model of circular DNA which are negatively charged and semiflexible, where radius r_{ex} corresponds to the screening length. For various prime and composite knots we numerically show that a compact formula describes the knotting probabilities for the cylindrical SAP as a function of segment number N and radius r_{ex}.

From the factorization property of the knotting probability we derive a sum rule among the estimates of a fitting parameter, which we call the knot coefficient, for all prime knots, which suggests the local knot picture and the dominance of the trefoil knot in the case of large excluded volume.

[1] E. Uehara and T. Deguchi, Knotting probability of self-avoiding polygons under a topological constraint, J. Chem. Phys. Vol. 147, 094901 (2017) (Received February 18, 2018)

1139-92-477 **Diana Hubbard*** (dianahub@umich.edu) and **Jordan Katz**. *A characterization of the products arising from site-specific recombination on certain DNA substrates.*

Following work of Buck, Flapan, Wong, and others, we model circular DNA (arising naturally in bacteria and mitochondria) as a topological knot in order to classify the possible products that can arise from site-specific recombination on substrates of a certain form. In particular, we show that all products of site-specific recombination on substrates of the topological form T(2,n)#C(2,r) (a connected sum of torus knots and twist knots) are contained in one of two families. (Received February 19, 2018)

1139-92-489 **Dorothy Buck** and **Danielle O'Donnol*** (odonnol@indiana.edu). *Unknotting θ-curves and DNA replication.*

Replication is when a single DNA molecule is reproduced to form two new identical DNA molecules. In the middle of replication a more complex structure is formed. When a circular piece of DNA is replicated the intermediate structure is that of a θ-graph. A θ-graph has two vertices and three edges between them. I study embedded graphs and graph embeddings. This talk will focus on my work on unknotting numbers of θ-graphs and understanding DNA replication. (Received February 19, 2018)

1139-92-508 **Adam Y He*** (ayh8@cornell.edu) and **Erica L Flapan**. *A topological model of lasso proteins.*

The presence of topologically complex structures such as knots and links in proteins has received significant attention from both theoreticians and experimentalists. In this talk, we focus on lasso proteins, a more recently discovered class of proteins that have not been very well characterized from a topological perspective. These proteins consist of a closed loop pierced by some number of chain termini. This geometric complexity is believed to influence their stability and play a role in their physiological functions. We propose a topological model of these proteins that allow us to treat lassos like other topologically complex proteins. We then show that our model allows us to distinguish between known lasso structures. (Received February 19, 2018)

1139-92-509 **Keith Alexander*** (keith.alexander@bristol.ac.uk), **Alexander J. Taylor** and **Mark R. Dennis**. *Using virtual knots to identify ambiguously knotted conformations of proteins and open random walks.*

While the topology of protein backbones and other linear polymers is strictly trivial, they can bear a conformational similarity to closed knotted structures. This self-entangled geometry can have an important effect on protein function, making open knot identification important. An effective approach to this problem is to close the chain e.g. with lines to a distant point. By choosing many different closure points uniformly distributed around the chain, the most common knot type is found and taken as representative of the knotting of the curve [1]. We proposed an alternative knot recognition scheme called virtual closure which takes projections from uniform directions, joining the ends by virtual crossings to form virtual knots [2]. This extended category of knots captures projections in between classical knot types. Using this technique, we have surveyed knotting of proteins and identified a set of weakly knotted proteins previously not recognised [3]. We also present explorations of knotting in confined random walk models of polymers, using virtual closure to quantify the ambiguity of knotting in various conditions.

1. M Jamroz, et al, Nuc. Acids Res. 43, D306 (2014)
2. LH Kauffman, European J. of Combin. 20, 663 (1999)
3. K Alexander, et al, Sci. Rep. 7, 42300 (2017) (Received February 19, 2018)

1139-92-529 **Javier Arsuaga*** (jarsuaga@ucdavis.edu), 1 Shields Avenue, Davis, CA 95616. *Chromosome conformation capture data suggests that the Rabl conformation reduces the topological complexity of the yeast genome.*

Genomes are highly condensed in all organisms. Theoretical studies suggest that condensation induces topological complexity in the form of knotting and linking. How organisms prevent excess knotting and linking so their genomes are fully functional remains to be determined. In this talk we use Chromosome Conformation Capture (CCC) Data and statistical topology to show that the Rabl conformation, an organizational feature conserved through evolution, plays a key role in the topological simplification of the yeast genome during the early phases of the cell cycle. (Received February 19, 2018)

1139-92-535 **Chris Soteros***, 106 Wiggins Road, Saskatoon, SK S7N 5E6, Canada. *Knot and link statistics for lattice models of biopolymers in tubes and nanochannels.* Preliminary report.

Motivated in part by experimental studies of DNA in viral capsids or in nanochannels, there is interest in understanding and characterizing the entanglement complexity of confined polymers. For this, we have been studying systems of self-avoiding polygons in lattice tubes using transfer-matrix methods and Monte Carlo computer simulations. In this talk I will review results on knotting statistics as a function of polygon length and tube size as well as recent results about the likelihood of "non-local" knotted patterns in tubes versus "local" knotted patterns. I will also discuss preliminary exact transfer matrix and Monte Carlo results about linking probabilities. (Received February 19, 2018)

1139-92-543 **Jonathan M. Fogg**, Houston, TX 77030, **Qian Wang**, Galveston, TX, **Rossitza N. Irobalieva**, Houston, TX 77030, **Muyuan Chen**, Houston, TX 77030, **Steven J. Ludtke**, Houston, TX 77030, and **Sarah A. Harris** and **Wah Chiu**, Houston, TX 77030, and **B. Montgomery Pettitt** and **E. Lynn Zechiedrich*** (elz@bcm.edu), One Baylor Plaza, Mail-Stop: BCM-280, Baylor College of Medicine, Houston, TX 77030. *Beyond the static DNA models of Watson and Crick.*

Despite its importance, much about supercoiled DNA (positively supercoiled DNA, in particular) remains unknown. We utilized electron cryo-tomography to investigate the 3D structures of individual 336 bp (32 exact turns of the helix) DNA minicircles with defined supercoiling. Minicircles in each supercoiling state adopt a unique and wide distribution of 3D conformations (Irobalieva 2015 Nat Comm 6, 8440). Increased mono- or divalent cations increased minicircle compaction, and thus mobility, of (-) supercoiled minicircles but had no effect on (+) supercoiled topoisomers. Assays revealed increased exposed DNA bases with increased (-) supercoiling. Our data support the "cooperative kinking model" of Lionberger 2011 Nuc Acids Res 39, 9820), in which an apical bend on one side of the supercoiled minicircle renders a site 180 degrees away susceptible to nuclease. Modeling these bending sites, we simulated minicircles with new supercoiling-dependent shapes (Wang 2017 Nuc Acids Res 45, 7633). Beyond a sharp supercoiling threshold, we detected exposed bases in (+) supercoiled DNA. These experiments reveal unexpected and dynamic supercoiling-dependent structural alterations in DNA and represent a step toward creating designer gene therapy vectors for use in treating human diseases. (Received February 19, 2018)

1139-92-560 **Jared O Barber*** (jarobarb@iupui.edu), Department of Mathematical Sciences, 402 N Blackford St, LD 270E, Indianapolis, IN 46202, and **Julia C Arciero** and **Erin Zhao**. *Mathematical model of vascular adaptations to a major arterial occlusion in the rat hind limb.* Preliminary report.

Blood vessel adaptation to different situations, such as exercise, is critical for maintaining healthy tissue. Understanding adaptation better can help lead to earlier and less invasive treatments for victims of major events like heart attacks and strokes and major vascular diseases like peripheral arterial disease where lower leg circulation is severely limited. A compartmental model of the vessel network in the rat hindlimb is used to study the roles of different sized vessels (e.g. arteries vs capillaries) in providing blood flow to the hindlimb before and after a major arterial conclusion. The model includes vascular response mechanisms for changes in pressure (myogenic response), vessel wall shear stress (shear response), and oxygen levels (metabolic response). Simulations include varying levels of activity both before and after a major arterial occlusion and at varying time scales. Results suggest that vessel mechanisms cannot fully restore normal oxygen levels immediately following a major occlusion and that long term flow restoration depends on the strength and type of long term vascular adaptation (arteriogenesis vs angiogenesis). Results also suggest that to obtain realistic vessel dynamics, there must be some level of heterogeneity in the metabolic response. (Received February 19, 2018)

1139-92-575 **Anastasios Matzavinos*** (matzavinos@brown.edu), Division of Applied Mathematics, Brown University, 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. This work was partially supported by the NSF through grants DMS-1521266 and DMS-1552903. (Received February 19, 2018)

1139-92-584 **Eleni Panagiotou***, Department of Mathematics, South Hall, University of California Santa Barbara, Santa Barbara, CA 93106, and **Kevin Plaxco**. *A topological model for protein folding.*

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 February 20, 2018)

1139-92-587 **Marcio Gameiro***, gameiro@math.rutgers.edu, and **Konstantin Mischaikow**, mischaik@math.rutgers.edu. *Analysis of Protein Structure via Persistent Homology.*

Though tremendous progress has been made over the years, it is still not possible to predict with sufficient certainty the geometric structure of a protein from its defining amino acid sequence. The Protein Data Bank (PDB) provides a database for the experimentally determined three-dimensional structures of well over 100,000 proteins and thus provides a baseline against which predictions can be tested. There are a variety of reasons why current techniques for predicting protein folding may fail, including uncertainties and the existence of local minima in the energy functional used to optimize the protein structure. Our work focuses on the question of whether there are particular global geometric structures that give rise to a significant portion of the error. With this in mind, we are applying persistent homology to search for correlations between global geometric structures and the failure to predict the desired folding. Our hope is that this technique could help guide the energy minimization techniques to the correct minimum corresponding to the correctly folded protein. (Received February 20, 2018)

1139-92-600 **Erica Flapan**, **Kenji Kozai*** (kozai@rose-hulman.edu) and **Ryo Nikkuni**. *Random linear embeddings of spatial graphs and configurations of Mobius ladders.*

Random knots have been investigated extensively to model knotting behavior of linear polymers like DNA. Generalizations into random embeddings of graphs can be thought of as models for the spatial configuration of non-linear molecules, polymers, and substructures. For a given graph, one might ask which configurations are typical. Leveraging known and new results about random knotting and linear embeddings of graphs, we show that certain "simple" graphs, including the 3-rung Mobius ladder, nearly always show up in their topologically simplest configurations. (Received February 20, 2018)

1139-92-627 **Jim Cronin**, **Jerome Goddard II*** (jgoddard@aum.edu) and **R. Shivaji**. *Effects of patch matrix and individual movement response on population persistence at the patch-level.*

Fragmentation creates landscape-level spatial heterogeneity leading to declines in abundance of a resident species as the fragmented landscape becomes more susceptible to edge effects between the remnant habitat patches and the surrounding lower quality matrix. In this presentation, we formalize the connection between small-scale movement and patch-level predictions of persistence through a reaction-diffusion model. This model incorporates essential information about edge-mediated effects such as patch preference and movement behavior. We mathematically analyze the model's predictions of persistence with a general logistic-type growth term and explore their sensitivity to demographic attributes both in the patch and matrix, as well as patch size. Finally, we illustrate the utility of this framework with a well-studied planthopper species living in a highly fragmented landscape. Using experimentally derived data from various sources to parameterize the model, we show that, qualitatively, the model results are in accord with experimental predictions regarding minimum patch size of the species. Through application of a sensitivity analysis, we also suggest a ranking of the most important model parameters based on which parameter will cause the largest model output variance. (Received February 20, 2018)

1139-92-642 **Jordan Hoffmann** (jhoffmann@g.harvard.edu), **Seth Donoughe** (donoughe@fas.harvard.edu), **Kathy Li** (kathy2132@gmail.com), **Mary K Salcedo** (maryksalcedo@gmail.com) and **Chris H Rycroft*** (chr@seas.harvard.edu), 29 Oxford Street, Cambridge, MA 02138. *Modeling the diverse geometry of insect wings.*

The formation of geometric patterns in tissues has long been a topic of fascination. The patterns of "veins" that provide structure to the insect wing are especially intriguing because they often form a wide diversity of arrangements within a single wing. Moreover, for many insect species, even the left and right wings from the same individual have veins with unique topological arrangements. We present the first large-scale quantitative study of the fingerprint-like "secondary veins". We compile a dataset of wings from 232 species and 17 families from the order Odonata (dragonflies and damselflies), a group with particularly elaborate vein patterns. We characterize the geometric arrangements of veins and then develop a simple model of secondary vein patterning. Finally, we show that our model is capable of reproducing the vein geometries of species from other, distantly related winged insect clades. (Received February 20, 2018)

1139-92-668 **Rebecca S. Terry*** (terry@math.utah.edu) and **Frederick R. Adler**. *Dynamics of Cooperation in Temporally Varying Environments.* Preliminary report.

An organism's phenotype is defined as the expression of its genetic material. This expression may change under different environmental conditions. The ability to alter one's phenotype by turning on or off specific genes in response to changes in one's environment is known as phenotypic plasticity. Cooperation in certain microbial species is an example of phenotypic plasticity whereby some individuals express particular genetic machinery to produce a resource available to the entire population while others fail to express that same machinery but benefit from consumption of the resource without the cost of its production. Depending on the availability of the resource in the environment, an organism may switch from an expressing to a non-expressing state or vice versa. We develop a mechanistic model to explore the dynamics of cooperation and phenotypic plasticity in social microbes under varying environmental conditions. Using an adaptive dynamics approach, we examine whether there exists an evolutionarily stable switching strategy between states. (Received February 20, 2018)

93 ► Systems theory; control

1139-93-305 **Lorenza Viola***, Department of Physics & Astronomy, Dartmouth College, Hanover, 03755. *Advances and challenges in Markovian quantum state stabilization under resource constraints.*

Dissipative quantum control techniques are attracting increasing attention in quantum information processing. I will focus on the task of designing Markovian dynamics which admits a desired pure entangled state as its unique stable steady state, subject to specified quasi-locality constraints. While the problem is well understood in a setting where purely dissipative dynamics suffice, and stabilizable pure states may be identified with unique ground states of frustration-free quasi-local Hamiltonians, a characterization of the general case where Hamiltonian and dissipative control must be simultaneously employed has been lacking. I will provide necessary and sufficient conditions filling this gap, by showing how quasi-local stabilizability of a pure state is determined by the existence of a quasi-local Hamiltonian that leaves the state invariant, while having no other eigenstates in a certain subspace determined by the dissipative component. It follows that unique ground states of frustrated quasi-local Hamiltonians need not be stabilizable using quasi-local resources alone. I will illustrate this through an example involving W-states on qubits under a nearest-neighbor constraint, and discuss alternative stabilization strategies, when quasi-local stabilization is not feasible. (Received February 14, 2018)

1139-93-656 **Juntao Chen*** (jc6412@nyu.edu) and **Quanyan Zhu** (qz494@nyu.edu). *Dynamic Cyber Risk Management with Uncertainty under Asymmetric Information.* Preliminary report.

With the massive connections between different agents in the Internet network, cyber threats become ubiquitous and raise critical concerns for resource owners, e.g., data storage and cloud service providers. To address this issue, the owners can outsource their cyber risk management tasks to the professional security entities. In this paper, we use a principal-agent framework to capture the service relationships between two parties, i.e., the resource owner and the cyber risk manager. Specifically, we consider a dynamic risk management problem with uncertainty where the owner only has the observations of cyber risk outcome rather than the effort that the manager spends on protecting the resources. Under this asymmetric information, the owner aims to minimize the cyber risks by designing a dynamic contract specifying the payment flows and preferred efforts by taking the manager's rational behaviour into account. We obtain the optimal contracts by reformulating the problem into a stochastic optimal control program which can be solved using dynamic programming. We further investigate some special cases where the form of solutions can be characterized. Finally, we discuss some features of the obtained optimal dynamic contracts. (Received February 20, 2018)

97 ► Mathematics education

1139-97-35 **Maritza M. Branker*** (mbranker@niagara.edu). *Enhancing a complex analysis course with historical context.*

This talk will discuss how my research into the history of complex numbers has impacted my teaching of the introductory complex analysis course. It will include details on how the course has evolved and the pedagogical choices made as a result of the increased historical knowledge of the instructor. (Received January 14, 2018)

1139-97-43 **Alexander Karp*** (apk16@columbia.edu), Box 210, Program in Mathematics, Teachers College, Columbia University, 525 West 120 Street, New York, NY 10027. *Mathematical mistakes in mathematics education: a topic for research.*

Research mathematicians often accuse mathematics educators of making mistakes in textbooks, workbooks, and exams. Such accusations are not unfounded. In many cases, however, unquestionable mathematical inaccuracies result not from ignorance, but from a different view on the objectives of an educational text. This presentation will examine several examples from different countries and eras, which may spur a more detailed study of this under-researched topic. (Received January 18, 2018)

1139-97-263 **Rebecca Kathryn Vinsonhaler*** (vinsonhaler@utexas.edu), 2303 E 17th St, Austin, TX 78702. *Teaching Calculus with Infinitesimals.*

I argue that first semester calculus courses for non-mathematics majors should be taught using infinitesimals. This applies to both high school and undergraduate calculus courses. The use of infinitesimals in calculus, though more intuitive than the approach developed in the 19th Century, has been controversial for over two millennia. However, in the 20th Century their use was shown to be equa-consistent with the approach developed in the 19th Century. I will provide a brief history of infinitesimals, why they were controversial, and how they were finally put on a firm footing. Then I will illustrate the intuitive nature of the use of infinitesimals. I will conclude that at least students not continuing on to more advanced analysis courses would be better served by learning calculus via infinitesimals. (Received February 13, 2018)

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16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory; homological algebra
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20 Group theory and generalizations
22 Topological groups, Lie groups
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34 Ordinary differential equations
35 Partial differential equations
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39 Difference and functional equations
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43 Abstract harmonic analysis
44 Integral transforms, operational calculus
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92 Biology and other natural sciences
93 Systems theory; control
94 Information and communication, circuits
97 Mathematics education

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