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PAPERS PRESENTED AT MEETINGS

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

MEETING #	DATE	PLACE	ABSTRACT DEADLINE	ABSTRACT ISSUE
1130	July 24–28, 2017	Montréal, Canada	EXPIRED	NONE
1131	September 9–10, 2017	Denton, TX	July 18	Vol 38, No. 3
1132	September 16–17, 2017	Buffalo, NY	July 25	Vol 38, No. 3
1133	September 23–24, 2017	Orlando, FL	August 1	Vol 38, No. 4
1134	November 4–5, 2017	Riverside, CA	September 12	Vol 38, No. 4
1135	January 10–13, 2018	San Diego, CA	September 26	Vol 39, No. 1
1136	March 17–18, 2018	Columbus, OH	January 22	Vol 39, No. 2
1137	April 14–15, 2018	Portland, OR	February 6	Vol 39, No. 2
1138	April 14–15, 2018	Nashville, TN	February 13	Vol 39, No. 2
1139	April 21–22, 2018	Boston, MA	February 20	Vol 39, No. 2
1140	June 11–14, 2018	Shanghai, Peoples Rep of China	TBA	NONE
1141	September 29–30, 2018	Newark, DE	July 31	Vol 39, No. 3
1142	October 6–7, 2018	Fayetteville, AR	August 7	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

CHARLESTON, SC, March 10–12, 2017

Abstracts of the 1126th Meeting.

00 ► General

1126-00-56 **Shaina L Race*** (shaina_race@ncsu.edu), NC. *Exponential Random Graph Models (ERGMs): An Introduction and an Application.*

Exponential random graph models can be expressed as an analogy to logistic regression for network data. The goal is to use structural information about a network (typically a social network) as well as node-level and edge-level attributes to develop a model that explains how localized social processes and structures combine to form global network patterns. From such a model, inferences about network attributes like mutuality and homophily can be made. We offer an entry-level introduction to exponential random graph modeling and the types of attributes that can be accomodated, as well as a practical example regarding professional relationships at a consulting firm. (Received December 21, 2016)

1126-00-115 **Matthew J Sequin*** (msequin@saintpeters.edu). *Accumulation Points of Folding Sequences.*

Imagine a thin strip of paper labeled with the interval $[0,1]$, where 0 is on the very left edge of the paper and 1 is on the right edge. If this strip of paper is folded in a certain way, the creases from the folds will correspond to different numbers in the interval. Folding the paper an infinite number of times will yield a sequence, called a *folding sequence*. In this talk, we will introduce folding sequences and discuss some of their properties. In particular, we will focus on the accumulation points of these sequences, and briefly discuss how folding sequences can be used to introduce concepts in an undergraduate point-set topology or analysis course. (Received January 08, 2017)

1126-00-174 **Roozbeh Gharakhloo*** (`rgharakh@iupui.edu`), 402 N. Blackford St., Indianapolis, IN 46202, and **Alexander Its** (`aits@math.iupui.edu`), 402 N. Blackford St., Indianapolis, IN 46202. *On the asymptotic analysis of Toeplitz + Hankel determinants.* Preliminary report.

We want to analyse the asymptotics of a Toeplitz+Hankel determinant with Toeplitz symbol $\phi(z)$ and Hankel symbol $w(z)$. When symbols $\phi(z)$ and $w(z)$ are related in specific ways, the asymptotics of T+H determinants have been studied by E. Basor and T. Ehrhardt and by P. Deift, A. Its and I. Krasovsky. The distinguishing feature of this work is that we do not assume any relations between the sympbols $\phi(z)$ and $w(z)$. In this talk, the Hankel symbol is a modified Jacobi weight and the Toeplitz symbol is assumed to be analytic in a neighborhood of the unit circle. we approach this problem by analysing a 4 by 4 Riemann Hilbert problem. This work is part of the joint research project with Alexander Its, Percy Deift and Igor Krasovsky. (Received January 12, 2017)

1126-00-184 **Rachel E Bass*** (`rb06280@georgiasouthern.edu`). *Graph invariants defined on degrees and distances.* Preliminary report.

Graph invariants are functions defined on the graph structures that stay the same under taking graph isomorphism. 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 result. (Received January 12, 2017)

1126-00-191 **Travis W. Morrison*** (`txm950@psu.edu`). *Diophantine definability of the non-squares in a global field.*

In joint work with Kirsten Eisenträger, we show that the ring of S-integers in a global function field with characteristic not 2 has a first-order universal definition. This follows work of J. Koenigsmann and J. Park who gave first-order universal definitions of $\mathbb{Z}$ in $\mathbb{Q}$ and the ring of integers in a number field, respectively. I will discuss how we use the ideas developed in these papers to prove that the non-squares of a global field K with $\mathrm{char}(K) \neq 2$ are diophantine over K, which was first shown by B. Poonen. (Received January 12, 2017)

1126-00-202 **Jennifer L Priestley***, 1235 Briarwood Drive, Kennesaw, GA 30144. *Why Data Science is so dependent upon Mathematics.* Preliminary report.

Data Science is a nascent but popular field of study with "data science" and "analytics" programs emerging on almost every college campus across the country.

These programs have integrated varying degrees of Mathematics into their curriculum.

In this session, Kennesaw State University - which houses one of the country's few Ph.D. programs in Data Science, will explain the foundational role that Mathematics plays in the Data Science curriculum.

Specifically, KSU will discuss how Linear Algebra, Graph Theory and Discrete Optimization should be considered to be foundational concepts in any data science curriculum. (Received January 13, 2017)

1126-00-354 **Scott C. Batson*** (`scott.batson@navy.mil`). *Data Science Panel Discussion: Challenges, Open Problems and the Future.*

A panel of experts will discuss their current mathematical challenges, open problems of interest, and vision of the future for Data Science. This forum will be used to bring awareness of these problems for the purpose of stimulating discussion and cross-collaboration. Time will be allotted in this session for audience questions and answers. (Received January 17, 2017)

01 ► History and biography

1126-01-353 **Lucas A. Overbey*** (`lucas.overbey@navy.mil`) and **Scott C. Batson** (`scott.batson@navy.mil`). *A Brief Survey of Data Science.*

Over 50 years ago, John Tukey noted that academic statistics could be reformed into a (then unrecognized) science by which one may study and learn from data. Data Science has since evolved into one of the fastest growing academic fields. Motivated by both intellectual and commercial developments, Data Scientists study today's abundant data in number of different application areas, expanding upon statistics and machine learning to emphasize modeling and prediction of events. In this talk we will provide a brief mathematical introduction to Data Science. We will discuss some of the field's history and its current state, then overview a few applications with thoughts on the future of Data Science. This survey lecture will be accessible to graduate students and non-specialists who may be thinking of switching fields. (Received January 17, 2017)

03 ► Mathematical logic and foundations

1126-03-74 **David Marker*** (marker@uic.edu), Dept Mathematics (MC 249), University of Illinois at Chicago, 851 S. Morgan St., Chicago, IL 60607. *Complexity of counterexamples to Schanuel's Conjecture.* Preliminary report.

Using ideas of Kirby we show that if Schanuel's Conjecture is false, then there are computable counterexamples. Indeed there are natural closure operators on the complex numbers such that there are counterexamples in the smallest closed set. Using these observations we show that Schanuel's Conjecture, which at first glance is a Π^1_1 statement, has a Π^0_3 formulation. These observations arose in discussions with Lou van den Dries and Angus Macintyre. (Received January 02, 2017)

1126-03-158 **Rachael Alvir**, **Julia F. Knight*** (knight.1@nd.edu) and **Charles McCoy**. *Complexity of Scott sentences.*

We consider effective versions of some results of A. Miller and Montalbán. We show that if a countable structure $\mathcal{A}$ has a computable $\Sigma_{\alpha+1}$ Scott sentence and one that is $\Pi_{\alpha+1}$, then it has a computable d-Σ_α Scott sentence. We also show that if $\mathcal{A}$ has a computable $\Pi_{\alpha+1}$ Scott sentence, then the orbits of all tuples are defined by computable Σ_α formulas. The converse fails. Applying the general results, we show that a finitely generated group has a d-Σ_2 Scott sentence iff the orbit of some generating tuple is defined by a Π_1 formula, and a computable finitely generated group has a computable d-Σ_2 Scott sentence iff the orbit of some generating tuple is defined by a computable Π_1 formula. (Received January 10, 2017)

1126-03-227 **Russell Miller*** (russell.miller@qc.cuny.edu), Mathematics Dept. – Queens College, 65-30 Kissena Blvd., Queens, NY 11367. *Relatively simple sets and subrings of* $\mathbb{Q}$.

A computably enumerable set S is *relatively simple* if it is undecidable and every c.e. set which can enumerate an infinite subset of the complement $\overline{S}$ can in fact compute S. We will use such sets to show that, if there is a c.e. set C which cannot be computed by $HTP(\mathbb{Q})$, then there is a polynomial f which gives a diophantine definition (over $\mathbb{Z}$) of a set S Turing-equivalent to C, but for which $HTP(\mathbb{Q})$ cannot even begin to enumerate the complement of S. (Received January 14, 2017)

1126-03-237 **Michael C. Laskowski*** (mcl@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742. *What about strong types?* Preliminary report.

The talk will discuss the behavior of *strong types* versus *types* in the context of computing the complexity of isomorphism between structures. Most of the examples will be models of either 'independent unary predicates' or 'binary splitting, refining equivalence relations' but the behaviors exhibited by these structures are also present in more algebraic settings. (Received January 15, 2017)

1126-03-249 **William DeMeo*** (williamdemeo@gmail.com). *On the Complexity of the Existence of Difference Terms in Idempotent Locally Finite Varieties.*

We give a positive answer to the following practical question: Given a finite idempotent algebra $\mathbf{A}$, can we efficiently decide whether the variety generated by $\mathbf{A}$ has a difference term? It is well known that a locally finite variety $\mathcal{V}$ has a difference term if and only if the variety generated by $\mathbf{F}_{\mathcal{V}}(2)$ has a difference term. In fact, this is equivalent to $\mathbf{F}_{\mathcal{V}}(2)$ itself having a difference term operation. We use this fact and an adaptation of Valeriote and Willard's "local term condition" strategy to devise a polynomial-time algorithm for deciding whether the variety generated by a finite idempotent algebra has a difference term. (Received January 15, 2017)

1126-03-313 **Alexander Melnikov***, Massey University, INMS, Auckland, New Zealand. *Computability and the classification of compact groups.*

In my talk I will try to explain how one can use computability to attack classification problems in topological group theory. It follows that compact connected topological (abelian) groups are "unclassifiable". We will also look at computability of profinite groups and see that the index set of computably categorical profinite abelian groups is Π^0_4-complete. (Received January 17, 2017)

1126-03-316 **Matthew A Harrison-Trainor*** (matthew.h-t@berkeley.edu), **Alexander Melnikov** and **Russell Miller**. *Extending automorphisms of normal algebraic fields.*

Every automorphism of an algebraic field extends to an automorphism of its algebraic closure. We investigate computable analogues of this fact for normal fields, and in particular, we look for connections to the existence of a splitting algorithm for the field. (Received January 17, 2017)

1126-03-318 **Wesley Calvert*** (wcalvert@siu.edu), Department of Mathematics, Mail Code 4408, 1245 LINCOLN DRIVE, Carbondale, IL 62901, and **Douglas Cenzer** and **Valentina Harizanov**. *Generically and Coarsely Computable Structures.* Preliminary report.

The usual study of computable structures is largely driven by worst-case analysis: we show that something is not computable by contriving an example, however artificial, of something that cannot be decided. To circumvent such artificiality, two asymptotic notions of computability, motivated by work in group theory, have seen significant recent interest in computability. Under these notions, a function is "effective" if and only if it is computable on a set of high density (in two different senses).

In the present work, we undertake the version of effective structure theory resulting from these alternate approaches to computability. In particular, we explore questions of existence of computable copies and of effective categoricity, both in the context of equivalence structures (where these questions are classically well-explored). (Received January 17, 2017)

1126-03-323 **Karen Lange*** (karen.lange@wellesley.edu), **Russell Miller** and **Rebecca Steiner**. *Classifications of algebraic structures.*

Let $\mathcal{K}$ be a family of structures closed under isomorphism. A *computable classification* of $\mathcal{K}$ is a uniformly computable enumeration of the computable models in $\mathcal{K}$ such that each computable model is represented exactly once up to isomorphism. We discuss computable classifications of families of various algebraic structures. Although there is no computable classification of all (computable) fields, we prove that there is a computable classification of algebraic fields. Using a $\mathbf{0}'$ oracle, we can obtain similar classifications of the families of equivalence structures and of finite-branching trees. However, there is no computable classification of the family of finite-branching trees, nor of the family of torsion-free abelian groups of rank 1, even though these families are both closely allied with algebraic fields. To obtain these results, we leverage Friedberg's approach for showing that there is a computable enumeration of the family of all computably enumerable (c.e.) sets without repetitions. (Received January 17, 2017)

1126-03-361 **Matthew Moore*** (matthew.moore@math.mcmaster.ca). *Decidability in Universal Algebra.*

Many properties associated with the relational and operational clones of total algebras are suspected to be undecidable. We will examine two such properties: finite relatedness and finite dualizability. Both properties can be generalized to partial algebras, thus making the respective decision problems more computationally difficult. Of these two more computationally difficult problems, it can be shown that it is undecidable whether a partial algebra is finitely dualizable. Specifically, given a Minsky machine M, we construct a partial algebra A(M) such that A(M) is finitely dualizable if and only if M halts. (Received January 17, 2017)

05 ► Combinatorics

1126-05-8 **R. Gu**, **X. Gu**, **Y. Shi** and **H. Wang*** (hwang@georgiasouthern.edu). *Random graphs and ℓ-connectivities.* Preliminary report.

For an integer $\ell \geq 2$, the ℓ-connectivity $\kappa_\ell(G)$ of a graph G is defined to be the minimum number of vertices of G whose removal produces a disconnected graph with at least ℓ components or a graph with fewer than ℓ vertices. The ℓ-edge-connectivity $\lambda_\ell(G)$ of a graph G is the minimum number of edges whose removal leaves a graph with at least ℓ components if $|V(G)| \geq \ell$, and $\lambda_\ell(G) = |E(G)|$ if $|V(G)| < \ell$. In this paper, we establish sharp threshold functions for the ℓ-connectivity and ℓ-edge-connectivity of random graphs, which generalize the result of Erdős and Rényi, and Stepanov. In fact, further strengthening our results, we show that in the random graph process, with high probability the hitting times of minimum degree at least k and of ℓ-connectivity (or ℓ-edge-connectivity) at least $k(\ell-1)$ coincide. This can be seen as a generalization of the results of Bollobás and Thomassen. (Received September 30, 2016)

1126-05-27 **Nick Zhao*** (yzhao@mail.ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Vizing's Planar Graph Conjecture and related problems.*

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 of characteristic $\chi \leq 0$. (Received December 08, 2016)

1126-05-61 **Rao Li*** (raol@usca.edu), Dept. of mathematical sciences, 471 University Parkway, University of South Carolina Aiken, Aiken, SC 29801. *Spread Conditions for Some Hamiltonian Properties of Graphs.*

The spread of a graph is defined as the difference between the largest and smallest eigenvalues of the graph. Spread conditions for some Hamiltonian properties of graphs will be presented in this talk. (Received December 27, 2016)

1126-05-67 **Xueliang Li*** (lxl@nankai.edu.cn), Center for Combinatorics, Nankai University, Tianjin, 300071, Peoples Rep of China, **Wasin So**, CA , and **Ivan Gutman**, , Serbia. *Constructions of Graphs and Trees with Partially Prescribed Spectrum.* Preliminary report.

It is shown how a connected graph and a tree with partially prescribed spectrum can be constructed. These constructions are based on a recent result of Salez that every totally real algebraic integer is an eigenvalue of a tree. Our result implies that for any (not necessarily connected) graph G, there is a tree T such that the characteristic polynomial $P(G,x)$ of G can divide the characteristic polynomial $P(T,x)$ of T, i.e., $P(G,x)$ is a divisor of $P(T,x)$. (Received January 01, 2017)

1126-05-69 **Eddie Cheng*** (echeng@oakland.edu), Department of Mathematics and Statistics, Rochester, MI 48309, and **Justin Kelm** and **Omer Siddiqui**. *Strong matching preclusion of (n,k)-star graphs and arrangement graphs.*

The strong matching preclusion number of a graph is the minimum number of vertices and edges whose deletion results in a graph with neither perfect matchings nor almost-perfect matchings. This was introduced by Park and Ihm as an extension of the matching preclusion problem. The class of (n,k)-star graphs and the class of arrangement graphs were introduced as common generalizations of star graphs, and to provide a rich class of interconnection networks. In this talk, we discuss the strong matching preclusion number of (n,k)-star graphs and arrangement graphs, and to categorize all optimal strong matching preclusion sets of these graphs. (Received January 01, 2017)

1126-05-70 **Ken-ichi Kawarabayashi**, **Kenta Ozeki** and **Michael Plummer*** (michael.d.plummer@vanderbilt.edu). *Matching Extension missing Vertices and Edges in Triangulations of surfaces.*

Let G be a 5-connected triangulation of a surface Σ different from the sphere and let $\chi = \chi(\Sigma)$ be the Euler characteristic of Σ. Suppose that $V_0 \subseteq V(G)$ with $|V(G) - V_0|$ even and that M and N are two matchings in $G - V_0$ of sizes m and n respectively such that $M \cap N = \emptyset$. It is shown that if the pairwise distance between any 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 $\max\{20m - 8\chi - 23, 6\}$, then there is a perfect matching M_0 in $G - V_0$ containing M such that $M_0 \cap N = \emptyset$. (Received January 01, 2017)

1126-05-78 **Geir Agnarsson*** (math.geir@gmail.com), George Mason University, 4400 University Drive, MS: 3F2, Fairfax, VA 22030. *On the rooted-subtree problem and the Game-Over Attack Strategy.*

Let T be a tree with $n \in \mathbb{N}$ non-root vertices, $p : V(T) \to \mathbb{Q}$ and $c : E(T) \to \mathbb{Q}$ be two weight functions on the vertices and the edges respectively, and $B, G \in \mathbb{Q}^+$ be two fixed numbers. We consider the *Game-Over Attack Strategy (GOAS)* of finding a rooted subtree $T' \subseteq T$ such that $p(T') = \sum_{u \in V(T')} p(u) \geq G$ and $c(T') = \sum_{e \in E(T')} c(e) \leq B$. Although in general this decision problem is NP-complete, there are many special cases that can be solved in polynomial time in n, and these cases can be viewed as models for many security protocols in computer networks. This shows that *hacking into a computer network is computationally easy!* – This is joint work with Ray Greenlaw and Sanpawat Kantrabutra. (Received January 03, 2017)

1126-05-81 **Guantao Chen*** (gchen@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303, and **Shushan He**, **Zhiquan Hu** and **Feifei Song**. *linkage and Hadwiger's conjecture.* Preliminary report.

A graph G is called ℓ-knitted if, for any $S \subseteq V(G)$ with $|S| = \ell$ and every partition of S into non-empty subsets $S_1, S_2, \ldots, S_t$, there exist disjoint connected subgraphs $C_1, C_2, \ldots, C_t$ in G so that $S_i \subseteq V(C_i)$ for $1 \leq i \leq t$. Clearly, every $2k$-knitted graph is k-linked. We obtain a new sufficient degree condition for ℓ-knitted graphs and use it to study the connectivity of minimum counterexamples (if such examples exist) to Hadwiger's conjecture: *every k-chromatic graph contains K_k as a minor.* (Received January 04, 2017)

1126-05-90 **Michael Ferrara*** (michael.ferrara@ucdenver.edu). *Ore and Chvátal-type Degree Conditions for Fast Bootstrap Percolation.*

Bootstrap percolation is a deterministic cellular automaton in which vertices of a graph G begin in one of two states "dormant" or "active". Given a fixed integer r, a dormant vertex becomes active if at any stage is has at least r active neighbors, and remains active for the duration of the process. Given an initial set of a active vertices A, we say that G r-percolates (from A) if every vertex in G becomes active after some number of steps. Let $m(G, r)$ denote the minimum size of a set A such that G r-percolates from A.

Here, we provide degree-based density conditions than ensure $m(G, 2) = 2$. In particular, we give an Ore-type degree sum result that states if a graph G satisfies $\sigma_2(G) \geq n - 2$, then either $m(G, 2) = 2$ or G is in one of several exceptional classes. We also give a Chv'atal-type degree condition: If G is a graph with degree sequence $d_! \leq d_2 \leq \cdots \leq d_n$ such that $d_i \geq i+1$ or $d_{n-i} \geq n-i-1$ for all $1 \leq i < \frac{n}{2}$, then $m(G, 2) = 2$. Tthese results are inspired by, and extend [D. Freund, M. Poloczek, and D. Reichman, Contagious sets in dense graphs, to appear in *European J. Combin.*]/ Joint with Michael Dairyko, Bernard Lidicky, Ryan R. Martin, Florian Pfender and Andrew Uzzell. (Received January 05, 2017)

1126-05-92 **Chun-Hung Liu*** (chliu@math.princeton.edu). *Packing and covering immersions in 4-edge-connected graphs.*

A graph G immerses another graph H if H can be obtained from a subgraph of G by repeatedly splitting off edges and deleting isolated vertices. Given a graph H, does there exist a function f such that for every positive integer k, every graph G either contains k edge-disjoint subgraphs where each immerses H, or contains a set of $f(k)$ edges intersecting all subgraphs that immerse H? Various necessary conditions for graphs H with the property mentioned above are known, and the characterization for such graphs H is expected to be complicated. However, we will prove that such a characterization is extremely simple if we require the host graph G having high edge-connectivity. Formally, we prove that for every graph H, there exists a function f such that for every positive integer k, every 4-edge-connected graph G either contains k edge-disjoint subgraphs where each immerses H, or contains a set of $f(k)$ edges intersecting all subgraphs that immerse H. The theorem is best possible in the sense that the 4-edge-connectivity cannot be replaced by the 3-edge-connectivity. (Received January 06, 2017)

1126-05-107 **Adam Jump** and **Alexander Halperin*** (adhalperin@salisbury.edu), 1101 Camden Ave., Salisbury, MD 21801. *A Sharp Upper Bound on the k-Color Connectivity of a Graph.* Preliminary report.

How much security is needed to optimally harden a network against cyberattack? How many types of cargo need exist between a freight carrier and its destination in order to guarantee it has the most possible supplies? These problems can be phrased in terms of edge-colored connectivity of graphs: how many edge colors does a graph need to contain a path with k distinct colors between every pair of vertices? Equivalently, what is the *k-color connection number* of a graph? Denoting the k-color connection number of G as $cc_k(G)$, Coll et al. conjectured $cc_k(G) \leq 2k - 1$ and, for a sharp condition, observed that $cc_k(C_{2k-1}) = 2k - 1$. We prove $cc_k(G) \leq 2k - 1$ by analyzing the k-color connection number of chorded cycles. Additionally, we display our Mathematica package that determines the k-color connection number of chorded cycles. (Received January 07, 2017)

1126-05-108 **Baogang Xu** (baogxu@njnu.edu.cn), 1 Wenyuan Road, Nanjing, 210023, China, Nanjing, Jiangsu 210023, Peoples Rep of China, and **Xiaoya Zha*** (xzha@mtsu.edu), KOM 271, 1301 East Main Street, Murfreesboro, TN 37132. *Nonhomotopic loop system and thinkness of graphs embedded in surfaces.* Preliminary report.

A *nonhomotopic loop system* $\mathcal{L} = \{l_i, i = 1, \cdots t\}$ of a 2-dimension compact closed surface is a collection of loops with a common base point x such that l_i and l_j only intersect (transversely or not) at x and are not homotopic to each other for $1 \leq i < j \leq t$. The thickness of a graph G is the minimum number of planar subgraphs that G can be edge-partitioned into. Study of nonhomotopic loop system may help to estimate the thickness of graphs in terms of their genera (orientable or nonorientable). In this talk, we discuss the upper and lower bounds for maximum nonhomotopic loop systems of surfaces. (Received January 07, 2017)

1126-05-112 **Xia Zhang*** (pandarhz@gmail.com). *Disconnected critical graphs on g_c-colorings.*

Every critical graph is connected on proper edge-colorings of simple graphs. In contrast, there not only exist connected critical graphs but exist disconnected critical graphs on g_c-colorings of simple graphs. In this talk, the structure characteristics of disconnected g_c-critical graphs are depicted. (Received January 08, 2017)

1126-05-113 **Mark Ellingham*** (mark.ellingham@vanderbilt.edu), **Songling Shan**, **Dong Ye** and **Xiaoya Zha**. *Toughness for bounded treewidth.* Preliminary report.

Toughness is an important graph theory parameter that seems to play an essential role in traversability properties such as the existence of a hamilton cycle. However, in general it is difficult (NP-hard) to compute. We use dynamic programming to show that toughness can be computed in polynomial time for graphs of bounded treewidth. Our algorithm is not fixed-parameter tractable, since the degree of the polynomial depends on the treewidth. However, it does seem to be practical for treewidth 2, or in other words for series-parallel graphs. (Received January 08, 2017)

1126-05-120 **Hui Lei** and **Yongtang Shi*** (shi@nankai.edu.cn), No. 94 Weijin Road, Nankai District, Center for Combinatorics, Nankai University, Tianjin, 300071, Peoples Rep of China, and **Zixia Song**. *Star chromatic index of subcubic multigraphs.*

The star chromatic index of a multigraph G, denoted $\chi'_s(G)$, is the minimum number of colors needed to properly color the edges of G such that no path or cycle of length four is bi-colored. A multigraph G is star k-edge-colorable if $\chi'_s(G) \leq k$. Dvořák, Mohar and Šámal [Star chromatic index, *J. Graph Theory* **72** (2013), 313–326] proved that every subcubic multigraph is star 7-edge-colorable. They conjectured in the same paper that every subcubic multigraph should be star 6-edge-colorable. In this paper, we first show that the problem of deciding whether a subcubic multigraph is star 3-edge-colorable is NP-complete. We then apply the structure results, along with a simple discharging method, to prove that every subcubic multigraph G is star 6-edge-colorable if $mad(G) < 5/2$ and star 5-edge-colorable if $mad(G) < 24/11$, respectively, where $mad(G)$ is the maximum average degree of a multigraph G. This partially confirms the conjecture of Dvořák, Mohar and Šámal. (Received January 08, 2017)

1126-05-121 **Songling Shan*** (songling.shan@vanderbilt.edu), Nashville, TN 37203. *Spanning cycles, walks, and trails in $2K_2$-free graphs.*

A graph is called $2K_2$-free if it does not contain two independent edges as an induced subgraph. In this talk, we will survey some sufficient conditions for the existence of hamiltonian cycles, spanning k-walks (a closed walk with each vertex repeated at most k times), and spanning 2-trails (a 2-walk with distinct edges) in $2K_2$-free graphs. (Received January 08, 2017)

1126-05-128 **Hongliang Lu** and **Xingxing Yu*** (yu@math.gatech.edu). *On rainbow matchings for hypergraphs.*

For any posotive integer m, let $[m] := \{1, \ldots, m\}$. Let n, k, t be positive integers. Aharoni and Howard conjectured that if, for $i \in [t]$, $\mathcal{F}_i \subset [n]^k := \{(a_1, \ldots, a_k) : a_j \in [n] \text{ for } j \in [k]\}$ and $|\mathcal{F}_i| > (t-1)n^{k-1}$, then there exist $M \subseteq [n]^k$ such that $|M| = t$ and $|M \cap \mathcal{F}_i| = 1$ for $i \in [t]$. We show that this conjecture holds when $n \geq 3(k-1)(t-1)$.

Let $n, t, k_1 \geq k_2 \geq \ldots \geq k_t$ be positive integers. Huang, Loh and Sudakov asked for the maximum $\Pi_{i=1}^t |\mathcal{R}_i|$ over all $\mathcal{R} = \{\mathcal{R}_1, \ldots, \mathcal{R}_t\}$ such that each $\mathcal{R}_i$ is a collection of k_i-subsets of $[n]$ for which there does not exist a collection M of subsets of $[n]$ such that $|M| = t$ and $|M \cap \mathcal{R}_i| = 1$ for $i \in [t]$ We show that for sufficiently large n with $\sum_{i=1}^t k_i \leq n(1 - (4k \ln n/n)^{1/k})$, $\prod_{i=1}^t |\mathcal{R}_i| \leq \binom{n-1}{k_1-1}\binom{n-1}{k_2-1}\prod_{i=3}^t \binom{n}{k_i}$. This bound is tight. (Received January 09, 2017)

1126-05-132 **Yezhou Wu**, Zhejiang University, Hangzhou, Zhejiang 310027, Peoples Rep of China, **Dong Ye*** (dong.ye@mtsu.edu), Department of Mathematical Sciences, Middle Tennessee State University, Murfreesboro, TN 37132, and **Cun-Quan Zhang**, Department of Mathematics, West Virignia University, Morgantown, WV 26506. *Hamilton 2-factor and K_5-minor free graphs.* Preliminary report.

A graph G is 2-factor Hamiltonian if every 2-factor of G is a hamiltonian cycle. Abreu, Aldred, Funk, Jackson, Labbate and Sheehan conjecture that a 4-regular simple graph G is 2-factor hamiltonian if and only if G is isomorphic to K_5. In this paper, we show that a 2-factor Hamiltonian 4-regular graph must contain K_5 as a minor. (Received January 09, 2017)

1126-05-134 **Sebastian M. Cioabă**, Department of Mathematical Sciences, University of Delaware, Newark, DE 19716, and **Xiaofeng Gu***, Department of Mathematics, University of West Georgia, Carrollton, GA 30118. *Spectral conditions for toughness of regular graphs.*

The toughness $t(G)$ of a connected graph G is defined as $t(G) = \min\{\frac{|S|}{c(G-S)}\}$, where the minimum is taken over all proper subset $S \subset V(G)$ such that $c(G-S) > 1$. This parameter was introduced by Chvátal in 1973 and is closely related to many graph properties, including Hamiltonicity, pancyclicity and spanning trees. In this talk, we will discuss the relationship between toughness and eigenvalues of a regular graph, as well as some related problems. (Received January 09, 2017)

1126-05-139 **Joshua E Ducey*** (duceyje@jmu.edu) and **Ian Hill**. *The critical group of the Kneser graph $KG(n,2)$.* Preliminary report.

Consider the graph with vertex set consisting of the 2-subsets of an n-element set. A pair of 2-subsets are adjacent when they are disjoint. This is the Kneser graph $KG(n,2)$, and is a nice example of a strongly regular graph.

An interesting invariant that can be attached to any finite graph is a finite abelian group known as the critical group (or sandpile group). Some interesting properties of the graph are reflected in the structure of this group; in particular, the order of the critical group is the number of spanning forests of the graph.

In this talk we will compute the critical group of the graph $KG(n,2)$ by applying some representation theory of the symmetric group. We will also give a combinatorial interpretation of the generators of a direct sum decomposition of the critical group. (Received January 09, 2017)

1126-05-142 **Pouria Salehi Nowbandegani*** (pouria.salehi.nowbandegani@vanderbilt.edu), 2601 Hillsboro Pike, A11, Nashville, TN 37212. *Chvátal-Erdős Condition of Prism-Hamiltonicity.*

Let G be a graph and by $\kappa(G)$ and $\alpha(G)$ we mean the connectivity and independence number of G respectively. The *prism* over a graph G is the Cartesian product $G\Box K_2$ of G with the complete graph K_2. If $G\Box K_2$ is Hamiltonian, we say that G is prism-Hamiltonian.

In this project we find sharp Chvátal-Erdős condition for the existence of a Hamiltonian cycle in $G\Box K_2$ and $G\Box K_k$. D. West asked the following question [1];

Given a positive integer k, what is the largest value of α such that if G has connectivity k and independence number α, then the prism over G is Hamiltonian? There are sharp examples which show that such α must be between k and $2k$.

We show the sharp result, that for a k-connected graph G with $\alpha(G) \leq 2k$, is prism-Hamiltonian. As a generalization of this result, for a graph G we proved that if $\alpha(G) \leq (k-1)\kappa(G)$ then $G\Box K_k$ is Hamiltonian.

References

[1] Douglas B. West, Hamiltonian Cycles in Prisms, Douglas B. West's Home Page http://www.math.illinois.edu/~dwest/regs/hamprism.html, Downloaded Dec. 2016.

(Received January 10, 2017)

1126-05-143 **Karimah Sweet*** (ksweet@oakland.edu), **Li Li**, **Eddie Cheng**, **Laszlo Liptak** and **Daniel E. Steffy**. *A Conjecture on determining which (n,k)-star graphs are not Cayley Graphs.*

We continue previous work on classifying which of the (n,k)-star graphs are Cayley graphs. We present a conjecture for the complete classification, and prove an asymptotic version of the conjecture, that is, the conjecture is true for all $k \geq 2$ when n is sufficiently large. For $k = 2, \cdots, 15$ we prove that the conjecture is true for all $n \geq k+2$ (with the exception of $n = 17$ for $k = 14$). (Received January 10, 2017)

1126-05-144 **Freddie Zhao*** (freddiezhao1@gmail.com), 4777 Northfield Parkway, Troy, MI 48098, and **Eddie Cheng**, **Spencer Liu** and **Chittesh Thavamani**. *Strong matching preclusioncProblem of the folded Petersen cube.* Preliminary report.

The strong matching preclusion number of a graph is the minimum number of vertices and/or edges whose deletion results in a graph that has neither perfect matchings nor almost perfect matchings. For many interconnection networks, the optimal sets are precisely those induced by a single vertex. This is an extension of the matching preclusion problem that was introduced by Park and Ihm. In this talk, we discuss the strong matching preclusion number of the folded Petersen cube $FPQ(n,k)$ and the classification of optimal strong matching preclusion sets of these graphs. (Received January 10, 2017)

1126-05-157 **Zoltán Füredi**, Alfréd Rényi Institute, **Alexandr Kostochka**, University of Illinois at Urbana-Champaign, **Ruth Luo*** (ruthluo2@illinois.edu), University of Illinois at Urbana-Champaign, and **Jacques Verstraete**, University of California San Diego. *On the number of edges and other subgraphs in graphs without long cycles.*

We consider two classical theorems for graphs without long cycles. The first theorem, due to Erdős, provides an upper bound for the number of edges in an n-vertex graph with minimum degree d and no hamiltonian cycle. The second theorem is Kopylov's strengthening of the Erdős–Gallai theorem for cycles and paths. It gives an upper bound for the number of edges in a 2-connected n-vertex graph with circumference less than k. In this talk we present stability versions of both theorems as well as generalizations in which we maximize the number of other fixed subgraphs in a graph without long cycles. (Received January 10, 2017)

1126-05-161 **Minfang Huang**, **Michael Santana** and **Gexin Yu***, Department of Mathematics, College of William and Mary, Williamsburg, VA. *Strong chromatic index of graphs with maximum degree four.* Preliminary report.

A strong edge-coloring of a graph G is a proper edge-coloring such that each color class forms an induced matching. The strong chromatic index is the minimum number of colors that allow G to have a strong edge-coloring. In this paper, we show that the strong chromatic index of a graph with maximum degree 4 is at most 21, which improves the previous 22 by Cranston (2006), and 1 away from the conjectured 20 by Erdős and Nešetřil (1987). (Received January 11, 2017)

1126-05-185 **Martin Rolek*** (mrolek@knights.ucf.edu) and **Zi-Xia Song**. *Double-critical graph conjecture for claw-free graphs.*

A connected graph G with chromatic number t is *double-critical* if $G\backslash\{x,y\}$ is $(t-2)$-colorable for each edge $xy \in E(G)$. The complete graphs are the only known examples of double-critical graphs. A long-standing conjecture of Erdős and Lovász from 1966, which is referred to as the *Double-Critical Graph Conjecture*, states that there are no other double-critical graphs. That is, if a graph G with chromatic number t is double-critical, then G is the complete graph on t vertices. This has been verified for $t \leq 5$, but remains open for $t \geq 6$. In this paper, we first prove that if G is a non-complete double-critical graph with chromatic number $t \geq 6$, then no vertex of degree $t+1$ is adjacent to a vertex of degree $t+1$, $t+2$ or $t+3$ in G. We then use this result to show that the Double-Critical Graph Conjecture is true for double-critical graphs G with chromatic number $t \leq 8$ if G is claw-free. (Received January 12, 2017)

1126-05-234 **Andrew Cooper*** (andrew.cooper@math.ncsu.edu), **Vin de Silva** and **Radmila Sazdanovic**. *A 'chromatic' polynomial for simplicial complexes.* Preliminary report.

We introduce a new polynomial invariant of simplicial complexes, motivated by the chromatic polynomial and the work of Eastwood-Huggett. We will describe the construction and discuss some of the polynomial's formal properties. (Received January 15, 2017)

1126-05-236 **Jiansheng Cai*** (healthcai@163.com), Peoples Rep of China. *C_4-Factor in Random Graphs.*

For a graph G with n vertices, where 4 divides n, a C_4-factor is a subgraph of G. consisting of $n/4$ vertex disjoint C_4. We consider the minimal probability $p = p(n)$, for which a random graph $G = G(n,p)$ almost surely contains a C_4-factor. In this paper, we prove that for $p = O(n^{-\frac{2}{3}})$, the random graph $G(n,p)$ almost surely contains a C_4-factor. (Received January 15, 2017)

1126-05-286 **Hanmeng Zhan*** (h3zhan@uwaterloo.ca), Combinatorics and Opimization, University of Waterloo, Waterloo, ON N2L3G1, Canada. *From covers to tight frames.*

An equiangular tight frame is a set of equiangular lines that meets the Welch bound. In this talk, we give an overview of the relation between equiangular tight frames (ETF) and distance-regular antipodal covers of the complete graphs (DRACKN). We show that for each abelian DRACKN, we can construct two complex EFTs in different dimensions. This is joint work with Gabriel Coutinho, Chris Godsil and Hamed Shirazi. (Received January 16, 2017)

1126-05-287 **Libby Taylor*** (libbyrtaylor@gmail.com), **Heather Smith**, **Fidel Barrera-Cruz** and **Tom Trotter**. *Boolean Dimension, Local Dimension, and Ramsey Theory on Binary Trees.* Preliminary report.

In this paper, we explore two variants of Dushnik-Miller dimension on posets, namely boolean dimension and local dimension. In our main result, we prove that the local dimension of a poset is not bounded in terms of the tree-width of its cover graph. The proof requires the development of some ramsey-theoretic tools for a class of posets called binary trees, which may prove to be of independent interest. In addition, we prove that the local dimension of a poset is not bounded in terms of its boolean dimension. (Received January 16, 2017)

1126-05-294 **Chris Godsil*** (cgodsil@uwaterloo.ca), Combinatorics & Optimization, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada. *Covers of graphs and equiangular tight frames.*

An r-fold cover of a graph X is obtained by replacing each vertex of X by a set of r vertices, and then replacing each edge by a set of r vertex-disjoint edges (an r-matching) joining the corresponding r-tuples. Covers of the complete graph are interesting, in part because in highly regular cases they give rise to equiangular tight frames. I will present my view of how this construction works, and I will discuss some generalizations. (Received January 16, 2017)

1126-05-340 **Pramod Achar** and **Maitreyee Kulkarni*** (mkulka2@lsu.edu), 3942, Gourrier Avenue, Apt no 209, Baton Rouge, LA 70808, and **Jacob Matherne**. *Combinatorial Fourier transform for quiver representation varieties in type A.*

For a given dimension vector, consider the moduli space of representations of the linearly-oriented type A quiver $\bullet \longrightarrow \bullet \longrightarrow \cdots \longrightarrow \bullet$. This affine space has a stratification by orbits for a product of general linear groups, so we can study the equivariant constructible derived category of sheaves on it. The Fourier–Sato transform, which plays a crucial role in Springer theory and throughout geometric representation theory, gives an equivalence between this derived category and the derived category for the reversed quiver. We introduce certain triangular arrays of nonnegative integers and, with them, give a combinatorial algorithm for computing the Fourier–Sato transform in this setting. This is joint (in progress) work with Pramod N. Achar and Jacob P. Matherne. (Received January 17, 2017)

1126-05-357 **Meghann Moriah Gibson*** (nikkicollins@georgiasouthern.edu), Georgia Southern University, 65 Georgia Ave. Room 3008, P.O. Box 8093, Statesboro, GA 30460, and **Daniel Gray** and **Hua Wang**. *Combinatorics of n-Colored Cyclic Compositions.* Preliminary report.

Integer compositions and related enumeration problems have been of interests to combinatorialists and number theorists for a long time. The cyclic and colored analogues of this concept, although interesting, have not been extensively studied. We explore the combinatorics of n-colored cyclic compositions, presenting generating functions, bijections, asymptotic formulas related to the number of such compositions, and the number of parts and the number of restricted parts of certain cyclic compositions. (Received January 17, 2017)

1126-05-360 **Wei-Hsuan Yu*** (u690604@gmail.com), 619 Red Cedar Rd, east lansing, MI 48862, 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 17, 2017)

1126-05-367 **Yaping Mao**, **Christopher Melekian*** (ccmeleki@oakland.edu) and **Eddie Cheng**. *Constructing Internally Disjoint Pendant Steiner Trees in Lexicographic Product Networks.*

The concept of pendant tree-connectivity was introduced by Hager in 1985. For a graph $G = (V, E)$ and a set $S \subseteq V(G)$ of at least two vertices, *an S-Steiner tree* or *a Steiner tree connecting S* (or simply, *an S-tree*) is a such subgraph $T = (V', E')$ of G that is a tree with $S \subseteq V'$. For an S-Steiner tree, if the degree of each vertex in S is equal to one, then this tree is called a *pendant S-Steiner tree.* Two pendant S-Steiner trees T and T' are said to be *internally disjoint* if $E(T) \cap E(T') = \varnothing$ and $V(T) \cap V(T') = S$. For $S \subseteq V(G)$ and $|S| \geq 2$, the *local pendant tree-connectivity* $\tau_G(S)$ is the maximum number of internally disjoint pendant S-Steiner trees in G. For an integer k with $2 \leq k \leq n$, *pendant tree k-connectivity* is defined as $\tau_k(G) = \min\{\tau_G(S) \mid S \subseteq V(G), |S| = k\}$. In this paper, we prove that for any two connected graphs G and H, $\tau_3(G \circ H) \geq \tau_3(G)|V(H)| + \min\{|V(H)| - 2\tau_3(G) - 2, 0\}$, where $G \circ H$ denotes the lexicographic product of G and H. Moreover, the bound is sharp. We also derive an upper bound of $\tau_3(G \circ H)$. (Received January 17, 2017)

1126-05-370 **Charles Lanning*** (cl04438@georgiasouthern.edu). *Pattern Containment in Circuler Permutaions.* Preliminary report.

Pattern containment in permutations, as opposed to pattern avoidance, involves two aspects. The first is to contain every pattern at least once from a given set, known as superpatterns; while the second is to contain some given pattern as many times as possible, known as pattern packing. In this talk we explore these two questions in circular permutations and present some interesting observations. We also raise some questions and propose directions for future study. (Received January 17, 2017)

1126-05-398 **Julianna Tymoczko*** (jtymoczko@smith.edu), Department of Mathematics and Statistics, Smith College, 44 College Lane, Northampton, MA 01060. *Equivariant cohomology of certain affine Springer fibers.*

The (finite) Springer fiber is a subvariety of the flag manifold whose geometry encodes information about the representations of the symmetric group. We describe an infinite analogue: the affine Springer fiber sitting inside the affine Grassmannian. Using the methods of Goresky-Kottwitz-MacPherson, we give explicit generating sets for the equivariant cohomology of certain affine Springer fibers. Part of this work is joint with Holly Mandel of Rutgers University and Claudia Yun of Smith College. (Received January 18, 2017)

08 ► General algebraic systems

1126-08-60 **David M. Clark*** (clarkd@newpaltz.edu). *Benefits of Term to Term Operation Continuity.* Preliminary report.

A finite groupoid is term continuous if small changes in a term result in small changes in its term operation. A precise formulation of this notion, modeled after biological evolution, recently made it possible to prove that two testable conditions on a finite groupoid imply that it is term continuous. It was conjectured that these two conditions hold for almost all finite groupoids, although one fails for every non-trivial quasigroup. Subsequently an efficient algorithm for finding terms for given term operations was shown experimentally to succeed if and only if the groupoid was idemprimal and term continuous.

This talk presents a new theorem that connects these results, giving a consequence of term continuity that shows why a broad class of evolutionary-inspired search algorithms will efficiently find terms for a given term operation if and only if the groupoid is idemprimal and term continuous. This work has led to a number of well motivated open questions about finite groupoids. (Received December 26, 2016)

1126-08-153 **Clifford Bergman*** (cbergman@iastate.edu). *Finding sharply congruence-k-permutable algebras.* Preliminary report.

A variety $\mathcal{V}$ is *congruence-k-permutable* if for any algebra $\mathbf{A} \in \mathcal{V}$ and any two congruences θ and ψ of $\mathbf{A}$, the join of θ and ψ in the congruence lattice is equal to $\theta \circ \psi \circ \theta \circ \cdots$ (with $k-1$ many relative products). The traditional notion of congruence permutability coincides with congruence-2-permutable. We shall call an algebra *sharply k-permutable* if it generates a variety that is congruence-k-permutable but not $(k-1)$-permutable.

For $k > 2$ the task of finding finite sharply k-permutable algebras is surprisingly difficult. Few examples appear in the literature. We shall discuss methods for finding "random" k-permutable algebras and the potential for success. (Received January 10, 2017)

1126-08-186 **Matt Valeriote*** (matt@math.mcmaster.ca), Department of Mathematics & Statistics, McMaster University, Hamilton, Ontario L8S 4K1, Canada. *Testing Assignments to Constraint Satisfaction Problems.*

For a finite relational structure A, let CSP(A) denote the CSP instances whose constraint relations are taken from A. We consider CSP(A) from the perspective of property testing: given an instance of CSP(A) and query access to an assignment, one wants to decide whether the assignment satisfies the instance, or is far from doing so. We establish a dichotomy theorem completely characterizing the structures A such that CSP(A) is constant-query testable: (i) If A has a majority polymorphism and a Maltsev polymorphism, then CSP(A) is constant-query testable with one-sided error. (ii) Else, testing CSP(A) requires a super-constant number of queries. This is joint work with Hubie Chen and Yuichi Yoshida. (Received January 12, 2017)

1126-08-241 **Andrew P. Moorhead*** (andrew.moorhead@colorado.edu). *Higher Commutator Theory for Congruence Modular Varieties.*

A general binary commutator theory for a universal algebra was developed in the seventies and eighties. This theory was found to be as powerful as the theory of the ordinary commutator for groups in the context of a congruence modular variety. Bulatov generalized this commutator to a commutator of higher arity at the beginning of the century, thereby identifying a tool that allows for finer distinctions than those possible with the binary commutator. Recent work of the author demonstrates that the theory of this higher commutator is as powerful as that of the binary commutator for congruence modular varieties. The first portion of this talk will be a survey of these results.

A fundamental result in the theory of the binary commutator for congruence modular varieties is the classification of the abelian algebras, or more generally the abelian congruences of an algebra, as those structures that are affine. This classification follows from the observation that the difference term becomes a Mal'cev operation on equivalence classes and that this operation is a homomorphism. The second portion of this talk will discuss results that generalize these ideas to higher dimensions. (Received January 15, 2017)

1126-08-252 **Nathan E. Faulkner*** (nathanfaulkner@gmail.com), 3320 Wide Country Rd., Tobaccoville, NC 27040. *Some efforts in sharpening finite basis theory: Studies of nilpotence inspired by Oates and Powell.*

In 1952, Lyndon found that any nilpotent group has a finite basis (for its equational theory). Relying on a proof of Lyndon's result, Oates and Powell (1964) found that any finite group also has a finite basis. This talk introduces some efforts to generalize the techniques used by Oates and Powell, with an eye toward further finite basis results: generalizing Oates and Powell and resolving whether or not all finite, Mal'cev, nilpotent algebras are finitely based.

For V, a variety generated by a finite group A, its local finiteness, its exponent, its bound on the cardinality on its chief factors, and the nilpotence class of any nilpotent groups therein, for high enough n, can be "lifted" to V^n, the class of groups which satisfy all of the n-variable equations true in A. Oates and Powell use this to establish a bound on the critical factors of V^n. We will indicate how to manage those four tasks in settings that generalize groups or, at least, nilpotent groups, as well as showing what connection supernilpotence has to criticality via a result that parallels a crucial one in the Oates-Powell proof. (This work is based on a portion of a 2015 dissertation carried out at the University of South Carolina under the direction of George F. McNulty.) (Received January 15, 2017)

1126-08-269 **Ross Willard***, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada. *My favorite open problems in universal algebra.* Preliminary report.

My favorite open problems involve finite algebras having only finitely many basic operations, and the subdirectly irreducible models of their equational theories. In this talk I will reminisce on work over the last 40 years that has failed to solve these problems. (Received January 16, 2017)

1126-08-375 **Hubie Chen** and **Peter Mayr*** (peter.mayr@colorado.edu), University of Colorado, Boulder, CO. *Quantified constraint satisfaction on monoids.*

The quantified constraint satisfaction problem QCSP for a fixed finite relational structure has as input a first order sentence over this structure built from atoms, conjunction, and both existential and universal quantifiers. The problem is then to decide whether the sentence is true. This is well-known to be always in PSPACE. We aim to classify structures by the computational complexity of their QCSP.

Using an established algebraic viewpoint we can replace a relational structure by its polymorphism algebra and ask about the complexity of the QCSP for this algebra instead. We show that the QCSP of any finite monoid is either in P or NP-complete. (Received January 17, 2017)

1126-08-377 **John F Boozer*** (mostillogical@gmail.com), 800 State St, Apt 159, West Columbia, SC 29169. *On the Finite Axiomatizability of Equational Theories of Automatic Algebras.*

An algebra is a set of elements equipped with some finitary operations represented by a selected set of operation symbols. Using the operation symbols, we can form equations that describe identities in the algebra. We can investigate to see if the set of equations that hold in an algebra is axiomatizable by a finite set of equations, for which we call the algebra finitely based. If not, we can further ask if the algebra satisfies a stronger condition we call inherently nonfinitely based. For instance all finite groups and rings were shown in 1964 and 1973, respectively, to be finitely based.

A finite automaton can be represented in an algebraic way to give us a type of groupoid, which we call an automatic algebra. Automatic algebras are of interest because, unlike groups and rings, among finite automatic algebras there are examples, already in the literature, of finitely based algebras, inherently nonfinitely based algebras, and those that are neither.

In this dissertation we will begin to classify the finite automatic algebras into the three categories, as well as developing tools and methods useful for dealing with automatic algebras. (Received January 17, 2017)

1126-08-385 **Ralph N. McKenzie*** (ralph.n.mckenzie@vanderbilt.edu), Department of Mathematics, Vanderbilt University, 1326 Stevenson Center, Nashville, TN 37240. *How I approached research problems, and sometimes solved them.*

I will talk (by request) about how I have gone about the work of mathematical research (which I have been doing for fifty years). How did I select problems, go about tackling them, develop ideas, and so on? I have collaborated with more than fifty researchers over the years, and I will be talking about some of these colleagues. My research methods have of course changed over time (hopefully, developed). (Received January 17, 2017)

1126-08-399 **Keith Kearnes*** (kearnes@colorado.edu), **Emil W. Kiss** and **Agnes Szendrei**.
Varieties whose finitely generated algebras are free.

I will explain why a variety of algebras whose finitely generated members are free must be definitionally equivalent to the variety of sets, the variety of pointed sets, a variety of vector spaces over a division ring, or a variety of affine vector spaces over a division ring. (Received January 18, 2017)

1126-08-400 **Agnes E. Szendrei*** (szendrei@colorado.edu) and **Peter Mayr**. *Algebras from Congruences.* Preliminary report.

Peter Mayr proved that the subpower membership problem for every finite supernilpotent Mal'cev algebra A of finite type is in P. We will discuss a construction that allows us to extend this result to finite Mal'cev algebras A such that for every subdirectly irreducible $B \in HS(A)$ the centralizer of the monolith of B is supernilpotent. (Received January 18, 2017)

11 ► Number theory

1126-11-84 **Kirsten Eisentraeger*** (eisentra@math.psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802. *A quantum algorithm for computing the unit group of a number field of arbitrary degree.*

Computing the group of units in a number field is one of the central tasks of computational algebraic number theory. It is believed to be hard classically, which is of interest for cryptography. In the quantum setting, efficient algorithms were previously only known for number fields of constant degree. We give a quantum algorithm that is polynomial in the degree of the field and the logarithm of its discriminant. We will show how this result can be used to break some of the recently proposed lattice-based cryptosystems. This is joint work with Sean Hallgren, Alexei Kitaev, and Fang Song. (Received January 05, 2017)

1126-11-85 **Kirsten Eisentraeger*** (eisentra@math.psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802. *Undecidability for the perfect closure of function fields of positive characteristic.*

Let K be the perfect closure of the rational functional field over the finite field with p elements. We show that the theory of K is undecidable and discuss how this can be generalized to the perfect closure of global fields of positive characteristic. (Received January 05, 2017)

1126-11-160 **Alexandra Shlapentokh*** (shlapentokha@ecu.edu), Department of Mathematics, East Carolina University, Greenville, NC 27858. *Defining Valuation Rings over Function Fields of Characteristic 0.* Preliminary report.

Given a function field K of characteristic 0 and a prime (or a valuation) of this field, we discuss how to construct an existential definition of the subring of K containing functions without a pole at the given prime. This problem was solved for a class of rational function fields in 1992 by Kim and Roush but was not completely generalized to algebraic extensions until now. (Received January 10, 2017)

1126-11-265 **Dane C Skabelund*** (skabelu2@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W Green Street (MC-382), Urbana, IL 61801-2975.
New maximal curves as ray class fields over Suzuki and Ree curves.

We give a concrete description of new covers of the Suzuki and Ree curves which are maximal with respect to the Hasse-Weil bound over suitable finite fields. These covers are analogues of the Giulietti-Korchmáros curve, which covers the Hermitian curve. We show that the maximality of these curves implies that certain ray class field extensions of each of the Deligne-Lusztig curves are also Hasse-Weil maximal. Moreover, we show that the Giulietti-Korchmáros curve is equal to the above-mentioned ray class field extension of the Hermitian curve. (Received January 16, 2017)

1126-11-277 **Anne M. Ho*** (aho@coastal.edu), Coastal Carolina University, Department of Mathematics and Statistics, P.O. Box 261954, Conway, SC 29528, and **Rachel Pries**.
Counting Artin-Schreier Curves Over Finite Fields. Preliminary report.

A number of authors have considered the weighted sum of various types of curves with a certain genus g over a finite field $k := F_q$ of a specific characteristic. These include elliptic curves (Howe), hyperelliptic curves (Van der Geer, Van der Vlught), and Artin-Schreier curves (Cardona, Nart, Pujolás, Sadornil). We extend the work of these authors by considering a related weighted sum for Artin-Schreier curves with a given genus g over fields of any characteristic p. We will discuss our results and methods of counting, which include looking at ramification divisors, finding associated rational models $y^p - y = u(x)$, and examining the actions of $PGL_2(k)$ on the models. In addition, we will discuss the geometric connections to the moduli space of Artin-Schreier curves. (Received January 16, 2017)

1126-11-325 **Alia Hamieh** (alia.hamieh@uleth.ca), University of Lethbridge, Lethbridge, AB T1K 3M4, Canada, and **Naomi Tanabe*** (naomi.tanabe@dartmouth.edu), Dartmouth College, Hanover, NH 03755. *Non-vanishing of Central Values of Rankin-Selberg L-functions.*

In this talk, we study some nonvanishing results on the central L-values of Rankin-Selberg convolutions with two Hilbert modular forms. Such results are established by obtaining bounds on their twisted moments. (Received January 17, 2017)

1126-11-362 **Beth Malmskog*** (beth.malmskog@gmail.com), **Katie Haymaker** and **Gretchen Matthews**. *Locally Recoverable Codes with Multiple Recovery Sets: A General Fiber Product Construction.*

Locally recoverable codes (LRCs) have benefits for distributed storage applications. Barg, Tamo, and Vladut recently constructed LRCs with one and two recovery sets from algebraic curves. This talk presents a generalization of this construction to $t \geq 3$ recovery sets, using iterated fiber products of curves. Codes with arbitrarily many recovery sets are constructed, employing maximal curves from fiber products devised by Van der Geer and Van der Vlugt. (Received January 17, 2017)

1126-11-389 **Rodney Keaton***, keatonr@etsu.edu. *On the matrix partition function of Ozeki.* Preliminary report.

In a paper from 1984, Michio Ozeki defined a partition function for a certain class of matrices. In many ways, this function mirrors the more well known integer partition function. In this talk, we will introduce Ozeki's partition function and present several properties which are analogous to those satisfied by the integer partition function. (Received January 17, 2017)

1126-11-391 **Ricardo Conceicao*** (rconceic@gettysburg.edu), **Rodrigo Gondim** and **Miguel Rodriguez**. *On a Frobenius problem for polynomials.*

We extend the famous diophantine Frobenius problem to the setting of polynomials over a field k. Similar to the classical problem, we show that the $n = 2$ case of the Frobenius problem for polynomials is easy to solve. In addition, we translate a few results from the Frobenius problem over $\mathbb{Z}$ to $k[t]$. When k is a finite field, we discuss some striking contrasts between the classical and the polynomial case, and mention a few ideas for future research. (Received January 17, 2017)

1126-11-393 **Kirsten Eisentraeger** (eisentra@math.psu.edu), State College, PA 16802, **Russell Miller** (russell.miller@qc.cuny.edu), New York, NY 11367, **Jennifer Park*** (jmypark@umich.edu), Ann Arbor, MI 48109, and **Alexandra Shlapentokh** (shlapentokha@ecu.edu), Greenville, NC 27858. *Hilbert's tenth problem for subrings of Q.*

Determining whether there is an algorithm that decides the $\mathbb{Q}$-solvability of polynomials with integer coefficients is a very difficult open problem, although we know that there are no algorithms that decides the $\mathbb{Z}$-solvability of polynomials by the work of Matiyasevich, Davis, Putnam, and Robinson. In this talk, we construct a ring R that is "close" to $\mathbb{Z}$: namely, a ring of the form $\mathbb{Z}[S^{-1}]$, where S is a "small" set of primes that are inverted in R. Then we will show that determining the R-solvability of polynomials is just as hard as determining the $\mathbb{Q}$-solvability of polynomials, using the notion of Turing equivalence. This work is joint with K. Eisentraeger, R. Miller, and A. Shlapentokh. (Received January 17, 2017)

12 ► *Field theory and polynomials*

1126-12-308 **Daniel Panario*** (daniel@math.carleton.ca). *Iterating Rédei Functions over Finite Fields.*

The dynamics of iterations of polynomials and rational functions over finite fields have attracted much attention in recent years, in part due to their applications in cryptography and integer factorization methods like Pollard rho algorithm. We study the action of Rédei functions over nonbinary finite fields. Rédei functions have been applied in several areas including pseudorandom number generators and cryptography. They are defined as $R_n(x,a) = \frac{N(x,a)}{D(x,a)}$ over $\mathbb{D}_q^a = \mathbb{P}^1(\mathbb{F}_q) \setminus \{\pm\sqrt{a}\}$, where $\mathbb{P}^1(\mathbb{F}_q) := \mathbb{F}_q \cup \{\infty\}$, $a \in \mathbb{F}_q$, and $N(x,y), D(x,y)$ are given by $(x+\sqrt{y})^n = N(x,y) + D(x,y)\sqrt{y}$. We completely characterize the functional graph of these actions studying the cycle length and tail length of its orbits, as well as the number of periodic points, and the number of cycles of $R_n(x, a)$ as a map over $\mathbb{P}^1(\mathbb{F}_q)$.

Based on joint works with Claudio Qureshi (Unicamp) and Rodrigo Martins (UTFPR). (Received January 16, 2017)

13 ► Commutative rings and algebras

1126-13-16 **Michael C Steward*** (steward.57@osu.edu). *Factoring Integrally Closed Homogeneous Monomial Ideals in Three Variables.* Preliminary report.

In a ring $k[x, y, z]$, where k is a field, some ideals are non-cancellative. This complicates the investigation of ideal factorization, since for instance, $(x, y)(x, y)(x, y) = (x, y)(x^2, y^2)$. If we instead consider only integrally closed ideals, we avoid this issue. To simplify, we restrict our attention to integrally closed homogeneous monomial ideals of $k[x, y, z]$. I will discuss a connection to convex hulls in the plane and demonstrate that the elasticity of the monoid is infinite. (Received November 02, 2016)

1126-13-22 **Christopher Park Mooney*** (christopher.mooney@westminster-mo.edu), Westminster College, 501 Westminster Avenue, Fulton, MO 65251. *On Labelings of Zero-Divisor Graphs.* Preliminary report.

We study graphs associated with a commutative ring with zero-divisors, R, called the zero-divisor graph, $\Gamma(R)$. This is the simple, undirected graph whose vertices are the non-zero, zero-divisors and has an edge between distinct vertices x and y if $xy = 0$. Much of the initial research surrounding these graphs revolved around coloring the zero-divisor graph, which can be viewed as a particular type of vertex labeling. In this talk, we focus on other important labelings that have received significant attention in graph theory. We present several results about infinite classes of rings whose zero-divisor graphs either do or do not satisfy these various labeling properties. We also discuss current and future related research. (Received November 21, 2016)

1126-13-49 **Olivier A. Heubo-Kwegna***, 7400 Bay Road, University Center, MI 48710, and **Bruce Olberding** and **Andreas Reinhart**. *Group-Theoretic and Topological Invariants for Completely Integrally Closed Prüfer Domains.*

We consider the lattice-ordered groups Inv(R) and Div(R) of invertible and divisorial fractional ideals of a completely integrally closed Prüfer domain. We prove that Div(R) is the completion of the group Inv(R). Among the class of completely integrally closed Prüfer domains, we focus on the one-dimensional Prüfer domains. This class includes Dedekind domains, the latter being the one-dimensional Prüfer domains whose maximal ideals are finitely generated. However, numerous interesting examples show that the class of one-dimensional Prüfer domains includes domains that differ quite significantly from Dedekind domains by a number of measures, both group-theoretic (involving Inv(R) and Div(R)) and topological (involving the maximal spectrum of R). We examine these invariants in connection with the class of SP-domains, those domains for which every proper ideal is a product of radical ideals. For this last class of domains, we show that if in addition the ring has nonzero Jacobson radical, then the lattice-ordered groups Inv(R) and Div(R) are determined entirely by the topology of the maximal spectrum of R. (Received December 19, 2016)

1126-13-59 **David E. Dobbs*** (dobbs@math.utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 37996-1320. *On the commutative rings with at most two proper subrings.* Preliminary report.

The (commutative unital) rings R with at most two proper (unital) subrings are characterized. In the case of characteristic 0, such rings R are classified up to isomorphism. In the case of positive characteristic, the problem of classifying such rings R up to isomorphism is reduced to the problems, for a prime number p and an integer $n \geq 2$, of classifying up to isomorphism (1) the rings A such that $\mathbb{Z}/p^n\mathbb{Z} \subset A$ is a ramified extension and (2) the rings B such that $\mathbb{Z}/p^n\mathbb{Z} \subset A \subset B$ is a tower of ramified extensions with B having a generator satisfying certain specific relations. For (1) (resp., (2)), this question of classification up to isomorphism is answered in case p is arbitrary and $n = 2$ (resp., in case $p^n = 4$), while for arbitrary p and n, nontrivial bounds are given for the relevant number of isomorphism classes. (Received December 24, 2016)

1126-13-62 **Ashley K. Wheeler*** (ashleykw@uark.edu), Department of Mathematical Sciences, SCEN 309, University of Arkansas, Fayetteville, AR 72701, **Roberto Barrera** (rbarrera@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A & M University, College Station, TX 77843-3368, and **Jeffrey Madsen** (madsen4@purdue.edu), Department of Mathematics, Purdue University, 150 North University Street, West Lafayette, IN 47907-2067. *Finiteness of associated primes of local cohomology modules over Stanley-Reisner rings.* Preliminary report.

Local cohomology modules, even over a Noetherian ring R, are typically unwieldy. As such, it is of interest whether or not they have finitely many associated primes. We prove the affirmative in the case where R is a Stanley-Reisner ring, over a field, whose associated simplicial complex is a T-space. (Received December 28, 2016)

1126-13-68 **S. Estrada**, **X. Fu** and **A. Iacob*** (aiacob@georgiasouthern.edu). *Totally acyclic complexes.*

It is known that over an Iwanaga-Gorenstein ring the Gorenstein projective (Gorenstein injective, Gorenstein flat) modules are simply the cycles of the exact complexes of projective (injective, flat) modules. We consider the question: are these characterizations working only over Iwanaga-Gorenstein rings?
Among other results we prove the following theorem:
Let R be a two sided noetherian ring of finite finitistic flat dimension that satisfies the Auslander's condition. The following are equivalent:
1. R is Iwanaga-Gorenstein.
2. Every acyclic complex of injective left (right) R-modules is totally acyclic. (Received January 01, 2017)

1126-13-86 **Eloísa Grifo***, eloisa.grifo@virginia.edu, and **Craig Huneke**. *Symbolic powers of ideals defining F-pure rings.* Preliminary report.

Given a radical ideal I in a regular ring R, the containment problem of symbolic and ordinary powers of I consists of determining which symbolic powers of I are contained in each power of I. By work of Ein-Lazersfeld-Smith and Hochster-Huneke, there is a uniform answer to this question, but the containments it provides are not necessarily best possible.

In this talk, we will discuss the containment problem and present new results for the case when R/I is F-pure or when R/I is strongly F-regular; in particular, that a conjecture of Harbourne holds in the F-pure case. (Received January 05, 2017)

1126-13-106 **Luchezar L. Avramov**, **Courtney Gibbons** and **Roger A. Wiegand*** (rwiegand1@unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130. *Syzygies and Betti tables over short Gorenstein algebras.* Preliminary report.

Let k be a field and R a short, standard graded Gorenstein k-algebra with embedding dimension $e \geq 3$. (Thus the Hilbert series of R is $1 + es + s^2$.) The additive semigroup $\mathbf{B}$ of all Betti tables of finitely generated graded R-modules is atomic but very far from being factorial. We will show how the atoms of $\mathbf{B}$ arise as Betti tables of cosyzygies of ideals of R and describe some specific relations among these atoms. (Received January 07, 2017)

1126-13-111 **Gyu Whan Chang** and **Hwankoo Kim*** (hkkim@hoseo.edu), School of Computer & Information Engineering, Hoseo University, Asan, 31499, South Korea. *When is the w-integral closure of a domain a Krull domain?* Preliminary report.

Let D be an integral domain with quotient field K and let $D^{[w]}$ be the so-called the w-integral closure of D in K; so if D is Noetherian or $\dim(D) = 1$, then $D^{[w]}$ is the integral closure of D. Mori–Nagata theorem states that the integral closure of a Noetherian domain is a Krull domain. In this talk, we show when $D^{[w]}$ is a PvMD (resp., Krull domain). (Received January 08, 2017)

1126-13-135 **Michael C Axtell*** (axte2004@stthomas.edu), University of St. Thomas, St. Paul, MN 55105, and **Nick Baeth** and **Joe Stickles**. *Factorizations in self-idealizations of PIRs.*

The self-idealization of a commutative ring R is isomorphic to the ring $R[x]/(x^2)$ or, equivalently, the ring of upper-triangular Toeplitz matrices over R, $T(R)$. Recently, Chang and Smertnig characterized the sets of lengths of factorizations in $T(D)$ where D is a principal ideal domain. In this talk, in addition to correcting an error in their paper, we extend the study to $T(R)$ when R is a principal ideal ring. (Received January 09, 2017)

1126-13-147 **Richard Erwin Hasenauer*** (hasenaue@nsuok.edu). *A characterization of non-Noetherian BFDs and FFDs.*

Characterizations of bounded and finite factorization domains are given using topological notions. Using our characterizations, the almost Dedekind domain and Prüfer domain constructed by Grams are shown to be a BFD and an FFD respectively. For a class of almost Dedekind (not Dedekind) domains it is shown that satisfying the ascending chain condition for principal ideals implies BFD. (Received January 10, 2017)

1126-13-148 **Nicholas Baeth**, **Michael Axtell** and **Joe Stickles*** (jstickles@millikin.edu). *Factorizations in self-idealizations of UFRs.*

The self-idealization of a commutative ring R is isomorphic to the ring $R[x]/(x^2)$ or, equivalently, the ring of upper-triangular Toeplitz matrices, $T(R)$, over a ring R. Recently, Chang and Smertnig characterized the sets of lengths of factorizations in $T(D)$ where D is a principal ideal domain. In this talk, we extend the study to $T(R)$ when R is a unique factorization ring that is not a principal ideal ring. (Received January 10, 2017)

1126-13-150 **Adela Vraciu*** (vraciu@math.sc.edu). *When are generic forms exact zero divisors?* Preliminary report.

Let (R, m) be an Artinian ring. A pair of elements (x, y) is a pair of exact zero divisors if $\operatorname{ann}(x) = (y)$ and $\operatorname{ann}(y) = (x)$.

Conca showed that a standard graded ring with $m^3 = 0$ defined by generic quadratic equations has a Conca generator, i.e. an element $x \in m$ such that $x^2 = 0$ and $m^2 = xm$. If moreover $\operatorname{rank}(m/m^2) = \operatorname{rank}(m^2)$, then a Conca generator is an exact zero divisor. In fact, a generic linear form in a ring as described above is an exact zero divisor. More generally, if a standard graded ring with $m^3 = 0$ admits exact zero divisors, then a generic linear form in that ring is an exact zero divisor.

We investigate a converse of this statement. More precisely, if (R, m) is a standard graded ring and $d \geq 1$ is an integer such that a generic form of degree d is an exact zero divisor, then we prove that $m^3 = 0$. (Received January 10, 2017)

1126-13-151 **Lee Klingler*** (klingler@fau.edu), 777 Glades Road, Boca Raton, FL 33431, and **Warren McGovern**, 5353 Parkside Drive, Jupiter, FL 33458. *Pseudo-Valuation Domains and $C(X)$.* Preliminary report.

Let D be a local integral domain with maximal ideal M and field of fractions K. We consider the following conditions on D.

(1) D is a valuation domain, i.e., the ideals of D are linearly ordered by inclusion.

(2) D is a pseudo-valuation domain, i.e., $M : M = \{a \in K : aM \subseteq M\}$ is a valuation domain with maximal ideal M.

(3) $M : M$ is a valuation domain.

(4) D is a divided domain, i.e., $PD_P = P$ for all prime ideals $P \subseteq D$.

(5) The prime ideals of D are linearly ordered by inclusion.

It is well-known that (1) implies (2), (2) implies both (3) and (4), and each of (3) and (4) implies (5). We show that in fact (3) implies (4), and we explore which of these conditions hold for domains of the form $C(X)/P$, where $C(X)$ is the ring of continuous, real-valued functions on the compact, Tychonoff space X, and $P \subseteq C(X)$ is a prime ideal. (Received January 10, 2017)

1126-13-155 **Andrew R. Kustin***, kustin@math.sc.edu. *Degree bounds for local cohomology.*

Let R be a non-negatively graded Cohen-Macaulay ring with R_0 a Cohen-Macaulay factor ring of a local Gorenstein ring. Let $d = \dim R$, $\mathfrak{m}$ be the maximal homogeneous ideal of R, and M be a finitely generated graded R-module.

It has long been known how to read information about the socle degrees of the local cohomology module $H^0_{\mathfrak{m}}(M)$ from the twists in position d in a resolution of M by free R-modules. It has also long been known how to use local cohomology to read valuable information from complexes which approximate resolutions in the sense that they have positive homology of small Krull dimension. The present paper reads information about the maximal generator degree (rather than the socle degree) of $H^0_{\mathfrak{m}}(M)$ from the twists in position $d-1$ (rather than position d) in an approximate resolution of M.

This is joint work with Claudia Polini and Bernd Ulrich. (Received January 10, 2017)

1126-13-164 **Florian Enescu*** (fenescu@gsu.edu), Department of Mathematics and Statistics, 758 CEHD, Georgia State University, Atlanta, GA 30303. *On the finiteness of Frobenius complexity.* Preliminary report.

The notion of Frobenius complexity for local rings of prime characteristic has been introduced by the presenter and Yongwei Yao, who raised the question whether this number is finite. I will present work performed with Mel Hochster and, independently, Felipe Peréz that shows that this holds for local, normal complete rings and, respectively, standard graded algebras over a field. (Received January 11, 2017)

1126-13-194 **Eliana M Duarte*** (emduart2@illinois.edu), Department of Mathematics, 1409 W Green St, Urbana, IL 61801. *Syzygies and Tensor product surfaces.*

A tensor product surface is the image of a map $\lambda : \mathbb{P}^1 \times \mathbb{P}^1 \to \mathbb{P}^3$, such surfaces arise in geometric modeling and in this context it is important to know their implicit equation. Currently, syzygies are one of the main tools to find implicit equations of parameterized curves and surfaces. In this talk I will overview the main techniques to find implicit equations of tensor product surfaces using syzygies. Additionally, I will present recent results on the structure of the syzygies that determine the implicit equation for tensor product surfaces. It turns out that for tensor product surfaces with basepoints the degree of the syzygies that determine the implicit equations is directly related to the geometry of the base locus of λ. (Received January 13, 2017)

1126-13-206 **Nicholas R Baeth*** (baeth@ucmo.edu), W.C. Morris 213, UCM, Warrensburg, MO 64064. *Examples of unbounded length sets in commutative rings with zerodivisors.*

When D is a commutative integral domain, the degree to which factorization in D is unique can be studied by considering length sets. For a nonzero element x in an integral domain D,

$$\mathsf{L}_d(x) = \{n \colon x = a_1 \cdots a_n \text{ with each } a_i \text{ irreducible}\}$$

is its length set. If D is a UFD, then $|\mathsf{L}_D(x)| = 1$ for all $x \in D \backslash \{0\}$, and larger length sets indicate a degree of nonunique factorization in D. This concept has been well studied, and has been extended to the study of factorization in cancellative noncommutative rings. In this talk we give examples of elements in commutative rings with zerodivisors having unbounded length sets. In particular, we will classify the sets that occur as length sets of elements in quotients of principal ideal domains and in so-called rings of single-valued matrices. (Received January 13, 2017)

1126-13-208 **Scott T Chapman*** (scott.chapman@shsu.edu). *The Catenary Degrees of elements in Numerical Monoids generated by Arithmetic Sequences.* Preliminary report.

We compute the catenary degree of elements contained in numerical monoids generated by arithmetic sequences. We find that this can be done by describing each element in terms of the cardinality of its length set and of its set of factorizations. As a corollary, we find for such monoids that the catenary degree becomes fixed on large elements. This allows us to define and compute the *dissonance number*- the largest element with a catenary degree different from the fixed value. We determine the dissonance number in terms of the arithmetic sequence's starting point and its number of generators. (Received January 13, 2017)

1126-13-212 **Giulio Peruginelli** and **Nicholas J Werner*** (wernern@oldwestbury.edu), Department of Mathematics, SUNY College at Old Westbury, Old Westbury, NY 11568. *RD-pure Elements of an Algebra.* Preliminary report.

Given a commutative ring R and two R-modules $N \subseteq M$, we say that N is *relatively divisible pure (RD-pure)* in M (or that N is an *RD-pure* submodule of M) if for every $r \in R$, $rM \cap N = rN$; i.e., every element $n \in N$ that is divisible by some $r \in R$ in M is already divisible by r in N. Let D be an integrally closed domain and A a torsion-free D algebra. We say that $a \in A$ is *RD-pure* if for all $d \in D$ we have $dA \cap D[a] = dD[a]$; that is, if $D[a]$ is an RD-pure D-submodule of A.

Our motivation for this topic comes from working with companion matrices and attempting to isolate properties of them that may be useful in other algebras. RD-purity is one such property, because any companion matrix in the matrix algebra $M_n(D)$ is RD-pure (although they are not the only RD-pure elements of $M_n(D)$) and RD-purity has a surprising number of equivalent definitions in a general D-algebra A. In addition to the definitions given above, RD-pure elements of A can be characterized in terms of their minimal polynomials over D, their null ideals over residue rings of D, or polynomials integer-valued at elements of A. In this preliminary report, we will discuss these definitions and related musings. (Received January 13, 2017)

1126-13-215 **Uwe Nagel*** (uwe.nagel@uky.edu), Department of Mathematics, University of Kentucky, 715 Patterson Office Tower, Lexington, Lexington, KY 40506. *Equivariant Hilbert Series.*

Consider a homogenous ideal in a polynomial ring in countably many variables that is invariant under a suitable action of the monoid of strictly increasing functions. Recently, it has been shown that such an ideal is generated by finitely many orbits and that it admits a rational equivariant Hilbert series. Moreover, a description of the denominator of this series has been given. If the ideal is generated by the orbit of a monomial there is an explicit formula of the Hilbert series. It suggests that the general description of the denominator is rather efficient.

This is based on joint work with Tim Römer and Sema Güntürkün. (Received January 13, 2017)

1126-13-216 **Neil Epstein*** (nepstei2@gmu.edu) and **Jay Shapiro**. *The Ohm-Rush content function II: Noetherian rings and valuation domains.*

Following on our previous work on the Ohm-Rush content function (a concept that mimics the notion of content for polynomial extensions, but which is defined for any faithfully flat ring extension), we further analyze the properties of weak content and semicontent algebras. We show for example that given a Noetherian base ring, or an INC extension, the notions of weak content and semicontent algebras coincide. When the base ring is Artinian, even more can be said. We analyze the semicontent property for various extensions $R \subset S$, e.g. for $R = K[x_1, ...x_n]$ and $S = L[x_1, x_2, ..., x_n]$, where $K \subset L$ are fields, or for R and S valuation rings, or when R is Prüfer. Connections are drawn to valuation theory, dimension theory, and the recently solved Stillman conjecture. (Received January 14, 2017)

1126-13-218 **J B Coykendall** and **B G Goodell***, bggoode@clemson.edu. *Elaborating on homological approaches in factorization.*

An integral domain is atomic if every non-zero non-unit is a product of irreducibles, but arbitrary integral domains cannot be assumed to be atomic. The theory describing factorization in non-atomic domains is not fully mature. We study factorization by studying localizations of arbitrary integral domains using groups of divisibility as a proxies. We construct natural sequences of po-group epimorphisms that peel off layers of atomicity like layers of an onion. We obtain cochain complexes, their associated cohomology groups, and some structure theorems corresponding to a relaxation of the idea of universal factorization. The direct limit of the sequence of po-group epimorphisms is "antimatter" in the sense that it has no minimal positive elements. This leads to the result that every integral domain has an antimatter overring. (Received January 14, 2017)

1126-13-223 **Ela Celikbas** and **Christina Eubanks-Turner** (swiegand@math.unl.edu), Lincoln, NE 68502, and **Sylvia M Wiegand*** (swiegand1@unl.edu), Department of Mathematics, 203 Avery Hall, University of Nebraska Lincoln, Lincoln, NE 68588-0139. *Prime ideals in mixed polynomial-power series rings.* Preliminary report.

We give a general description of the partially ordered sets that occur as Spec B, for some homomorphic image B of a three-dimensional mixed polynomial-power series ring over a field or over a one-dimensional Noetherian integral domain. More precisely, $B = R[y][\![x]\!]/Q$, $R[\![x]\!][y]/Q$ or $k[\![x]\!][z, y]/Q$, where R is a one-dimensional Noetherian integral domain, k is a field, x, y and z are indeterminates, and Q is a height-one prime ideal of the appropriate ring such that $x \notin Q$. We describe the partially ordered set $U :=$ Spec B. If the field k, respectively the ring R, is countable, then Spec$(k[\![x]\!][z, y]/Q)$, respectively Spec$(R[y][\![x]\!]/Q)$, are characterized. (Received January 15, 2017)

1126-13-225 **Grace E McClurkin*** (mike@math.utk.edu) and **D Anderson**. *Extensions of the Congruence-based Zero-divisor Graph.* Preliminary report.

In this talk, I will extend the idea of congruence-based zero-divisor graph, first introduced by Anderson and Lewis (2016), to other variations of the zero-divisor graph, such as the annihilator graph and the extended zero-divisor graph. In addition to defining the congruence-based graphs, examples and properties of these graphs will be examined. (Received January 14, 2017)

1126-13-231 **Darrin Weber*** (dweber3@vols.utk.edu). *Cut-Sets in the Ideal-Divisor Graph.* Preliminary report.

Cut-sets were introduced in the study of zero-divisor graphs in 2010 where they were classified for all nonlocal finite commutative rings. A cut-set is a minimal set of vertices that when removed from the graph increase the number of connected components in the graph. In this talk we study cut-sets further and examine them in the ideal-divisor graph. The ideal-divisor graph of a ring R and ideal I is a graph with vertices $\{x \in R \setminus I \mid xy \in I \text{ for some } y \in R \setminus I\}$, and two vertices x and y are connected by an edge if and only if $xy \in I$. (Received January 14, 2017)

1126-13-244 **Louiza Fouli** and **Bruce Olberding*** (olberdin@nmsu.edu), Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003-8001. *Reductions in Noetherian local rings with finite residue field.* Preliminary report.

A reduction of an ideal I of a commutative ring R is a subideal J of I such that $I^{n+1} = JI^n$ for some $n > 0$. Reductions play an important role in the study of Noetherian local rings by allowing a given ideal to be replaced by a "simpler" one in the form of a well-chosen reduction. However, much of the theory of reductions depends on the local ring having an infinite residue field. For example, if R is a Noetherian local ring with infinite residue field and Krull dimension $d > 0$, then every ideal of R has a reduction that can be generated by d elements, an assertion that need not be true if R has a finite residue field. We examine the number of generators needed for reductions of ideals in Noetherian local rings with finite residue field. (Received January 15, 2017)

1126-13-250 **Warren Wm. McGovern*** (warren.mcgovern@fau.edu), Jupiter, FL 33458. *Applications of Ultrafilters to Commutative Rings with Identity.* Preliminary report.

Let R be a commutative ring with identity. Furthermore, we impose the condition that R is Jacobson semi-simple, that is, the intersection of the maximal ideals of R is 0. Denote the set of maximal ideals of R by $\mathrm{Max}(R)$. Given an ideal $I \subseteq R$, define

$$V(I) = \{M \in \mathrm{Max}(R) : I \subseteq M\}.$$

The collection $Z = \{V(I) : I \text{ is a f.g. ideal}\}$ is closed under finite unions and finite intersections. Thus, it is a bounded distributive lattice of sets. Moreover, Z is a Wallman lattice. Therefore, the collection of Z-ultrafilters, $\mathrm{Ult}(Z)$, is a compact T_1-space when equipped with the Wallman topology. There is a one-to-one correspondence between the collection of z-ideals of R and the collection of Z-filters. In particular, $\mathrm{Max}(R)$ and $\mathrm{Ult}(Z)$ are homeomorphic.

Our goal is to generalize this to the lattice $Z^{\#} = \{cl\ int\ V(I) : I \text{ is f.g. ideal}\}$. The goal is to describe $\mathrm{Ult}(Z^{\#})$ as well as the corresponding maximal $Z^{\#}$-ideals. (Received January 15, 2017)

1126-13-255 **K Alan Loper*** (loper.4@osu.edu), 1179 University Drive, Newark, OH 43055. *Directed limits of monoidal quadratic transforms.* Preliminary report.

Let D be a regular local ring of dimension at least three. We consider limits of iterated chains of quadratic transform of D. A central question is to determine when the limit is a valuation ring. We make surprising connections with several areas of elementary number theory. (Received January 15, 2017)

1126-13-259 **Tony Se*** (ttse@olemiss.edu). *Covariant Functors and Asymptotic Stability of Associated Primes.*

Let R be a commutative Noetherian ring, I an ideal of R and M a finitely generated R-module. M. Brodmann showed that the sets of associated primes $\mathrm{Ass}_R(M/I^nM)$ stabilize for large n. Now let F be a covariant functor. We will investigate when the sets of associated primes $\mathrm{Ass}_R\, F(M/I^nM)$ stabilize for large n and when they do not. (Received January 16, 2017)

1126-13-261 **Alessandro De Stefani*** (ads@kth.se), Department of Mathematics, 100 44 Stockholm, Sweden, **Luis Núñez-Betancourt**, Centro de Investigación en Matemática, Guanajuato, Mexico, and **Felipe Pérez**, Georgia State University, GA. *On the existence of F-thresholds and related limits.*

The F-thresholds are numerical invariants that can be defined for rings of prime characteristic. Roughly speaking, they measure the asymptotic interplay between regular powers and Frobenius powers of two given ideals. In this talk we will present some recent results about existence of F-thresholds, as well as relations with other invariants such as F-pure thresholds and a-invariants of Frobenius powers of an ideal. This talk is based on joint work with Luis Núñez-Betancourt and Felipe Pérez. (Received January 16, 2017)

1126-13-275 **Sandra Spiroff***, Department of Mathematics, P.O. Box 1848, Hume Hall 305, University, MS 38677, and **John Norton**. *Tropical Algebra in Higher Dimensions.*

We discuss the generalization, in higher dimensions, of the tropical semiring, whose two binary operations on the set of real numbers are defined to be the minimum and the sum, respectively. In particular, our objects are (possibly infinite) closed convex sets, and for any such pair the binary operations are defined to be the (closed) convex hull of their union and their Minkowski sum, respectively. (Received January 16, 2017)

1126-13-276 **Josh Stangle*** (jjstangl@syr.edu), 215 Carnegie Builting, Syracuse, NY 13210. *Auslander's Theorem and Path Algebras over Gorenstein rings.*

Auslander's Theorem (1984) is a pinnacle result in the study of the Cohen-Macaulay (CM) type of commutative local rings. It states that if a ring has finite CM type, then it must be an isolated singularity, i.e., the localisation at each non-maximal prime ideal is a regular local ring. In this talk we introduce a certain type of non-commutative ring that satisfies some nice homological properties. We are able to use these properties and the fact that path algebras over Gorenstein rings are examples of this to prove a generalization of Auslander's theorem in the case where R is a Gorenstein ring. (Received January 16, 2017)

1126-13-279 **Arindam Banerjee*** (banerj19@purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907. *Graph Connectivity and Binomial Edge Ideals.*

In this talk we shall discuss some results proved in a joint work with Luis Nunez Betancourt that shed light on relations between toughness and connectivity properties of finite simple graphs and homological algebra of their binomial edge ideals. (Received January 16, 2017)

1126-13-297 **Uwe Nagel** (uwe.nagel@uky.edu) and **Bill Trok*** (william.trok@uky.edu). *Regularity Bounds on Fat Point Ideals.*

Given an ideal I corresponding to fat points in $k[x_0,...,x_n]$, there is an integer r(I), past where the Hilbert Function is equal to the degree of I. (That is $H_I(t) = deg(I)$ for t >= r(I).) In this we establish a conjecture of Fatabbi, Lorenzini, and Trung placing an upper bound, known as the Segre Bound, on r(I). A key is results on partitions of Matroids into independent sets. (Received January 16, 2017)

1126-13-299 **Rebecca R.G.*** (rirebhuh@syr.edu) and **Geoffrey D. Dietz**. *Directed families of big Cohen-Macaulay algebras in equal characteristic.*

Previously, Geoffrey Dietz proved that big Cohen-Macaulay algebras in characteristic $p > 0$ form a directed family. In joint work with Geoffrey Dietz, we extend these results to the equal characteristic 0 case using work of Schoutens on reduction to characteristic p via ultraproducts. When combined with results on closure operations by Geoffrey Dietz and the speaker, this work has implications for the use of big Cohen-Macaulay algebras in classifying singularities. (Received January 16, 2017)

1126-13-310 **Patricia Klein*** (triciajk@umich.edu). *Asymptotic Behavior of Certain Koszul Cohomology Modules.*

Let (R, m) be a local ring, M a finitely generated module over R, and $f_1, \dots, f_d$ a system of parameters on M. Lech's limit formula states that as $\min_i t_i \to \infty$

$$\frac{\ell(M/(f_1^{t_1}, \dots, f_d^{t_d})M)}{t_1 \cdots t_d} \longrightarrow e(f_1, \dots, f_d \mid M),$$

the multiplicity of $(f_1, \dots, f_d)$ on M. One may ask whether powers of a fixed sequence of parameters may be replaced in this formula by any sequence of parameter ideals I_n such that $I_n \subseteq m^n$. Recalling that the multiplicity may be realized as the alternating sum of the lengths of Koszul cohomology modules and that $H^n(f_1^{t_1}, \dots, f_d^{t_d} \mid M) \cong M/(f_1^{t_1}, \dots, f_d^{t_d})M$, we may rewrite Lech's limit formula as follows

$$\frac{\sum_{j=0}^{n}(-1)^{n-j}\ell(H^i(f_1^{t_1}, \dots, f_d^{t_d}; M))}{\ell(H^n(f_1^{t_1}, \dots, f_d^{t_d}))} \longrightarrow 1.$$

From this point of view, it is also natural to ask in the case where $\dim M = \dim R = d$ for which $i < d$ we have $\ell(H^i(I_n; M))/\ell(R/I_n R) \to 0$. In this talk, we will consider the latter question. The main result is that when M is faithful, the M satisfying the above condition are exactly those M that are locally Cohen-Macaulay. (Received January 17, 2017)

1126-13-331 **Ryan Kinser** and **Jenna Rajchgot*** (rajchgot@math.usask.ca), 142 McLean Hall, 106 Wiggins Road, Saskatoon, SK S7N 5E6, Canada. *Remarks on commutative algebraic properties of types A and D quiver loci.* Preliminary report.

A quiver is a finite directed graph and a representation of a quiver is an assignment of vector space to each vertex and linear map to each arrow. Once the vector spaces have been fixed, the space of representations is an algebraic variety. This variety carries an action of a product of general linear groups, which acts by change of basis.

When the quiver's underlying graph is a type A Dynkin diagram, orbit closures (a.k.a. quiver loci) are well understood: prime defining ideals are particular generalizations of determinantal ideals, and quiver loci are normal and Cohen-Macaulay with rational singularities. Over a field of char. p>0, type A quiver loci in a fixed representation space are simultaneously compatibly Frobenius split. One way to prove all of these results is to explicitly relate type A quiver loci to Schubert varieties.

I'll discuss this, and then briefly explain an analogous approach for studying commutative algebraic properties of quiver loci in type D.

This is joint work with Ryan Kinser. (Received January 17, 2017)

1126-13-343 **Mohammed Tesemma*** (mtesemma@spelman.edu), 350 Spelman Lane. SW, Atlanta, GA 30314. *SAGBI bases and applications to invariant theory.*

In this talk I will introduce SAGBI bases in conjunction with the concept of Gröbner bases. Early results by Robbiano and Sweedler as well as some examples will be presented. We will also explore applications of SAGBI bases to characterize certain invariant rings. I will conclude with some open problems. (Received January 17, 2017)

1126-13-344 **Tyler Lewis*** (lewistn@email.sc.edu) and **Jesse Kass**. *A Family of Simple Codimension Two Singularities with Infinite Cohen-Macaulay Representation Type.*

Maurice Auslander and Idun Reiten in 1989 proved the classification for scrolls of finite Cohen-Macaulay representation type. Using a similar construction of Auslander and Reiten, in this talk we will show a family of rings with simple codimension two Cohen-Macaulay singularities are of infinite Cohen-Macaulay representation type. (Received January 17, 2017)

1126-13-345 **Douglas J Dailey** and **Thomas Marley*** (tmarley1@unl.edu), Department of Mathematics, 203 Avery Hall, University of Nebraska-Lincoln, Lincoln, NE 68588. *A change of rings result for Matlis reflexivity.*

Let R be a commutative Noetherian ring and E the minimal injective cogenerator of the category of R-modules. An R-module M is (Matlis) reflexive if the natural evaluation map $M \to \operatorname{Hom}_R(\operatorname{Hom}_R(M,E),E)$ is an isomorphism. We prove that if S is a multiplicatively closed subset of R and M is an R_S-module which is reflexive as an R-module, then M is a reflexive R_S-module. The converse holds when S is the complement of the union of finitely many nonminimal primes of R, but fails in general. (Received January 17, 2017)

1126-13-364 **Andrew R. Kustin** and **Jaree M. Hudson*** (jmhudson@math.sc.edu). *Generators of Special Fiber Rings.*

We discuss a generating set for the ideal defining the special fiber ring of certain Artinian Gorenstein algebras. We approach this problem from the point of view of Macaulay inverse systems. (Received January 17, 2017)

1126-13-382 **D. D. Anderson**, **J. R. Juett*** (jason.juett@txstate.edu) and **C. P. Mooney**. *Module cancellation properties.* Preliminary report.

Over the years, several different cancellation properties of modules have been studied. For example, a module A over a commutative ring R is (resp., is *restricted*, is *weak*, is *half*, is *half weak*) (*quasi-*)*cancellation* if $IA = JA \Rightarrow I = J$ (resp., $IA = JA \neq 0 \Rightarrow I = J$, $IA = JA \Rightarrow I + (0:A) = J + (0:A)$, $A = IA \Rightarrow I = R$, $A = IA \Rightarrow I + (0:A) = R$) for all (finitely generated) ideals. A module is (*half*) *join principal* if every homomorphic image is (half) weak cancellation. A particularly interesting question is which commutative rings have every nonzero (finitely generated) ideal (resp., module) satisfying some cancellation property. This presentation will review some basic facts and classic theorems on these topics, and then present several new results. (Received January 17, 2017)

1126-13-402 **Haydee Lindo***, 08hml@williams.edu. *Trace ideals of modules and algebras over commutative rings.* Preliminary report.

I will present some new results regarding trace ideals of modules and algebras over commutative rings. This continues the project begun in arXiv:1603.08576 relating the center of the endomorphism ring of a module M, over a commutative noetherian ring, to the endomorphism ring of the trace ideal of M. (Received January 18, 2017)

14 ► *Algebraic geometry*

1126-14-23 **Changho Keem*** (ckeem1@gmail.com), Department of Mathematics, College of Natural Sciences, Seoul National University, Seoul, 151-752, South Korea, and **YunHwan Kim**. *Irreducibility of the Hilbert scheme of space curves of degree g.*

We denote by $\mathcal{H}_{d,g,r}$ the Hilbert scheme of smooth curves, which is the union of components whose general point corresponds to a smooth irreducible and non-degenerate curve of degree d and genus g in $\mathbb{P}^r$. In this note, we show that any non-empty $\mathcal{H}_{g,g,3}$ is irreducible without any restriction on the genus g. This extends the result obtained earlier by Hristo Iliev(2006). (Received November 24, 2016)

1126-14-34 **Lei Song*** (lsong@ku.edu), 405 Snow Hall, 1460 Jayhawk Blvd., Lawrence, KS 66045. *On the projective normality of cyclic coverings over a rational surface.*

A conjecture of Mukai says that for any smooth projective complex surface X, and an ample line bundle A on X, the adjoint line bundle $\omega_X \otimes A^k$ is normally generated for every integer $k \geq 4$. The conjecture is quite open for surfaces of general type and non-minimal surfaces. We verify the conjecture in the case that X is a branched cyclic covering over a rational surface S with the anticanonical linear system moves and A is the pullback of an ample line bundle on S. (Received December 12, 2016)

1126-14-102 **Alexander Varchenko*** (anv@email.unc.edu), Department of Mathematics, Chapel Hill, NC. *Elliptic dynamical quantum group $E_{\tau,h}(gl_2)$ and elliptic equivariant cohomology of the cotangent bundles of Grassmannians.* Preliminary report.

The torus T equivariant elliptic cohomology defines a functor $Ell_T : \{T-\text{spaces}\, X\} \to \{\text{schemes}\}$. For example, for the cotangent bundle of a Grassmannian the scheme $Ell_T(T^*Gr(k,n))$ is some explicitly given sub-scheme of $S^kE \times S^{n-k}E \times E^n \times E^2$ with coordinates $t_1,\dots,t_k,s_1,\dots,s_{n-k},z_1,\dots,z_n,h,\lambda$, where t_i, s_j correspond to the Chern roots of the two standard vector bundles over the Grassmannian, z, y correspond to the torus parameters, λ is the dynamical parameter also called the Kähler parameter, and E is an elliptic curve.

I will define a class of line bundles on the scheme $\cup_{k=0}^n Ell_T(T^*Gr(k,n))$ such that the operator algebra of the elliptic dynamical quantum group $E_{\tau,h}(gl_2)$ will act on sections of those line bundles (a generator of the operator algebra will send a section of such a line bundle to a section of possibly another line bundle). That construction is an analog of the Yangian $Y(gl_2)$ action on the direct sum $\oplus_{k=0}^n H_T^*(T^*Gr(k,n))$ of equivariant cohomology.

This is a joint work with G.Felder and R.Rimanyi. (Received January 07, 2017)

1126-14-103 **Yiqiang Li*** (yiqiang@buffalo.edu), 244 Mathematics Building, SUNY at Buffalo, Buffalo, NY 14260. *σ-quiver varieties.*

I'll report on the recent progress of the study of a new class of automorphisms on Nakajima quiver varieties and the associated fixed point varieties, called the σ-quiver varieties. Its connection with the partial Springer resolutions of nilpotent Slodowy slices of classical type will be discussed and a rectangular symmetry for the partial Springer resolutions will be presented. (Received January 07, 2017)

1126-14-271 **Asilata Bapat*** (asilata@uga.edu). *Cohomology of perverse sheaves on T-varieties.*

I will discuss some methods and results for the global cohomology of perverse sheaves on varieties with a torus action. I will describe a Künneth-type formula for the tensor products of simple perverse sheaves on these varieties. (Received January 16, 2017)

1126-14-356 **Neal Livesay*** (nlives1@lsu.edu). *Moduli spaces of irregular singular* GSp*-connections.*

A fundamental problem in the study of differential equations is the classification of first-order singular differential operators up to gauge equivalence. A modern version of this problem, rephrased in the language of algebraic geometry, involves the construction of moduli spaces of meromorphic G-connections (or, equivalently, flat G-bundles) on $\mathbb{CP}^1$, for G a reductive group. P. Boalch (2001) has constructed moduli spaces for GL_n-connections in the case that the connection matrix at each singularity — an element of the formal loop algebra $\mathfrak{gl}_n(\mathbb{C}((z)))$ — is diagonalizable. More recently, C. Bremer and D. Sage (2012) have used representation-theoretic methods to develop a new approach to studying G-connections. Furthermore, they have used this approach to construct moduli spaces of GL_n-connections with certain classes of non-diagonalizable connection matrices (such as the generalized Airy connection matrices). In this talk, I will describe my recent work to further extend this theory for the study of GSp_{2n}-connections, and demonstrate the theory for some small rank examples. (Received January 17, 2017)

15 ► Linear and multilinear algebra; matrix theory

1126-15-326 **Haesun Park***, hpark@cc.gatech.edu, and **Rundong Du**, **Da Kuang** and **Barry L. Drake**. *Divide-and-Conquer Nonnegative Matrix Factorization (NMF) for Scalable Clustering and Topic Modeling.*

Nonnegative Matrix Factorization (NMF) has been widely utilized in large scale data analytics problems. We show a fast algorithm for NMF when the reduced rank is 2, and how this fast algorithm can be combined with decision rules to generate highly scalable divide-and-conquer algorithms for clustering, topic modeling of text data, and community detection. Some substantial experimental results illustrate the utility of the divide-and-conquer NMF and our open source software, SmallK (smallk.github.io). (Received January 17, 2017)

1126-15-355 **Rebecca Goolsby*** (rebecca.goolsby@navy.mil). *Beyond Information Wars: Understanding the Flow and Strategy of Disinformation.* Preliminary report.

Yellow journalism and disinformation campaigns have reached "big data" levels of activity. The threat this poses to society, national security, and peace in the world today have never been more evident. This talk will discuss the strategic objectives and tactics of "bad behavior on the Internet"; how to understand these tactics and how to manage and adapt to a dynamically changing information environment. Topics to be addressed include the history of crowd manipulation on the Internet, social hysteria propagation, and social and psycho-social dynamics involved in duplicitous information competitions. Social media analysis, social network analysis, and the development of a new applied "cyber-social science" will be discussed as frameworks for discovering adversarial information campaigns, interpreting their tactics, messaging, and uncovering their strategic objectives. Preliminary hypotheses about countering these campaigns will be discussed, focusing on red team analysis. (Received January 18, 2017)

1126-15-405 **Minsung Kim** (kimminsung@wustl.edu) and **Richard Kyung*** (nycrick@gmail.com). *A New Transformation Method to Solve Eigenvalue Problems.*

This paper examines the efficiency of numerical optimization algorithms on solving eigenvalue problems. Using a classical mathematics method, most of the general eigenvalue problems, using optimal eigenvalues, cannot compute the exact closed-form solutions. As a result, alternative algorithms that use a numerical iteration method, must be examined in order to produce the desired dynamic characteristics. Through an analysis of the improved algorithm, its reduced degree of freedom of a system allows for practical usefulness and relative easiness in solving eigenvalue problems. (Received January 18, 2017)

16 ► Associative rings and algebras

1126-16-91 **Jesse Elliott*** (jesse.elliott@csuci.edu), 305 Channel Islands Drive, Camarillo, CA 93012. *Radicals, torsion theories, and closure operations on ideals and submodules.*

Radicals and torsion theories are important tools for studying rings and their modules. We show that both are equivalent to certain functorial closure operations on submodules, and, furthermore, any "cohereditary" radical is completely determined by the closure operation it induces on left ideals. This allows us to prove the equivalence of the following categories, for any ring R: (1) the category of all cohereditary radicals on the category of left R-modules; (2) the category of all closure operations on submodules of left R-modules that are "minimal," in a certain sense; and (3) the poset of all "semiprime" closure operations on the left ideals of R. These equivalences allow one to treat the theory of closure operations on ideals within the theory of radicals. (Received January 05, 2017)

1126-16-116 **Ivan Loseu*** (i.loseu@neu.edu), 360 Huntington Avenue, Boston, MA 02115, and **Ben Elias**. *Modular representation theory of type A via diagrammatic Soergel bimodules.*

We express the multiplicities of modular representation theoretic categories of type A in terms of affine p-KL polynomials of Elias and Williamson. The representation theoretic categories we deal with include the category of rational representations of GL_n and of the quantum group $U_q(\mathfrak{gl}_n)$, representations of (degenerate) cyclotomic Hecke and Schur algebras, and the base field is an algebraically closed field of arbitrary prime characteristics. In order to approach this problem we define Soergel theoretic version of parabolic categories $\mathcal{O}$ in characteristic p. (Received January 08, 2017)

1126-16-136 **Natasha Rozhkovskaya*** (rozhkovs@math.ksu.edu), Manhattan, KS 66502. *Segal-Sugawara vectors for the Lie algebra of type G_2.*

The center of the affine vertex algebra $V_{crit}(\mathfrak{g})$ at the critical level of a simple Lie algebra $\mathfrak{g}$ is a commutative algebra whose structure was described by B.Feigin and E.Frenkel. Explicit formulas for Segal-Sugawara vectors associated with classical Lie algebras were found by A. Molev using the constructions of Schur-Weyl-duality. In this talk we report on the results on the explicit formulas for Segal-Sugawara vectors associated with the exceptional Lie algebra of type G_2, which is a joint work with A. I. Molev and E. Ragoucy. (Received January 09, 2017)

1126-16-247 **Galyna Dobrovolska*** (galdobr@gmail.com). *Combinatorial properties of wall-crossing for the rational Cherednik algebra.* Preliminary report.

We discuss certain combinatorial properties of wall-crossing for the rational Cherednik algebra, which can be observed after applying the KZ functor. (Received January 15, 2017)

1126-16-290 **Nicholas Cooney***, nicholas.cooney@math.univ-bpclermont.fr, and **Iordan Ganev** and **David Jordan**. *Quantized Multiplicative Quiver Varieties at Roots of Unity.* Preliminary report.

To a quiver Q with dimension vector $\mathbf{d}$, one can associate an algebra $\mathcal{D}_q(Q)$, a flat q-deformation of the algebra of differential operators on the space of $\mathbf{d}$-dimensional representations of the quiver. There is also a quantum moment map compatible with various degenerations of the source and target. One can then form the quantum Hamiltonian reduction to obtain a new algebra A.

I will discuss the case where q is a root of unity. In this case, the algebra $\mathcal{D}_q(Q)$ attains a large centre. For dimension $\mathbf{d} = (1, 1, \ldots, 1)$, $\mathcal{D}_q(Q)$ is locally a matrix algebra. One can associate multiplicative analogues of hypertoric varieties to Q with this dimension vector. In this case, the algebras A are quantizations of these varieties which are again locally matrix algebras. The category of coherent A-modules is derived equivalent to that of modules over the global sections algebra.

I will place this work in the context of a paradigm prevalent in geometric representation theory before giving a more detailed technical treatment, including a discussion of possible extensions of some of these results to higher dimension vectors. This is joint work with I.Ganev and D.Jordan. (Received January 16, 2017)

1126-16-341 **Tom Braden** and **Carl Mautner*** (mautner@math.ucr.edu). *Matroidal Schur Algebras.*

Let k be a field. We associate a quasi-hereditary algebra $R(M)$ over k to any matroid M, such that the Ringel dual of $R(M)$ is $R(M^*)$, where M^* is the dual matroid. The representation theory of this algebra is closely related to certain bilinear forms introduced by Schechtman-Varchenko and Brylawski-Varchenko. Like the classical Schur algebras, our algebras are semisimple over fields of characteristic zero. In this generic setting, our algebras can be used to categorify a formula of Kook-Reiner-Stanton. Our work is motivated by the geometry of symplectic resolutions and, in particular, hypertoric varieties. (Received January 17, 2017)

17 ► Nonassociative rings and algebras

1126-17-9 **Ashley Walls White*** (anwalls@ncsu.edu), Department of Mathematics, Box 8205, NC State University, Raleigh, NC 27695. *Companion Lie Algebras to Leibniz Algebras.*

It is popular to investigate where Lie algebra results extend to their Leibniz algebra generalizations. In Lie algebras, establishing properties of algebras in certain classes, such as nilpotent, is a constant theme in the literature. In this talk, we offer some Leibniz algebra analogues of such results. A useful tool, called the companion Lie algebra, is developed to help in the investigation. (Received October 05, 2016)

1126-17-93 **Kailash C Misra*** (misra@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695-8205. *Affine Geometric Crystal of $A_n^{(1)}$ and Limit of Kirillov-Reshetikhin Perfect Crystals.*

Consider the affine Lie algebra $g = A_n^{(1)}$ with index set $I = \{0, 1, 2, \cdots, n\}$. Then the Langlands dual $g^L = g$. In 2008 it was conjectured by Kashiwara, Nakashima and Okado that for each $k \in I \setminus \{0\}$ the affine Lie algebra g has a positive geometric crystal whose ultra-discretization is isomorphic to the limit of certain coherent family of perfect crystals for g^L. Motivated by this conjecture we construct a positive geometric crystal for the affine Lie algebra g for each Dynkin index $k \in I \setminus \{0\}$ and show that its ultra-discretization is isomorphic to the limit of a certain coherent family of perfect crystals for $g = A_n^{(1)}$. This is joint work with Toshiki Nakashima. (Received January 06, 2017)

1126-17-94 **Kailash C Misra*** (misra@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695-8205. *Imaginary Verma Modules for $U_q(\widehat{\mathfrak{sl}(2)})$ and Crystal-like bases.*

Consider the affine Lie algebra $\widehat{\mathfrak{sl}(2)}$ with simple roots $\{\alpha_0, \alpha_1\}$. Let $S = \{\alpha_1 + k\delta \mid k \in \mathbb{Z}\} \cup \{l\delta \mid l \in \mathbb{Z}_{>0}\}$ where $\delta = \alpha_0 + \alpha_1$. Then $S \cup -S$ is a closed partition of the root system Δ which is not Weyl group conjugate to the standard partition. The Verma module $M(\lambda)$ with highest weight λ induced by the corresponding nonstandard Borel subalgebra is called the imaginary Verma module for $\widehat{\mathfrak{sl}(2)}$. We consider the imaginary Verma modules for the quantum affine algebra $U_q(\widehat{\mathfrak{sl}(2)})$ and define a crystal-like base which we call an imaginary crystal basis using the Kashiwara algebra $\mathcal{K}_q$ we constructed earlier. In particular, we prove the existence of imaginary crystal bases for a suitable category of reduced imaginary Verma modules for $U_q(\widehat{\mathfrak{sl}(2)})$. This is joint work with Ben Cox and Slava Futorny. (Received January 06, 2017)

1126-17-187 **Brian D. Boe***, Mathematics Department, University of Georgia, Athens, GA 30602, and **Jonathan R. Kujawa** and **Daniel K. Nakano**. *Tensor Triangular Geometry in Lie Theory.* Preliminary report.

Tensor triangular geometry as introduced by Balmer is a powerful tool which can be used to extract geometry from a tensor triangulated category. I will present a general setting for a compactly generated tensor triangulated category which enables one to classify thick tensor ideals and the Balmer spectrum. I will then apply this general setup to a situation of interest in Lie theory. (Received January 12, 2017)

1126-17-221 **Bojko Bakalov*** (bojko_bakalov@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695. *Logarithmic vertex algebras.*

In logarithmic conformal field theory the operator product expansion (OPE) of quantum fields involves logarithms. I will introduce a notion of a logarithmic vertex algebra, which provides a rigorous algebraic formalism for studying such OPEs. I will derive a Borcherds identity for logarithmic vertex algebras and present the examples of free bosons and symplectic fermions. (Received January 14, 2017)

1126-17-222 **McKay Sullivan*** (smsulli4@ncsu.edu) and **Bojko Bakalov**. *Fock Space Constructions of Twisted Logarithmic Modules.*

Given an automorphism φ of a vertex algebra V, φ-twisted modules of V are useful in the construction of untwisted representations of the orbifold subalgebra of elements of V fixed by φ. Recently defined twisted logarithmic modules of vertex algebras allow us to choose φ to be non-semisimple. In the case when V is generated by free fields, we construct examples of such modules using highest weight representations of certain infinite-dimensional Lie algebras on a Fock space. We also briefly discuss the construction of twisted logarithmic modules of lattice vertex algebras. (Received January 14, 2017)

1126-17-224 **Antun Milas***, SUNY-Albany, 1400 Washington Avenue, Albany, NY 12110. *Logarithmic Modules for Quantum Groups.* Preliminary report.

Motived by recent developments in logarithmic conformal field theory, we introduce a category of *logarithmic* modules for certain quantum groups at root of unity. This is a natural extension of the well-studied category of finite-dimensional *weight* modules. We will present several results on the structure of the logarithmic category for the unrolled quantum group of $\mathfrak{sl}_2$. Our results allow us to make prediction about categories of logarithmic modules for certain vertex algebras. (Received January 14, 2017)

1126-17-258 **Dijana Jakelić*** (jakelicd@uncw.edu) and **Adriano Moura** (aamoura@ime.unicamp.br). *Partition identities arising from Demazure flags and outer multiplicities.*

The study of characters and related structural problems of representations of an affine Kac-Moody algebra $\hat{\mathfrak{g}}$ often leads to proofs of interesting identities of combinatorial nature. In this talk, we discuss the relation between two such structural problems: the one of computing outer multiplicities of irreducible modules in tensor products of two integrable irreducible modules of $\hat{\mathfrak{g}}$ and that of computing multiplicities in Demazure flags of a given Demazure module. Our main result expresses the former in terms of the latter. By combining our result in the case of $\hat{\mathfrak{sl}}_2$ with the existing answers to the first problem, we obtain interesting partition identities. (Received January 16, 2017)

1126-17-268 **Gordon Brown**, Dept. of Mathematics, University of Oklahoma, Norman, OK 73069, and **Jonathan Kujawa***, Dept. of Mathematics, University of Oklahoma, Norman, OK 73069. *Webs of Type Q.*

In recent years there is a growing interest in describing categories diagrammatically (i.e. with pictures). In groundbreaking work Kuperberg first did this twenty years ago for the rank 2 Lie algebras via diagrams he called "webs". Recently webs have been generalized to various settings. In this talk we describe the analogue of webs for type Q Lie superalgebras. (Received January 16, 2017)

1126-17-273 **Andrew Cavaness*** (andrew.cavaness@mavs.uta.edu) and **Dimitar Grantcharov**. *Bounded weight modules of the Lie algebra of vector fields on the affine space.* Preliminary report.

In this talk we will discuss weight modules of the Lie algebra W_2 of vector fields on $\mathbb{C}^2$. A classification of all simple weight modules of W_2 with a uniformly bounded set of weight multiplicities is provided. To achieve this classification we introduce a new family of generalized tensor W_n-modules. This is a joint work with D. Grantcharov. (Received January 16, 2017)

1126-17-288 **Darlayne Addabbo*** (addabbo2@illinois.edu), 1409 West Green Street, Urbana, IL 61801. *Q-systems and Generalizations in Representation Theory.*

In this talk, we will define tau-functions given as matrix elements for the action of $\widehat{GL_n}$ on n-component Fermionic Fock space. We will explain how to show that the tau-functions for the $n = 2$ case satisfy the $A_{\infty/2}$ Q-system. Since Q-systems are of interest in various places in mathematics, for example in combinatorics and in representation theory, it is natural to expect that the tau-functions for the $n > 2$ cases also satisfy interesting systems of difference equations. We will discuss the difference equations satisfied by the $n = 3$ tau-functions and will give conjectures for the general n case. We will conclude the talk by discussing the progress we have made in analyzing these systems of equations. If time permits, a generalization of this work will be discussed. (Joint with Maarten Bergvelt) (Received January 16, 2017)

1126-17-300 **Lisa Carbone***, 110 Frelinghuysen Rd, Hill Center, Piscataway, NJ 08854. *Commutation relations and structure constants for Kac-Moody algebras.* Preliminary report.

In any Kac–Moody algebra $\mathfrak{g}$, the question of determining the commutation relations between real root vectors x_α and x_β corresponding to real roots α and β may be reduced to the rank 2 root subsystem generated by α and β. Then the commutator $[x_\alpha, x_\beta]$ is trivial if the sum $\alpha+\beta$ is not a real root and otherwise lies in the real root space corresponding to $\alpha+\beta$. We completely determine the structure constants between real root vectors in rank 2 Kac–Moody algebras $\mathfrak{g}$. We also describe all possible systems of signs for these structure constants. This requires a knowledge of the root strings containing real roots and the cases where sums of real roots are not real roots. We indicate how to give an algorithm for extending these results to give integral structure constants for root vectors corresponding to imaginary roots. (Received January 16, 2017)

1126-17-307 **Evgeny Mukhin**, **Vitaly Tarasov*** (vtarasov@iupui.edu) and **Alexander Varchenko**. *Bethe ansatz for the isotropic Heisenberg spin chain and more.*

The Heisenberg chain (XXX model) is a quantum system with the Hamiltonian $H = \sum_{a=1}^{n} P_{a,a+1}$ acting on $(\mathbb{C}^2)^{\otimes n}$, where P_{ab} is the swap of the a-th and b-th factors of $(\mathbb{C}^2)^{\otimes n}$ modulo n. H can be included into a family of commuting operators called the transfer-matrix. The Bethe ansatz is a method going back to H. Bethe (1931) to find eigenvectors and eigenvalues of the transfer-matrix. It assigns an (expected) eigenvector of the transfer-matrix to any solution of the system $(t_j+1)^n \prod_{k=1}^{m}(t_j - t_k - 1) = -t_j^n \prod_{k=1}^{m}(t_j - t_k + 1)$, $j = 1, \dots, m$, with no zero factors and distinct $t_1, \dots, t_m$. However, this system fails to have enough solutions of this kind to produce all eigenvectors of the transfer-matrix, and should be modified. I will describe the required modification for the XXX model and related quantum integrable systems, including recent progress for the higher spin version of the XXX model. (Received January 17, 2017)

1126-17-314 **Katrina Barron*** (kbarron@nd.edu), 255 Hurley Hall, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556, and **Nathan Vander Werf** and **Jinwei Yang**. *Aspects of higher level Zhu's algebras.* Preliminary report.

We present some recent results regarding higher level Zhu's algebras for a vertex operator algebra and implications for indecomposable modules for a vertex operator algebra. (Received January 17, 2017)

1126-17-366 **William Graham**, **Martha Precup** and **Amber Russell*** (acrusse3@butler.edu). *A new approach to the generalized Springer correspondence: Part 2.* Preliminary report.

Let G be a semisimple algebraic group with Weyl group W. The Springer correspondence is an injective map from the irreducible representations of W to G-equivariant simple perverse sheaves on the nilpotent cone of G. This correspondence can be constructed by considering the pushforward of the constant sheaf from the Springer resolution of the nilpotent cone. However, this construction does not realize all the simple perverse sheaves on the nilpotent cone; to achieve this, Lusztig introduced the generalized Springer correspondence. However, Lusztig's construction uses an induction functor from certain Levi's rather than considering the pushforward of the constant sheaf from a single variety.

In previous work, Graham introduced an analogue of the Springer resolution where the dense G-orbit in the nilpotent cone is replaced by the universal cover of that orbit. Russell showed that in type A, all the irreducible equivariant perverse sheaves on the nilpotent cone appear as direct summands in the pushforward of the constant sheaf from this analogue of the Springer resolution. In joint work of Graham, Precup, and Russell, we show that in type A, this pushforward of the constant sheaf recovers Lusztig's generalized Springer correspondence. (Received January 17, 2017)

19 ► K-theory

1126-19-20 **Seth Baldwin*** (seth.e.baldwin@gmail.com) and **Shrawan Kumar**. *Positivity in T-equivariant K-theory of flag varieties associated to Kac-Moody groups.*

The cohomology ring of flag varieties has long been known to exhibit positivity properties. One such property is that the structure constants of the Schubert basis with respect to the cup product are non-negative. Brion (2002) and Anderson-Griffeth-Miller (2011) have shown that positivity extends to K-theory and T-equivariant K-theory, respectively. In this talk I will discuss recent work (joint with Shrawan Kumar) which generalizes these results to the case of Kac-Moody groups. (Received November 16, 2016)

20 ► Group theory and generalizations

1126-20-19 **Marshal Imeh Sampson*** (bravemarshal@yahoo.com), P.M.B. 1167, Uyo, Akwa Ibom 520261, Nigeria, and **Gabriel Otobong Udoaka**. *Alternative Method for Computing Rank of a Semigroup.*

The computation of rank of semigroup S has been discretely done for some semigroups. However, the computation is generally a tedious task. A new computational technique for rank of some semigroup is presented. The technique is based on matrix representation and simplifies the computational efforts encountered using direct definition technique of computing ranks. The importance of this idea for the study of abstract groups seems to depend on the fact that group-theoretical calculations are easier to carry out in groups of matrices than in abstract groups. Its effectiveness is demonstrated in the computation of the rank of certain transformation semigroup, Brandt semigroup , symmetry semigroup (S3), Dihedral group (D4), monogenic semigroup and the inverse semigroup. (Received November 12, 2016)

1126-20-180 **Alex J Feingold*** (alex@math.binghamton.edu), Dept of Math Sci, 4400 Vestal Parkway East, P O Box 6000, Binghamton, NY 13902-6000. *Rank 2 Kac-Moody group actions on twin trees.* Preliminary report.

The action of a rank 2 affine Kac-Moody group on twin trees was developed by Ronan-Tits [Invent Math 116, 463-479 (1994)] (see also Abramenko-Brown[*Buildings*, Grad Texts in Math 248, Springer 2008]). I will discuss the application of this material to questions about the structure of certain rank 2 hyperbolic Kac-Moody groups. (Received January 12, 2017)

1126-20-213 **Pramod N Achar*** (pramod@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803-4918. *Representations of algebraic groups via algebraic topology.*

This talk will pursue two parallel threads: (i) computational questions in representation theory, and (ii) cohomology of topological spaces, especially certain subsets of Grassmannians and flag manifolds. Since the early 1980s, a number of major breakthroughs in representation theory have been made by showing that a difficult question in (i) can be turned into a tractable question in (ii), especially when working with complex coefficients. In the first half of the talk, I will discuss a few examples of this pattern.

The second half of the talk will be about representation theory with coefficients in a field of positive characteristic. The links between (i) and (ii) are considerably more difficult to study in this case, especially because some powerful tools available in the complex case (e.g., Hodge theory) are missing. Nevertheless, the past few years have seen a burst of new activity in this area, with new approaches to linking (i) and (ii), and new methods for computing on the topological side. I will survey some of the discoveries in representation theory that have emerged from this activity. This includes joint work with S. Makisumi, S. Riche, L. Rider, and G. Williamson. (Received January 13, 2017)

1126-20-217 **Skip Garibaldi** (skip@garibaldibros.com), Center for Communications Research, San Diego, CA 92121, and **Daniel K. Nakano*** (nakano@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30602. *Bilinear and Quadratic Forms of Rational Modules of Split Reductive Groups.*

The representation theory of semisimple algebraic groups over the complex numbers (equivalently, semisimple complex Lie algebras or Lie groups, or real compact Lie groups) and the question of whether a given complex representation is symplectic or orthogonal has been solved since at least the 1950s. Similar results for Weyl modules of split reductive groups over fields of characteristic different from 2 hold by using similar proofs. This paper considers analogues of these results for simple, induced and tilting modules of split reductive groups over fields of prime characteristic as well as a complete answer for Weyl modules over fields of characteristic 2.

This represents joint work with Skip Garibaldi. (Received January 14, 2017)

1126-20-303 **Pramod N. Achar**, **Shotaro Makisumi*** (makisumi@stanford.edu), **Simon Riche** and **Geordie Williamson**. *Modular Koszul duality for Kac–Moody groups.*

I will introduce (or more realistically, give a rough sense of) a monoidal category of “free-monodromic tilting sheaves” on a Kac–Moody flag variety. The main result is that this category is equivalent to the monoidal category of parity sheaves on the Langlands dual Kac–Moody flag variety. This result implies the Riche–Williamson conjecture on characters of tilting modules of reductive groups. This is joint work with Pramod Achar, Simon Riche, and Geordie Williamson. (Received January 16, 2017)

1126-20-311 **Pramod Achar** (pramod@math.lsu.edu), **William Hardesty*** (whardesty@lsu.edu) and **Simon Riche** (simon.riche@math.univ-bpclermont.fr). *Some remarks on exotic t-structures in positive characteristic.*

In this talk we will discuss joint work with P. Achar and S. Riche involving exotic t-structures for the Springer resolution and the nilpotent cone in positive characteristic. Specifically, we will examine how a number of classical results due to R. Bezrukavnikov in characteristic 0 can be adapted to the positive characteristic case by certain base change arguments. (Received January 17, 2017)

1126-20-372 **William Graham*** (wag@uga.edu), **Martha Precup** and **Amber Russell**. *A new approach to the generalized Springer correspondence: Part 1.* Preliminary report.

Let \$G\$ be a semisimple algebraic group with Weyl group \$W\$. The Springer correspondence is an injective map from the irreducible representations of W to G-equivariant simple perverse sheaves on the nilpotent cone of \$G\$. This correspondence can be constructed by considering the pushforward of the constant sheaf from the Springer resolution of the nilpotent cone. However, this construction does not realize all the simple perverse sheaves on the nilpotent cone; to achieve this, Lusztig introduced the generalized Springer correspondence. However, Lusztig's construction uses an induction functor from certain Levi's rather than considering the pushforward of the constant sheaf from a single variety.

In previous work, Graham introduced an analogue of the Springer resolution where the dense \$G\$-orbit in the nilpotent cone is replaced by the universal cover of that orbit. Russell showed that in type \$A\$, all the irreducible equivariant perverse sheaves on the nilpotent cone appear as direct summands in the pushforward of the constant sheaf from this analogue of the Springer resolution. In joint work of Graham, Precup, and Russell, we show that in type \$A\$, this pushforward of the constant sheaf recovers Lusztig's generalized Springer correspondence. (Received January 17, 2017)

1126-20-401 **M. Ryan Julian*** (mrjulian@math.wisc.edu), 480 Lincoln Drive, Madison, WI 53706. *Codes Over Non-Abelian Groups Do Not Have MacWilliams Duality.*

There is a well established theory of dual codes over finite fields along with MacWilliams identities relating the weight enumerator polynomials of these codes. Dougherty, Kim, and Solé have asked whether there is a similar duality theory for codes over non-abelian groups. We show that there does not exist any finite non-abelian group G with a MacWilliams-type duality on the subgroups of G^n for all n. (Received January 18, 2017)

22 ► Topological groups, Lie groups

1126-22-200 **Laura Rider*** (laurajoy@uga.edu). *The centralizer of a regular nilpotent and tilting modules of a reductive group.* Preliminary report.

In this talk, I'll discuss the representation theory of a reductive group in positive characteristic with an emphasis on the role played by tilting modules. We will consider their restriction to the (graded) centralizer of a regular nilpotent, and two geometric constructions of this restriction functor: one via the geometric Satake equivalence and another employing exotic coherent sheaves on the Springer resolution. (Received January 13, 2017)

1126-22-245 **Sam Evens*** (sevens@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *The complex Gelfand-Zeitlin system.*

The complex Gelfand-Zeitlin system is an integrable system on either of the Lie algebras gl(n,C) or so(n,C). I will explain ways to use Luna's theory of slices to understand the Gelfand-Zeitlin system. This talk is based on joint work with Mark Colausso. (Received January 15, 2017)

1126-22-337 **Cheng-Chiang Tsai*** (chchtsai@mit.edu), MA. *A categorification for invariant distributions on the nilpotent cone of a reductive p-adic Lie algebra.*

We propose a categorification for the space of invariant distributions on the Lie algebra of a reductive p-adic group that relies on the well-known generalized Springer theory for the residue field. This allows us to redefine and prove new properties about certain "cuspidal" distributions that were used by Waldspurger (and DeBacker-Kazhdan) to construct and analyze stable distributions. (Received January 17, 2017)

30 ► Functions of a complex variable

1126-30-173 **Seung-Yeop Lee*** (lees3@usf.edu), Tampa, FL 33647, and **Roman Riser**, Holon, Israel. *Asymptotics of planar orthogonal polynomials via the Riemann-Hilbert problem on the Schottky double.*

We show that the asymptotics of planar orthogonal polynomials can be studied using the scalar Riemann-Hilbert problem on the Schottky double, which is the two copies of the exterior domain of the droplet glued together. We present the universal subleading correction term. (Received January 13, 2017)

1126-30-351 **G. Brock Williams*** (brock.williams@ttu.edu), Dept of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409-1042. *Applications of the Brooks Parameter.*

Bowers and Stephenson used Brooks's parameterization of quadrilateral interstices to great effect in proving the density of packable surfaces in Teichmüller space. We will describe the use of Brooks parameters to study quasiconformal and planar harmonic mappings. (Received January 17, 2017)

33 ► Special functions

1126-33-181 **Robert Milson*** (rmilson@dal.ca), Department of Mathematics & Statistics, Dalhousie University, Halifax, Nova Scota B3H3J5, Canada, and **David Gomez-Ullate** (david.gomez-ullate@icmat.es) and **Maria-Angeles Garcia-Ferrero** (mag.ferrero@icmat.es). *Towards the classification of Exceptional Orthogonal Polynomials.*

Exceptional Orthogonal Polynomials are orthogonal polynomial families that arise as solutions for second-order eigenvalue problems. They generalize the classical families of Hermite, Laguerre, and Jacobi because 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. We will present a foundational theorem in this subject that asserts that all exceptional orthogonal polynomials arise in precisely this fashion. This result is an essential component of the ongoing classification programme for XOP. (Received January 12, 2017)

34 ► Ordinary differential equations

1126-34-260 **Jean-Guy Caputo*** (caputo@insa-rouen.fr), Laboratoire de Mathematiques, INSA de Rouen, 76801 St-Etienne du Rouvra, Normandy, France. *Miscible flows on networks: soft nodes and λ soft graphs.*

To describe the flow of a miscible quantity on a network, for example the flow of power on the electric grid, we recently studied the graph wave equation where the standard continuous Laplacian is replaced by the graph Laplacian. This symmetric negative matrix has an orthogonal basis of eigenvectors. Using these, we obtained amplitude equations which revealed the importance of soft nodes, i.e. nodes where an eigenvector is zero. On these, no forcing or damping is effective and the system cannot be observed or controlled. Because soft nodes are crucial in the dynamics, it is useful to detect them in general networks. For that, we classified small λ soft graphs, that have at least one soft node for eigenvalues $\lambda = 1, 2$ and 3. In addition, we established transformations connecting members of a given lambda soft class. This approach enables to predict the occurrence of soft nodes in a network or conversely helps build networks with given soft nodes. (Received January 16, 2017)

1126-34-296 **Brenton J LeMesurier*** (lemesurierb@cofc.edu), Departmentof Mathematics, College of Charleston, Charleston, SC 29403. *PDE Models for Pulses in Binary Wave Guide Arrays.*

Binary waveguide arrays are linear arrays of optical waveguides with binary alternation of parameters, and have been of recent interest. They can be modeled by systems of nonlinear ODE's with forms related to the discrete nonlinear Schrödinger equation. Such equations can also arise in semi-classical molecular models of polymers with excitable states in each monomer, and coupling between these.

An important class of solutions arises from an initially highly localized signal, such as a single element of the array. Simulations show that for a wide array of parameter values and of such initial data, a pulse is generated that travels approximately as a traveling wave. After a suitable phase shift in the variables, this pulse quickly develops a slow spatial variation, leading to a long-wave approximation by a system of coupled third order PDE's; one each for nodes of even and odd indices.

This system of PDE's is presented, and verified to quite accurately reproduce the pulse propagation seen in the ODE system; further there is a strong tendency for the behavior of the two PDE components to converge, with a corresponding convergence of the even and odd index parts of the ODE system solution. The PDE model gives some indication of why this occurs. (Received January 16, 2017)

1126-34-321 **A. David Trubatch*** (david.trubatch@montclair.edu), Department of Mathematical Sciences, Montclair State University, Montclair, NJ 07043, and **Gino Biondini**. *Reduced-mode model for recurrence in KdV-type lattices.* Preliminary report.

A reduced-mode model, due to Infeld, is used to predict recurrence in spatial discretizations of KdV. These predictions are compared to measured recurrences in numerical simulations of the full systems. (Received January 17, 2017)

1126-34-328 **Todd Kapitula*** (tmk5@calvin.edu), Department of Mathematics and Statistics, Grand Rapids, MI 49546. *Plurality and Stability in Continuous Time Opinion Formation on Weighted Directed Graphs.* Preliminary report.

Ideas that challenge the status quo either evaporate and are forgotten, or eventually become the new status quo. An ODE mathematical model of such behavior arises when taking a mean field approximation over a large number of interacting individuals. Such a model was recently derived and analyzed by Strogatz et al. for the case of one community. Working with four undergraduate students at SUMMER@ICERM 2016 at Brown University, the Strogatz model was extended to include multiple communities and their interaction by using a weighted directed graph. Preliminary results will be presented concerning the dynamics associated with the extension. (Received January 17, 2017)

1126-34-329 **Gino Biondini***, State University of New York at Buffalo, Department of Mathematics, Buffalo, NY 14260. *The Ablowitz-Ladik system with linearizable boundary conditions.*

I will discuss boundary value problem (BVPs) for the Ablowitz–Ladik (AL) system on the natural numbers with linearizable boundary conditions. In particular, I will present: (i) a discrete analogue of the Bäcklund transformation that was used to solved similar BVPs for the nonlinear Schrödinger equation; (ii) an explicit linearizing transformation for the Bäcklund transformation is provided; (iii) explicit relations among the norming constants associated with symmetric eigenvalues; (iv) conditions for the existence of self-symmetric eigenvalues; (v) several exact soliton solutions, illustrating the above results and describing the soliton reflection at the boundary, with or without the presence of self-symmetric eigenvalues. (Received January 17, 2017)

35 ► Partial differential equations

1126-35-5 **Elisabeth MM Brown*** (embrown5@ncsu.edu) and **Michael Shearer**. *A Dual-Flux Conservation Law for Plume Migration in Carbon Sequestration.*

A quasi-linear hyperbolic partial differential equation with a discontinuous flux models geologic carbon dioxide (CO_2) migration and storage. Dual flux curves emerge in this model, giving rise to flux discontinuities. One flux describes the invasion of the plume into pore space, and the other captures the flow as the plume leaves CO_2 bubbles behind, which are then trapped in the pore space. Flux functions with discontinuities in space have been previously studied; the flux in this model depends on how the unknown is changing at any position and time. We prove the existence of an entropy solution of the Cauchy problem for any initial CO_2 plume using wave-front tracking. During our analysis, we introduce a new construction with *cross-hatch characteristics* in regions of the characteristic plane where the solution is constant, and the characteristic speed depends on which flux is invoked. We present a computer simulation that tracks CO_2 plume migration in the characteristic plane.

Some wave interactions yield novel phenomena due to the dual flux, such as shock-rarefaction interactions that would persist for all time with a single flux, here are completed in finite time. (Received September 11, 2016)

1126-35-6 **Tien Khai Nguyen*** (tnguye13@ncsu.edu), North Carolina State University, Raleigh, NC 27606, and **Alberto Bressan**, Penn State University, State College, PA 16802. *Global Existence of Weak Solutions for the Burgers-Hilbert Equation.*

The Burgers-Hilbert equation has been derived by J. Biello and J. Hunter as a model for nonlinear waves with constant frequency. This talk will present some recent results (in collaboration with Alberto Bressan). Namely: the global existence of entropy weak solutions, a priori estimates in L^2 and in L^∞, and a uniqueness result in the spatially periodic case (Received September 13, 2016)

1126-35-10 **Nancy Rodriguez*** (nrod@unc.edu), 100 Rock Spring Ct, Carrboro, NC 27510. *On the obstruction and propagation of entire solutions to a non-local reaction diffusion equation with a gap.*

In this talk I will discuss the propagation properties of a bistable spatially heterogeneous reaction-diffusion equation where the diffusion is generated by a jump process. Here the spatial heterogeneity is due to a small region with decay. First, I will focus on the existence of a "generalized transition front". Then I will give some partial results about propagation and obstruction of the transition front. Throughout the talk I will point out many interesting differences between the non-local and local reaction-diffusion equations. (Received October 05, 2016)

1126-35-11 **Nemanja Kosovalic*** (kosovalic@southalabama.edu), Mobile, AL , and **Brian Pigott**, Spartanburg, SC. *Self-excited vibrations in damped 1-D wave equations.*

We discuss a result concerning the bifurcation of periodic solutions in damped wave equations, which are induced by the presence of a time delay in the feedback. In contrast with forced vibrations, the bifurcating periodic solutions are self-excited and the mechanism is a Hopf bifurcation. (Received October 11, 2016)

1126-35-17 **Marianna A. Shubov** (marianna.shubov@gmail.com) and **Laszlo P. Kindrat*** (laszlokindrat@gmail.com). *Asymptotic and spectral analysis of bending-torsion vibration model with non-conservative boundary conditions.*

This talk is concerned with mathematical results on the initial boundary-value problem for the coupled bending-torsion vibration model, which is important in different areas of engineering sciences (e.g. design of bridges and tall buildings, aerospace eng., etc.). Mathematically, the model is represented by a system of two hyperbolic PDEs equipped with a 3-parameter family of non-self-adjoint (feedback type) boundary conditions. The system is represented as a first order in time evolution equation in the state space, a Hilbert space of 4-component Cauchy-data. The dynamics generator – a non-self-adjoint matrix differential operator – is the main object of interest. Asymptotic, spectral, and stability results will be presented. In particular, the precise asymptotic formulas for the two-branch discrete spectrum will be discussed. Practical effectiveness of analytical formulas will be demonstrated via numerical simulations. (Received November 04, 2016)

1126-35-21 **Joceline Lega*** (lega@math.arizona.edu), Department of Mathematics, 617 N. Santa Rita Avenue, Tucson, AZ 85721. *The phase structure of grain boundaries.*

I will present numerical and analytical results on grain boundaries of the Swift-Hohenberg and Cross-Newell equations. It is well known that as the angle made by the roll patterns on each side of this line defect is decreased, dislocations appear at the core of the grain boundary. Understanding this transition is an interesting problem since it provides an example of defect formation in a system that is variational and therefore more amenable to analysis.

I will show numerical results of the Swift-Hohenberg equation that aim to analyze the phase structure of far-from-threshold grain boundaries and connect these observations to properties of the associated phase diffusion equation, the regularized Cross-Newell equation.

This work is part of a long-term project whose goal is to understand the role played by phase derivatives in the creation of defects in pattern forming systems, and is joint with Nick Ercolani and Nikola Kamburov. (Received November 21, 2016)

1126-35-31 **Chenyun Luo*** (cyluo@mah.jhu.edu), 3400 North Charles Street, Baltimore, MD 21218. *On the motion of a compressible gravity water wave.*

In this talk, I would like to go over some recent results on a compressible water wave. We generalize the apriori energy estimates for the compressible Euler equations established in Lindblad-Luo to when the fluid domain is unbounded. In addition, we establish weighted elliptic estimates that allow us to find initial data in some weighted Sobolev spaces with weight $w(x) = (1 + |x|^2)^\mu, \mu \geq 2$, and we show this propagates within short time ; in other words, we are able to prove a weighted energy estimates for compressible water waves. These results serve as good preparation for proving long time existence also for compressible water waves. (Received December 10, 2016)

1126-35-36 **Earl H Dowell*** (earl.dowell@duke.edu), Box 90300, Duke University, Durham, NC 27708, and **Deman Tang** and **S Chad Gibbs**. *Nonlinear Self Excited Oscillations of a Cantilevered Flexible Plate in a Fluid Flow.*

Flexible structures may undergo self excited oscilaltion when exposed to the wind. Linear theory is usually adequate to predict the wind speed above which the oscillations may occur and also their frequency. However to predict the amplitude of the oscillations and thus the mechanical energy which may transformed into electrical power, a nonlinear theory and computational model is required. Also the results must be verified by experiment. In addition such oscillations must occur for a range of wind directions.

In the presentation, the nonlinear oscillations of a flexible cantilevered plate will be discussed based upon a new nonlinear structural model and a linear potential flow aerodynamic model.A wide range of wind directions will be considered and the results of computations will be compared to those from wind tunnel experiments. (Received December 13, 2016)

1126-35-41 **Carla Cederbaum*** (cederbaum@math.uni-tuebingen.de), Fachbereich Mathematik, Auf der Morgenstelle 10, 72070 Tuebingen, Germany. *On foliations related to the center of mass in General Relativity.*

We will discuss new developments in the analysis of asymptotic foliations by prescribed curvature in relativistic initial data sets with prescribed asymptotic decay, generalizing results by Huisken and Yau. We will relate these foliations to the definition of the center of mass of the initial data sets under consideration. The results presented are joint work with Cortier–Sakovich and with Nerz. (Received December 15, 2016)

1126-35-53 **Yuanzhen Shao*** (shao92@purdue.edu), 150 N University St, West Lafayette, IN 47907, **Gieri Simonett** (gieri.simonett@vanderbilt.edu), Nashville, 37240, and **Jan Pruss**. *Regularity of the interface of a thermodynamically consistent two-phase Stefan problem.*

We study the regularity of solutions to a thermodynamically consistent two-phase Stefan problem with or without kinetic undercooling. It is shown that the free interface of the problem immediately becomes analytic jointly in time and space, provided the initial surface satisfies a mild regularity assumption. The proof is based on a combination of a family of parameter-dependent diffeomorphisms, Lp-maximal regularity theory, and the implicit function theorem. (Received December 20, 2016)

1126-35-63 **Suzanne Lenhart***, University of Tennessee and NIMBioS, Knoxville, TN 37996. *Optimal control of competitive population models.*

We present an optimal control problem for a system of parabolic partial differential equations, representing two competing populations. The controls are the advective movement coefficients. The goal is to maximize a weighted sum of the populations while taking into account the cost of risks due to movement. Analysis and numerical results with heterogeneous resources will be presented (Received December 28, 2016)

1126-35-64 **Lorena Bociu**, **Daniel Toundykov*** (dtoundykov@unl.edu) and **Jean-Paul Zolesio**. *Semigroup well-posedness for the total linearization of a free boundary hydro-elastic model.*

We will look at a new linearized model of a free boundary fluid-structure interaction. The hydro-elastic equations and the free boundary were linearized together which yields a system quite different from the classical coupling of the Stokes flow and linear elasticity, going back to 1960's. Additional terms emerge on the common interface, some of them involving boundary curvatures. Despite many new features, the system shares a number of properties with the classical model. We proceed to demonstrate that when the linearization is performed around slow steady regimes, the associated evolution operator generates a strongly continuous semigroup. (Received December 29, 2016)

1126-35-73 **Virgil U Pierce*** (virgil.pierce@utrgv.edu). *Enumeration of Mobius Graphs.* Preliminary report.

The partition function of N-by-N symmetric random matrices has a natural interpretation in terms of a tau-function for the Pfaff lattice hierarchy. The asymptotic expansion of the log-partition function gives generating functions for the enumeration of maps indexed by genus, and the parameters of the deformation index the maps by the valency of their vertices. The Pfaff lattice hierarchy then gives a hierarchy of governing equations that in principle determine the terms in the asymptotic expansion. (Received January 02, 2017)

1126-35-76 **Wen-Xiu Ma*** (mawx@cas.usf.edu), 4202 E Fowler Avenue, Tampa, FL 33620. *Lump solitons to integrable wave equations.*

Lump solitions to integrable wave equations will be talked about. The key technique is to use bilinear forms and positive multivariate polynomials. Illustrative examples of lumps are presented for the Kadomtsev-Petviashvili, B-Kadomtsev-Petviashvili and Jimbo-Miwa equations through symbolic computation with Maple. (Received January 02, 2017)

1126-35-82 **Milena Stanislavova*** (stanis@ku.edu), Department of Mathematics, University of Kansas, Lawrence, KS 66045. *Spectral Stability for Classical Periodic Waves of the Ostrovsky and Short Pulse Models.*

We consider the Ostrovsky and short pulse models in a symmetric spatial interval, subject to periodic boundary conditions. For the Ostrovsky case, we re-derive the formulas for the classical periodic traveling waves, while for the short pulse model, we explicitly construct traveling waves in terms of Jacobi elliptic functions. In both cases, we show spectral stability, for all values of the parameters. This is achieved by studying the non-standard eigenvalue problems in the form $L[u] = \lambda u'$, where L is a Hill operator. (Received January 05, 2017)

1126-35-98 **David M. Ambrose*** (dma68@drexel.edu), Department of Mathematics, Drexel University, Philadelphia, PA 19104. *Nonexistence of small time-periodic solutions for dispersive equations.*

In joint work with J. Douglas Wright, we have developed a method to prove nonexistence of nontrivial small doubly periodic (i.e., both spatially and temporally periodic) solutions for nonlinear evolution equations. This method formulates the question of existence of time-periodic solutions as a fixed point problem, and we show in certain circumstances that the only fixed point of the relevant operator is the trivial solution. The operator in question is the composition of a linear operator and the Duhamel integral for the evolution. We use small divisor estimates to control the linear part. We show applications to the KdV equation and nonlinear Schrodinger equations, proving that for almost every temporal period, arbitrarily small doubly periodic solutions cannot exist. (Received January 06, 2017)

1126-35-104 **David M. Ambrose*** (dma68@drexel.edu), Department of Mathematics, Drexel University, Philadelphia, PA 19104. *Ill-posedness of truncated series models for water waves.*

A number of approximate models have been introduced for the study of water waves, to avoid the full complexity of the Euler equations. Truncated series models are a family of approximate water wave models which are popular for computing, as they can be treated efficiently by pseudospectral methods. These models are formed by expanding the Dirichlet-to-Neumann operator as a series, truncating the series, and substituting the result into the equations of motion. The full water wave problem is well-known to have a well-posed initial value problem. This leads us to ask whether the truncated series models inherit this feature. We show evidence that the truncated series models of gravity water waves in fact have ill-posed initial value problems. We discuss the case of stronger dispersion; for sufficiently strong dispersion, such as in the case of an elastic bending force, the initial value problem is well-posed. Ill-posedness or well-posedness in the case of surface tension remains an open problem. This includes joint work with Jerry Bona, Shunlian Liu, David Nicholls, and possibly Michael Siegel. (Received January 07, 2017)

1126-35-105 **Anna Ghazaryan** and **Yuri Latushkin*** (latushkiny@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, and **Xinyao Yang**. *Stability of one-dimensional and multi-dimensional fronts in exponentially weighted norms.*

We consider a class of systems of reaction diffusion equations that frequently appears in combustion theory and chemical modeling. We study stability of traveling fronts in both one-dimensional and multi-dimensional cases. The essential spectrum of the operator obtained by linearizing the system about the front touches the imaginary axis, and thus we have to work in the intersection of the spaces of functions with and without exponential weights. For the one-dimensional case we prove the existence of stable foliation in vicinity of the front (these results are obtained jointly with R. Schnaubelt). For the multi-dimensional case we extend the stability theorems to the case of exponentially weighted spaces, and prove algebraic decay of perturbations of the front. (Received January 07, 2017)

1126-35-110 **Tien Khai Nguyen*** (khai@math.ncsu.edu), 2311 stinson drive, Box 8205, Raleigh, NC 27695. *Conservation laws and some applications to traffic flows.* Preliminary report.

In this talk, I will introduce a new class of models of traffic flow on a network of roads. In these models, the percentage of drivers who travel along an incoming road and wish to turn into an outgoing road is not a constant.

Moreover, the drivers who enter a congested road are placed in a buffer of limited capacity, waiting their turn in line. The main goal is to describe traffic flow at intersections and study optimization problems on a network of roads.

I will present the well-posedness result for a new intersection model of traffic flows, and the existence of globally optimal solutions, Nash equilibrium solutions for a decision problem involving a continuum of drivers on the network. (Received January 07, 2017)

1126-35-126 **Lorena Bociu*** (lvbociu@ncsu.edu), SAS 3236, Stinson Drive, Raleigh, NC 27695.
Sensitivity Analysis in Poro-Elastic and Poro-Visco-Elastic Models.
We consider poro-elastic and poro-visco-elastic models inspired by problems in medicine and biology, and we perform sensitivity analysis on the solutions of these fluid-solid mixtures problems with respect to the imposed boundary data, which are the main drivers of the systems. Moreover, we compare the results obtained in the elastic case vs. visco-elastic case, as it is known that structural viscosity of biological tissues decreases with age and disease. (Received January 09, 2017)

1126-35-138 **Benjamin Dodson*** (bdodson4@jhu.edu). *Global well - posedness and scattering for the cubic wave equation in three dimensions.*
In this talk, I will be discussing the cubic wave equation in three dimensions with radial data. I will discuss some recent proofs of scattering for almost critical data. I will also discuss the proof of scattering for radial data lying in a critical Besov space. (Received January 09, 2017)

1126-35-163 **Yakov Shlapentokh-Rothman***, Fine Hall, Washington Road, Princeton, NJ 08544.
Asymptotically Self-Similar Solutions to 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 Chrisotodulou'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 January 11, 2017)

1126-35-166 **Justin T Webster*** (websterj@cofc.edu), 66 GEORGE ST, Charleston, SC 29424.
Effectiveness of velocity-dependent structural damping in nonlinear flutter models.
When a thin elastic structure is immersed in a fluid flow, certain conditions may bring about structural excitations. We consider a panel configuration (clamped at the boundary) for a nonlinear plate in a potential flow, and investigate the effect of damping on long-time behavior. We discuss recent results on end-behavior of the dynamics. There are results which describe full flow-structure trajectories, and others which only describe the end-behavior of the structure. A second distinction occurs between results which require some damping, and those which require large damping.

Results will be presented on "stabilization" of the dynamics, albeit in various senses of the word. For arbitrary flow velocities, we prove that structural dynamics converge to a smooth, finite dimensional global attractor in the presence of any internal damping. We then show that large damping in the structure improves this global attractor to an exponential attractor. In the case of subsonic flow velocities, we show the strong stabilization of full flow-plate trajectories to the equilibria set. Results are in good agreement with experimental findings. (Received January 11, 2017)

1126-35-170 **Anna R Ghazaryan*** (ghazarar@miamioh.edu), **Stephane Lafortune** and **Peter McLarnan**. *Traveling waves in a combustion model.*
We study the stability of fronts in a reduction of a model of combustion in hydraulically resistant porous media. We first consider the model with the Lewis number chosen in a specific way and with initial conditions of a specific form. We then show that the stability results for that system extend to the fronts in the full system with the same Lewis number. The fronts are either absolutely unstable or convectively unstable. (Received January 12, 2017)

1126-35-176 **Scipio Cuccagna** (scuccagna@units.it), Department of Mathematics and Geosciences, University of Trieste, 34127 Trieste, Italy, **Masaya Maeda** (maeda@math.s.chiba-u.ac.jp), Department of Mathematics and Informatics, Faculty of Science, Chiba University, Chiba , Japan, and **Tuoc Phan*** (phan@math.utk.edu), Department of Mathematics, University of Tennessee, Knoxville, 227 Ayres Hall. 1403 Circle Drive., Knoxville, TN 37996-1320. *On small energy stabilization in the NLKG with a trapping potential.*

We consider a nonlinear Klein Gordon equation (NLKG) with short range potential with eigenvalues and show that in the contest of complex valued solutions the small standing waves are attractors for small solutions of the NLKG. This extends the results already known for the nonlinear Schrödinger equation and for the nonlinear Dirac equation. In addition, this extends a result of Bambusi and Cuccagna (which in turn was an extension of a result by Soffer and Weinstein) which considered only real valued solutions of the NLKG. (Received January 12, 2017)

1126-35-178 **Vahagn Manukian*** (manukive@miamioh.edu), 1601 University Blvd, Hamilton, OH 45011. *The Gray-Scott Model: Bistable Regime.*

Using singularly perturbed nature of the Gray-Scott model, we apply multi-scale analysis in a systematic way to show the existence and stability of a traveling front and a traveling pulse. While the traveling front is stable, the pulse is unstable. (Received January 12, 2017)

1126-35-188 **Lorena Bociu** and **Steven Derochers*** (sjderoch@ncsu.edu), 1211 Ridge Trace Dr., Raleigh, NC 27606, and **Daniel Toundykov**. *Feedback Stabilization of a Hydro-Elasticity Model.* Preliminary report.

We investigate the stability of a linear fluid-elasticity model obtained recently using shape optimization techniques. As the linearization took into account the geometry of the problem through the moving common interface, the linear system contains boundary terms involving curvature and boundary acceleration. The C_0-semigroup generator for this evolution is ω-dissipative, instead of dissipative, like in the classical coupling of the linear problems. This observation, along with numerical investigations performed on the linearization, prompted us to consider interior and boundary feedback stabilization terms, in order to obtain exponential stability for the system. (Received January 12, 2017)

1126-35-192 **George Avalos*** (gavalos@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Analysis of a Compressible Fluid - Structure PDE Interaction.*

In this talk, we present recently derived results for a partial differential equation (PDE) system which models a fluid-structure interaction of current interest within the mathematical literature. The coupled PDE model under discussion involves a Stokes system, which evolves on a three dimensional domain, interacting with a Lamé system of elasticity which evolves on a flat portion of said fluid domain. Moreover there is an additional coupling PDE which determines the associated pressure variable of the fluid-structure system. In addition, because of the presence of an "ambient flow" vector field, the coupled PDE is not dissipative. This is joint work with Pelin Güven Geredeli of Hacettepe University (Ankara, Turkey) and Justin Webster of The College of Charleston. (Received January 12, 2017)

1126-35-204 **Feride Tiglay*** (tiglay.1@osu.edu). *Integrating the μHS equation.* Preliminary report.

We describe how to use Fredholm determinants to construct special functions and integrate an evolution equation from mathematical physics. (Received January 13, 2017)

1126-35-209 **Jeanne N. Clelland*** (jeanne.clelland@colorado.edu), Dept. of Mathematics, 395 UCB, University of Colorado, Boulder, CO 80309-0395, and **Thomas A. Ivey** (iveyt@cofc.edu). *Towards a classification of quasi-linear Bäcklund transformations of wavelike PDEs, and a new example.* Preliminary report.

We consider the problem of classifying Bäcklund transformations between hyperbolic Monge-Ampère equations with the following properties:

(1) The underlying equations are *wavelike* and *translation-invariant*; i.e., of the form

$$u_{xy} = f(u, u_x, u_y), \qquad v_{xy} = g(v, v_x, v_y).$$

(2) The transformation is *quasi-linear*, which implies that it can be written in the form

$$u_x = F_1(u, v)v_x + F_0(u, v), \qquad v_y = G_1(u, v)u_y + G_0(u, v).$$

These conditions lead to an overdetermined PDE system for the functions F_0, F_1, G_0, G_1 whose analysis is quite complicated.

In the process of conducting this analysis, we have found what appears to be a new example of a PDE possessing a 1-parameter family of auto-Bäcklund transformations (i.e., transformations between solutions of the same PDE). We will present this example and explore the question of whether it has additional features typically associated with integrable systems. (Received January 13, 2017)

1126-35-226 **Yuan Zhou*** (zhouy@mail.usf.edu), Department of Mathematics & Statistics, University of South Florida, 4202 East Fowler Ave, CMC 014, Tampa, FL 33620-5700, and **Wen-Xiu Ma** (mawx@cas.usf.edu). *Bilinear differential forms and applications.*

The Hirota bilinear method is an effective approach to integrable equations. Integrable equations are transformed into bilinear forms, including Hirota forms and generalized bilinear forms, under the logarithmic dependent variable transformations. In this talk, we will discuss about subspaces of solutions to integrable equations by the linear superposition principle, The considered equations possess generalized bilinear forms and the resulting solutions contain solitons, lumps and complexitons. (Received January 14, 2017)

1126-35-228 **Efstathios G Charalampidis*** (charalamp@math.umass.edu), Department of Mathematics and Statistics, Lederle Graduate Research Tower, University of Massachusetts, Amherst, MA 01003-9305. *"Multi-component nonlinear Schrödinger (NLS) systems: From theory to Numerical Computations.*

In this talk, we will present a two-component NLS system in various spatial dimensions. States that support a dark solitary wave in 1D (and its generalization in 2D) in the one-component will be considered, and we will explore the possibility of forming bright solitonic bound states in the second component. Bifurcation points are identified by studying the underlying linear limit numerically and (wherever possible) analytically. Then, nonlinear states are identified by employing a Newton-Raphson method and their stability is discussed. Finally, a new, yet powerful continuation method, called *deflated continuation*, will be discussed where results on its application to the NLS equation will be shown. (Received January 14, 2017)

1126-35-235 **Anudeep Kumar*** (anudeep@gwu.edu). *Long time behavior of solutions to the Generalized Hartree equation.*

We study the long time behavior of solutions in the nonlinear dispersive equations, in particular, the generalized Hartree-type equation, where the potential is of nonlocal type and is expressed as a convolution. The behavior of solutions has been studied quite extensively for some basic model equations such as nonlinear wave equation and nonlinear Schrödinger equation and various regimes were exhibited such as finite time existing solutions (or so called blow-up in finite time), or solutions existing globally in time: solitary waves or scattering (approaching linear solutions as $t \to \pm\infty$). In this talk we present small data theory, dichotomy for scattering versus blow-up, and criteria for solutions that blow-up in finite time with an emphasis on the method of concentration - compactness. (Received January 15, 2017)

1126-35-240 **Irena Lasiecka*** (lasiecka@memphis.edu), Department of Mathematical Sciences, Dunn Hall, University of Memphis, Memphis, TN 38152. *Minimizing pressure in a fluid structure interaction problem.*

Fluid structure interaction modeled by NS-equation coupled with a dynamic system of elasticity is considered. The goal is to minimize pressure on the moving interface between the fluid and the solid. The actuators are Dirichlet controls located on a part of the external boundary of the fluid. The main result is an existence of optimal control for the model described above. The proof is based on the estimates presented in joint work with M. Ignatova, I. Kukavica and A. Tuffaha 'Small data global existence for a fluid-structure model" to appear in Nonlinearity, 2017. (Received January 15, 2017)

1126-35-242 **Marius Beceanu** and **Michael Goldberg*** (goldbeml@ucmail.uc.edu). *Pointwise bounds for the three-dimensional wave propagator.* Preliminary report.

The wave equation in $\mathbb{R}^3$ is subject to a number of "reversed Strichartz" estimates in which solutions are integrated over a time interval and the resulting function is bounded in $L^p(\mathbb{R}^3)$. One elementary bound in this spirit is that the kernel $K(t, x, y)$ of the sine propagator $\frac{\sin(t\sqrt{-\Delta})}{\sqrt{-\Delta}}$ satisfies $\int_{\mathbb{R}} |K(x, y, t)|\, dt = (4\pi|x-y|)^{-1}$.

We examine the analogous propagator $\frac{\sin(t\sqrt{H})}{\sqrt{H}} P_{ac}(H)$ for operators $H = -\Delta + V$, with the potential V belonging to the Kato-norm closure of test functions. It is already known that many L^p bounds are preserved by such perturbations. We show that the stronger pointwise bound $\int_{\mathbb{R}} |K(x, y, t)|\, dt \le C|x-y|^{-1}$ is preserved as well. It appears that pointwise bounds for other spectral multipliers follow as a natural consequence. (Received January 15, 2017)

1126-35-246 **Stephane Lafortune*** (lafortunes@cofc.edu), Department of Mathematics, College of Charleston, Charleston, SC 29424, **Annalisa Calini** (calini@cofc.edu), Department of Mathematics, College of Charleston, Charleston, SC 29424, and **Brenton Lemesurier** (lemesurierb@cofc.edu), Department of Mathematics, College of Charleston, Charleston, SC 29424. *Linear and Orbital Stability of Solutions to the VFE and the VFE Hierarchy.*

By the term vortex filament, we mean a mass of whirling fluid or air (e.g. a whirlpool or whirlwind) concentrated along a slender tube. The most spectacular and well-known example of a vortex filament is a tornado. A waterspout and dust devil are other examples. In more technical applications, vortex filaments are seen and used in contexts such as superfluids and superconductivity. One system of equations used to describe the dynamics of vortex filaments is the Vortex Filament Equation (VFE). The VFE is a system giving the time evolution of the curve around which the vorticity is concentrated. In this talk, we develop a framework for studying the orbital stability of VFE soliton solutions, based on the Hamiltonian formalism. If time permits, we will also tackle the case of solutions to other members of the VFE hierarchy of integrable equations. (Received January 15, 2017)

1126-35-253 **H. T. Banks**, **Kidist Bekele-Maxwell**, **Lorena Bociu**, **Marcella Noorman*** (mjnoorma@ncsu.edu) and **G. Guidoboni**. *Sensitivity analysis in poro-visco-elasticity.*

Poro-elastic and poro-visco-elastic models find many applications in bioengineering and medicine. Inspired from applications in geophysics and petroleum engineering, they are more and more frequently being applied to biological tissues. For many of these biological applications, the boundary data plays a crucial role. In a recent theoretical and numerical analysis of poro-elastic and poro-visco-elastic models, the time regularity of the imposed boundary traction was identified as a crucial factor in guaranteeing boundedness of the solutions. Here, we further extend that analysis by studying the sensitivity of model solutions to the imposed boundary traction and comparing the results obtained in the purely elastic case versus the visco-elastic case. This analysis will direct and inform the development of relevant control and optimization problems for the given poro-visco-elastic model. (Received January 15, 2017)

1126-35-256 **Lorena Bociu** and **Lucas Castle*** (lcastle@ncsu.edu), 2311 Stinson Dr., Box 8205, NC State University, Raleigh, NC 27695. *Optimal Control in a Free Boundary Fluid Structure Interaction.* Preliminary report.

We consider an optimal control for the problem of minimizing flow turbulence in the case of a nonlinear fluid-structure interaction model. If the initial configuration is regular, then a class of sufficiently smooth control inputs contains an element that minimizes, within the control class, the vorticity of the fluid flow around a moving and deforming elastic solid. We establish this existence and discuss the first order optimality conditions on the optimal control. (Received January 15, 2017)

1126-35-280 **Marcelo Mendes Disconzi*** (marcelo.disconzi@vanderbilt.edu), 1326 Stevenson Center, Nashville, TN 37240, and **Igor Kukavica**. *A priori estimates for the free-boudary Euler equations with surface tension in three dimensions.*

We derive a priori estiamtes for the incompressible free-boundary Euler equations in three spatial dimensions with surface tension. We work in Lagrangian coordinates. Our methods are reather direct and involve three key elements: good estimates for the pressure, the boundary regularity provided by the mean curvature, and the Cauchy invariance. (Received January 16, 2017)

1126-35-284 **Luiz Gustavo Farah*** (lgfarah@gmail.com), ICEx, Universidade Federal de Minas Gerais, Av. Antônio Carlos, 6627, Caixa Postal 702, Belo Horizonte, MG 30161-970, Brazil, and **Brian Pigott** and **Henrique Versieux**. *Linear and nonlinear profile decomposition for Supercritical Generalized KdV Equations with applications.*

A linear and nonlinear profile decomposition are established for solutions of supercritical generalized Korteweg-de Vries equations. As a consequence, we prove the existence of maximizers for some Airy-Strichartz inequalities (joint work with Henrique Versieux (UFMG-Brazil)) and also a concentration result for finite time blow-up solutions of the supercritical generalized Korteweg-de Vries equations that are of Type II (joint work with Brian Pigott (Wofford College)). (Received January 16, 2017)

1126-35-285 **Gideon Simpson*** (grs53@drexel.edu), Philadelphia, PA 19104. *Adaptive Methods for Derivative Nonlinear Schr̈dinger Equations.* Preliminary report.

Numerical simulations of L^2 supercritical derivative nonlinear Schrödinger equations suggest the existence of finite time singularities. Thus far, the numerical studies have relied upon either integration of the original equation or the dynamic rescaling method. The first approach is limited because of the singularity, while the latter appraoch is limited by the hyperbolic character of the nonlinearity. In both cases, simulations have been restricted to relatively supercritical cases, bounded away from the limiting critical case. Using locally adaptive meshing methods, we are able to overcome prior difficulties, integrating closer to the singularity time with nonlinearities closer to the critical value. (Received January 16, 2017)

1126-35-289 **Giusy Mazzone*** (giusy.mazzone@vanderbilt.edu), Department of Mathematics, 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240. *Long-time behavior of rigid bodies with a fluid-filled gap.*

We consider the system constituted by a rigid body $\mathcal{B}$ having a hollow cavity which (strictly) contains a homogeneous rigid ball B_R. The gap between these rigid bodies is completely filled by a viscous incompressible fluid, whose motion is governed by the Navier-Stokes equations. We assume that the whole system $\mathcal{S}$ of rigid bodies with a fluid-filled gap is constrained to move (without friction) around the center, G, of the ball B_R. For a large class of configurations for the fluid and the solid $\mathcal{B}$, we show that the long-time behavior of weak solutions corresponding to initial data having (arbitrary) finite kinetic energy is characterized by a steady state. In this steady state, $\mathcal{S}$ rotates as a whole rigid body with constant angular velocity. In particular, the velocities of the fluid relative to $\mathcal{B}$ and to B_R tend to zero as time approaches to infinity, respectively. (Received January 16, 2017)

1126-35-291 **Roberto Triggiani***, Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152. *Domains of fractional powers of the heat-structure operator with visco-elastic damping: Regularity and control-theoretic implications.*

We consider a heat-structure interaction model where the structure is subject to visco-elastic (strong) damping. The system displays high order boundary coupling at the interface between the two media. If A is the free dynamic operator, we characterize its domains of fractional powers. Implications include optimal (maximal) regularity of the map: boundary control -> solution, where the control acts in the Dirichlet boundary conditions either at the external boundary of the heat-domain, or else at the interface between the two domains. The optimal control theory and min-max game theory then applies with the parameter gamma = 3/4 +(epsilon). (Received January 16, 2017)

1126-35-295 **Jason Metcalfe*** (metcalfe@email.unc.edu), Department of Mathematics, University of North Carolina, Chapel Hill, NC 27599-3250. *Localized energy estimates for wave equations in the presence of degenerate trapping.*

This is a joint work with R. Booth, H. Christianson, and J. Perry. We examine the wave equation on a warped product manifold that has degenerate trapping. A localized energy estimate with an algebraic loss is proved, and it is shown that this loss is sharp. This is a wave equation analog of the preceding work of Christianson and Wunsch for the Schroedinger equation, but the current scenario requires a significant new low frequency analysis that was not needed for the local-in-time estimates of Christianson and Wunsch. (Received January 16, 2017)

1126-35-306 **Marco Bertola**, **Gennady El** and **Alexander Tovbis*** (alexander.tovbis@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Maximal amplitude of multiphase (finite-gap) solutions of the focusing Nonlinear Schrödinger equation and large amplitude (rogue) waves.*

We derive the sharp estimate for a maximum amplitude of a finite gap solution to the focusing Nonlinear Schrödinger equation (Received January 16, 2017)

1126-35-312 **Tadahiro Oh** and **Geordie Richards*** (geordie.richards@usu.edu), Mechanical & Aerospace Engineering, Utah State University, 4130 Old Main Hill, Logan, UT 84322, and **Laurent Thomann**. *On invariant Gibbs measures for generalized KdV.*

We will discuss some recent results on invariant Gibbs measures for the periodic generalized KdV equations (gKdV). Proving invariance of the Gibbs measure for gKdV is nontrivial due to the low regularity of functions in the support of this measure. Bourgain proved this invariance for KdV and mKdV, which have quadratic and cubic nonlinearities, respectively. Previously, we proved invariance of the Gibbs measure for the quartic gKdV by exploiting a nonlinear smoothing induced by initial data randomization. More recently, in joint work with Tadahiro Oh (Edinburgh) and Laurent Thomann (Lorraine), we have established this invariance for gKdV with any odd power (defocusing) nonlinearity. This argument relies on a probabilistic construction of solutions using the Skorokhod representation theorem. (Received January 17, 2017)

1126-35-315 **Irena lasiecka**, Memphis, TN, **Michael Pokojovy**, Karlsruhe, Germany, and **Xiang Wan*** (xw5he@virginia.edu), Charlottesville, VA. *On the Global Well-posedness and Stability of Nonlinear Thermo-elastic Plate Equations with Fourier or Maxwell-Cattaneo Laws.* Preliminary report.

We consider a nonlinear thermo-elastic system defined on a bounded domain $\Omega \subset \mathbb{R}^n, n = 2$ or 3 with the boundary conditions imposed on $\Gamma = \partial\Omega$ corresponding to the simply supported plate. The main goal of this talk is to discuss the well-posedness and long term behavior of suitable solutions of the system.

We will discuss the challenge for the case of Kirchhoff-Love plate, of which the system is either of hyperbolic-parabolic type corresponding to the Fourier Law, or of completely hyperbolic type corresponding to the Maxwell-Cattaneo Law. From a mathematical point of view, the most important message is that the analyticity and maximal regularity of the associated linear system are gone. We will show how to choose suitable topologies to overcome this difficulty.

This is a joint work with Irena Lasiecka, University of Memphis, and Michael Pokojovy, Karlsruhe Institute of Technology. Germany. (Received January 17, 2017)

1126-35-322 **Barbara Prinari*** (bprinari@uccs.edu), 1420 Austin Bluffs Pkwy, Colorado Springs, CO 80918. *Inverse scattering transform for a square matrix nonlinear Schrödinger equation with nonzero boundary conditions.* Preliminary report.

In this talk we discuss the Inverse Scattering Transform (IST) under nonzero boundary conditions for a square matrix nonlinear Schrödinger equation which has been proposed as a model to describe hyperfine spin $F = 1$ spinor Bose-Einstein condensates with either repulsive interatomic interactions and anti-ferromagnetic spin-exchange interactions, or attractive interatomic interactions and ferromagnetic spin-exchange interactions.

We formulate the IST in terms of a suitable uniformization variable, which allows to define the direct and inverse problems on the complex plane, instead of a two-sheeted Riemann surface or the cut plane with discontinuities along the cuts; and we discuss the soliton solutions. (Received January 17, 2017)

1126-35-324 **Michael Jenkinson*** (jenkim2@rpi.edu) and **Michael I Weinstein**. *On-Site and Off-Site Bound States of the Discrete Nonlinear Schroedinger Equation and The Peierls-Nabarro Barrier.*

We construct several families of symmetric localized standing waves (breathers) to the one-, two-, and three-dimensional discrete nonlinear Schroedinger equation (DNLS) with cubic nonlinearity using bifurcation methods about the continuum limit. Such waves and their energy differences play a role in the propagation of localized states of DNLS across the lattice. The energy differences, which we prove to exponentially small in a natural parameter, are related to the Peierls-Nabarro Barrier in discrete systems, first investigated by M. Peyrard and M.D. Kruskal (1984). These results may be generalized to different lattice geometries and inter-site coupling parameters. Finally, we discuss the local stability properties of these bound states. This is joint work with Michael I. Weinstein. (Received January 17, 2017)

1126-35-333 **Mathew A Johnson*** (matjohn@ku.edu), 1460 Jayhawk Blvd., 405 Snow Hall, Lawrence, KS 66045. *Dynamics of Unstable Solitary Waves: A Case Study.* Preliminary report.

When studying inclined, viscous thin film flow one finds a family of solitary wave solutions that have unstable essential spectrum and stable point spectrum. The long-time dynamics of such unstable waves appear to have a considerable amount of structure that one might want to try to explain analytically. In this talk, I will review some recent work in this direction, as well as discuss another instance of such a phenomena arising in the field of nanoscale pattern formation. Parts of this work are joint work with Blake Barker, Greg Lyng, and Connor Smith. (Received January 17, 2017)

1126-35-334 **Peter D. Miller*** (millerpd@umich.edu). *Semiclassical Aspects of the Three-Wave Resonant Interaction.*

I will describe joint work with Robert Buckingham and Robert Jenkins to analyze the initial-value problem for the three-wave resonant interaction equations, an integrable system governing three quadratically coupled fields, in an appropriate semiclassical limit. As the system is non-dispersive, long time limits do not reveal any particular simplification of the dynamics, but the semiclassical limit allows for the practical calculation of the interaction process. I will describe the construction of an appropriate semiclassical soliton ensemble and show how such ensembles can be used to understand the behavior of resonant triads in a wide variety of systems. (Received January 17, 2017)

1126-35-336 **A J Meir*** (ajmeir@smu.edu), Department of Mathematics, Southern Methodist University, Dallas, TX 75275, and **Y Cao** (yzc0009@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849. *On Some Nonlinear Problems in Poromechanics.*

Poromechanics is the science of energy, motion, and forces, and their effect on porous material and in particular the swelling and shrinking of fluid-saturated porous media. Modeling and predicting the mechanical behavior of fluid-infiltrated porous media is significant since many natural substances, for example, rocks, soils, clays, shales, biological tissues, and bones, as well as man-made materials, such as, foams, gels, concrete, water-solute drug carriers, and ceramics are all elastic porous materials (hence poroelastic).

After a brief overview I will describe some nonlinear problems in poroelasticity and their mathematical analysis. I will also describe finite element based numerical methods for efficiently and accurately approximating solutions of (nonlinear) model problems in poroelasticity, and the available a-priori error estimates. (Received January 17, 2017)

1126-35-339 **Gino Biondini*** (biondini@buffalo.edu), State University of New York at Buffalo, Department of Mathematics, Buffalo, NY 14260. *Long-time asymptotics of focusing nonlinear Schrodinger equations with non-zero boundary conditions.*

This talk is divided into three parts. First, I will describe how Deift-Zhou nonlinear steepest descent techniques for oscillatory Riemann-Hilbert problems can be used to study the long-time asymptotic behavior of solutions of the focusing nonlinear Schrodinger (NLS) equation with nonzero boundary conditions at infinity. Second, I will describe in detail the properties of the asymptotic state, including the number of oscillations and the local structure of the solution near each peak, showing in particular that in the long-time limit the solution tends to an ensemble of classical (i.e., sech-shaped) solutions of the NLS equation. Third, I will show that the existence of a similar asymptotic state is a property shared among a broad class of systems of NLS type possessing modulational instability. (Received January 17, 2017)

1126-35-347 **Matthias Eller*** (mme4@georgetown.edu), Department of Mathematics, Georgetown University, 37th & O Street NW, Washington, DC 20007. *On the Neumann trace of the Cauchy-Dirichlet problem for the wave equation.* Preliminary report.

The Cauchy-Dirichlet problem for the wave equation is considered. The Neumann trace of the spatial boundary of finite energy solutions is known to be square integrable. In this talk we discuss the relation between the initial velocity and the Neumann trace in more detail. We will explain how discontinuities of the initial velocity travel along bicharacteristic rays toward the boundary and produce a discontinuity of the Neumann trace. Furthermore, a new estimate of the Neumann trace in terms of the initial velocity will be given. (Received January 17, 2017)

1126-35-358 **Ziad Musslimani***, Department of Mathematics, Tallahassee, FL 32311. *Integrable nonlocal nonlinear equations,.*

A nonlocal nonlinear Schrodinger (NLS) equation was recently found and shown to be an integrable infinite dimensional Hamiltonian equation. Unlike the classical (local) case, here the nonlinearly induced "potential" is PT symmetric thus the nonlocal NLS equation is also PT symmetric. In this talk, new reverse space-time and reverse time nonlocal nonlinear integrable equations are introduced. They arise from remarkably simple symmetry reductions of general AKNS scattering problems where the nonlocality appears in both space and time or time alone. They are integrable infinite dimensional Hamiltonian dynamical systems. These include the reverse space-time, and in some cases reverse time, nonlocal NLS, modified Korteweg-deVries (mKdV), sine-Gordon, (1+1) and (2+1)dimensional three-wave interaction, derivative NLS, "loop soliton," Davey–Stewartson (DS), partially PT symmetric DS and partially reverse space-time DS equations. Linear Lax pairs, an infinite number of conservation laws, inverse scattering transforms are discussed and one soliton solutions are found. (Received January 17, 2017)

1126-35-368 **Gary A. Moon*** (garymoon@live.unc.edu) and **Sarah G. Raynor** (raynorsg@wfu.edu). *Neumann Solutions to a Two-Phase Elliptic Free Boundary Problem in Two Dimensions.*

We discuss a two-phase elliptic free boundary problem with mixed boundary conditions. We focus on solutions minimizing the functional

$$J(v) = \int_{\Omega\cap B_r} |\nabla v|^2 + q^2(x)\lambda^2(v)dx$$

over a suitable class of functions where $q(x) \neq 0$, $\lambda^2(v) = \lambda_1^2$ for $v \leq 0$, $\lambda^2(v) = \lambda_2^2$ for $v > 0$ and Ω is a bounded, convex subset of two-dimensional Euclidean space. We are concerned with the behavior of solutions as well as the free boundary near the Neumann part of the fixed boundary. We will establish the Lipschitz continuity of solutions near the Neumann fixed boundary via the use of a monotonicity formula. Additionally, we will discuss the behavior of the free boundary using numerical experiments, specifically focusing on how the free boundary intersects the Neumann fixed boundary. (Received January 17, 2017)

1126-35-383 **Ziad H Musslimani***, Department of Mathematics, Tallahassee, FL 32306. *Nonlinear waves and integrable nonlocal models.*

In this talk we will present recent results related to the field of integrable nonlocal models. In particular we will introduce the space-time and time only nonlocal NLS equation, give detailed analysis of the inverse scattering transform and give soliton solutions (Received January 17, 2017)

1126-35-388 **Andrii Anikushyn** and **Michael Pokojovy*** (michael.pokojovy@kit.edu). *Multidimensional Thermoelasticity for Nonsimple Materials – Well-Posedness and Long-Time Behavior.*

We consider a PDE system

$$\begin{aligned} \rho \ddot{u}_i &= \big(A_{iJKj} u_{j,K} - \beta_{Ji}\dot{\tau} - (C_{iJKLIj} u_{j,IL} + M_{iJKL}\tau_{,L})_{,K}\big)_{,J} - E(|\dot{u}|)\dot{u}_i, \\ a\ddot{\tau} &= -\beta_{Ki}\dot{u}_{i,K} + m_{IJ} q_{I,J} + M_{jLKI} u_{j,LKI} + K_{IJ}\tau_{,IJ}, \\ \kappa \dot{q}_i &= \dot{\tau}_{,i} - q_i \end{aligned}$$

in $\Omega \times (0,\infty)$ subject to the boundary conditions

$$u_i = 0, \quad u_{i,J} = 0, \quad \tau = 0 \text{ in } \partial\Omega \times (0,\infty)$$

and the initial conditions

$$\begin{aligned} &u_i(\cdot,0) = u_i^0, \quad \dot{u}_i(\cdot,0) = \dot{u}_i^0, \\ &\tau(\cdot,0) = \tau^0, \quad \dot{\tau}(\cdot,0) = \dot{\tau}^0, \quad q_i(\cdot,0) = q_i^0 \text{ in } \Omega. \end{aligned}$$

Under appropriate assumptions, well-posedness and uniform stability are obtained. In the absence of a frictional damping, the lack of asymptotic stability is shown. (Received January 17, 2017)

1126-35-394 **C. M. Schober*** (cschober@ucf.edu), PO Box 622147, Orlando, FL 32816, and **A. Calini**. *Characterizing JONSWAP Rogue Waves and their Statistics via Inverse Spectral Data.*

Rogue waves in random sea states modeled by the JONSWAP power spectrum are high amplitude waves arising over non-uniform backgrounds that cannot be viewed as small amplitude modulations of Stokes waves. In the context of Nonlinear Schrodinger (NLS) models for waves in deep water, this poses the challenge of identifying appropriate analytical solutions for JONSWAP rogue waves, investigating possible mechanisms for their formation, and examining the validity of the NLS models in these more realistic settings. In this talk we investigate JONSWAP rogue waves using the inverse spectral theory of the periodic NLS equation for moderate values of the period. For typical JONSWAP initial data, numerical experiments show that the developing sea state is well approximated by the first few dominant modes of the nonlinear spectrum and can be described in terms of a 2- or 3-phase periodic NLS solution. As for the case of uniform backgrounds, proximity to instabilities of the underlying 2-phase solution appears to be the main predictor of rogue wave occurrence, suggesting that the modulational instability of 2-phase solutions of the NLS is a main mechanism for rogue wave formation and that heteroclinic orbits of unstable 2-phase solutions are plausible models of JONSWAP rogue waves. (Received January 17, 2017)

1126-35-395 **Hong-Chan Zheng**, **Wen-Xiu Ma** and **Xiang Gu*** (xianggu@mail.usf.edu), Department of Mathematics & Statistics, University of South Florida, 4202 E Fowler Ave, CMC342, Tampa, FL 33620-5700. *Hirota Bilinear Equations with Linear Subspaces of Hyperbolic and Trigonometric Function Solutions.*

We applied linear superposition principles to the linear subspaces of hyperbolic and trigonometric function solutions to construct solutions for some Hirota bilinear equations, with the purpose of searching for a specific subclass of N-soliton solutions formulated by linear combinations of hyperbolic and trigonometric functions. Furthermore, an algorithm using weights is discussed together with a few illustrative examples. (Received January 17, 2017)

1126-35-396 **Timur Akhunov*** (akhunov@gmail.com), Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902-6000. *Wellposedness and regularity of quasilinear equations of KdV type.* Preliminary report.

We study the well-posedness of the initial value problem on the real line for the fully nonlinear evolution equations for which the leading-order terms have three spatial derivatives.

$$\partial_t u + f(\partial_x^3 u, \partial_x^2 u, \partial_x u, u, x, t) = 0$$

This problem generalizes KdV to scenarios, where there is a competition between the dispersive effects which stem from the leading- order term, and anti-diffusion which stems from the lower-order terms with two spatial derivatives. This talk reports on a wide class of equations for which weighted Sobolev spaces are not needed. In particular, these equations include quasilinear type, which exhibit this competition between dispersion and anti-diffusion: a Rosenau-Hyman compacton equation, the Harry Dym equation, and equations which arise in the numerical analysis of finite difference schemes for dispersive equations. For these quasilinear equations, our well-posedness theorem requires that the initial data be uniformly bounded away from zero.

We report on new progress in these problems and regularity properties of the solutions that arise naturally. (Received January 17, 2017)

1126-35-397 **Robert Jenkins*** (rjenkins@math.arizona.edu), **Jiaqi Liu**, **Peter Perry** and **Catherine Sulem**. *Large time asymptotic behavior for the Derivative Nonlinear Schrödinger Equation.*

I will describe joint work with Jiaqi Liu, Peter Perry, and Catherine Sulem on the derivative nonlinear Schrödinger (DNLS) equation. Using the inverse scattering formulation of DNLS and the $\overline{\partial}$ generalization of the nonlinear steepest descent method we will show that for initial data in a certain open dense subset of $H^{2,2}(\mathbb{R})$ that the initial data resolves into a train of bright solitons plus a radiative term. This is part of larger work on the global well-posedness of the DNLS equation. (Received January 17, 2017)

1126-35-406 **Luiz Gustavo Farah**, UFMG, Brazil, **Justin Holmer**, Providence, RI , and **Svetlana Roudenko*** (roudenko@gwu.edu), Washington, DC 20052. *Instability of solitary waves in the KdV-type equations.* Preliminary report.

We revisit the instability of solitons in the critical and supercritical cases of the KdV equation, and investigate a similar phenomenon in the higher dimensional generalizations of the KdV equation (Received January 18, 2017)

1126-35-408 **Vince J. Ervin** (vjervin@clemson.edu), Clemson University, Department of Mathematical Sciences, Martin Hall O-110, Box 340975, Clemson, SC 29634, and **Javier Ruiz-Ramírez*** (javier@clemson.edu), Clemson University, Department of Mathematical Sciences, Martin Hall O-110, Box 340975, Clemson, SC 29634. *Stokes-Darcy flow with deposition.*

As a model for a filtration process, in this presentation we discuss a Stokes-Darcy fluid flow problem, coupled with a deposition equation in the porous (Darcy) domain. The deposition changes the porosity of the porous domain which in turn affects the fluid flow.

Existence and uniqueness for the modeling equations (Stokes+Darcy+Deposition) is established. Numerical simulations are presented which investigate how the initial distribution of porosity in the Darcy flow influences the overall performance of the filter. (Received January 18, 2017)

1126-35-410 **Justin Holmer*** (justin_holmer@brown.edu), Providence, RI 02912. *Dynamics of mKdV solitons under perturbation.*

We consider the mKdV (modified Korteweg-de Vries) equation for which there is a two parameter family of solitary waves (parameters of position and scale). When a slowly varying potential is added to the equation, we construct, to arbitrarily high order, a distorted soliton manifold and prove that solutions that start close to this manifold remain close to this manifold, with precisely given parameter dynamics, up to a dynamically relevant time scale. Results for other equations are surveyed. (Received January 18, 2017)

37 ► Dynamical systems and ergodic theory

1126-37-47 **Rudy L Horne*** (rhorne@morehouse.edu), 830 Westview Drive S.W., Atlanta, GA 30314. *Parity-Time (PT) Symmetric systems: An analysis of dimer and trimer models.*

In the late 1990s, a novel idea came to fruition concerning the study of the fundamentals of quantum mechanics. In the works of Bender and Boettcher, it was proposed that Hamiltonians that respect the physical symmetries of the dynamics, namely parity (P) and time-reversal (T), could have real eigenvalues even if said Hamiltonian were non-Hermitian. In this talk, we will discuss the cases of two-site (dimer) and three-site (trimer) PT-symmetric models respecting the parity-time (PT) symmetry with linear and nonlinear gain/loss profiles. We also examine solutions arising from these dimer and trimer models and their regions of stability. In addition, we will examine both dimer and trimer models with a rapidly-varying gain/loss profile. In this part of the work, we discuss the derivation of a set of averaged equations and examine its solutions and stability regions. We also compare these results with those obtained by direct simulation of the full set of nonlinear equations. (Received December 17, 2016)

1126-37-75 **Wen-Xiu Ma*** (mawx@cas.usf.edu), 4202 E Fowler Avenue, Tampa, FL 33620.
Symmetries and conservation laws of evolution equations. Preliminary report.

The talk is about formulations of conservation laws of evolution equations. Symmetries, adjoint symmetries, Hamiltonian pairs, and Lax pairs are key objects used in generating schemes. The talk is self-contained and shows a few basic theories in soliton theory. (Received January 02, 2017)

1126-37-83 **Paul Cornwell*** (pcorn@live.unc.edu) and **Christopher Jones**. *Stability of traveling waves and the Maslov index.*

The Maslov index is a topological invariant assigned to curves of Lagrangian subspaces of a symplectic vector space. It arises naturally in attempts to generalize Sturm-Liouville theory to systems of equations. Our motivation is twofold; first, we wish to broaden the class of stability problems to which the Maslov index can be applied. Second, we would like to calculate the Maslov index using geometric properties of the wave itself. We consider traveling waves for a generalized FitzHugh-Nagumo equation to accomplish both of these goals. The timescale separation in this problem is key in the calculation of the Maslov index. (Received January 05, 2017)

1126-37-219 **Bojko Bakalov*** (bojko_bakalov@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695, and **William Wheeless**. *The extended bigraded Toda hierarchy and its symmetries.*

The extended bigraded Toda hierarchy is an integrable system satisfied by the Gromov–Witten total descendant potential of $\mathbb{CP}^1$ with two orbifold points. We construct its additional symmetries and describe explicitly their action on the Lax operator, wave operators, and tau-function of the hierarchy. In particular, we obtain infinitesimal symmetries that act on the tau-function as a subalgebra of the Virasoro Lie algebra. (Received January 14, 2017)

1126-37-267 **Luen-Chau Li*** (luenli@math.psu.edu), Department of Mathematics, Pennsylvania State University, University Park, PA 16802. *An exact discretization of a Lax equation for shock clustering and Burgers turbulence.*

We consider a finite dimensional system which arises as an exact discretization of the Lax equation for shock clustering and Burgers turbulence, which describes the evolution of the generator of a Markov process with a finite number of states. In contrast with the extension of this equation to $N \times N$ generic matrices, the system is by its nature not a completely integrable system. Nevertheless, the system can be solved exactly and is conjugate to a straight line motion. In this talk, we will discuss a few results on this interesting system. (Received January 16, 2017)

1126-37-409 **Ron K Perline*** (rperline@math.drexel.edu), **Sergei Tabachnikov**, **Mark Levi** and **Gil Bor**. *Bicycle Mathematics.* Preliminary report.

We discuss the "Bicycle Transform", an elementary transformation on curves which can be interpreted as a special case of Backlund tranformations of curves related to the spectral problem associated to the (integrable) cubic NLS equation. We indicate its relation to the Floating Body Problem, as well as the Auerbach problem (essentially asking which curves are bicycle transforms of themselves). This is joint work with S. Tabachnikov, G. Bor, and M. Levi. (Received January 18, 2017)

39 ► Difference and functional equations

1126-39-4 **Michael F Singer*** (singer@math.ncsu.edu). *Finite automata, automatic sets, and difference equations.*

A finite automaton is one of the simplest models of computation. Initially introduced by McCulloch and Pitts to model neural networks, they have been used to aid in software design as well as to characterize certain formal languages and number-theoretic properties of integers. A set of integers is said to be m-automatic if there is a finite automaton that decides if an integer is in this set given its base-m representation. For example powers of 2 are 2-automatic but not 3-automatic. This latter result follows from a theorem of Cobham describing which sets of integers are m- and n-automatic for sufficiently distinct m and n. In recent work with Reinhard Schaefke, we gave a new proof of this result based on analytic results concerning normal forms of systems of difference equations. In this talk, I will describe this circle of ideas. No previous knowledge of any of these subjects will be assumed. (Received August 19, 2016)

1126-39-243 **Maarten Bergvelt*** (bergv@illinois.edu). *Birkhoff Factorization and Hirota Equations.*
We will discuss Birkhoff factorization and Hirota equations, with applications to Q and T systems and their generalizations. (Received January 15, 2017)

41 ► *Approximations and expansions*

1126-41-156 **Keaton Hamm*** (keaton.hamm@vanderbilt.edu). *Radial Basis Functions in Sampling Theory.*
We will discuss some analogues of results in classical and modern sampling theory which use the theory of radial basis function interpolation. In particular, we will discuss the use of shift-invariant, and more generally quasi shift-invariant spaces associated with radial basis functions and their role in the sampling methods. These spaces take the form $V_p(\phi,\mathcal{X}) := \{\sum_{j\in\mathbb{Z}} a_j\phi(\cdot - x_j) : a \in \ell_p\}$. Of interest to us are finding what spaces of target signals can be well-approximated by functions in these quasi shift-invariant spaces, and determining how the radial basis kernel ϕ and the sampling set $\mathcal{X}$ impact the approximation orders of the underlying sampling scheme. (Received January 10, 2017)

1126-41-232 **Yang Wang*** (yangwang@ust.hk), Department of Mathematics, HKUST, Hong Kong, Hong Kong. *On Generalized Phase Retrieval.* Preliminary report.
In many applications such as X-ray Crystallography, imaging, communication and others one must construct a function/signal from only the magnitude of the measurements. These measurements can be, for example, the Fourier transform of the density function. While it is well known that we can recover a function from its Fourier transform, the classical phase retrieval problem asks whether we can recover a function from only the magnitude of its Fourier transform. The phase retrieval problem has since been extended to a much broader class of settings, referring to the reconstruction of a signal from only the magnitude of its linear measurements or more generally, from quadratic measurements. The problem, even in finite dimensions, turns out to be quite challenging. Many fundamental theoretical problems remain unresolved. Equally challenging is to develop fast and robust algorithms for phase retrieval. The problem has, not surprisingly, links to a many problems in science and engineering. But more surprisingly it has also links to some classical problems on the embedding of projective spaces into Euclidean spaces and nonsingular bilinear forms. In this talk I'll give a brief overview and discuss some of the recent progresses. (Received January 14, 2017)

42 ► *Fourier analysis*

1126-42-29 **Joseph W. Iverson*** (jiverson@math.umd.edu), **John Jasper** (john.jasper@uc.edu) and **Dustin G. Mixon** (dustin.mixon@afit.edu). *Equiangular Tight Frames from Association Schemes.*
Association schemes are combinatorial objects that simultaneously generalize the notions of strongly regular graphs, finite abelian groups, and Gelfand pairs of (possibly nonabelian) finite groups. We explain how an association scheme naturally produces a finite number of unit-norm tight frames (FUNTFs). When our scheme is an abelian group, we precisely obtain its harmonic frames, but for general association schemes, we get a much broader family of FUNTFs. Among them are equiangular tight frames which are *not* harmonic, and which do not obey the integrality conditions imposed by abelian groups. (Received December 09, 2016)

1126-42-42 **Matthew Fickus*** (matthew.fickus@gmail.com). *Equiangular tight frames that contain simplices.*
An equiangular tight frame (ETF) is a type of optimal packing of lines in Euclidean space. They arise in various applications, including coding theory and compressed sensing. Some ETFs are a union of regular simplices. For example, there is an optimal packing of sixteen lines in six-dimensional real space that consists of the vertices of four tetrahedra, each lying in a particular three-dimensional subspace. Examples of such ETFs include Steiner ETFs as well as harmonic ETFs arising from McFarland difference sets. We give some results that hold about such ETFs in general. (Received December 15, 2016)

1126-42-117 **Christopher Heil*** (heil@math.gatech.edu), School of Mathematics, Georgia Tech, Atlanta, GA 30332-0160. *Duals of Gabor systems and weighted exponentials at the critical density.*

A Gabor system can only be a Riesz basis when the Beurling density of its index set is exactly 1. There exist Gabor systems that are Schauder bases but not Riesz basis, but it is not known whether every Gabor Schauder basis must have density 1. For lattice Gabor systems there is a complete characterization in terms of the Zak transform of the generating atom. We investigate the properties of subsets of lattice Gabor systems and systems of weighted exponentials at the critical density, which can still be complete and even minimal. Can these systems be bases? We will show that many properties of the dual system are tied to the behavior of the zeros of the atom and the number of lattice elements that are missing from the lattice. (Received January 08, 2017)

1126-42-118 **Michael Carr Northington V*** (mcnv3@gatech.edu), **Shahaf Nitzan** and **Alexander Powell**. *Sharp Balian-Low Type Theorems.* Preliminary report.

When shift-invariant spaces and Gabor systems are used as approximation spaces, it is advantageous for the generators of such spaces to be localized and for the spaces to be representative of a large class of functions. However, the celebrated Balian-Low Theorem shows that if a Gabor system generated by a function forms a Riesz basis for $L^2(\mathbb{R})$, then the function must be poorly localized in either time or frequency. In this talk, I will discuss several sharp results similar to the Balian-Low Theorem which hold either for Gabor systems or shift-invariant spaces, and which follow from a more general theorem placing constraints on unbounded Fourier multipliers. (Received January 08, 2017)

1126-42-193 **John I Haas*** (haasji@missouri.edu), 105 Redwood, Columbia, MO 65203, and **Pete Casazza**, **Janet Tremain** and **Jameson Cahill**. *Constructions of biangular tight frames and their relationships with equiangular tight frames.* Preliminary report.

We present several constructions of biangular tight frames - unit norm tight frames admitting exactly two distinct pairwise absolute inner products - and, in each case, highlight their striking relationship(s) with equiangular tight frames. In addition, we introduce a new notion of "equiangular" for fusion frames based on the Plücker embedding along with an example which manifests as biangular relative to the usual chordal metric. (Received January 13, 2017)

1126-42-210 **J. Alejandro Chávez-Domínguez***, jachavezd@math.ou.edu, and **Daniel Freeman** and **Keri Kornelson**. *Finite unit norm tight frames for Banach spaces via a frame potential.* Preliminary report.

A well-known theorem of Benedetto and Fickus states that a sequence of k norm-one vectors in an n-dimensional Hilbert space (where $k \geq n$) has frame potential at least k^2/n, with equality if and only if the sequence is a tight frame.

The main result of this paper is a generalization of the aforementioned result to the context of finite-dimensional (smooth) Banach spaces. We define a frame potential for a sequence of k norm-one vectors in an n-dimensional Banach space (where $k \geq n$), which is a generalization of the Hilbert-space case. This generalized potential is also bounded below by k^2/n, with the equality case characterizing tight frames. (Received January 13, 2017)

1126-42-230 **Kasso Okoudjou*** (kasso@math.umd.edu), University of Maryland, College Park, MD 20742, **M. Bownik**, University of Oregon, Eugene, OR 97403, **M. Jakobsen**, Technical University of Denmark, Lyngby, Denmark, and **J. Lemvig**, Technical University of Denmark, Lyngby, Denmark. *On Wilson bases in $L^2(\mathbb{R}^d)$.*

It is known that starting from a tight Gabor frame for $L^2(\mathbb{R})$ with redundancy 2, one can construct an orthonormal Wilson basis for $L^2(\mathbb{R})$ whose generator is well-localized in the time-frequency plane. But it remains unknown whether such construction can be done if the initial tight Gabor frame has a redundancy different from 2. In this talk, we show that one can construct multi-dimensional orthonormal Wilson bases starting from tight Gabor frames of redundancy 2^k where $k = 1, 2, \ldots, d$. These results generalize most of the known results about the existence of orthonormal Wilson bases. The talk is based on a joint work with M. Bownik, M. Jokobsen, and J. Lemvig. (Received January 14, 2017)

1126-42-264 **Bernhard G Bodmann*** (bgb@math.uh.edu), 651 PGH, Math Department, Univ of Houston, Houston, TX 77204, and **Robert P Mendez**. *Binary Parseval frames from groups.*

The theory of binary Parseval frames shares similarities with that of real and complex ones. On the other hand, it exhibits subtle differences, for example that the Gram matrices of Parseval frames are idempotent symmetric matrices with at least one row having an odd weight. Here, we study binary Parseval frames whose vectors are orbits under an orthogonal group representation. In the case of abelian groups, we identify such Parseval frames with binary functions on the group that satisfy a convolution identity. More detailed structural consequences are explained. (Received January 16, 2017)

1126-42-266 **John Haas**, **Nathaniel Hammen*** (nhammen@gmail.com) and **Dustin Mixon**. *Achieving equality with the second degree Levenstein bound.* Preliminary report.

Optimally low coherence frames lead to good compressed sensing matrices. Nearly all currently known optimal packings satisfy equality with either the Welch or orthoplex bounds. For a frame in d dimensional space, this requires a maximum frame size of $d(d+1)$ vectors. We study packings that achieve equality with the Levenstein or Delsarte bounds as a way to achieve optimality beyond this ceiling. (Received January 16, 2017)

1126-42-270 **Mark C Lammers*** (lammersm@uncw.edu), 601 South College Road, Wilmington, NC 28401, and **Kyle Bowman** (bowmank@uncw.edu), 601 South College Road, Wilmington, NC 28401. *Uncertainty Principles and Finite Gabor Systems.*

We review some properties of the Finite Zak Transform and discuss uncertainty principles for critically sampled finite Gabor systems. We finish by providing some numerical results regarding the minimizer of this uncertainty principle. (Received January 16, 2017)

45 ► Integral equations

1126-45-404 **Andrei Ludu*** (ludua@erau.edu), ERAU, COAS-301.11, Daytona Beach, FL 32114. *ODE with Variable Order of Differentiation.*

We introduce a new type of evolution equation where the order of differentiation is considered itself a continuous independent or dependent variable. Such systems having continuously variable order of differentiation can be mapped into a nonlinear fractional partial differential equation and from here into a Volterra integral equation with singular kernel. We elaborate on the existence and qualitative properties of time-dependent solutions through the formalism of FPDE in the Riemann-Liouville-Jumarie sense. Some of the exact solutions represented in integral form, or expanded Mittag-Leffler functions series are compared numerically with piece-wise solutions of traditional evolution equations of different, yet constant order. The idea in this approach is related to the observational connection between the evolution of the degree of complexity, and rate of accelerated change on one hand, and the degree of time non-locality (history dependent) of the model differential equation, on the other hand. (Received January 18, 2017)

46 ► Functional analysis

1126-46-131 **Daniel Freeman*** (dfreema7@slu.edu) and **Darrin Speegle**. *The discretization problem for continuous frames and coherent states.*

There is a long history of creating frames by sampling coherent states and continuous frames. For instance, Gabor frames are formed by sampling the short time Fourier transform at a lattice. Continuous frames often arise naturally in mathematics and physics, but the sampled frames are usually more useful for computations. Using the results of Marcus-Spielman-Srivastava in their solution of the Kadison-Singer problem, we prove that every bounded continuous frame may be sampled to obtain a frame. This solves the discretization problem as posed by Ali, Antoine, and Gazeau in their textbook: Coherent States, Wavelets, and Their Generalizations. (Received January 09, 2017)

1126-46-137 **Nick Edelen***, 182 Memorial Dr, Cambridge, MA 02142. *Quantitative Reifenberg for Measures.*

In joint work with Aaron Naber and Daniele Valtorta, we demonstrate a quantitative structure theorem for measures in R^n under assumptions on the Jones β-numbers, which measure how close the support is to being contained in a subspace. Measures with this property have arisen in several interesting scenarios: in obtaining measure estimates on the singular set of minimal surfaces; in characterizing L^2-boundedness of Calderon-Zygmund operators; and as an "analyst's" formulation of the traveling salesman problem. (Received January 09, 2017)

1126-46-349 **Elliot Blackstone*** (eblackstone@knights.ucf.edu), 4393 Andromeda Loop N, Orlando, FL 32816, and **Alexander Tovbis** and **Alexander Katsevich**. *Deift-Zhou method for the asymptotics of operators with an integrable kernel: transition from discrete to continuous spectrum.* Preliminary report.

We study the spectrum of an operator with an integrable kernel, related to the finite Hilbert transform on several disjoint intervals, where δ is the size of the minimal gap between the intervals. For any $\delta > 0$ the operator is a Hilbert-Schmidt operator and its eigenvalues and eigenfunctions can be asymptotically recovered from the leading order solution of the corresponding Riemann-Hilbert Problem. Our research is focused on the limit $\delta \to 0$, when the limiting operator has continuous spectrum. (Received January 17, 2017)

1126-46-373 **Darrin Speegle***, speegled@slu.edu, and **Dan Freeman**. *Discretization of continuous frames.*

We characterize when a coherent state or continuous frame for a Hilbert space may be sampled to obtain a frame, which solves the discretization problem for continuous frames. In particular, we prove that every bounded continuous frame for a Hilbert space may be sampled to obtain a frame. In this talk, we will give special consideration to what happens in the Gabor frame case. (Received January 17, 2017)

49 ► Calculus of variations and optimal control; optimization

1126-49-26 **Harbir Antil*** (hantil@gmu.edu), Department of Mathematical Sciences, 4400 University Drive, MS: 3F2, Exploratory Hall, room 4201, Fairfax, VA 22030, **Michael Hintermueller**, Weierstrass Institute, Prof. Dr. Michael Hintermueller, Mohrenstrasse 39, 10117 Berlin, Germany, **Ricardo H. Nochetto**, Department of Mathematics, University of Maryland, College Park, MD 20742, **Thomas M. Surowiec**, University of Marburg, Department of Mathematics, MZG Raum 06D26, Marburg, Germany, and **Donat Wegner**, Humboldt University, Department of Mathematics, Berlin, Germany. *Finite Horizon Model Predictive Control of Electrowetting on Dielectric with Pinning.*

A time-discrete spatially-continuous electrowetting on dielectric (EWOD) model with contact line pinning is considered as the state system in an optimal control framework. The pinning model is based on a complementarity condition. In addition to the physical variables describing velocity, pressure, and voltage, the solid-liquid-air interface, i.e., the contact line, arises as a geometric variable that evolves in time. Due to the complementarity condition, the resulting optimal control of a free boundary problem is thus a mathematical program with equilibrium constraints (MPEC) in function space. In order to cope with the geometric variable, a finite horizon model predictive control approach is proposed. Dual stationarity conditions are derived by applying a regularization procedure, exploiting techniques from PDE-constrained optimization, and then passing to the limit in the regularization parameters. Moreover, a function-space-based numerical procedure is developed by following the theoretical limit argument used in the derivation of the dual stationarity conditions. The performance of the algorithm is demonstrated by several examples; including barycenter matching and trajectory tracking. (Received December 05, 2016)

1126-49-58 **Jiongmin Yong*** (jiongmin.yong@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Forward-Backward Evolution Equations.*

For a standard optimal control problem of evolution equations, by applying Pontryagin's maximum principle, one obtains a necessary condition for the optimal control, involving a coupled system of two evolution equations, one is an initial value problem (a forward equation) and the other is a terminal value problem (a backward equation). We therefore call the system a forward-backward evolution equation (FBEE, for short). Once such an FBEE is solvable, we obtain a candidate of optimal state-control pair. Usually, one has to assume that the time duration to be small enough to guarantee the solvability of such an FBEE. In this talk, we will report some results from an on-going research of FBEEs. (Received December 23, 2016)

1126-49-133 **P. Jameson Graber*** (jameson_graber@baylor.edu), One Bear Place #97328, Waco, TX 76708. *Existence of Solutions for the Master Equation in Mean Field Type Control.* Preliminary report.

"Mean field type control" refers to the optimal control problem for a McKean-Vlasov type stochastic differential equation, in which the dynamics of the state variable depend on its law (probability distribution). In this talk we examine the corresponding "master equation" on the space of random variables. Such an equation can be derived formally by differentiating a Hamilton-Jacobi equation, so if the latter has smooth enough solutions, the former will also have solutions. (Received January 09, 2017)

1126-49-177 **Harbir Antil*** (hantil@gmu.edu), Department of Mathematical Sciences, 4400 University Drive, MS: 3F2, Fairfax, VA 22030, and **Carlos Rautenberg** (carlos.rautenberg@wias-berlin.de), Weierstrass Institute, Mohrenstrasse 39, 10117 Berlin, Germany. *Fractional elliptic quasi-variational inequalities: theory and numerics.*

This talk introduces an elliptic quasi-variational inequality (QVI) problem class with fractional diffusion of order $s \in (0,1)$, studies existence and uniqueness of solutions and develops a solution algorithm. As the fractional diffusion prohibits the use of standard tools to study the QVI, instead we realize it as a Dirichlet-to-Neumann map for a nonuniformly elliptic equation posed on a semi-infinite cylinder. We first study existence and uniqueness of solution for this extended QVI and then transfer the results to the fractional QVI. This introduces a new paradigm in the field of fractional QVIs. We truncate the semi-infinite cylinder and show that the solution to the truncated problem converges to the solution to the extended problem, under fairly mild assumptions, as truncation parameter $\tau \to \infty$. Since the constraint set changes with the solution, we develop an argument using Mosco convergence. We state an algorithm to solve the truncated problem and show its convergence in function spaces. Finally, we conclude with several illustrative numerical examples. (Received January 12, 2017)

1126-49-189 **Cory Wright*** (cwright11@unl.edu), Lincoln, NE 68588, and **Mikil Foss** and **Petronela Radu**. *Existence and regularity of minimizers for nonlocal energy functionals.*

Over the past two decades there has been a surge of mathematical and engineering interest in problems that model phenomena with potentially discontinuous behavior. In 2000 Silling introduced peridynamics, a nonlocal unified framework, which has successfully captured deformations, the structure of fractures, and propagation of cracks in solid materials. Motivated by this theory, we consider energy functionals that involve integral operators with weakly singular kernels. In this talk I will present results with sufficient conditions associated with the existence of minimizers, the necessity of Euler-Lagrange equations, and regularity of nonlocal solutions. (Received January 12, 2017)

1126-49-220 **Philipp Reiter*** (philipp.reiter@uni-due.de), University of Duisburg-Essen, Faculty of Mathematics, 45117 Essen, Germany. *On elastic knots.*

What actually happens if one forms a knot in a piece of springy wire and releases it?

We will formulate this question as a minimization problem and apply techniques from the calculus of variations.

We discuss analytical solutions as the thickness of the wire tends to zero, physical experiments, and numerical simulations.

This is joint work with Henryk Gerlach and Heiko von der Mosel. (Received January 14, 2017)

51 ► Geometry

1126-51-43 **Pei-Ken Hung*** (pkhung@math.columbia.edu), Rm 408, MC 4447 2990 Broadway, New York, NY 10027. *The Gibbons-Penrose inequality.*

The Gibbons-Penrose inequality, like the Penrose inequality, is a conjecture proposed by Penrose as a test of the weak consmic censorship. It's also a spacetime generalization of the Minkowski inequality. I will discuss the heuristic argument of Penrose and some known results in this direction. (Received December 15, 2016)

1126-51-45 **Pushpi J Paranamana*** (pushpi.paranamana@ttu.edu), Department of Mathematics & Statistics, Texas Tech University, Lubbock, TX 79409, **Eugenio Aulisa** (eugenio.aulisa@ttu.edu), Department of Mathematics & Statistics, Texas Tech University, Lubbock, TX 79409, and **Magdalena Toda** (magda.toda@ttu.edu), Department of Mathematics & Statistics, Texas Tech University, Lubbock, TX 79409. *Fracture Model Reduction and Optimization for Nonlinear Flows in Porous Media.* Preliminary report.

Fracture Model Reduction and Optimization for Nonlinear Flows in Porous Media

Pushpi J. Paranamana

In collaboration with Eugenio Aulisa and Magdalena Toda

Abstract

In this work, we analyze the flow filtration process of slightly compressible fluids in porous media containing fractures with complex geometries. We model the coupled fracture-porous media system where the linear

Darcy flow is considered in porous media and the nonlinear Forchheimer equation is used inside the fracture. The optimal length of the fracture is analyzed using "the diffusive capacity", a functional that measures the performance of the reservoir. Also, we devise a model to address the complexity of the fracture geometry which examines the flow inside fractures with variable thickness on a general manifold. The fracture is represented as a parametric surface on Riemannian manifold where the thickness changes in the normal direction from the barycentric surface. Using Laplace Beltrami operator, we formulate an equation that describes the flow and then further simplifications were done. Using the model, pressure profile of a nonlinear flow is analyzed and compared with the actual pressure profile obtained numerically in order to validate the model. (Received December 16, 2016)

1126-51-100 **Alexander I. Bobenko**, **Nikolay D. Dimitrov*** (futurolog@gmail.com) and **Stefan Sechelmann**. *Discrete uniformization via hyper-ideal circle patterns.*

In this talk I will present a discrete version of the classical uniformization theorem based on the theory of hyper-ideal circle patterns. It applies to surfaces represented as finite branched covers over the Riemann sphere as well as to compact polyhedral surfaces with non-positive cone singularities. The former include all Riemann surfaces realized as algebraic curves, and more generally, any closed Riemann surface with a choice of a meromorphic function on it. The latter include any closed Riemann surface with a choice of a quadratic differential on it. The main result is that for such surfaces discrete uniformization via hyper-ideal circle patterns always exists and is unique (up to isometry). Furthermore, there is an algorithm, using convex optimization, that constructs the desired discrete uniformization. This kind of discrete uniformization is the result of an interplay between realization theorems for ideal polyhedra (Rivin) and hyper-ideal polyhedra (Bao and Bonahon) in hyperbolic three-space, and their generalization to hyper-ideal circle patterns on surfaces with cone singularities (Schlenker). (Received January 06, 2017)

1126-51-124 **Otis Chodosh*** (ochodosh@princeton.edu). *New results concerning the large scale behavior of area in asymptotically flat manifolds.*

I will survey some recent results that expand our understanding of the relationship between scalar curvature, asymptotically flat manifolds, and the large scale behavior of area and volume. In particular I will mention recent results concerning the isoperimetric problem (joint work with M. Eichmair, Y. Shi, and H. Yu) and area minimizing surfaces (joint work with M. Eichmair). (Received January 09, 2017)

1126-51-182 **Bach Nguyen***, bnguy38@lsu.edu, and **Kurt Trampel** and **Milen Yakimov**. *Discriminant of Quantum Schubert Cell Algebras via Poisson Geometry.*

The notion of discriminant is an important tool in number theory, algebraic geometry and noncommutative algebra. However, in concrete situations, it is difficult to compute and this has been done for few noncommutative algebras by direct methods. In this talk, we will describe a general method for computing noncommutative discriminants which relates them to representation theory and Poisson geometry. As an application we will provide explicit formulas for the discriminants of the quantum Schubert cell algebras at roots of unity. (Received January 12, 2017)

1126-51-327 **Kenneth Stephenson*** (kstephe2@tennessee.edu), Ayres Hall, Univ. of Tennessee, Knoxville, TN 37996. *Configurations of circles: beyond packings.*

We survey the study of configurations of circles inspired by Bill Thurston's circle packings. Inversive distance packings involve configurations with prescribed overlaps, tangencies, and/or separations of the circles. Their study provides an intriguing mash up of theory, computation, experimentation, and application. We discuss existence, rigidity, and notions of discrete conformality, with an emphasis on concrete examples and emerging applications. (Received January 17, 2017)

1126-51-332 **John C. Bowers** and **Philip L. Bowers*** (bowers@math.fsu.edu), 208 Love Building, 1017 Academic Way, Tallahassee, FL 32306-4510. *The geometry of circle space and the rigidity of circle frameworks.* Preliminary report.

We present a partial duality between the incidence geometry of real projective 3-space and incidence geometries defined on both the spaces of oriented circles and un-oriented circles in the Riemann sphere. We show how this duality can be used to approach questions of rigidity of circle frameworks and packings. Finally, we hint at its use in understanding the existence of circle frameworks and packings with given inversive distances. (Received January 17, 2017)

52 ► Convex and discrete geometry

1126-52-25 **Wai Yeung Lam*** (lam@math.brown.edu). *Minimal surfaces from deformations of circle patterns.*

William Thurston introduced circle packings to approximate holomorphic functions. Burt Rodin and Dennis Sullivan proved the convergence of the analogue of Riemann maps for circle packings. Oded Schramm further extended the idea by considering circle patterns, where circles are allowed to intercept with each other.

We present a discrete analogue of the Weierstrass representation for minimal surfaces in terms of data from infinitesimal deformations of circle patterns. Given a triangle mesh in the plane, a circle pattern is induced by the circumscribed circles. We investigate infinitesimal deformations of the triangle mesh that preserve the intersection angles of the circumscribed circles. By analyzing the change in cross ratios, every such an infinitesimal deformation yields a polyhedral surface with vanishing mean curvature. With this approach, we unify previous notions of discrete minimal surfaces.

It is joint work with Ulrich Pinkall. (Received January 12, 2017)

1126-52-44 **Robert Connelly*** (connelly@math.cornell.edu), Department of Mathematics, Malott Hall, Ithaca, NY 14853. *The isostatic conjecture for circle packings.* Preliminary report.

If a circle packing in a compact container with non-negative curvature is locally maximally dense, then it has an infinitesimally rigid tensegrity packing subgraph, the spine. If the radii of the packing disks are chosen generically, then it has been conjectured, and verified experimentally, that the spine has the minimum number of contacts as predicted by rigidity theory. An outline of a proof of this conjecture in the plane will be given using an Andreev-type theorem and inversive distances. (Received December 16, 2016)

1126-52-165 **Ciprian S. Borcea*** (borcea@rider.edu), Rider University, Department of Mathematics, Lawrenceville, NJ 08648, and **Ileana Streinu**, Smith College. *Auxetics and convexity.*

Periodic bar-and-joint frameworks with auxetic deformations model (meta-)materials with auxetic behavior, which entails lateral widening upon stretching. We find rather stringent structural constraints, expressed as convexity conditions (ellipsoids and convex polytopes), which must be satisfied by all periodic frameworks with auxetic capabilities. For frameworks with two vertex orbits under periodicity, a complete classification becomes possible. (Received January 11, 2017)

1126-52-168 **Ileana Streinu*** (istreinu@smith.edu), Smith College, Computer Science Department, Green Street 100, Northampton, MA 01063. *Rigidity of frameworks: a survey.*

A survey of problems, theorems and proof techniques from the rigidity theory of bar-and-joint (and other types of) mechanical frameworks: classical results and recent developments. (Received January 11, 2017)

1126-52-319 **John C. Bowers***, MSC 4103, James Madison Uiversity, 701 Carrier Dr, Harrisonburg, VA 22807, and **Philip L. Bowers** and **Kevin Pratt**. *Almost All c-Polyhedra are Rigid.*

Ma and Schlenker showed the first example of inversive distance circle packings on the sphere that are not globally rigid (i.e. two separate configurations exist with the same inversive distance data). This surprising result raises the question of whether any *flexible* inversive distance circle packings exist. In this work, we show that the set of rigid inversive distance circle packings (and the more general circle-polyhedra) is open and dense in the space of all circle-polyhedra. Our work follows a similar development in the theory of Euclidean polyhedra due to Gluck. (Received January 17, 2017)

1126-52-338 **William Wood***, bill.wood@uni.edu. *Combinatorial methods in discrete conformal geometry.*

Discrete conformal geometry can be modeled by assigning weights to the edges or vertices of a triangulation graph and mimicking classical length-area methods. We will survey some of the techniques and results of this approach and their application to circle packings. (Received January 17, 2017)

53 ► Differential geometry

1126-53-30 **Michael T. Anderson** and **Jeffrey L. Jauregui*** (jaureguj@union.edu). *Bartnik's quasi-local mass in general relativity.*

In general relativity, the quasi-local mass problem is to find a "good" definition for the amount of mass contained within a compact 3-dimensional spatial region, Ω. Bartnik's definition considers all possible asymptotically flat extensions of Ω (subject to certain natural geometric conditions), and minimizes the total (ADM) mass among such spaces. He conjectured that this infimum is attained. In joint work with Michael Anderson, we show that for a large family of regions, the infimum is not achieved. I will discuss our recent results, including (time-permitting), further results pertaining to Bartnik mass minimizers and static vacuum solutions of Einstein's equations. (Received December 09, 2016)

1126-53-52 **Magdalena D Toda***, Texas Tech University, Dept Mathematics and Statistics, Lubbock, TX 79410, and **Eugenio Aulisa**. *Generalized bending energies and protein folding.*
This report studies certain generalizations of Willmore energy functionals (bending energies with structural constraints). The critical points of these functionals have special applications to secondary structures in proteins, and in particular to alpha coils and beta barrels. Symmetries will be studied from a geometric and topological viewpoint. This work is at the interface between differential geometry, boundary value problems in PDE and numerical applications. (Received December 20, 2016)

1126-53-54 **Ling Xiao*** (`lx70@math.rutgers.edu`). *Translating Solitons in Euclidean Space.*
Xujia Wang conjectured that every entire translating graph in R^3 is convex. In this talk I will show how to prove this conjecture. I will also talk about the background of this problem as well as some related results. This is a joint work with Joel Spruck (Received December 20, 2016)

1126-53-79 **Tom Needham*** (`needham.71@osu.edu`). *Kähler Structures on Spaces of Framed Curves.*
Symplectic structures on moduli spaces of polygons have recently been used to give new sampling algorithms for closed random walks. In this talk we extend this idea to the space of smooth framed curves and show that this space is an infinite-dimensional Kähler manifold. Working with smooth curves allows us to consider the action of the infinite-dimensional Lie group of reparameterizations. This group action interacts with the Kähler structure of framed loop space in interesting ways. On the symplectic side, we will show that the reparameterization action is Hamiltonian and has a momentum map which is related to the twist functional. On the Riemannian side, we show that the action is also by isometries and use this fact to induce a metric on the quotient space of unparameterized framed curves. Geodesic distance with respect to this metric is invariant under rigid motions and can be efficiently calculated, so this gives a practical solution to the curve matching problem. (Received January 03, 2017)

1126-53-87 **Ivan C Sterling*** (`isterling@smcm.edu`), 18952 E Fisher Rd, St Marys City, MD 20686-3002, and **Josef F. Dorfmiester**. *Box Surfaces, Lorentz Surfaces and PS-Fronts.* Preliminary report.
Joint work with Josef F. Dorfmeister. Immersions $f : S \longrightarrow \mathbb{R}^3$ with constant curvature $K = -1$ have been extensively studied in the case where S is a rectangular domain with standard Minkowski coordinates. In particular Toda's algorithm may be used to produce all examples. In this talk we generalize the existing definitions and theories to the more intriguing case where S is in arbitrary surface. Here not all box surfaces are Lorentz surfaces. In particular the theory of ps-fronts and Todo's algorithm in this more general setting will be explored. (Received January 05, 2017)

1126-53-122 **Xinliang An*** (`xinliang.an@utoronto.ca`), Department of Mathematics, University of Toronto. *Emergence of Apparent Horizon in Gravitational Collapse.*
In this talk, I will present a new result on gravitational collapse. With hyperbolic PDE techniques, 3+1 dimensional Einstein vacuum equations are solved in a spacetime region up to the "center". Within this region, using elliptic PDEs an apparent horizon is constructed emerging from a point. (Received January 08, 2017)

1126-53-127 **Marcus Khuri***, Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *Vacuum Black Lenses.*
We construct asymptotically flat solutions of the bi-axisymmetric stationary vacuum Einstein equations in 5-dimensions having nondegenerate black holes of lens space topology. This is accomplished by producing the appropriate singular harmonic maps from $\mathbb{R}^3$ to $SL(3, R)/SO(3)$. The method is robust in that it can be used to construct black holes in this setting with all possible topologies, and applies also to the case of 5-dimensional minimial supergravity. This is joint work with Gilbert Weinstein and Sumio Yamada. (Received January 09, 2017)

1126-53-146 **Pengzi Miao*** (pengzim@math.miami.edu), Department of Mathematics, University of Miami, 1365 Memorial Drive, Ungar 515, Coral Gables, FL 33146. *Effect of minimal surfaces on boundary behavior of manifolds with nonnegative scalar curvature.*

In 2002, Shi and Tam proved a remarkable theorem concerning the boundary behavior of compact manifolds with nonnegative scalar curvature. Their theorem states that if (Ω^n, g) is a compact manifold with nonnegative scalar curvature with boundary Σ, and if Σ has positive mean curvature H and Σ can be isometrically embedded in $\mathbb{R}^n$ as a strictly convex hypersurface, then

$$\int_\Sigma H\, d\sigma \leq \int_\Sigma H_0\, d\sigma,$$

where H_0 is the mean curvature of the isometric embedding of Σ in $\mathbb{R}^n$. In this talk, I will discuss a recent work with Siyuan Lu, in which we give a generalization of Shi-Tam's theorem to incorporate the effect of apparent horizon on the geometry of Σ. (Received January 10, 2017)

1126-53-207 **Michael R Benfield**, **Helge Kristian Jenssen** and **Irina A. Kogan*** (iakogan@ncsu.edu). *Jacobians with prescribed eignvectors.*

We consider the problem of constructing all possible maps from an open subset $\Omega \subset \mathbb{R}^n$ to $\mathbb{R}^n$, such that the set of eigenvector fields of the Jacobian matrix of each of these maps contains a given set of $m \leq n$ independent vector fields on Ω. Our initial motivation for considering this problem comes from the geometric study of hyperbolic conservation laws. This problem is, however, of independent geometric interest and, in turn, leads to an interesting systems of overdetermined systems of PDEs, which can be studied via classical integrability theorems and their appropriate generalizations. (Received January 13, 2017)

1126-53-214 **Mohammad Ghomi*** (ghomi@math.gatech.edu). *The length, width, and inradius of space curves.*

The width w of a curve c in Euclidean space is the infimum of the distances between all pairs of parallel hyperplanes which bound c, while its inradius r is the supremum of the radii of all spheres which are contained in the convex hull of c and are disjoint from c. We use a mixture of topological and integral geometric techniques, including the Borsuk Ulam theorem and Crofton's formulas, to obtain lower bounds on the length of c subject to constraints on r and w. Our estimates confirm some conjectures of Zalgaller up to 99% of their stated value, while we also disprove one of them. (Received January 13, 2017)

1126-53-248 **Ekaterina Shemyakova*** (shemyake@newpaltz.edu), 1 Hawk dr., New Paltz, NY 12561. *Differential Operators on the algebras of densities. Factorization and Darboux transformations.* Preliminary report.

In this talk we report a preliminary result on some differential-geometric aspects of Darboux transformations.

We consider differential operators acting on the algebra of densities on a manifold M. It is an $\mathbb{R}$-graded commutative algebra which naturally arises from tensor multiplication of densities of various weights. Differential operators on it are understood in algebraic sense but can be interpreted in a simpler way as particular differential operators on an auxiliary graded manifold $\hat{M}$. They are effectively described as particular polynomial operators' pencils.

There is a non-trivial factorization problem for such operators or pencils, and we explore possibilities arising here. (Received January 15, 2017)

1126-53-281 **Jason Cantarella***, University of Georgia Math Department, Boyd GSRC, 102 D.W. Brooks Drive, Athens, GA 30602, and **Eric Rawdon** and **Clayton Shonkwiler**. *A probabilistic approach to open knotting.* Preliminary report.

This talk presents some (very) preliminary results from a program which attempts to define knotting for arcs in probabilistic terms: given a k-edge arc A, we can define a probability distribution $P(A, n)$ on n-gons by conditioning the standard probability distribution on n-gons on the hypothesis that the first k edges form arc A.

The *n-edge knot probability spectrum* of the arc A is then the probability of knots in the n-gon distribution $P(A, n)$. In this talk, we'll present algorithms for sampling from $P(A, n)$ in an unbiased way, and hopefully discuss some experimental results comparing the distribution of knots we obtain to the distribution generated by other random closure methods.

The dependence of the results on n obviously makes the resulting framework less pretty, so we may include some speculation on how to remove it. (Received January 16, 2017)

1126-53-304 **Po-Ning Chen***, poningc@ucr.edu. *Quasi-local mass at the null infinity of the Vaidya spacetime.*

There are two important statements regarding the Trautman-Bondi mass at null infinity: one is the positivity, and the other is the Bondi mass loss formula. Both are both global in nature. The positivity of the quasi-local mass can potentially lead to a local description at null infinity. This is confirmed for the Vaidya spacetime. In this talk, we discuss how to evaluate the Wang-Yau quasi-local mass on surfaces of fixed size at the null infinity of the Vaidya spacetime. The optimal embedding equation is solved explicitly and the quasi-local mass is evaluated in terms of the mass aspect function of the Vaidya spacetime.

This talk is based on joint work with Mu-Tao Wang and Shing-Tung Yau. (Received January 16, 2017)

55 ► Algebraic topology

1126-55-376 **Justin M Mauger*** (jmauger@spawar.navy.mil), 53560 Hull St, Code 56150, Seaside Building 605, San Diego, CA 92152-5001. *Topological Data Analysis of Radar Pulses.* Preliminary report.

Topological Data Analysis (TDA) is a burgeoning field applying algebraic topology to the study of high-dimensional data sets. We present results from our use of TDA on commercial maritime radar data. When data from radar pulses is transformed to a point cloud in Euclidean space, an embedding of S^1 results, which can be detected in homology. In this way, pulses from unknown radars can be compared against known models to determine if they are from a new model class. (Received January 17, 2017)

1126-55-378 **John M Sullivan*** (sullivan@math.tu-berlin.de) and **Robert B Kusner** (kusner@math.umass.edu). *Ropelength and the space of unlinks.* Preliminary report.

We consider various configurations of unlinks (of two and three components) that are critical for ropelength, and explore how these may be related Morse-theoretically to the topology of the space of unlinks. (Received January 17, 2017)

57 ► Manifolds and cell complexes

1126-57-35 **Oliver Dasbach** and **Adam Lowrance*** (adlowrance@vassar.edu). *Invariants of Turaev genus one links.*

Each link diagram has an associated Turaev surface, constructed from the all-A and all-B Kauffman states of the diagram. The Turaev genus of a link is the minimum genus of a Turaev surface for any diagram of the link. In this talk, we provide a Jones polynomial and a Khovanov homology obstruction for a link to be of Turaev genus one. (Received December 13, 2016)

1126-57-39 **Colin Adams*** (cadams@williams.edu), Bronfman Science Center, 18 Hoxsey St., Williamstown, MA 01267. *Multi-crossing number of knots and links.*

The most fundamental approach to understanding knots and links is through their projections, where at each crossing, two strands intersect one another. Recently, this has been extended to consider multi-crossing projections, where more than two strands cross at each crossing. We can then define multi-crossing number to be the least number of n-crossings in an n-crossing projection of a knot or link. We will discuss what is known for multi-crossing numbers and the closely related petal number and ubercrossing number of knots and links and their relations to hyperbolic invariants. We will also discuss what is not known. (Received December 14, 2016)

1126-57-46 **Eric J Rawdon*** (ejrawdon@stthomas.edu). *Unknotting and unlinking DNA via Topoisomerase IV.*

Type II topoisomerases have been shown to be 10 to 100 times more effective than random crossing changes in unknotting and unlinking DNA. The exact mechanism for such efficiency is a problem of modern curiosity. Buck and Zechiedrich proposed that type II topoisomerases might perform strand passages preferably at hooked juxtapositions. Simulations have shown that strand passages at such hooked juxtapositions on random knot configurations do preferably simplify knotting. Furthermore, Witz et al. showed that supercoiling induces a tightening of the knotted regions during simulations. In our work, we show how supercoiling creates special geometrical attributes in simulated knotted and linked DNA that could be identified by Topoisomerase IV, a bacterial type II topoisomerase. This is joint work with Julien Dorier, Dusan Racko, Kenneth Millett, and Andrzej Stasiak. (Received December 16, 2016)

1126-57-55 **Erica Flapan*** (eflapan@pomona.edu), 610 N. College Ave., Claremont, CA 91711, and **Will Rowan Fletcher** and **Ryo Nikkuni**. *Generalized Simon invariants of spatial graphs.*

We introduce invariants of spatial graphs which are a generalization of the Simon invariant for embeddings of K_5 and $K_{3,3}$ in S^3. Then we use our invariants to prove that K_7, all Möbius ladders with an odd number of rungs, and the Heawood graph each have the property that all of their embeddings in S^3 are chiral. We also use our invariants to obtain lower bounds for the minimal crossing number of particular embeddings of graphs in S^3. (Received December 20, 2016)

1126-57-65 **Kenneth C Millett*** (millett@math.ucsb.edu), Department of Mathematics, University of California, Santa Barbara, Santa Barbara, CA. *Still more knots in knots: a study of classical knot diagrams.* Preliminary report.

The structure of classical minimal prime knot presentations suggests that there are often, perhaps always, sub segments that present either the trefoil or the figure-eight knot. In joint work with Alex Rich, we undertook a comprehensive study of all the sub knots of the minimal prime knot presentations through 15 crossings and showed that this is always the case for, at least, these standard knot presentations. Among this set of knots, there are some that contain quite a few distinct sub knots while others contain few. We report the detailed statistics of sub knots of prime knots, illustrate the complex character of the sub knots of these classic minimal prime knot presentations, and discuss some interesting conjectures they suggest. (Received December 30, 2016)

1126-57-77 **Hugh N Howards*** (wakeknot@yahoo.com), Department of Mathematics, Wake Forest University, Winston Salem, NC 27109, and **Erica Flapan**, Department of Mathematics, Pomona College, Claremont, CA 91711. *Intrinsic Chirality.*

We will survey results from a paper of Erica Flapan and Hugh Howards on intrinsic chirality of graphs. The main result of the paper is that for every closed, connected, orientable, irreducible 3-manifold M, there is an integer n_M such that if γ is a graph with no involution and a 3-connected minor λ with genus(λ) $> n_M$, then every embedding of γ in M is chiral. By contrast, the paper also proves that for every graph γ, there are infinitely many closed, connected, orientable, irreducible 3-manifolds M such that some embedding of γ in M is pointwise fixed by an orientation reversing involution of M. (Received January 03, 2017)

1126-57-119 **Ellie Dannenberg*** (edanne2@uic.edu), University of Illinois at Chicago, Mathematics & Comp Sci MC 249, 851 S Morgan St, Chicago, IL 60607. *Circle Packings on Complex Projective Surfaces.*

The classical circle packing theorem of Koebe, Andreev, and Thurston says that given a triangulation τ of a closed, orientable surface, there is a unique constant curvature metric on the surface so that the surface with this metric admits a circle packing with dual graph τ. Circles are also key objects in studying complex projective surfaces. Kojima, Mizushima, and Tan give a definition of a circle packing on such a surface. Unlike in the metric case, there is a deformation space of complex projective circle packings with combinatorics given by τ. This space is parametrized by cross ratio type coordinates. Kojima, Mizushima, and Tan describe this space in the case where τ has 1 vertex. I expand some of their results to classes of higher vertex triangulations. (Received January 08, 2017)

1126-57-130 **Allison K Henrich*** (henrichatemp@seattleu.edu), 901 12th Ave, PO Box 222000, Seattle, WA 98122. *Knot Fertility and Heredity.* Preliminary report.

In this talk, we will introduce and explore the following new knot theoretical notions. A knot D is said to be a *descendant* of another knot P if there is a minimal crossing diagram of P on which some subset of crossings can be changed to produce a diagram of D. In this case, P is said to be a *parent* of D. A knot P is *fertile* if all knots with smaller crossing number are descendants of P. More generally, a knot K is *n-fertile* if all knots with crossing number less than or equal to n are descendants of K. We will discuss families of related (and insular) knots as well as knots that have many parents and knots that are particularly fertile.

This is joint work with Jason Cantarella, Elsa Magness, Kayla Perez, Eric Rawdon, and Briana Zimmer. (Received January 09, 2017)

1126-57-154 **Yuanan Diao*** (ydiao@uncc.edu), 11908 Three Vistas Ct, Charlotte, NC 28277, and **Gabor Hetyei** and **Pengyu Liu**. *HOMFLY polynomial formulation and braid index.*

In this talk I will discuss the HOMFLY polynomial in closed forms for special link diagrams such as closed braids, and how such closed forms may be used to prove results concerning the braid index of a link. (Received January 10, 2017)

1126-57-162 **Nicolas Petit*** (nicolas.petit@oberlin.edu), Oberlin, OH 44074. *The framed Polyak algebra and finite-type invariants.* Preliminary report.

We will discuss a generalization of finite-type invariants of virtual knots, in the Goussarov-Polyak-Viro sense, to framed virtual knots. This will lead us to investigate a modified version of the Polyak algebra, which is suitable to classify finite-type invariants of framed virtual knots. We will conclude with some open questions. (Received January 11, 2017)

1126-57-167 **Ian M Banfield*** (ian.banfield@bc.edu), Department of Mathematics, Maloney Hall, Boston College, Chestnut Hill, MA 02467. *Constructing tight fibered links.*

A fibered link is tight if it induces the tight contact structure on S^3. I will give a braid-theoretic construction for tight fibered links and explain how this algebraic condition is equivalent to a very nice geometric condition on Seifert surfaces. This class of links generalizes the notion of positive braid closures and I will discuss their properties, including some ongoing research. Lastly, we relate this class to a conjecture on the geometric meaning of annular Khovanov homology. (Received January 11, 2017)

1126-57-172 **Robert Adler**, **Moshe Cohen*** (mcohen@vassar.edu) and **Sunder Ram Krishnan**. *Towards a central limit theorem for random 2-bridge Chebyshev billiard table diagrams.*

Koseleff and Pecker show that all knots can be realized as trajectories on billiard tables together with crossing information. We randomize this knot diagram model by flipping a coin at each 4-valent vertex of the trajectory.

We truncate this model to study 2-bridge knots together with the unknot, giving the exact probability of a knot arising here. Furthermore, with Chaim Even-Zohar and Sunder Ram Krishnan we give the exact probability of obtaining a knot with crossing number c.

I will discuss preliminary work towards a central limit theorem for the probability of obtaining a knot with crossing number c in this truncated model. (Received January 12, 2017)

1126-57-175 **Claus Ernst*** (claus.ernst@wku.edu), Department of Mathematics, 1906 College Heights Blvd, Bowling Green, KY 42101, and **Van Pham** (vanpab@gmail.com), Department of Mathematics, 1906 College Heights Blvd, Bowling Green, KY 42101. *When are loop numbers knot invariants?*

For a given knot diagram D one can traverse the knot diagram and count the number of loops created by the traversal. The number of loops created depends on the starting point in the diagram D and on the traversal direction. Looking at the minimum or maximum number of loops over all starting points and directions one can define two positive integers as loop numbers of the diagram D. In this talk we identify conditions under which these loop numbers become knot invariants. In particular we study the question when these numbers are invariant under flypes in the diagram D. (Received January 12, 2017)

1126-57-190 **Louis H Kauffman*** (kauffman@uic.edu), 5530 South Shore Drive, Apt 7C, Chicago, IL 60637-1946. *Knots, Knotoids and Virtual Knot Theory.* Preliminary report.

A knotoid is an equivalence class of an embedding of an arc into Euclidean 3-space with respect to isotopy that fixes the projection of its endpoints via a specific projection of 3-space into the plane that keeps the image of the arc under this isotopy in the complement of two lines that project to the endpoints. In this way one can use the planar diagram of the knottoid with Reidemeister moves that do not shift arcs across the endpoints. This talk discusses the application of virtual knot theory to the study of knotoids. The work is joint work with Neslihan Gugumcu. (Received January 12, 2017)

1126-57-196 **Heather M Russell*** (hrussell@richmond.edu) and **Oliver T. Dasbach**. *Equivalence of edge bicolored graphs on surfaces.* Preliminary report.

Consider the collection of edge bicolored graphs cellularly embedded on some orientable surface. In this talk, we seek to count the number of equivalence classes of such graphs under two relations: reversing colors around a face and reversing colors around a vertex. In the case of the plane, this is well studied, but for other surfaces, the computation is more subtle. While this question can be stated purely graph theoretically, it has interesting connections to knot theory. (Received January 13, 2017)

1126-57-205 **Harrison Chapman*** (hchapman@math.uga.edu). *Slipknotting in the Knot Diagram Model.*

The presence of slipknots in configurations of proteins and DNA has been shown to affect their functionality, or alter it entirely. Historically, polymers are modeled as polygonal chains in space. As an alternative to space curves, we provide a framework for working with subknots inside of knot diagrams. We prove using a pattern theorem for knot diagrams that not only are almost all knot diagrams slipknotted, almost all *unknot* diagrams are slipknotted. This proves in the random diagram model a conjecture yet unproven in random space curve models. (Received January 13, 2017)

1126-57-233 **Radmila Sazdanovic*** (rsazdan@ncsu.edu), Department of Mathematics, PO Box 8205, Raleigh, NC 27695, and **Adam Lawrence**. *Torsion in Khovanov link homology.* Preliminary report.

In this talk we offer further insight into torsion of Khovanov link homology via an isomorphism with the chromatic cohomology that categorifies the chromatic polynomial of a graph related to the link. In particular, we show that the categorification of the chromatic polynomial only contains torsion of order two, and hence Khovanov homology only contains torsion of order two in the gradings where the isomorphism is defined. (Received January 14, 2017)

58 ► *Global analysis, analysis on manifolds*

1126-58-48 **Christina Sormani*** (sormanic@gmail.com), New York, NY 10016. *Scalar Curvature and Intrinsic Flat Convergence.*

While Gromov proved sequences of manifolds with nonnegative Ricci curvature have subsequences converging with respect to his intrinsic Hausdorff convergence, Ilmanen's famous example demonstrates no such theorem holds for sequences of manifolds with nonnegative scalar curvature. In joint work with Wenger, the intrinsic flat distance was introduced applying techniques of Ambrosio-Kirchheim, and was shown to produce a limit for Ilmanen's Example. I will survey conjectures of Gromov and Lee-Sormani and results of Basilio, Huang, Jauregui, Lang, Lakzian, Lee, LeFloch, Matveev, Munn, Perales, Portegies, Sinaei, Sormani, Stavrov and Wenger. See https://sites.google.com/site/intrinsicflatconvergence/ for links to all papers. There are many open questions in this area. (Received December 18, 2016)

1126-58-109 **Nicholas M. Ercolani*** (ercolani@math.arizona.edu). *Ginzburg-Landau Equations on Riemann Surfaces of Higher Genus.*

It is well known that there is a critical value in the coupling parameter of the Ginzburg-Landau (GL) equations that separates superconductors into two classes with different properties: Type I superconductors, which exhibit first-order phase transitions from the non-superconducting state to the superconducting state, and Type II superconductors, which exhibit second-order phase transitions and the formation of vortex lattices. Mathematically the existence and description of these latter vortex lattice states (known as Abrikosov lattices) can be reformulated in terms of studying the GL equations on a line bundle over a genus 1 Riemann Surface.

In this talk we will describe and study the extension of this model to the setting of line bundles over a higher genus Riemann surface. This brings into play methods related to the integrable systems approach to abelian Yang-Mills-Higgs theory, but also critical extensions thereof. Time permitting, we will briefly indicate extensions of this study to the vector bundle setting which has relevance for Hilbert's 21st problem. This is joint work with Dmitry Chouchkov, Steve Rayan and Michael Sigal. (Received January 07, 2017)

1126-58-152 **Anna Sakovich*** (anna.sakovich@math.uu.se). *The Jang equation and the positive mass theorem in the asymptotically hyperbolic setting.* Preliminary report.

A complete Riemannian manifold is called asymptotically hyperbolic if its ends are locally modeled on neighborhoods of infinity in hyperbolic space. This can be naturally interpreted through the notion of conformal compactification as introduced in general relativity in the early 1960s by Penrose. Since then, conformally compact manifolds have played an important role in conformal geometry, relativity, string theory through the AdS/CFT correspondence, and scattering theory. An important question is the problem of scalar curvature rigidity, which is closely related to positive mass theorems in this setting. The notion of mass here is rather delicate: unlike in the asymptotically Euclidean case, it is not natural to isolate a 'scalar' mass, but rather there is a family of mass-like invariants. For the Wang mass, defined by integrating a mass aspect density, there is a positive mass theorem on spin manifolds. In the general case, Andersson, Cai, and Galloway used an innovative technique based on the Witten-Yau BPS brane action to prove that this mass aspect cannot be everywhere negative. In this talk, we will discuss the proof of the fact that the mass itself is non-negative, which relies on the original ideas of Schoen and Yau and involves a blow-up analysis of the Jang equation. (Received January 10, 2017)

60 ► Probability theory and stochastic processes

1126-60-201 **Jason Cantarella**, **Thomas Needham** and **Clayton Shonkwiler*** (clay@shonkwiler.org), Colorado State University, Department of Mathematics, Campus Delivery 1874, Fort Collins, CO 80523, and **Gavin Stewart**. *Concavity, a question of Sylvester, and how to generate random quadrilaterals.*

"Show that the chance of 4 points forming the apices of a reentrant quadrilateral is 1/4 if they be taken at random in an indefinite plane."

This was Mathematical Question #1491 from the April, 1864 issue of the Educational Times, posed by J. J. Sylvester. Cayley provided a solution, but many others including De Morgan's son proposed alternative fractions as the correct answer, and after some spirited debate Sylvester came to believe that his question, as stated, does not "admit of a determinate solution".

While Sylvester asked about four points chosen randomly in the plane, perhaps a better question would be: is there a reasonable way of generating random quadrilaterals and, if so, what is the probability that a random quadrilateral is reentrant (or, if you like, concave)? As a special case of a more general theory which was originally developed to study random knots and polymers, we can identify quadrilaterals with points on the Grassmann manifold $G_2(\mathbb{R}^4)$ of planes in 4-dimensional space and, taking advantage of the symmetries of this space, give a satisfying answer to this modified version of Sylvester's question. This also leads to a new duality operation on quadrilaterals, the implications of which remain unexplored. (Received January 13, 2017)

1126-60-384 **Robert Buckingham*** (buckinrt@uc.edu) and **Karl Liechty**. *Nonintersecting Brownian motions on the unit circle with drift.*

Recently, Dong and Liechty determined the large-n asymptotic behavior of n Brownian walkers on the unit circle with non-crossing paths conditioned to start from the same point at time zero and end at the same point at time T. We analyze the analogous problem with a nonzero drift μ. We show there is a critical value μ_c for which the total winding is asymptotically zero with probability 1 for $|\mu| < \mu_c$. We compute μ_c explicitly in terms of T and discuss the positive winding case. Our results follow from asymptotic analysis of related discrete orthogonal polynomials carried out via the nonlinear steepest-descent method for Riemann-Hilbert problems. (Received January 17, 2017)

62 ► Statistics

1126-62-263 **Elizabeth C Bradfield*** (bradfiee@erau.edu). *Introducing Secular Cycles into the Black-Scholes Equation.*

The purpose of this experiment was to create a new method for determining volatility for the S&P500. Via a multiple linear regression model, one is able to create a statistically significant model for the S&P500 using macroeconomic indicators as independent variables. From there, plotting the residuals compared to historical data gives a basic framework for this new definition of volatility, and by an extension of the famous Black-Scholes model, is hypothesized to instead of using stochastic methods for volatility, rather, the idea of secular cycles is introduced into the modeling. Numerical interpretation is utilized from the prior example residuals to fit a sinusoid wave which is hypothesized to be fit as a perturbation term into the modeling of Black-Scholes.
(Received January 16, 2017)

1126-62-390 **J. Marcus Jobe** and **Michael Pokojovy*** (michael.pokojovy@kit.edu). *The Taut String Estimator: Weak Convergence and Confidence Bands.*

Davies and Kovac (2001) proposed their taut string estimator to estimate the conditional mean from a set of process data with iid errors within the framework of nonparametric regression. We prove the convergence of the taut string estimator in negative Sobolev spaces at the optimal rate of $n^{-1/2}$ as the sample size n goes to infinity and derive the confidence bands for the (unknown) conditional expectation, which is only assumed Hölder-continuous. Further, under an additional regularity assumption, the explicit form of the leading error term is derived. As an application, we show how the taut string estimator can be used to solve inverse problems with noise. An illustration based on real data is given and a numerical study on the robustness of our approach is presented. (Received January 17, 2017)

65 ► Numerical analysis

1126-65-7 **Mingchao Cai*** (mingchao.cai@morgan.edu), 1700 E Cold Spring Ln, Baltimore, MD 21251. *Fast solvers for fluid and structure problems with multiphysics.*

In this talk, I will study Multigrid solvers, domain decomposition methods, and preconditioning techniques that used in fluid and structure mechanics. Speci cally, for incompressible fluid flow models, the Cahouet-Chabard preconditioner using exact and inexact Multigrid solvers will be theoretically and numerically investigated; For linear elasticity problems, some scalable two-level overlapping Schwarz methods will be introduced and analyzed. Extensions of the preconditioners and the methods to fluid flow interacting with porous media flow model and fluid structure interaction model will also be discussed. (Received September 29, 2016)

1126-65-13 **Giacomo Capodaglio*** (giacomo.capodaglio@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, **Eugenio Aulisa** (eugenio.aulisa@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, **Giorgio Bornia**, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, and **Sara Calandrini**, Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409. *Convergence estimates for a multigrid algorithm with domain decomposition smoother.*

In this talk we present convergence estimates for a multigrid algorithm with domain decomposition smoother applied to symmetric elliptic PDEs. First, we reconsider a general convergence analysis on a class of multigrid algorithms, in a fairly general setting where no regularity assumptions are made on the solution. In this framework we explicitly highlight the dependence of the multigrid error bound on the number of smoothing steps. We observe that an increase in the number of smoothing steps can improve the convergence rate, a result that was already known in the literature although not yet shown under no regularity assumptions. A second purpose of this work is to fit the domain decomposition theory in the multigrid context, choosing the smoother of the multigrid to be a multiplicative Schwarz type algorithm. We conclude with uniform and local refinement applications of the general theory where we explicitly derive bounds for the multigrid error. (Received October 25, 2016)

1126-65-24 **Fangjun Arroyo*** (farroyo@fmarion.edu), Department of Mathematics, Francis Marion University, PO Box 100547, Florence, SC 29502, and **Edward Arroyo**, **Xiezhang Li** and **Jiehua Zhu**. *Numerical studies of the generalized l1-greedy algorithm for sparse signals.*

E. Candes, et. al. introduced the reweighted l1-minimization algorithm which was a significant improvement over the l1-minimization algorithm in both recovering random sparse signals and images with sparse gradients. Since then different weight functions for the reweighted l1-minimization algorithm has been studied. One of these new algorithms, the l1-greedy algorithm, was shown to significantly outperform the original reweighted l1-minimization algorithm. X. Li and J. Zhu discovered that much better performances could be obtained by combining the weight functions of the original reweighted l1-minimization and l1-greedy algorithms. Their generalized l1-greedy algorithm was shown to be superior to the other two algorithms in recovering medical images. In this talk, we compare the performance of the generalized l1-greedy algorithm with the other two algorithms in recovering random sparse signals. Statistical experiments indicate that the new algorithm performs extremely well in detecting small entries of unknown sparse signals thereby dramatically speeding up their recovery via l1-minimization. We also discuss recent modifications to this new algorithm to further improve its performance. (Received November 26, 2016)

1126-65-80 **Thinh Kieu*** (thinh.kieu@ung.edu), 3820 Mundy Mill Rd., Oakwood, GA 30566. *Galerkin finite element method for Generalized Forchheimer Flows of Slightly Compressible Fluids.*

We consider the generalized Forchheimer flows for slightly compressible fluids. Using Muskat's and Ward's general form of Forchheimer equations, we describe the fluid dynamics by a nonlinear degenerate parabolic equation for the density. We study Galerkin finite elements method for the initial boundary value problem. The existence and uniqueness of the approximation are proved. The prior estimates for the solutions and its gradient are established. Then the error estimates for the density variable are derived in several norms for both continuous and discrete time procedures. Numerical experiments using backward Euler scheme agreed with the theoretical analysis regarding convergence rates. (Received January 03, 2017)

1126-65-88 **Jiangyong Hou**, **Meilan Qiu**, **Chaohua Guo**, **Xiaoming He*** (hex@mst.edu), **Mingzhen Wei** and **Baojun Bai**. *Coupling dual-porosity flow and free flow.*

We propose and numerically solve a new model considering confined flow in dual-porosity media coupled with free flow in embedded macro-fractures and conduits. Such situation arises, for example, for fluid flows in hydraulic fractured tight/shale oil/gas reservoirs. The flow in dual-porosity media, which consists of both matrix and micro-fractures, is described by a dual-porosity model. And the flow in the macro-fractures and conduits is governed by the Stokes equation. Then the two models are coupled through four physically valid interface conditions on the interface between dual-porosity media and macro-fractures/conduits, which play a key role in a physically faithful simulation with high accuracy. All the four interface conditions are constructed based on fundamental properties of the traditional dual-porosity model and the well-known Stokes-Darcy model. The weak formulation is derived for the proposed model and the well-posedness of the model is analyzed. A finite element semi-discretization in space is presented based on the weak formulation. The full discretization with backward Euler scheme is utilized and analyzed. Four numerical experiments are presented to validate the proposed model and demonstrate the features of both the model and numerical method. (Received January 05, 2017)

1126-65-96 **Aziz Takhirov***, 3368 MailStop TAMU, College Station, TX 77843, and **Alexander Lozovskiy**. *Computationally efficient modular nonlinear filter stabilization for high Reynolds number flows.* Preliminary report.

The nonlinear filter based stabilization proposed by (Modular nonlinear filter stabilization of methods for higher Reynolds numbers flow, JMFM 14 (2), 325-354) allows to incorporate an eddy viscosity model into an existing laminar flow codes in a modular way. However, the proposed nonlinear filtering step requires the assembly of the associated matrix at each time step and solving a linear system with an indefinte matrix. We propose computationally efficient version of the filtering step that only requires the assembly once, and the solution of two symmetric, positive definite systems at each time step. We also test a new indicator function based on the entropy viscosity model. (Received January 06, 2017)

1126-65-97 **Andrea Bonito** and **Alan Demlow*** (demlow@math.tamu.edu). *Adaptive finite element methods for the Laplace-Beltrami operator on smooth surfaces.*

FEM for elliptic PDE on smooth surfaces involve approximating both the surface itself (leading to a "geometric" consistency error) and the PDE (leading to a standard Galerkin error). The behavior of the geometric error depends heavily on the choice of surface representation. Parametric representations based on mappings from Euclidean domains are more flexible and generally easier to implement, but lead to a lower-order (larger) geometric error. Implicit representations based on a closest-point projection are less flexible because they require a C^2 surface and because the closest-point projection is not usually analytically computable. However, the geometric error derived from such representations is of higher order due to special properties of the closest-point projection. Because existing estimators based on the closest-point projection require actually computing it, non-computability of the closest-point projection becomes critical when carrying out adaptive computations. In this talk we merge these two perspectives by constructing estimators which preserve many of the best properties of closest-point and parametric estimators and discuss behavior of AFEM based on our new estimators. (Received January 06, 2017)

1126-65-99 **Noel J Walkington*** (noelw@andrew.cmu.edu), Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213. *Numerical Approximation of Multiphase Flows in Porous Media.*

This talk will review the structure of mathematical models of geophysical flows involving multiple components undergoing phase transitions essential for the development of stable numerical schemes. Simulations of these problems only model the gross properties of these flows since a precise description of the physical system is neither available nor computationally tractable. In this context mathematics provides an essential foundation to facilitate the integration of phenomenology and physical intuition with computational algorithms so that codes inherit essential physical properties of the underlying problem. (Received January 06, 2017)

1126-65-101 **Zhu Wang*** (wangzhu@math.sc.edu), Department of Mathematics, 1523 Greene Street, Columbia, SC 29208. *An efficient algorithm for simulating ensembles of parameterized flow problems.*

Many applications of computational fluid dynamics require multiple simulations of a flow under different input conditions. In this talk, a numerical algorithm is developed to efficiently determine a set of such simulations in which the individually independent members of the set are subject to different viscosity coefficients, initial conditions, and/or body forces. The proposed scheme applied to the flow ensemble leads to need to solve a single linear system with multiple right-hand sides, and thus is computationally more efficient than solving for all the simulations separately. We show that the scheme is nonlinearly and long-term stable under certain conditions on the time-step size and a parameter deviation ratio. Rigorous numerical error estimate shows the scheme is of first-order accuracy in time and optimally accurate in space. Several numerical experiments are presented to illustrate the theoretical results. (Received January 07, 2017)

1126-65-140 **Qi Tang***, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180, and **J. W. Banks**, **W. D. Henshaw** and **D. W. Schwendeman**. *A Stable FSI Algorithm for Rigid Bodies and Incompressible Flows.*

A stable added-mass/added-damping partitioned algorithm is developed for fluid-structure interaction (FSI) problems involving viscous incompressible flow and rigid bodies. The algorithm remains stable, without sub-iterations, even for light rigid-bodies when added-mass and viscous added-damping effects are large. A fully second-order accurate implementation of the scheme is developed based on a fractional-step method for the incompressible Navier-Stokes equations using finite difference methods and overlapping grids to handle the moving geometry. A number of difficult benchmark problems will be presented to verify the proposed algorithm. (Received January 09, 2017)

1126-65-149 **Hyesuk Lee** and **Shuhan Xu*** (shuhanx@clemson.edu). *Numerical approximation on Viscoelastic Fluid-Structure Interaction Problems.* Preliminary report.

A viscoelastic fluid is a non-newtonian fluid where computational difficulties arise due to the hyperbolic character and the lack of a stabilizing term for the stress. In this talk, we consider a viscoelastic fluid-structure interaction (FSI) problem formulated in (i) a monolithic framework and (ii) a partitioned framework. The Finite Element Method (FEM) is used for the numerical solution, and the Arbitrary Lagrangian-Eulerian (ALE) formulation is applied to handle the time-dependent fluid domain. Numerical experiments concerning different schemes will be presented for comparison. (Received January 10, 2017)

1126-65-169 **Wenbin Chen**, **Daozhi Han** and **Xiaoming Wang*** (wxm@math.fsu.edu), Department of Mathematics, Florida State University, Tallahassee, FL 32306. *An energy stable and fully decoupled scheme for the Cahn-Hilliard-Stokes-Darcy system for two-phase flows in karstic geometry.*

We present an accurate, efficient, and stable scheme for the Cahn-Hilliard-Stokes-Darcy system for two-phase flows in karstic geometry. The scheme is first order accurate in time and satisfies a modified energy law at the discrete level. The most salient feature of the scheme is that it is completely decoupled in the sense that only a Cahn-Hilliard solver, a Stokes solver, and a Darcy solver are required at each time step. Our numerical experiments support our theoretical results. (Received January 11, 2017)

1126-65-195 **Amanda Diegel**, Louisianna State University, and **Shawn W. Walker*** (walker@math.lsu.edu), Dept. Of Mathematics, Lockett Hall, Baton Rouge, LA 70803-4918. *A Finite Element Scheme for a Phase Field Model of Nematic Liquid Crystals.*

We present a phase field model for nematic liquid crystals. Our model couples the Cahn-Hilliard equation to Ericksen's one constant model for nematic liquid crystals with variable degree of orientation. We present a special discretization of the liquid crystal energy that can handle the degenerate elliptic part without regularization. In order to develop time-stepping method, we derive a discrete gradient flow by computing variational derivatives and setting the discrete time derivatives equal to minus the gradient. A convex splitting finite element scheme is used for the Cahn-Hilliard equation. We prove that our discrete energy Gamma-converges to the continuous energy and our gradient flow scheme is energy minimizing. We also present numerical simulations to illustrate the method. (Received January 13, 2017)

1126-65-197 **Maxim Olshanskii*** (molshan@math.uh.edu), University of Houston, 651 PGH, Houston, TX 77204. *A hybrid finite volume - finite element method for bulk-surface coupled problems.*

In the talk we discuss a hybrid method for solving a system of advection-diffusion equations in a bulk domain coupled to advection-diffusion equations on an embedded surface. A monotone nonlinear finite volume method for equations posed in the bulk is combined with a trace finite element method for equations posed on the surface. In our approach, the surface is not fitted by the mesh and is allowed to cut through the background mesh in an arbitrary way. As an example of an application, we consider the modeling of contaminant transport in fractured porous media. One standard model leads to a coupled system of advection-diffusion equations in a bulk (matrix) and along a surface (fracture). The method demonstrates great flexibility in handling curvilinear or branching lower dimensional embedded structures. (Received January 13, 2017)

1126-65-262 **Fidele Ngwane*** (ngwanef@mailbox.sc.edu), 807 Hampton Street, Walterboro, SC 29488, and **Samuel Jator** (jators@apsu.edu), 601 College Street, Clarksville, TN 37044. *A trigonometrically-fitted second derivative extended backward differentiation formula for solving oscillatory Hamiltonian systems.*

We construct a trigonometrically-fitted continuous second derivative extended backward differentiation formula whose coefficients are functions of the frequency and the step size. The continuous form is used to construct a trigonometrically-fitted block second derivative extended backward differentiation formula for numerically integrating oscillatory Hamiltonian systems in a block-by-block fashion. The convergence and stability properties of the method are discussed and numerical examples are presented to illustrate the accuracy of the method (Received January 16, 2017)

1126-65-282 **Thomas C Clevenger**, **Timo Heister*** (heister@clemson.edu), **Guido Kanschat** and **Martin Kronbichler**. *Flexible, Parallel, Adaptive Geometric Multigrid in deal.II.* Preliminary report.

We present data structures and implementation details of a geometric multigrid method on adaptively refined meshes for massively parallel finite element computations. The method uses local smoothing on the refined part of the mesh. Partitioning is achieved by using a space filling curve for the leaf mesh and distributing ancestors in the hierarchy based on the leaves. The method is flexible and shown to work with continuous, DG, and mixed elements of arbitrary order and is scaling to 10,000 cores and more than one billion DoFs. The algorithm is implemented as part of the deal.II finite element library and as such available to the public. (Received January 16, 2017)

1126-65-283 **Thomas S. Brown*** (tsbrown@udel.edu), Dept. of Mathematical Sciences, 112 Ewing Hall, 15 Orchard Road, Newark, DE 19716, and **Tonatiuh Sánchez-Vizuet** and **Francisco -Javier Sayas**. *Wave-Structure Interaction Problems with a Piezoelectric Solid.*

We present a novel time-domain analysis of a wave-structure interaction problem involving an acoustic wave propagating through a fluid in an unbounded domain interacting with an elastic solid with piezoelectric properties. The solid is initially at rest, and when the acoustic wave interacts with the solid it initiates an elastic wave coupled with an electric potential. While previous analysis has relied on the use of transforms to move the equations to the frequency domain, our analysis allows us to do everything in the time domain. Our theoretical results allow us to use data with less regularity in time than previous results.

In addition to analyzing the abstract problem, we also consider a discretized version of the problem which uses Finite Elements to discretize the solid and Boundary Elements to discretize the fluid. We will also present numerical experiments which we hope will illustrate the validity of our analysis and regularity results. (Received January 16, 2017)

1126-65-305 **Yanzhao Cao*** (yzc0009@auburn.edu), 233 Park Hall, Auburn, AL 36849. *Parallel domain decomposition algorithms for Stokes Darcy interface problems.*

In this talk we present several new parallel domain decomposition algorithms for Stokes Darcy interface problems. These algorithms solve the Stokes and Darcy problems on their physical domains independently and update the boundary conditions on the interface through iterations. Analysis and numerical experiments show that our algorithms are more efficient than the existing ones for "bad" physical parameters such as hydraulic conductivity. (Received January 16, 2017)

1126-65-335 **Wujun Zhang*** (wujun@math.rutgers.edu), 110 Frelinghuysen Rd, Piscataway, NJ 08854, and **Ricardo H Nochetto**. *Pointwise rate of convergence for the Monge-Ampere equation.*

The Monge-Ampere equation appears in several areas of mathematics and its applications, including differential geometry, calculus of variations, and optimal mass transportation problem.

In the talk, we shall discuss the numerical approximation of the Monge-Ampère equations based on its geometric interpretation and the discrete Alexandroff maximum principle. We show several applications of the Alexandroff maximum principle on the stability estimate of numerical methods and the rate of convergence to the viscosity solution for the Monge-Ampère equations. (Received January 17, 2017)

1126-65-352 **Mine Akbas** and **Abigail L Bowers*** (abowers@flpoly.org). *Improving accuracy in the Leray model for the incompressible magnetohydrodynamic equations via adaptive deconvolution-based nonlinear filtering.*

We study a finite-element discretization of the Leray model for the MHD equations that locally chooses the filtering radius using a deconvolution based indicator function to identify regions where regularization is needed. Because this indicator function is mathematically based, it allows us to establish a rigorous analysis of the resulting numerical algorithm. We prove well-posedness, unconditional stability, and convergence of the proposed algorithm, and test the model on several benchmark problems. (Received January 17, 2017)

1126-65-371 **Alina Chertock*** (chertock@math.ncsu.edu), Department of Mathematics, North Carolina State University, Campus Box 8205, Raleigh, NC 27695. *Numerical Methods for Chemotaxis and Related Models.*

Chemotaxis is a movement of micro-organisms or cells towards the areas of high concentration of a certain chemical, which attracts the cells and may be either produced or consumed by them. In its simplest form, the chemotaxis model is described by a system of nonlinear PDEs: a convection-diffusion equation for the cell density coupled with a reaction-diffusion equation for the chemoattractant concentration. It is well-known that solutions of such systems may develop spiky structures or even blow up in finite time provided the total number of cells exceeds a certain threshold. This makes development of numerical methods for chemotaxis systems extremely delicate and challenging task.

In this talk, I will present a family of high-order numerical methods for the Keller-Segel chemotaxis system and several related models. Applications of the proposed methods to to multi-scale and coupled chemotaxis–fluid system and will also be discussed. (Received January 17, 2017)

1126-65-407 **Truong Q Nguyen*** (tqn4@pitt.edu), 141 North Dithridge st, Apt 36, Pittsburgh, PA 15213, and **Ivan Yotov** (yotov@math.pitt.edu), Department of Mathematics, 301 Thackeray Hall, University of Pittsburgh, Pittsburgh, PA 15260. *A nonlinear Biot-Stokes model for the interaction of a non-Newtonian fluid with poroelastic media.* Preliminary report.

The interaction between a free fluid with a deformable porous medium has a wide range of application, including hydraulic fracturing, designing industrial filters, and blood flow. We investigate a mathematical model of the coupled Biot-Stokes equations and its finite element approximation. The free fluid flow is modeled by the Stokes equations and the poroelastic material is model by the Biot system. The continuity of flux interface condition is imposed using a Lagrange multiplier. We admit that the fluid possesses the shear-thinning property, i.e., the viscosity decreases under shear strain, which results in a non-linear Biot-Stokes model. We present the well-posedness of the continuous weak formulation as well as the semi-discrete continuous-in-time formulation. The stability and error analysis for the semi-discrete scheme are presented. Numerical experiments illustrate the convergence of the scheme and an application to modeling the interaction between a stationary fracture filled with fluid and the surrounding poroelastic reservoir. (Received January 18, 2017)

68 ► Computer science

1126-68-199 **Michael W Berry*** (mberry@tennessee.edu), 401 Min H. Kao Building, 1520 Middle Drive, Knoxville, TN 37996. *Concept Extraction Using Separable Nonnegative Matrix Factorization.*

In large-scale text mining applications such as tweet classification there is need for fast yet robust techniques to summarize or track concepts without prior knowledge of the content. A numerical procedure referred to as separable nonnegative matrix factorization (SNMF) has previously been shown to be quite successful in solving solving hyperspectral unmixing problems. We have adapted this method for automated summarization of time-sensitive documents, especially social media. SNMF is designed to extract a cone spanned by a small subset of the columns of the input nonnegative data matrix. In the context of text mining, this translates to the extraction of key documents (tweets) that may well summarize a current stream and thereby reduce the human effort of reading enormous numbers of documents to extract meaning (concepts) from the stream. In essence, SNMF can function as an unsupervised learner that does not require prior labeling or metadata. (Received January 13, 2017)

1126-68-211 **Ben Greco*** (bgreco@soteria.io), Soteria, LLC, P.O. Box 22572, Charleston, SC 29403, and **Nel Abdiel** (nabdiel@soteria.io), Soteria, LLC, P.O. Box 22572, Charleston, SC 29403. *Products, Challenges, and Solutions Related to Data Analytics in Cyber Security Consulting.*

Soteria is a cyber security consulting company based in Charleston, SC. We seek to leverage large-scale data analytics and machine learning to create value through automating tasks typically done by expensive security consultants. Our solutions include multiple security software products that work alone or in tandem with veteran consultants by augmenting their knowledge with automatic recognition and analysis of security events and indicators. Due to the complex nature of cyber security, effective event recognition and diagnosis has many challenges. Chief among these are high false positive rates, setting proper thresholds to detect malicious events, processing large amounts of data in near real time, and storing and accessing data in a massively scalable way while still allowing for full text search. We will discuss several ways we address these analytics challenges to provide value to clients. (Received January 16, 2017)

1126-68-278 **Paul E Anderson*** (andersonpe2@cofc.edu), 66 George St, Charleston, SC 29464. *Fastfood Ridge Regression: Combining Variable Importance with Kernel Expansion Approximations.* Preliminary report.

As the complexity of a prediction problem grows, simple linear approaches tend to fail, which has led to the development of algorithms to make complicated, nonlinear problems solvable both quickly and efficiently. Fastfood, a kernel approximation method, has been shown to generate reliable models, but its current state does not offer a variable importance measure necessary to be applicable to a wide array of complex real-world problems that span from cancer prediction to financial analysis.

The aim of this research is to extend Fastfood with variable importance by integrating ridge regression. This work in progress shows how it is possible to retain the variable importance offered by ridge regression and the ability to solve nonlinear problems efficiently with Fastfood. Further, our implementation explores the computational advantages of implementing such kernel approximation methods on the large-scale data processing engine, Spark. (Received January 16, 2017)

1126-68-320 **Naren Ramakrishnan*** (naren@cs.vt.edu), Discovery Analytics Center, Virgin, Arlington, VA 22203. *Forecasting Significant Societal Events using Open Source Indicators.*

We describe some of the key algorithmic foundations behind EMBERS - a system to forecast significant societal events such as protests, disease outbreaks, elections, domestic political crises, using a multitude of open source data feeds. Over the past several years, EMBERS has successfully forecast many international (and rare) events such as the “Brazilian Spring” (June 2013), Hantavirus outbreaks in Argentina and Chile (2013), student-led protests in Venezuela (Feb 2014), protests stemming from the kidnappings and killings of student-teachers in Mexico (Sep- Oct 2014), and protests in Paraguay (Feb 2015) against a new public-private partnership law. We outline some of the lessons learned in operating a large-scale forecasting system, especially as pertaining to system architecture, model evaluation, and continual improvement to changing societal dynamics. (Received January 17, 2017)

1126-68-330 **LaKeisha Williams*** (lakeisha.d.williams1@navy.mil), PO Box 190022, Attn: Keisha Williams, Code 71000, North Charleston, SC 29419, and **Lucas A Overbey** and **Bryan Williams**. *A Social Network Analysis of FEMA's Twitter Network.*

With the recent growth, capacity, and utility of social media platforms such as Twitter, many organizations have started taking advantage of online social media for emergency management, primarily focusing on response and recovery. Similarly, little work has investigated whether the generative social network inherent to emergency management organizations such as the Federal Emergency Management Agency (FEMA) is effectively reaching an optimal cross-section of the relevant population through their social media strategies. In this work, we study the intra-organizational social network of FEMA in Twitter to identify patterns related to the authoritative sources of information and the dissemination of this information through the Twitter populace. Specifically, we analyze the interactions among FEMA's national and regional Twitter accounts, and the flow of information from these sources to the wider Twitter community. The research uses a framework primarily drawn from social network theory to better understand the structure of the information dissemination network. (Received January 17, 2017)

1126-68-342 **Edgar J Fuller*** (ef@math.wvu.edu), 320 Armstrong Hall, Department of Mathematics WVU, West Virginia University, Morgantown, WV 26506. *Applications of Data Analytics to Security and Neuroscience.*

New software tools, increasing computational power and better understanding of the underlying mathematical problems have combined to enable the application of data analytics to 'use-cases' from a variety of fields. This talk will cover a number of applications arising in my recent work in computational neuroscience and currently in my role as a AAAS Science and Technology Policy Fellow at the Department of Homeland Security Science and Technology Directorate. I will give an overview of some of data streams and the tools that are being applied to analyze them. (Received January 17, 2017)

1126-68-350 **Ralph W Crosby*** (ralph.crosby@navy.mil), 1 Innovation Drive, N. Charleston, SC 29410. *Training Deep Neural Networks.*

Current methods for machine learning focus on the use of artificial neural networks (ANN) as a core technology for a number of processes associated with the classification of inputs into some set of outputs based on opaque characteristics of the data. These inputs potentially include visual data and network data. The outputs potentially include everything from simple classification into a known set (e.g. house, car) to translation from one natural language to another (e.g. English to French).

It has been shown that for any continuous function, it is possible for a single layer neural network of finite width to approximate the function (the Universality approximation theorem). But, even though the width is demonstrably finite, it can become extremely large for even modestly complex functions. The solution to this issue is to generate multi-layer neural networks substituting network depth for width.

The problem that occurs with increases in network depth is that classic methods of "training" the network become progressively less effective as the depth of the network increases. In this talk we present a discussion of the problem of training a deep neural network and further discuss the intuitions that guided the development of modern methods of training deep neural networks. (Received January 17, 2017)

1126-68-369 **Jamie R Lyle*** (jamie.lyle@navy.mil). *Soft Biometrics of Partial Face.*

Data analytics brings to mind large amounts of text or transactional data, but can also pertain to images. Given large numbers of images containing people, the identity of the individuals, or possibly some description of them, would make it easier to explore the data and find relevant images. Soft biometric information is any trait that can describe an individual, but not uniquely identify them, such as gender, ethnicity, height, or hair color. Images are often collected of individuals from a non-frontal angle or only part of the face is captured. This work looks at soft biometric classification, namely gender classification, on two publicly available datasets, Facial Recognition Grand Challenge (FRGC) and Labeled Faces in the Wild (LFW) using partial and/or unaligned faces. The classification techniques utilize L1-minimization and sparse representation. (Received January 17, 2017)

1126-68-386 **Scott Dean**, 4555 Overlook Avenue SW, Washington, DC 20375, **Seongwon Kim**, 4555 Overlook Avenue SW, Washington, DC 20375, **Dasha Leary**, 4555 Overlook Avenue SW, Washington, DC 20375, and **Trey Morris***, 4555 Overlook Avenue SW, Washington, DC 20375. *Identifying Protein Promoter Sequences using Character-Level CNNs and LSTMs.*

In an effort to reduce expensive bench-top investigations, deep learning frameworks were explored to identify promoter sequences in novel bacteria of interest to Navy. Character-level convolutional neural networks (CNNs) and long short-term memory (LSTM) recurrent neural networks were trained on known promoter sequences from well-characterized bacteria, including Escherichia coli and Bacillus subtilisand then used to predict sequences in a novel bacteria from the genera Lactobacillus, Vibrio, and Marinobacter. Overcoming problems of over-fitting and attempts at generalizing the networks utility beyond training data are discussed. A proposal for testing predicted sequences in the laboratory is outlined along with methods of fine-tuning the model with deep reinforcement learning depending upon positive or negative results of laboratory verification. (Received January 17, 2017)

70 ► Mechanics of particles and systems

1126-70-203 **J. Douglas Wright*** (jdoug@math.drexel.edu), 3141 Chestnut St, Philadelphia, PA 19104, and **Aaron Hoffman**. *Traveling Waves in Diatomic Fermi-Pasta-Ulam-Tsingou lattices.*

Consider an infinite chain of masses, each connected to its nearest neighbors by a (nonlinear) spring. This is an FPUT lattice. In the instance where the masses are identical, there is a well-developed theory on the existence, dynamics and stability of solitary waves and the system has come to be one of the paradigmatic examples of a dispersive nonlinear equation. In this talk, I will discuss recent rigorous results of mine (together with T. Faver, A. Hoffman, R. Perline, A. Vainchstein and Y. Starosvetsky) on the existence of traveling waves in the setting where the masses alternate in size. In particular I will address in the limit where the mass ratio tends to zero. The problem is inherently singular and as such the existence theory becomes rather complicated. In particular, we find that the traveling waves are not true solitary waves but rather "nanopterons", which is to say, waves which asymptotic at spatial infinity to very small amplitude periodic waves. Moreover, we can only find solutions when the mass ratio lies in a certain open set. The difficulties in the problem all revolve around understanding Jost solutions of a nonlocal Schrodinger operator in its semi-classical limit. (Received January 13, 2017)

1126-70-380 **Dmitry V. Zenkov*** (dvzenkov@ncsu.edu). *Moving Frames in Mechanics.*
Moving frames in mechanics have been utilized for more than 250 years. The key steps of this development were carried out by Euler, Poincaré, Hamel, and recently Marsden in relation to the dynamics and stability of rigid body, fluid, and interconnected mechanical systems. The talk will overview some of these ideas and discuss recent development of this formalism for infinite-dimensional mechanical systems and field theories. (Received January 17, 2017)

76 ► Fluid mechanics

1126-76-12 **Sara Calandrini*** (sara.calandrini@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, and **Eugenio Aulisa** (eugenio.aulisa@ttu.edu) and **Giorgio Bornia**. *Numerical Simulations and Benchmarking for Fluid-Structure Interaction Modeling of Artery Aneurysms.*
This talk addresses numerical simulations of fluid-structure interaction (FSI) problems involving artery aneurysms, which are common vascular problems with fatal implications. The physics of the problem is described using a monolithic approach and both the fluid flow and the hyperelastic material are considered to be incompressible. The deformation of the fluid domain is taken into account according to an Arbitrary Lagrangian Eulerian (ALE) scheme. In the first part of the talk, I will describe the numerical algorithm that we use to solve this FSI problem, meaning a Newton-Krylov method combined with geometric multigrid preconditioner and smoothing based on domain decomposition. Secondly, I will describe several benchmark settings that we used to test our numerical method on possible hemodymanics applications. The configurations consist of realistic artery aneurysms, both in 2 and 3 dimensions. Numerical results for the described aneurysm geometries we'll be shown. (Received October 20, 2016)

1126-76-14 **Giacomo Capodaglio*** (giacomo.capodaglio@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, and **Eugenio Aulisa** (eugenio.aulisa@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409. *A parallel particle tracking algorithm for finite element applications.*
Numerical simulations of a parallel particle tracking algorithm on unstructured finite element grids are presented. The algorithm is designed to work for both 2D and 3D applications and with linear and quadratic spatial discretization. In order to determine the position of the particle with respect to the mesh, a new inclusion test algorithm has been designed to work with parallel computing and finite element applications. Unlike existing works in the literature, we do not perform the advection of the given particle on the local domain, therefore the inversion of the isoparametric finite element mapping is requested. We comply with this demand implicitly using Newton-Raphson's iteration for all Lagrangian finite elements and all degrees of freedom. We conclude with tests that illustrate the performance of our algorithm and an application where the velocity field is obtained from the numerical solution of the Navier-Stokes equation. (Received October 25, 2016)

1126-76-15 **Nick Moore*** (mnmoore2@fsu.edu), 208 Love Building, Tallahassee, FL 32303. *How Focused Flexibility Maximizes the Thrust Production of Flapping Wings.*
Birds, insects, and fish all exploit the fact that flexible wings or fins generally perform better. It is not clear, though, how to best distribute flexibility: Should a wing be uniformly flexible, or should certain sections be more rigid than others? I will discuss this question by using a 2D small-amplitude model combined with an efficient Chebyshev PDE solver. Numerical optimization shows that concentrating flexibility near the leading edge of the wing maximizes thrust production. (Received October 26, 2016)

1126-76-71 **H. Reed Ogrosky*** (hrogrosky@vcu.edu), 1015 Floyd Ave., P.O. Box 842014, Richmond, VA 23284-2014, and **Roberto Camassa** and **Jeffrey Olander**. *Modeling air-driven film flows inside a tube.*
The flow of a liquid film along a curved surface arises in both biological and engineering problems. Asymptotic models consisting of a single evolution equation are frequently used to describe such flows in idealized settings. In this talk, I will discuss a series of such models developed recently for the flow of a viscous film lining the inside of a tube. These models capture many features observed in experiments including the growth and saturation of free-surface waves, the onset of liquid plug formation, and the topology of streamlines within the film. (Received January 02, 2017)

1126-76-89 **Bryan Quaife*** (bquaife@fsu.edu), 400 Dirac Science Library, Tallahassee, FL 32306, and **Nick Moore** (mnmoore2@fsu.edu), 1017 Academic Way, Tallahassee, FL 32306. *Eroding bodies in a Stokesian fluid.*

Erosion of solid material by flowing fluids plays an important role in shaping many objects in nature. For example, erosion of a porous media can be be used to describe groundwater flow. I will describe a high-order and fast method that couples a boundary integral equation method with erosion equations to simulate the erosion of multiple bodies in a Stokesian fluid. (Received January 05, 2017)

1126-76-229 **Longhua Zhao*** (lxz315@case.edu), Cleveland, OH 44106, and **Yang Ding**, Beijing, Peoples Rep of China. *Fluid dynamics for micro-fluidic tweezers in the Stokes regime.* Preliminary report.

Nanowire fluidic tweezers have been developed to capture and manipulate micro objects. The fluidic trapping force and the fluid field are important to achieve accurate control, but the mechanism has not been fully understood yet. Utilizing singularity method, we construct the analytical velocity field to flows induced by a spheroid nanowire tumbling in the Stokes regime. To further explore the trapping, we analyze the trajectories of rigid or deformable microspheres near the tumbling nanowire with regularized Stokeslet method. The fluid structure, the trapping phenomenon are illustrated with the trajectories of fluid tracer and the microspheres. Given the geometry, the tumbling rate is crucial to the volume of trapping zone. The preliminary results about trapping mechanism trapping are presented. (Received January 14, 2017)

1126-76-251 **Charles Armstrong*** (carms015@odu.edu), Old Dominion University, Department of Mathematics and Statistics, 2300 ECSB, Norfolk, VA 23529, and **Yan Peng**. *Efficeny of the Multigrid Lattice Boltzmann Method.* Preliminary report.

Various multigrid configurations are implemented to solve the lid driven cavity flow problem using the lattice Boltzmann method. The computational efficiency of the v-cycle and w-cycle are compared. Factors such as the resolution on the finest grid and the number of grid levels are discussed. The computational efficiency and accuracy of the results are presented and an optimal configuration is proposed. (Received January 15, 2017)

1126-76-257 **Anand U Oza*** (oza@cims.nyu.edu), 251 Mercer Street, Room 1007, New York, NY 10012, and **Leif Ristroph** and **Michael Shelley**. *Coarse-grained models for interacting flapping swimmers.*

We present the results of a theoretical investigation into the dynamics of interacting flapping swimmers. Our study is motivated by recent experiments using a one-dimensional array of wings in a water tank, in which the system adopts "schooling modes" characterized by specific spatial phase relationships between swimmers. We develop a discrete-time dynamical system that models the swimmers as hydrofoils shedding point vortices, and study the existence and stability of steady solutions. Our model may be used to understand how schooling behavior is influenced by hydrodynamics in more general contexts. (Received January 15, 2017)

1126-76-272 **Richard M. McLaughlin*** (rmm@eailu.nc.edu), CB 3250, Phillips Hall, UNC Chapel Hill, Chapel Hill, NC 27599, and **Manuchehr Aminian**, **Francesca Bernardi**, **Roberto Camassa** and **Daniel M. Harris**. *How boundaries shape chemical delivery in microfluidics.*

We present the results of a combined computational, theoretical, and experimental study of the dispersion of a passive scalar in laminar shear flow through rectangular and elliptical channels. We show through Monte Carlo simulation, asymptotic analysis, and laboratory experiments that the cross-sectional aspect ratio sets the sign of the average skewness at long times (relative to the Taylor diffusion timescale) which describes the longitudinal asymmetry of the tracer distribution. Universally, thin channels result in negative average skewness, whereas as thick channels result in positive average skewness. Our analysis also allows us to define a "golden" aspect ratio which separates thin from thick channels, the value of which is remarkably similar for both the rectangle and the ellipse. Further, by examining the median of the cross-sectionally averaged distribution, we establish that negative skewness correlates with solutes arriving with sharp fronts followed by a tapering tail. Future directions will be discussed. (Received January 16, 2017)

1126-76-381 **Francesca Bernardi*** (bernardi@live.unc.edu), **Manuchehr Aminian**, **Roberto Camassa**, **Daniel M. Harris** and **Richard M. McLaughlin**. *Tailoring Tails in Taylor Dispersion: How Boundaries Shape Chemical Delivery in Microfluidics - Experiments.*

We present the results of an experimental investigation of the spreading of an initial dye concentration in laminar shear flow through rectangular ducts. In particular, we demonstrate the critical role that the cross-sectional aspect ratio plays in defining the longitudinal asymmetry of the resulting tracer distribution. Thin ducts (aspect ratio $\ll 1$) generate distributions with sharp fronts and tapering tails, whereas thick ducts (aspect ratio ~ 1) produce the opposite effect. The experimental results are shown to be in strong agreement with recent theoretical predictions. Our findings could potentially be useful in a number of microfluidic applications, some of which will be discussed. (Received January 17, 2017)

1126-76-392 **Roberto Camassa**, **Matthew Hurley**, **Richard McLaughlin**, **Pierre-Yves Passaggia** and **Colin Thomson*** (cfct@live.unc.edu). *Dynamics of Fully Nonlinear Internal Solitary Waves in Deep Water.*

Weakly nonlinear models for internal waves have many attractive features, not least of which is that they are completely integrable. They fail, however, to accurately model large-amplitude waves commonly observed in the ocean. This talk will present a fully nonlinear model for internal waves in a deep two-layer system analogous to the classical Boussinesq system. We will then compare properties of solitary waves in this system to direct numerical simulations and laboratory experiments. (Received January 17, 2017)

1126-76-403 **Andrei Ludu*** (ludua@erau.edu), ERAU, COAS-301.11, 600 Clyde Morris Blvd., Daytona Beach, FL 32114. *Universality of Hollow Patterns in Rotating Fluids.*

Rotating hollow polygonal patterns ranging from convex or concave regular polygons (triangles to heptagons) to higher frequency periodic waves were studied. During the rapid evaporation of the liquid various stable modes (number of edges of polygons) take over in the process. The model is based on shallow water theory and predicts the existence of sharp rotational polygonal waves with peakon solutions. PIV measurements showed that the inner rotating polygons are generated by energy transfer waves (apparent shape rotation), and do not involve matter transport. Similar hollow polygonal patterns are noticed in eye of hurricanes, in fast rotational bodies of water, in Saturn's hexagon, and in some plasma systems. Consequently, a tentative universality model for these rotational effects is presented. (Received January 18, 2017)

78 ► Optics, electromagnetic theory

1126-78-254 **Alexey Sukhinin*** (asukhini@uvm.edu), Department of Mathematics and Statistics, University of Vermont, Burlington, VT 05405. *Modeling of lasers with PT-symmetry.* Preliminary report.

Recently, a new family of lasers based on parity-time(PT) symmetry has been introduced. It is believed that such lasers have a potential for greater tunability and single-mode generation with higher purity. The principle of PT-symmetry transpires in the dynamical balance between optical gain and loss. In this talk, I discuss the mathematical models of various laser configurations and present preliminary analysis of these models. (Received January 15, 2017)

1126-78-274 **Gregor Kovacic*** (kovacg@rpi.edu), Mathematical Sciences Department, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180, and **Gino Biondini**, **Daniel Kraus** and **Sitai Li**. *Nonlinear Schrodinger and Maxwell-Bloch systems with non-zero boundary conditions.*

The study of scalar and vector nonlinear Schrodinger (NLS) and Maxwell-Bloch (MB) systems with non-zero boundary conditions at infinity has received renewed interest recently. This talk will report on recent results on focusing scalar and vector NLS and MB equations with non-zero boundary conditions. It will be shown how the inverse scattering transform can be constructed in both cases, and a number of explicit soliton solutions will be discussed. (Received January 16, 2017)

1126-78-293 **Alejandro B Aceves*** (aaceves@smu.edu), Clements Hall 208, Box 0156, Dallas, TX 75275. *Light dynamics in nonlinear twisted multicore fibers.* Preliminary report.

Novel photonic structures such as multi-core fibers are all optical platforms to study novel spatio-temporal dynamics. Phenomena such as discrete soliton formation, light localization. bifurcation phenomena and phase tgransitions can be studied in state of the art photonic systems.

This work presents some pf the dynamical features mantioned below in a configurtion of fiber arrays having a mechanical twist and presenting loss/gain properties in a (P)arity (T)ime configuration [1]. For finite arrays we present studies on existence and stability of nonlinear modes. For large systems, we will implement a statistical mechanics approach to determine whether localized coherent modes form.

This work [2] is in collaboration wih Claudia Castro-Castro (Southern Methodist University), Yannan Shen (California State Northridge) , Gowri Srinivasan (Los Alamos National Labooratory) and Panayotis Kevrekidis (University of Massachusetts, Amherst).

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[2] C. Castro-Castro, Y. Shen, G. Srinivasan, A. B. Aceves and P. Kevrekidis, "Light dynamics in nonlinear trimers and twisted multicore fibers", submitted to Journal of Nonlinear Optical Physics and Materials", (2017).
(Received January 16, 2017)

81 ► Quantum theory

1126-81-302 **Yaping Yang***, 710 N. Pleasant Street, LGRT 16th floor, Amherst, MA 01003, and **Gufang Zhao**, 710 N. Pleasant Street, LGRT 16th floor, Amherst, MA 01003. *From homotopy theory to representation theory.*

We use cohomology theories from topology to construct and study quantum groups and their representations. In my talk, I will focus on two examples.

1. We use the Morava K-theory to construct a family of new quantum groups parametrized by a prime number and a positive integer. Those quantum groups are related to Lusztig's 2015 reformulation of his conjecture from 1979 on character formulas for algebraic groups over a field of positive characteristic.

2. We use the equivariant elliptic cohomology to establish a sheafified elliptic quantum group for any symmetric Kac-Moody Lie algebra. The rational sections give the algebra of elliptic R-matrix. If time permits, I will explain the relation of the sheafified elliptic quantum group and Mirkovic's loop Grassmannian over an elliptic curve.

This talk is based on my joint work with Gufang Zhao. (Received January 16, 2017)

82 ► Statistical mechanics, structure of matter

1126-82-66 **Thomas Joachim Bothner*** (bothner@umich.edu), 530 Church Street, Ann Arbor, MI 48109. *On the analysis of incomplete spectra in random matrix theory through an extension of the Jimbo-Miwa-Ueno differential.* Preliminary report.

Recently A. Its, O. Lisovyy and A. Prokhorov [1] have found a way to extend the classical Jimbo-Miwa-Ueno isomonodromic tau function [2] to the full space of extended monodromy data of systems of linear ordinary differential equations with rational coefficients. We shall use this method to analyze incomplete spectra in unitary random matrix models.

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(Received December 31, 2016)

83 ► Relativity and gravitational theory

1126-83-32 **Hubert L Bray*** (bray@math.duke.edu), Mathematics Dept., Box 90320, Durham, NC 27708. *An Elliptic Theory of Gravity between Special and General Relativity.*

We'll describe a new theory of gravity which is 2/3 of the way from special relativity to general relativity in the sense that it requires 4 functions of t,x,y,z to describe the spacetime metric instead of 6. Flatly foliated relativity is identical to general relativity in spherical symmetry (outside black holes, assuming positive energy density) and still includes gravity, black holes, and the big bang. While the action is the same as general relativity, complete with matter fields, flatly foliated relativity requires spacetime to be foliated by flat, 3 dimensional Euclidean spaces. This extra rigidity prevents gravitational waves, simplifying the theory in some important ways. In particular, the Einstein equation is replaced by an elliptic system of equations on each flat slice, making this theory an interesting stepping stone for understanding general relativity better. (Received December 12, 2016)

1126-83-33 **Hubert L Bray*** (bray@math.duke.edu), Mathematics Dept., Box 90320, Durham, NC 27708. *The Geometry of Special and General Relativity.*

General relativity can be described in three words: "Matter curves spacetime." But what is spacetime, and how does matter curve it? Amazingly, the answer to this question leads to the prediction for the big bang and black holes, noted by mathematicians before either phenomenom was observed by astronomers. Furthermore, natural geometric ideas, like minimal surfaces and scalar curvature, correspond to physical notions like black holes and energy density, allowing us to prove theorems with both geometric and physical interpretations. (Received December 12, 2016)

1126-83-38 **Chen-Yun Lin***, cylin@math.toronto.edu, and **Christina Sormani**. *Bartnik's mass and Hamilton's modified Ricci flow.*

Two of the most important quasilocal masses studied in Riemannian General Relativity are the Hawking mass and Bartnik mass of a surface. Via a quantity which we call the "asphericity mass", we relate these two quasilocal masses. In this talk, I will discuss that the Bartnik mass is bounded from above by the Hawking mass and the asphericity mass, defined by applying Hamilton's modified Ricci flow and depends only upon the restricted metric of the surface and not on its mean curvature. The theorem is proven by studying a class of asymptotically flat Riemannian manifolds foliated by surfaces satisfying Hamilton's modified Ricci flow with prescribed scalar curvature. Furthermore, I will discuss the rigid case when the Hawking mass of the inner surface of the manifold agrees with its ADM mass. (Received December 13, 2016)

1126-83-40 **Jordan M Keller*** (keller@math.columbia.edu), 2990 Broadway, Room 408, MC 4406, New York, NY 10027. *Linear Stability of Schwarzschild Spacetime Subject to Axial Perturbations.*

The Schwarzschild solution of the vacuum Einstein equation in general relativity is the unique static solution that represents an isolated gravitating system of a single black hole. Both experimental and theoretical studies of such a system are modeled on the Schwarzschild solution and its perturbations. The stability of the Schwarzschild solution is thus of great practical and theoretical significance.

This talk will discuss joint work with Pei-Ken Hung on the linear stability of Schwarzschild spacetime subject to certain axisymmetric perturbations. In particular, we prove that associated solutions to the linearized vacuum Einstein equations centered at a Schwarzschild metric, with suitably regular initial data, remain uniformly bounded and decay to a linearized Kerr metric. Our method employs a complex line bundle interpretation applied to connection-level objects, allowing for direct analysis of these connection-level objects by means of the linearized Einstein equations. (Received December 14, 2016)

1126-83-50 **Henri Petrus Roesch*** (henri@math.duke.edu), 120 Science Drive, 117 Physics Building, Box 90320, Durham, NC 27708-0320. *Proof of a Null Penrose Conjecture using a new Quasi-local Mass.*

We define an explicit quasi-local mass functional which is non-decreasing along all foliations (satisfying a convexity assumption) of null cones. We use this functional to prove the null Penrose conjecture under fairly generic conditions. (Received December 20, 2016)

1126-83-57 **Eric Ling*** (eling@math.miami.edu) and **Greg Galloway**. *C^0-Extensions of the Big Bang.*

Recently, Dafermos and Luk showed the C^0-stability of the Kerr-Cauchy horizon which suggests that the strong cosmic censorship conjecture does not hold if one requires the C^0-inextendability of the maximal globally hyperbolic development. This motivates the following two questions: (1) what regularity condition should one impose for the strong cosmic censorhsip conjecture and (2) which spacetimes are C^0-inextendable? In a recent paper, Jan Sbierski has shown that the maximal analytic Schwarzschild spacetime is C^0-inextendable. Motivated by some of Sbierski's techniques, we tackle the question of whether or not the classical FLRW spacetimes are C^0-extendable. We find that there is a certain class of FLRW spacetimes, which we call Milne-like, that actually do admit C^0-extensions through the big bang. For spacetimes that are not Milne-like, we prove some inextendability results within a certain class of spherically symmetric spacetimes. (Received December 22, 2016)

1126-83-95 **Gregory J Galloway** and **Carlos Vega*** (vegaca@slu.edu). *Spacetime rigidity and splitting.*

The Lorentzian splitting theorem is a close analog of the Cheeger-Gromoll splitting theorem in Riemannian geometry, and was originally conjectured by S.-T. Yau in 1982 as a way of addressing the rigidity of the classical singularity theorems of Hawking and Penrose. Ultimately, the splitting theorem did not settle this rigidity question, and Robert Bartnik formulated a precise conjecture in 1988. In this talk, we will discuss recent developments in Lorentzian rigidity theory more generally, including applications to the Bartnik splitting conjecture. (Received January 06, 2017)

1126-83-125 **Dan A Lee*** (dan.lee@qc.cuny.edu), 65-30 Kissena Blvd, Queens, NY 11367, and **Lan-hsuan Huang** and **Christina Sormani**. *Stability of the positive mass theorem.*

We consider the stability question for the rigidity part of the positive mass theorem. That is, consider a sequence of asymptotically flat manifolds with nonnegative scalar curvature whose masses are approaching zero. We explore in what sense such a sequence becomes closer to Euclidean space in the limit. Specifically, in some simple cases, we obtain the desired result where closeness is measured using Sormani and Wenger's intrinsic flat topology. We discuss prospects for a more general theorem. I will summarize work from papers written in collaboration with Christina Sormani, Lan-hsuan Huang, and Huang and Sormani. (Received January 09, 2017)

1126-83-183 **Paul T Allen*** (ptallen@lclark.edu), 0615 SW Palatine Hill Rd, Portland, OR 97219. *The hyperboloidal initial value problem in general relativity.*

In asymptotically flat solutions to the Einstein vacuum equations, certain spacelike slices extending towards future null infinity have asymptotically hyperbolic geometry. In order for the spacetime to admit a regular conformal compactification, the geometry induced on such slices, which necessarily satisfies the Einstein constraint equations, must satisfy the *shear-free condition* along the conformal boundary. We refer to a spacelike manifold with such data as *hyperboloidal*.

The hyperboloidal initial value problem seeks to construct asymptotically flat spacetimes that arise from hyperboloidal initial data. A first step in addressing this initial value problem is constructing appropriate initial data. In this talk we provide motivation for considering the hyperboloidal initial value problem, give an overview of some technical issues that arise, and present some recent work regarding the existence of hyperboloidal initial data. (Received January 12, 2017)

1126-83-359 **Noah Benjamin** and **Iva Stavrov Allen***, Department of Mathematical Sciences, Lewis & Clark College, MSC 110, 0615 SW Palatine Hill Road, Portland, OR 97219. *Conceptualizing Point Particles as Limits of Matter Distributions.* Preliminary report.

Due to the linearity of the Poisson equation for the gravitational potential, a Newtonian point mass can be interpreted as a limit of a sequence of dust clouds whose matter densities approach the Dirac delta distribution. In general relativity this idea is much more difficult to implement because the Einstein equations are non-linear. In this talk we present a mathematically rigorous argument which shows that (on the level of time-symmetric initial data) simply letting the sequence of matter densities converge to the Dirac delta distribution does not in fact produce a Schwarzschild-like point particle. We conclude our talk with a brief survey of some expansions of this result. (Received January 17, 2017)

91 ► *Game theory, economics, social and behavioral sciences*

1126-91-51 **Matthew E. Brashears*** (brasheam@mailbox.sc.edu), Sloan College rm. 321, 911 Pickens St., Columbia, SC 29208. *Dimensional Analysis in Blau space Models: Preliminary Report.* Preliminary report.

Blau space models (McPherson 1983) provide a probabilistic representation of underlying social networks through a combination of demographic propinquity and the homophily principle. While this method has proven effective in predicting the behavior of organizations (e.g., McPherson and Ranger-Moore 1991) and cultural products (e.g., Mark 1991), several significant methodological hurdles remain. There is no established way to identify sets of demographic traits that are appropriate for inclusion in the model. Likewise, no method currently exists to include discrete variables as dimensions when identifying individual, as opposed to organizational, positions in the space. The result is a considerable degree of arbitrariness in dimensions incorporated into the model, and an inability to use socially salient dimensions in many models. We report on new techniques for quantitatively assessing the quality of fit in these models, as well as transforming discrete variables into distances using random walks in a two-mode graph. Preliminary results are promising, but significant limitations remain. (Received December 20, 2016)

92 ► Biology and other natural sciences

1126-92-114 **W. Garrett Mitchener*** (mitchenerg@cofc.edu), Mathematics Department, 66 George St, Charleston, SC 29424. *An undergraduate exploration in models of human vision using Mathematica.* Preliminary report.

Natural vision is a bidirectional process. The human brain combines image data from the eyes with conceptual information from memory. Traditional artificial neural networks are primarily feed-forward, and although they are an effective tool for image processing, they are not especially useful for understanding natural vision. Over two summers, I worked with an undergraduate on several unusual neural networks that were specifically designed to include bi-directional information flow. We were interested in determining whether they could experience hallucinations, that is, can the feed-back connections superimpose features of an image from memory onto the image coming from the eye. We used Mathematica as the primary tool. We were able to formulate a bi-directional network and training process that was biologically reasonable, computationally feasible, and mostly comprehensible to an undergraduate. We trained it on simple videos of moving dots, and identified hints of stray features in its internal state, suggesting that it can indeed experience hallucinations. Mathematica was a good tool for this project, since it can process images and perform advanced calculations. The learning curve turned out to be appropriate for this student, who had minimal prior programming experience. (Received January 08, 2017)

1126-92-387 **Caitlin S Hult*** (chult@live.unc.edu), **Paula A Vasquez**, **David Adalsteinsson**, **Josh Lawrimore**, **M Gregory Forest** and **Kerry Bloom**. *Modeling nucleosomal DNA in living yeast: Dynamics and organization.*

The genome in living yeast cells is a highly dynamic system where entropic interactions and nuclear confinement drive the formation of domains of high chromosomal interaction, known as topologically associating domains. We investigate dynamic organization and territory formation of all 16 chromosomes in living yeast cells during interphase, using coarse-grained, entropic polymer chain models. We are interested in determining the mechanisms, such as packaging molecules that create loops within chromatin fibers, that govern inter- and intra-chromatin fluctuations and induce global features of the entire genome as well as more localized features of the nucleolus. The Bloom lab measures specific DNA sites in specific chromosomes using live cell fluorescence microscopy. Our goal is to identify the sufficient biological and biophysical assumptions necessary to reproduce the experimental data, from which we aim to shed insights into dynamics and structure that are beyond current experimental resolution. (Received January 17, 2017)

93 ► Systems theory; control

1126-93-129 **Ozkan A Ozer*** (ozkan.ozer@wku.edu), 1906 College Heights Hill Blvd, Ogden College of Science, Bowling Green, KY 42101. *Investigating the stabilizability issues for a smart piezoelectric composite.* Preliminary report.

In this talk, we present coupled infinite dimensional PDE models characterizing the vibration profile of a smart piezoelectric composite involving charge or voltage-driven piezoelectric layers. The non-dynamic (electro-static and quasi-static) electromagnetic field approaches due to the Maxwell's equations are adopted to model the piezoelectric layers. The vibration interaction of layers assumes the so-called Rao-Nakra sandwich beam theory. These PDE models consist of several wave equations and a single Kirchhoff (Rayleigh) beam equation with cantilevered (clamped-free) boundary conditions. We prove a uniform stability result with the minimal number of B^*-type feedback controllers by using a compact perturbation argument and the spectral multipliers. The results are compared to the ones corresponding to the models using the fully dynamic electromagnetic field approach. These models lack even asymptotic stability. (Received January 09, 2017)

1126-93-171 **Scott Hansen*** (shansen@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011. *Controllability of a basic cochlea model.*

Two variations of a basic model for a cochlea are described which consist of the basilar membrane coupled with a linear potential fluid. The basilar membrane is modeled as an array of oscillators which may or may not include longitudinal elasticity. Approximate controllability with locally distributed control on a portion of the basilar membrane is proved for both models and moreover exact controllability is shown to hold when longitudinal stffness is included. (Received January 12, 2017)

94 ► Information and communication, circuits

1126-94-141 **Amy N Langville*** (langvillea@cofc.edu), 1014 E. Ashley Ave-PO Box 295, Folly Beach, SC 29439. *Rankability of Graphs.* Preliminary report.

Many methods exist for analyzing data on pairwise assessments of items in order to create a ranking of these items from most to least important. However, very few of these ranking methods produce associated measures of how confident one can be in the ranking. The related question that we ask is: just how rankable is a dataset? After presenting several definitions for rankability, we wonder at what point a time-evolving dataset is rankable? That is, when do we have enough information to produce a meaningful ranking? Furthermore, if a dataset is not very rankable, can we solicit information and which information to make it more rankable? The talk will be a presentation of work-in-progress on rankability. (Received January 09, 2017)

1126-94-238 **Heide Gluesing-Luerssen*** (heide.gl@uky.edu) and **Tefjol Pllaha** (tefjol.pllaha@uky.edu). *Extension Theorem for Codes over Finite Frobenius Bimodules.*

We investigate the MacWilliams extension theorem for codes over alphabets that have the structure of a finite Frobenius bimodule over a finite ring. More precisely, for various weight functions we investigate whether weight-preserving linear maps between such codes extend to weight-preserving automorphisms on the entire ambient space. In order to do so we need to study partitions induced by the given weight function and introduce their character-theoretic dual. While the former is a partition of M^n, the ambient space of the code, the latter is a partition in the character-module of R^n, where R is the underlying finite ring. The resulting duality theory of these partitions allows us to answer the extension theorem in the affirmative for various weight functions. (Received January 15, 2017)

1126-94-298 **Guang Gong*** (ggong@uwaterloo.ca), 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada. *Strong Cryptographic Properties of WG Transformation Filtering on de Bruijn Sequences.* Preliminary report.

In this talk, I will introduce a filtering generator for which a WG transformation is used as a filtering function over a de Bruijn sequence. For a binary de Bruijn sequence of period 2^n, each n-tuple occurs exactly once in one period of the sequence. WG transformation and WG sequences have been used in WG stream cipher, which is to filter over an linear feedback shift register sequence. We investigate the cryptographic properties of the WG transformation filtering on a de Bruijn sequence. We have found a rather surprising result on WG transformations for the ideal k-tuple distribution property, namely, there is only one decimation from the WG transformation which yields the ideal k-tuple distribution. (Received January 16, 2017)

1126-94-317 **Jintai Ding*** (jintai.ding@gmail.com), 8770 wellerstation dr, cincinnati, OH 45249. *Post-Quantum Key Exchange from the LWE.*

In this lecture, we present practical and provably secure (authenticated) key exchange protocol and password authenticated key exchange protocol, which are based on the learning with errors problems. These protocols are conceptually simple and have strong provable security properties. This type of new constructions were started in 2011-2012. These protocols are shown indeed practical. We will explain that all the existing LWE based key exchanges are variants of this fundamental design. In addition, we will explain some issues with key reuse and how to use the signal function invented for KE for authentication schemes. (Received January 17, 2017)

1126-94-346 **Qi Cheng*** (qcheng@ou.edu), 110 W. Boyd St., Norman, OK 73072, and **Jincheng Zhuang**. *LWE from Non-commutative Group Rings.*

The Ring Learning-With-Errors (LWE) problem, whose security is based on hard ideal lattice problems, has proven to be a promising primitive with diverse applications in cryptography. There are however recent discoveries of faster algorithms for the principal ideal SVP problem, and attempts to generalize the attack to non-principal ideals. In this talk, we study the LWE problem on group rings, and build cryptographic schemes based on this new primitive. One can regard the LWE on cyclotomic integers as a special case when the underline group is cyclic, while our proposal utilizes non-commutative groups that eliminates the weakness associated with the principal ideal lattices. In particular, we show how to build public key encryption schemes from dihedral group rings, which maintains the efficiency of the Ring-LWE, and improves its security. We also propose a simple modification of the Peikert-Vaikuntanathan-Waters cryptosystem, which is an amortized version of Regev's original proposal based on LWE. Our modification improves the encryption and decryption complexity per bit to sublinear in the security level, without affecting the security. (Received January 17, 2017)

1126-94-363 **Beth Malmskog**, **Gretchen Matthews** and **Katie Haymaker*** (kathryn.haymaker@villanova.edu). *Locally Recoverable Codes with Multiple Recovery Sets: Theoretical Considerations.*

In this talk we discuss constructions of locally recoverable codes motivated by the recent work of Barg, Tamo, and Vladuts. We give theoretical reasons for considering multiple recovery sets, and provide an analysis of the case of transverse recovery sets. (Received January 17, 2017)

1126-94-374 **Robert Calderbank*** (robert.calderbank@duke.edu), Duke University, Durham, NC 27708, and **Georgios Mappouras**, **Daniel J Sorin** and **Alireza Vahid**. *Coding for Racetrack Memory.* Preliminary report.

Racetrack memory is a non-volatile memory engineered to provide both high density and low latency that is subject to synchronization or shift errors. This paper describes a very fast coding solution, in which "delimiter bits" assist in identifying the type of shift error, and easily implementable graph-based codes are used to correct the error, once identified. Previous proposals for handling shift errors in racetrack memory involved adding multiple read-write ports, and did not involve coding theory. (Received January 17, 2017)

1126-94-379 **Hiram Habid Lopez Valdez*** (hlopezv@clemson.edu). *Examples of evaluation codes.*

In this talk we introduce the linear codes known as evaluation codes. We are interested in this sort of codes because its parameters can be computed using basic tools of commutative algebra, and we will see how to do it.

The family of evaluation codes mainly depends on an affine or a projective set, thus we are going to present some examples using different families of affine and projective points. (Received January 17, 2017)

97 ► Mathematics education

1126-97-145 **Aubrey Kemp*** (akemp9@student.gsu.edu) and **Draga Vidakovic**. *The Use of Groupwork and Geometer's Sketchpad in Learning Taxicab Geometry: A Preliminary Report.* Preliminary report.

The Activities, Class Discussions, and Exercises (ACE) Teaching Cycle was implemented in a class of 18 students in Fall 2016 in a college geometry course. Students worked in groups to explore concepts and complete activities on a dynamic geometry software, Geometer's Sketchpad (GSP). During these activities, students were guided to construct certain figures and observe properties and relationships in geometry. Students then participated in class discussions guided by the instructor to reinforce certain concepts. During these discussions, concepts were formalized, including the proofs of theorems that were explored in the previously completed activities. In addition, students were given exercises to complete to help support the development of mental constructions. For this preliminary report, we are focusing on the dynamics of group participation in relationship to GSP within two selected groups from the teaching experiment during a Taxicab Geometry lesson. The first activity was an explorative activity to allow students to get an idea of how the Taxicab metric is measured. The second activity allowed students to use GSP to explore Taxi-circles, and create their own conjectures about Taxicab Geometry and some of its interesting properties. (Received January 10, 2017)

1126-97-198 **Darryl Chamberlain Jr.*** (dchamberlain2@gsu.edu) and **Draga Vidakovic**. *Active Learning in Transition-to-Proof courses: An example lesson of proof by contradiction.*

Proof is central to the curriculum for undergraduate mathematics majors. Students are typically first introduced to formal proof in a transition-to-proof course. The primary purpose of transition-to-proof courses is to move beyond the procedural approaches encountered in lower-level courses (e.g., Calculus) to the types of abstract approaches necessary to prove statements in higher-level courses (e.g., Abstract Algebra). Despite transition-to-proof courses, research shows students continue to exhibit difficulties constructing and comprehending proofs in higher-level mathematics courses. As part of the NSF grant Promoting Reasoning in Undergraduate Mathematics (PRIUM), we have developed a series of lessons on proof by contradiction that actively engage students in different aspects of proof in order to develop a robust understanding of the particular proof method. During this talk, we will present the context of our particular transition-to-proof course, provide an overview of how we designed these lessons utilizing the proof comprehension framework by Mejia-Ramos et al. (2012), and present evidence that attending to the different aspects of proof can foster the types of abstract approaches necessary for student success in higher-level courses. (Received January 13, 2017)

1126-97-301 **Divya Vernerey**, **Rebecca Machen** and **Harrison E. Stalvey*** (harrison.stalvey@colorado.edu). *Developing an Active Learning Environment in Precalculus.*

The notion of active learning is gradually becoming fundamental in the nature of mathematics courses at the undergraduate level. Here, we will discuss how instruction has evolved into active learning in the mathematics courses for STEM majors at the University of Colorado Boulder. Our presentation will focus on our recently redesigned Precalculus course and its recently developed corequisite lab. We will present examples of various group activities, each designed with particular goals in mind, such as fostering the development of students' conceptual knowledge, exposing students to applications, and engaging students in metacognition. Additionally, connections to established learning theories will be made. (Received January 16, 2017)

1126-97-309 **Greg Mayer*** (greg.mayer@gatech.edu), 686 Cherry St., Atlanta, GA 30332, and **Dia Sekayi** (dia.sekayi@morgan.edu). *The Pedagogical Practices of Teaching Assistants in Polysynchronous Classrooms: The role of Professional Autonomy.*

Polysynchronous learning involves the use of educational technologies to enable remote and face-to-face students to simultaneously participate in live classes. This presentation summarizes findings from a grounded theory study, based on self-determination theory, that utilized teaching observation, survey, and focus group data. The study explored the perspectives and instructional practices employed by teaching assistants tasked with facilitating a polysynchronous environment. Study findings suggest that without a sufficient knowledge base, community, and structure to facilitate a teaching environment that extended beyond lecturing, the assistants in this study used their autonomy to adopt a knowledge transmission teaching perspective. Based on these findings we discuss teaching practices that could be addressed to train and support teaching assistant instruction in blended and polysynchronous environments. (Received January 17, 2017)

00 ► General

1127-00-7 **Richard Evan Schwartz***, Brown University, Providence, RI 02912. *Modern scratch paper: Graphical explorations in geometry and dynamics* Preliminary report.

Over the years I've made a number of graphical user interfaces whose purpose is to help understand problems in geometry and dynamics. These interfaces let you discover patterns and organize information in a way that would be practically impossible using pencil and paper. Sometimes they also facilitate computational proofs that are a kind of deal with the devil: They give a rigorous proof for an appealing result without offering conventional insight into why the result is true. In this talk I will show some of my graphical user interfaces and explain the mathematics behind them. (Received September 12, 2016)

1127-00-91 **Hyoeun Lee*** (lee1487@purdue.edu), 250 N. University St., West Lafayette, IN 47907, and **Jose E. Figueroa-Lopez** and **Raghu Pasupathy**. *Optimal placement of a small order under a diffusive limit order book model.*

We study the optimal placement problem of a stock trader who wishes to clear his/her inventory by a predetermined time horizon by using a limit order or a market order. For a diffusive market, we characterize the optimal limit order placement and analyze its behavior under different market conditions. In particular, we propose a simple method to determine the optimal order placement and show its performance. This is joint work with Professors J. Figueroa-Lopez and R. Pasupathy. (Received January 25, 2017)

01 ► History and biography

1127-01-208 **donald a. sokol*** (vsokol@gmail.com), 11 s 047 Palisades Rd., Burrr Ridge, IL 60527. *Encryption and the Integer (Pythagorean) Triple.*

The algorithm the Babylonians used almost four thousand years ago to generate integer (Pythagorean) triples employed the ratio 60/15 and triangular numbers to construct a ,and x2 to construct c, and 2 y2 to construct b; thus c-a=x2 and c-b= 2 y2, About fifteen hundred years later, Euclid modified the Babylonian algorithm and x2+ y2 = c; x2 - y2 =b or c+b=2x2, c-b=2y2. Circa the year 2000, this author modified the Babylonian construct in the method of Euclid and c+a=x2 with c-b=2y2. Consequently, for the integer triple 4,5,3; x=1,y=1 for the Babylonian construct; x=2,y=1 for the Euclidian construct; and x=3, y=1 for the Sokolian construct. There are numerous other, if not an infinite number of constructs that produce similar results, thus raising the possibility for a system of encryption. (Received February 03, 2017)

03 ► Mathematical logic and foundations

1127-03-71 **Alfredo R Dolich*** (alfredo.dolich@kbcc.cuny.edu), Dept. fo Mathematics, The Graduate Center, 365 5th Ave., New York, NY 10016. *Generic Functions over Divisible Ordered Abelian Groups.*

Let T be the theory of divisible ordered Abelian groups given in a language $\mathcal{L}$ and let σ be a new function symbol. We may consider the $\mathcal{L} \cup \{\sigma\}$-theory, T_0, given by the axioms for T together with the axioms stating that "σ is an automorphism". It is well known that T_0 does not have a model companion and as such we can not find a theory of "generic" automorphisms of divisible ordered Abelian groups. In this talk I will consider what happens if we weaken the requirements on σ. In particular I will consider the theory, T_1, given by the axioms for T together with "σ is a linear bijection". T_1 has a model companion which we can consider as giving the theory of "generic" linear automorphisms over divisible ordered Abelian groups. The theory T_1 has a host of interesting properties which I will discuss. (Received January 22, 2017)

1127-03-112 **Uri Andrews**, **Julia F. Knight*** (knight.1@nd.edu), **Rutger Kuyper**, **Joseph S. Miller** and **Mariya Soskova**. *Generic Muchnik reducibility.*

Noah Schweber defined a notion that lets us compare the computing power of structures of arbitrary cardinality, using standard notions of computability. We have $\mathcal{A} \leq^*_w \mathcal{B}$, if, after collapse of cardinals so that both structures

are countable, every copy of $\mathcal{B}$ (with universe ω or a subset) computes a copy of $\mathcal{A}$. There are a number of results applying this notion to structures related to the ordered field of reals $\mathcal{R}$. The talk will summarize the earlier results, and then describe newer results on expansions of $\mathcal{R}$ by continuous functions, and by Borel relations. (Received January 28, 2017)

1127-03-113 **Vince N Guingona*** (vguingona@towson.edu), Towson University, Department of Mathematics, 7800 York Rd, Towson, MD 21252. *Generalized Indiscernibles and Dividing Lines.*

We discuss recent developments on the use of generalized indiscernibles to study positive local combinatorial dividing lines in model theory. The idea is to find a suitable generalization of the following result of S. Shelah: A theory is stable if and only if every indiscernible sequence is an indiscernible set. To do this, we develop a generalized notion of a "positive local combinatorial dividing line" and explore the connections between this and the collapse of generalized indiscernibles. If the index theory is unstable and the Fraisse limit of a simply Ramsey-expandable class, then the corresponding dividing line has a "collapse of generalized indiscernibles" characterization.

This work is joint with C. D. Hill. (Received January 28, 2017)

1127-03-122 **Athipat Thamrongthanyalak*** (thamrongthanyalak.1@osu.edu), 231 West 18th Avenue, Columbus, OH 43210. *D-minimal expansions of the real field have the $\boldsymbol{C^p}$ zero set property.*

If $E \subseteq \mathbb{R}^n$ is closed and the structure $(\mathbb{R}, +, \cdot, E)$ is d-minimal (that is, in every structure elementarily equivalent to $(\mathbb{R}, +, \cdot, E)$, every unary definable set is a disjoint union of open intervals and finitely many discrete sets), then for each $p \in \mathbb{N}$, there exist C^p functions $f \colon \mathbb{R}^n \to \mathbb{R}$ definable in $(\mathbb{R}, +, \cdot, E)$ such that E is the zero set of f. This is a joint work with Chris Miller. (Received January 29, 2017)

1127-03-187 **Santiago Camacho*** (scamach2@illinois.edu), 1409 West Green Street, Urbana, IL 61801. *Truncation is Robust and Independent.* Preliminary report.

Given a monomial group $\mathfrak{M}$ in a valued field K with residue field $\mathbf{k}$ and a truncation closed embedding from K into the Hahn field $\mathbf{k}[[\mathfrak{M}]]$ we can talk about the truncation of an element $f \in K$ at a monomial $mathfrakm \in \mathfrak{M}$. Truncation is a robust notion in the setting of Hahn fields. That is, several natural algebraic and transcendental extensions of truncation closed subsets of a Hahn field remain truncation closed. We show that theories extending the theory of valued fields in which truncation is defined carry the independence property. (Received February 05, 2017)

1127-03-212 **Steven Lindell*** (slindell@haverford.edu), 370 Lancaster Ave., Department of computer science, Haverford College, Haverford, PA 19041, and **Scott Weinstein** (weinstein@cis.upenn.edu). *Traversal-invariant elementary definability for logarithmic-space computation.* Preliminary report.

First-order logic is often portrayed as being insufficient to capture complexity classes of importance in theoretical computer science. Typically, inductive definitions such as transitive-closure are added as fixed-point operators, and the resulting logics characterize logarithmic-space computation over finite structures. We remedy this by insisting that all structures are input in some traversal order – one in which individual elements are related to previous elements. For example, a traversal of a connected undirected graph is a linear ordering of its vertices in which every initial segment is connected. First-order formulas invariant of the underlying traversal order are called traversal-invariant. Our results show that the traversal-invariant definitions capture logarithmic-space computability. If moreover the traversal corresponds to a breadth-first order, the breadth-first invariant elementary definitions capture nondeterministic logarithmic-space computability. To prove these results we rely heavily on some of the most important theorems in computational complexity: the existence of universal traversal sequences; as well as the celebrated closure of nondeterministic space under complementation. Time permitting, we will discuss extensions into the transfinite. (Received February 03, 2017)

1127-03-218 **Yuri Movsisyan***, Alex Manoogian 1, Yerevan State University, 0025 Yerevan, Armenia. *On functional equations and distributive second order formulae.*

The structure of invertible algebras with distributive second order formulae with specialized quantifiers is given. As a consequence, the applications for solutions of the some functional equations of distributivity on quasigroups are provided. (Received February 04, 2017)

1127-03-236 **Cameron Donnay Hill*** (cdhill@wesleyan.edu), CT. *Decomposition, amalgamation, and something like logic programming.*

I will discuss an abstract notion of hierarchical decomposition of finite structures that is morally, if not directly, related to tree-decomposition, clique-decomposition, and similar. Working in the context of a whole amalgamation class of structures, one can add some uniformity conditions to this kind of decomposition that are suggestive of the "context-free-ness" of clique-decomposition. I will point out some of the important points of proving that an amalgamation class that admits uniform hierarchical decomposition is rosy — i.e. that it carries a model-theoretic notion of geometry generalizing linear independence in vector spaces and algebraic independence in fields. (Received February 04, 2017)

1127-03-248 **Reese Johnston*** (rwjohnston@math.wisc.edu). *Computability in uncountable binary trees.*

Π^0_1-classes in Cantor space - sets of paths through binary trees of height ω - have been a topic of interest in computability for a considerable time. We present an extension of the topic into the realm of admissible recursion theory, restricting our attention specifically to the case of ω_1-recursion, in which we consider computation over the collection of hereditarily countable constructible sets. While in many ways computability in this setting mirrors the standard setting, we demonstrate that the analogues of some essential results about Π^0_1-classes in Cantor space do not hold in the uncountable setting. (Received February 05, 2017)

1127-03-264 **John T Baldwin*** (jbaldwin@uic.edu). *Generalized Fraïssé Constructions and Atomic models.*

I will discuss several results whose proofs depend on extensions of the Fraïssé method. I will outline the construction (with Koerwien and Laskowski) of an explicit complete $L_{\omega_1,\omega}$-sentence ϕ_n characterizing $\aleph_n$ for each n. This argument requires a new notion of n-dimensional amalgamation which allows the construction of *atomic* models in various uncountable cardinals. These considerations led to constructions (with Souldatos) of complete $L_{\omega_1,\omega}$-sentences which have maximal models in more than one cardinal, but all below $\aleph_{\omega_1}$. Note that an abstract elementary class with amalgamation and joint embedding can have at most one maximal model.

In contrast, Shelah and I have constructed (modulo presumably eliminable set theoretic hypotheses) a complete $L_{\omega_1,\omega}$-sentence with maximal models cofinally in the first measurable cardinal and forever if there is no measurable cardinal. (Received February 05, 2017)

1127-03-278 **Nathanael L. Ackerman** (nate@math.harvard.edu) and **Cameron E. Freer*** (cameron@remine.com). *On the computability of graph Turing machines.*

We consider graph Turing machines, a model of parallel computation on a graph, in which each vertex is only capable of performing one of a finite number of operations. This model of computation is a natural generalization of several well-studied notions of computation, including ordinary Turing machines, cellular automata, and parallel graph dynamical systems. We analyze the power of computations that can take place in this model, both in terms of the degrees of computability of the functions that can be computed, and the time and space resources needed to carry out these computations. We further show that properties of the underlying graph have significant consequences for the power of computation thereby obtained. In particular, we show that every arithmetically definable set can be computed by a graph Turing machine in constant time, and that every computably enumerable Turing degree can be computed in constant time and linear space by a graph Turing machine whose underlying graph has finite degree. (Received February 06, 2017)

1127-03-297 **Lynn Scow*** (lynn.scow@csusb.edu). *Transfer of the Ramsey property by semi-bi-interpretations.*

Given a class $\mathcal{K}$ of finite L-structures, say that a *copy* of A in B is an L-substructure of B isomorphic to A. We say that $\mathcal{K}$ has the Ramsey property if for all $A, B \in \mathcal{K}$ there is $C \in \mathcal{K}$ so that for all 2-colorings of copies of A in C, there is a copy B' of B in C, all of whose copies of A are colored the same color under this coloring.

In this talk we introduce a weaker form of bi-interpretability and see how it can be used to transfer the Ramsey property across classes in different first-order languages. This is a special case of a more general theorem about what we will call *color-homogenizing* embeddings. (Received February 06, 2017)

1127-03-299 **Sergei Starchenko*** (sstarche@nd.edu) and **Artem Chernikov**. *On strong Erdos-Hajnal property for definable relations.*

Let $\mathcal{M}$ be a first order structure, $X, Y \subseteq M$ definable sets and $E \subseteq X \times Y$ a definable relation.

We say that E has *strong Erdos-Hajnal property* if there is a real number $\alpha > 0$ such that for all finite $A \subseteq X$, $B \subseteq X$ there are $A_0 \subseteq A$, $B_0 \subseteq B$ with $|A_0| \geq \alpha|A|$, $|B_0| \geq \alpha|B|$ and either $A_0 \times B_0 \subseteq E$ or $A_0 \times B_0 \cap E = \emptyset$.

In this talk we discuss strong Erdos-Hajnal property for definable relations under various Model Theoretic assumptions. (Received February 06, 2017)

1127-03-322 **Erin Caulfield*** (ecaulfi2@illinois.edu), 1409 W. Green St., Urbana, IL 61801. *Classifying expansions of the real field by complex subgroups.*

We construct two classes of finite rank multiplicative subgroups of the complex numbers such that an expansion of the real field by one such group is model-theoretically well-behaved. As an application we show that a classification of expansions of the real field by cyclic multiplicative subgroups of the complex numbers due to Hieronymi does not even extend to expansions by subgroups with two generators. We also discuss some progress towards a new classification of expansions of the real field by finitely generated multiplicative subgroups of the complex numbers. (Received February 06, 2017)

1127-03-371 **Matthew Harrison-Trainor*** (matthew.h-t@berkeley.edu) and **Meng-Che "Turbo" Ho**. *Optimal Scott sentences of finitely generated groups.*

Every finitely generated structure has a Σ_3^0 Scott sentence. However most finitely generated groups have a simpler d-Σ_2^0 Scott sentence. I will talk about joint work with Meng-Che "Turbo" Ho where we constructed a finitely generated group whose optimal Scott sentence is Σ_3^0. Part of this work is a general characterization of the finitely generated structures with d-Σ_2^0 Scott sentences. (Received February 07, 2017)

1127-03-373 **Sylvia Carlisle*** (carlisle@rose-hulman.edu). *Non-Categoricity of Richly Branching Real-Trees.* Preliminary report.

An $\mathbb{R}$-tree is a metric space such that between any two points there is a unique geodesic segment. An $\mathbb{R}$-tree is richly branching if the set of points with at least 3 branches of a non-trivial length is dense. We consider bounded $\mathbb{R}$-trees as metric structures in an appropriate continuous signature. The theory rb$\mathbb{R}$T of richly branching $\mathbb{R}$-trees is the model companion of the theory of $\mathbb{R}$-trees. It is complete, has quantifier elimination, and is stable but not superstable. Here, we show that the theory rb$\mathbb{R}$T of bounded, richly branching $\mathbb{R}$-trees has the maximum possible number of non-isomorphic (and non-homeomorphic) models, namely, 2^κ models for any infinite cardinal κ. (Received February 07, 2017)

1127-03-378 **Nadja Hempel*** (nadja@math.ucla.edu), Department of Mathematics, University of California, Los Angeles, CA 90095-1555, and **Daniel Palacin**. *Division rings with ranks.*

In this talk we analyze division rings which admit a well-behaved ordinal valued rank function on definable sets that behaves like a rudimentary notion of dimension. These are called superrosy division rings. Examples are the quaternions, any superstable division ring (which are known to be algebraically closed fields by a theorem of Macintyre/Cherlin-Shelah) and more generally supersimple division rings (which are commutative by a result of Pillay, Scanlon and Wagner). We show that any superrosy division ring has finite dimension over its center, generalizing the aforementioned results. This is a joint work with Daniel Palacin. (Received February 07, 2017)

1127-03-382 **David Sprunger***, 2102 W Vernal Pike, Bloomington, IN 47404. *Behavioural equivlance in coalgebras of finitary functors.* Preliminary report.

Behavioural equivalence is a fundamental notion in the theory of coalgebras expressing when two states in a coalgebra have the same behaviour. This notion can be used, for example, in determining the minimization of various kinds of automata. Often times behavioural equivalence coincides with bisimilarity, most famously when the functor expressing the system type for the coalgebra preserves weak pullbacks. In this talk we present an alternative to bisimulation for coalgebras of finitary functors which coincide with behavioural equivalence even for functors which do not preserve weak pullbacks. Additionally we present an axiomatization of this notion which is sound and complete. Joint work with Larry Moss. (Received February 07, 2017)

1127-03-389 **Mike Haskel*** (mike.haskel@gmail.com) and **Anand Pillay**. *Stability in hyperdefinable sets.* Preliminary report.

In this talk, I will discuss topics surrounding stability theory in hyperdefinable sets. A hyperdefinable set is a $\star$-definable set, considered modulo a type-definable equivalence relation. The primary goal of the talk is to serve as a tutorial for how to adapt tools for local stability to this context.

Some aspects of the work are due to Anand Pillay. (Received February 07, 2017)

1127-03-394 **Siddharth Bhaskar*** (skbhaska@iu.edu). *A Survey of Approaches to Computability over Structures.* Preliminary report.

I will attempt to present a unified narrative surveying the basic approaches to and computability over structures. In particular, I will discuss programs and machine models of computation that operate over structure, and the various "computability classes" they induce. The existence or non-existence of a computable order pops up in a lot of this work, a curious phenomenon that I shall try to shed some light upon. (Received February 07, 2017)

1127-03-404 **Gregory Cousins*** (gcousins@nd.edu), 255 Hurley Hall, Notre Dame, IN 46556. *Ample Fields and Some Related Concepts in the Model Theory of Fields.* Preliminary report.

A field K is called ample, or large, if every every K-curve C with a smooth K-rational point has a Zariski dense set of points. In this talk, we discuss some properties of ample fields and some of their model theory. We also discuss the notion of "almost quantifier elimination" and its relation to ampleness. (Received February 07, 2017)

1127-03-405 **Noah Schweber*** (schweber@wisc.edu). *Measures of complexity in computable structure theory.*

I will discuss some results in computable structure theory. The main theme of this talk will be the {*dividing lines*} *these results indicate; for example, that counterexamples to Vaught's conjecture can be characterized in terms of the Muchnik degrees of their models (this is due to Montalban), and also in terms of the* {uniform} degree structures associated to them (this characterization is new). Another point of focus will be how we can apply ideas from computability theory to uncountable structures, both directly and as a tool for studying countable structures. (Received February 07, 2017)

05 ▶ Combinatorics

1127-05-44 **Drew J. Lipman*** (djlipma@clemson.edu) and **Michael Burr**. *Quadratic Generated Normal Domains from Graphs.*

Determining whether an arbitrary subring R of $k[x_1^{\pm 1},\dots,x_n^{\pm 1}]$ is a normal domain is, in general, a nontrivial problem, even in the special case of a monomial generated domain. In this talk, we consider the case where R is a quadratic-monomial generated domain. For the ring R, we consider the combinatorial structure that assigns an edge in a mixed directed signed graph to each monomial of the ring. We then use this relationship to provide a combinatorial characterization of the normality of R, and, when R is not normal, we use the combinatorial characterization to compute the normalization of R. Time permitting, we will discuss determining when the ring satisfies Serre's R_1 condition. All important concepts will be defined. (Received January 10, 2017)

1127-05-55 **Bruce E. Sagan***, Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Descent and peak polynomials.*

A permutation $\pi = \pi_1 \dots \pi_n$ in the summetric group $\mathfrak{S}_n$ has *descent set* $\operatorname{Des}\pi = \{i \mid \pi_i > \pi_{i+1}\}$. Given a set S of positive integers and $n > \max S$, the *descent polynomial* of S is the cardinality $d(S;n) = \#\{\pi \in \mathfrak{S}_n \mid \operatorname{Des}\pi = S\}$. It is easy to prove, using the Principle of Inclusion and Exclusion, that this is a polynomial in n. However, properties of this polynomail do not seem to have been studied much in the literature. The *peak set* of π is $\operatorname{Pea}\pi = \{i \mid \pi_{i-1} < \pi_i > \pi_{i+1}\}$. Recently Billey, Burdzy, and Sagan proved that $\#\{\pi \in \mathfrak{S}_n \mid \operatorname{Pea}\pi = S\} = p(S;n) \cdot 2^{n-\#S-1}$ where $p(S;n)$ is a polynomial in n which they dubbed the *peak polynomial* of S. These polynomials have since received the attention of a number of researchers. In this talk we will compare and contrast these two polynomials talking about their degrees, coefficients when expanded in the basis of binomial coefficients, roots, and analogues in other Coxeter groups. (Received January 13, 2017)

1127-05-64 **Colin D Cooper**, London, United Kingdom, **Alan Frieze*** (alan@random.math.cmu.edu), Pittsburgh, PA 15213, and **Alan M Frieze**. *Minors of a random binary matroid.* Preliminary report.

Let $\mathbf{A} = \mathbf{A}_{n,m,k}$ be a random $n \times m$ matrix over $\mathbf{GF}_2$ where each column consists of k randomly chosen ones. Let M be an arbitrary fixed binary matroid. We show that if m/n and k are sufficiently large then as $n \to \infty$ the binary matroid induced by $\mathbf{A}$ contains M as a minor. (Received January 18, 2017)

1127-05-76 **Charles Buehrle*** (cbuehrle@ndm.edu), Notre Dame of Maryland University, Department of Mathematics, 4701 N. Charles St., Baltimore, PA 21210. *Pancake Words.* Preliminary report.

The pancake problem is concerned with sorting a permutation (a stack of pancakes of different diameter) using only prefix reversals (spatula flips). Although the problem description belies simplicity, an exact formula for the maximum number of flips needed to sort n pancakes has been elusive.

Here we present a different approach to the pancake problem, as a word problem on the symmetric group. Pancake flips are considered as generators for a presentation of the symmetric group. At present the full list of relations for this presentation are not known. Many relations are exposed, though, by looking at what would be the Coxeter matrix of the generators. (Received January 22, 2017)

1127-05-79 **Patrick Bennett**, **Louis DeBiasio**, **Andrzej Dudek** and **Sean English*** (sean.j.english@wmich.edu). *Large Monochromatic Components in Sparse Random Hypergraphs.*

It is known, due to Gyárfás and Füredi, that for any r-coloring of the edges of K_n, there is a monochromatic component of order $(1/(r-1)+o(1))n$. They also showed that this is best possible if $r-1$ is a prime power. Recently, Dudek and Prałat showed that the binomial random graph $\mathcal{G}(n,p)$ behaves very similarly with respect to the size of the largest monochromatic component. More precisely, it was shown that a.a.s. for any r-coloring of the edges of $\mathcal{G}(n,p)$ and arbitrarily small constant $\alpha > 0$, there is a monochromatic component of order $(1/(r-1)-\alpha)n$, provided that $pn \to \infty$. As before, this result is clearly best possible.

In this talk we present a generalization of this result to hypergraphs. Specifically we show that in the k-uniform random hypergraph, $\mathcal{H}^{(k)}(n,p)$ a.a.s. for any k-coloring of the edges, there is a monochromatic component of order $(1-\alpha)n$ and for any $k+1$ coloring, there is a monochromatic component of order $(1-\alpha)\frac{k}{k+1}n$. (Received January 23, 2017)

1127-05-96 **Lauren Keough*** (keoulaur@gvsu.edu) and **Darren Parker**. *An Extremal Question for the Lights Out Game.* Preliminary report.

The original lights out game is played on a $n \times n$ grid in which some vertices are "on" at the start of the game. When you toggle a vertex that vertex and all of its neighbor switch their on/off status. This game has been generalized in several ways including playing the game on general graphs and playing the colored version in which the labels come from $\mathbb{Z}_k$. In the colored version of the game toggling a vertex means that vertex and all adjacent vertices have their labels increased by 1 modulo k.

We say a graph is always winnable if for any initial labeling there exists a sequence of togglings that terminate with all vertices having the label 0. Clearly the complete graph on n vertices is not always winnable. We seek the maximum number of edges a graph on n vertices can have and be always winnable. We'll answer this question in some cases using linear algebra techniques. (Received January 26, 2017)

1127-05-106 **David E Speyer*** (speyer@umich.edu), 530 Church Street, Ann Arbor, MI 48109-1043, and **John Wiltshire-Gordon**. *The reduced quiver of the category of finite sets.* Preliminary report.

Representation stability is now often understood through the representation theory of the category FI, finite sets with injections. Sam and Snowden showed that this is equivalent to the representations of the quiver with relations which has a vertex for every partition, an edge for adding a box, and the relations that any two paths between partitions λ and μ are equal to each other, and equal to zero if $\mu \setminus \lambda$ is not a horizontal strip. Recent progress has also made use of the category of all maps of finite sets. I will describe work in progress with John Wiltshire-Gordon, attempting to give a similar quiver description of the category of finite sets. (Received January 26, 2017)

1127-05-107 **David E Speyer*** (speyer@umich.edu), 530 Church Street, Ann Arbor, MI 48109-1043, and **Robert Kleinberg** and **Will Sawin**. *Large colored sum-free sets meeting the Ellenberg and Gijswijt upper bounds.*

Let A be an abelian group. A colored sum-free set in A is a list (a_1,b_1,c_1), (a_2,b_2,c_2), $\ldots$, (a_N,b_N,c_N) of triples of elements of A such that $a_i+b_j+c_k=0$ if and only if $i=j=k$. Extremal combinatorialists aim to construct large colored sum-free sets, both because it is fun and because it has applications in the construction of fast matrix multiplication algorithms. Until May of 2016, the best upper bounds on colored sum-free sets were of the form $A^(1-o(1))$. Then Ellenberg and Gijswijt, building on work of Croot, Lev and Pach, proved bounds on colored sum-free sets in $(\mathbb{Z}/p\mathbb{Z})^k$ of the form p^{ck} for $c<1$. We will present probabilistic constructions of sum-free sets of size $p^{(c-o(1))k}$, for the same c as in the Ellenberg-Gisjwijt bounds. (Received January 26, 2017)

1127-05-118 **Nir Gadish*** (nirg@uchicago.edu), 552 W. Aldine Ave. #1N, Chicago, IL 60657. *Categories of FI-type: a combinatorial structure underlying rep. stability.*

Following Church-Ellenberg-Farb's description of FI-modules and their representation stability, several generalizations were proposed by Wilson, Sam-Snowden, Gan-Li and others. The different examples share some combinatorial structure, which turns out to be sufficient for proving general representation stability results. This talk outlines a unifying approach to generalizing representation stability, via the theory of modules over so called 'categories of FI-type': we will see how simple combinatorial structures give rise to character polynomials with stabilizing inner products. (Received January 28, 2017)

1127-05-127 **Daniel Cranston*** (dcranston@vcu.edu) and **Landon Rabern**. *List-coloring Claw-free Graphs with $\Delta - 1$ Colors.*

For a graph G, let Δ, ω, χ, and χ_ℓ denote the maximum degree, clique number, chromatic number, and list chromatic number. In 1977, Borodin and Kostochka conjectured that if $\Delta \geq 9$ and $\omega \leq \Delta - 1$, then $\chi \leq \Delta - 1$. This is best possible in two ways. They also conjectured (unpublished) the same bound for the list-chromatic number, χ_ℓ. For claw-free graphs with $\Delta \geq 69$, we prove this list-coloring version of their conjecture. Our proof relies on both the Alon–Tarsi Theorem and the Kernel Method, as well as a Claw-free Structure Theorem, of Chudnovsky and Seymour. This is joint work with Landon Rabern (Franklin & Marshall). (Received January 30, 2017)

1127-05-135 **Benjamin Braun*** (benjamin.braun@uky.edu), **Robert Davis** and **Liam Solus**. *Detecting the Integer Decomposition Property and Ehrhart Unimodality in Reflexive Simplices.* Preliminary report.

The Ehrhart series of a lattice polytope P is a rational function encoding the number of lattice points in nonnegative integer scalings of P. The numerator of this series is the (Ehrhart) h^*-polynomial of P. An active topic of research is to characterize those polytopes for which the distribution of the coefficients of the h^*-polynomial is unimodal. A wide-open conjecture claims that all Gorenstein polytopes with the integer decomposition property (IDP) have unimodal h^*-polynomials. It is worthwhile to investigate the validity of this conjecture in the special case of reflexive simplices. The collection of reflexive simplices admits a classification in terms of arithmetic sequences. In this paper, we use this arithmetic classification to recast the open conjecture in the language of number theory. We first provide a number theoretic characterization of the h^*-polynomials and IDP for a subfamily of reflexive simplices. We develop a systematic framework by which to study this problem and validate the conjecture for families of reflexive simplices. We see there exist simplices within these families that meet only a necessary (but not sufficient) condition for IDP that also have unimodal h^*-polynomials. (Received January 31, 2017)

1127-05-140 **Deepak Bal**, **Patrick Bennett**, **Xavier Pérez-Giménez*** (xperez@unl.edu) and **Paweł Prałat**. *Rainbow perfect matchings and Hamilton cycles in the random geometric graph.*

Given a graph on n vertices and an assignment of colors to the edges, a rainbow Hamilton cycle is a cycle of length n visiting each vertex once and with pairwise different colors on the edges. Rainbow perfect matchings are defined analogously. We claim that if we randomly color the edges of a random geometric graph with sufficiently many colors, then a.a.s. the graph contains a rainbow perfect matching (rainbow Hamilton cycle) if and only if the minimum degree is at least 1 (respectively, at least 2). More precisely, consider n points (i.e. vertices) chosen independently and uniformly at random from the unit d-dimensional cube for any fixed $d \geq 2$. Form a sequence of graphs on these n vertices by adding edges one by one between each possible pair of vertices. Edges are added in increasing order of lengths. Each time a new edge is added, it receives a random color chosen uniformly at random and with repetition from a set of $\lceil Kn \rceil$ colors, where $K = K(d)$ is a sufficiently large fixed constant. Then, a.a.s. the first graph in the sequence with minimum degree at least 1 must contain a rainbow perfect matching (for even n), and the first graph with minimum degree at least 2 must contain a rainbow Hamilton cycle. (Received January 31, 2017)

1127-05-144 **Heather Smith** and **Laszlo Szekely*** (szekely@math.sc.edu), Dept. Mathematics, LeConte College, University of South Carolina, Columbia, SC 29208, and **Hua Wang** and **Shuai Yuan**. *On different "Middle parts" of a tree.*

We determine the maximum distance between any two of the center, centroid, and subtree core among trees with a given order. Corresponding results are obtained for trees with given maximum degree and also for trees with given diameter. The problem of the maximum distance between the centroid and the subtree core among trees with given order and diameter becomes difficult. It can be solved in terms of the problem of minimizing the number of root-containing subtrees in a rooted tree of given order and height. While the latter problem remains unsolved, we provide a partial characterization of the extremal structure. (Received February 01, 2017)

1127-05-147 **Amin Bahmanian** and **Sadegheh Haghshenas***, shaghsh@ilstu.edu. *Decomposition of complete uniform hypergraphs into Berge m-cycles.* Preliminary report.

The necessary condition for the existence of a decomposition of a complete h-uniform hypergraph on n vertices into Hamilton Berge cycles is that n divides $\binom{n}{h}$. In 2014, Kühn and Osthus proved that for $h \geq 4$ and $n \geq 30$

this condition is also sufficient. In this talk, we will discuss decomposition of complete h-uniform hypergraph into Berge m-cycles for any integer m. (Received February 01, 2017)

1127-05-156 **Jessica McDonald*** (mcdonald@auburn.edu), Auburn, AL 36849, and **Gregory J Puleo**. *The list chromatic index of simple graphs whose odd cycles intersect in at most one edge.*

We study the class of simple graphs $\mathcal{G}^*$ for which every pair of distinct odd cycles intersect in at most one edge. We give a structural characterization of the graphs in $\mathcal{G}^*$ and prove that every $G \in \mathcal{G}^*$ satisfies the list-edge-coloring conjecture. When $\Delta(G) \geq 4$, we in fact prove a stronger result about kernel-perfect orientations in $L(G)$ which implies that G is $(m\Delta(G) : m)$-edge-choosable and $\Delta(G)$-edge-paintable for every $m \geq 1$. (Received February 01, 2017)

1127-05-172 **Jonathan Cutler**, **Jamie Radcliffe*** (jamie.radcliffe@unl.edu) and **Charles Tomlinson**. *The Friendship Paradox and Homomorphism Counting Inequalities.*

I will discuss a number of homomorphism counting inequalities that arise in connection with Feld's Friendship Paradox (that, on average, your friends have more friends than you do). There are connections to Sidorenko's Conjecture and to other extremal problems for homomorphism counts. (Received February 02, 2017)

1127-05-177 **Lara Pudwell***, Department of Mathematics and Statistics, 1900 Chapel Drive, Valparaiso, IN 46383, and **Rebecca Smith**. *Sorting with Pop Stacks.* Preliminary report.

A classic result in the area of permutation patterns is that a permutation is sortable after one pass through a stack if and only if it avoids the permutation pattern 231; there are Catalan-many such permutations of length n. A more complicated characterization exists for permutations that are sortable after two passes through a stack. In this talk, we consider analogous questions for pop stacks. Here, a pop stack is a last-in-first-out data structure where elements may be input into the stack one at a time, but when one element is output from the stack, the entire contents of the stack must be output together. A permutation is k-pop-stack-sortable if it can be sorted after at most k passes through a pop stack. In particular, we'll give a new way to enumerate 1-pop-stack-sortable permutations and also enumerate 2-pop-stack-sortable permutations by showing each class to be in bijection with special families of polyominos. (Received February 02, 2017)

1127-05-181 **Catherine Erbes*** (erbescc@hiram.edu), **Michael Ferrara**, **Ryan Martin** and **Paul Wenger**. *Stability of the Potential Function.*

The potential number of a graph H, denoted $\sigma(H, n)$, is the minimum even integer such that any graphic sequence of length n has a realization containing H as a subgraph. This is the degree-sequence analogue of the extremal number, $\mathrm{ex}(n, H)$. Inspired by Simonovits' classical result on the stability of the extremal function, we investigate a notion of stability for the potential number, called σ-stability. Unlike in Simonovits' result, we show that there are classes of graphs which are not σ-stable. We will give a sufficient condition for a graph to be σ-stable, and characterize the stability of those graphs H which have an induced subgraph of order $\alpha(H) + 1$ that contains exactly one edge. (Received February 02, 2017)

1127-05-190 **Tao Jiang*** (jiangt@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056, and **Jie Ma**. *Cycles of given lengths in hypergraphs.* Preliminary report.

In this talk, we introduce a new method for studying cycle lengths in hypergraphs in place of the well-known lemma of Bondy and Simonovits. The new method appears to be more versatile. Using this new method, we prove a conjecture of Verstraëte that for $r \geq 3$, every r-uniform hypergraph with average degree $\Omega(k^{r-1})$ contains Berge cycles of k consecutive lengths. In addition, we prove that every r-uniform linear hypergraph with average degree at least $\Omega(k)$ contains linear cycles of k consecutive lengths. Both results are tight up to multiplicative constants.

In both of these results, we have additional control on the lengths of the cycles, which allows us to obtain corresponding bounds on the Turán numbers of Berge cycles and the linear Turán numbers of linear cycles that improve on the previous best known bounds. (Received February 02, 2017)

1127-05-194 **Louis DeBiasio*** (debiasld@miamioh.edu) and **Paul McKenney** (mckennp2@miamioh.edu). *Infinite graph-Ramsey theory.*

Ramsey's theorem guarantees a monochromatic copy of any countably infinite graph G in any r-coloring of the edges of the complete graph $K_{\mathbb{N}}$. It is natural to wonder how large of a monochromatic copy of G we can find with respect to some measure – for instance, the (upper) density of the vertex set of G in $\mathbb{N}$. Unlike finite graph-Ramsey theory, where this question has been studied extensively, the infinite version has been mostly overlooked.

Erdős and Galvin proved that in every 2-coloring of $K_{\mathbb{N}}$, there exists a monochromatic path whose vertex set has upper density at least 2/3, but it is not possible to do better than 8/9. They also showed that there exists a monochromatic path P such that for infinitely many n, the set $\{1, 2, ..., n\}$ contains the first $\frac{n}{3+\sqrt{3}}$ vertices of P, but it is not possible to do better than $2n/3$. We improve both results, in the former case achieving an upper density at least 3/4 and in the latter case obtaining a tight bound of 2/3. Inspired by this, we consider infinite analogs of well-known finite results on directed paths, trees (connected subgraphs), and graphs of bounded maximum degree. (Received February 06, 2017)

1127-05-205 **Nathan Kaplan** and **Joel Brewster Lewis***, Vincent Hall, 206 Church St SE, Minneapolis, MN 55455, and **Alejandro H. Morales**. *Counting matrices with prescribed 0s by rank.* Preliminary report.

Given positive integers m, n, r and a subset S of the $m \times n$ rectangular grid, one may ask for the number of $m \times n$ matrices of rank r over a finite field having those entries indexed by S equal to 0. When the set S is the Ferrers diagram of a partition, Haglund showed that the answer to this question is nice: it is a polynomial in the size of the field closely related to the classical q-rook polynomials. On the other hand, when S is arbitrary, the answer can be more complicated: Stembridge showed that with $r = m = n = 7$ there is a set S related to the Fano plane for which the matrix count is not a polynomial in the field size.

In this talk, we'll discuss ongoing work on both sides of this dichotomy. We'll describe a larger family of diagrams (the Rothe or inversion diagrams of permutations) for which the enumeration is always polynomial. We'll also sketch a construction of diagrams for which we can prove that the enumeration is "as bad as possible" as a function of the field size. (Received February 03, 2017)

1127-05-211 **Louis DeBiasio** and **Robert Krueger***, kruegera@miamioh.edu, and **Dan Pritikin** and **Eli Thompson**. *Hamiltonicity in k-Partite Graphs.* Preliminary report.

Chen, Faudree, Gould, Jacobson, and Lesniak determined a minimum degree threshold for which a balanced k-partite graph has a Hamiltonian cycle, extending a result of Moon and Moser about Hamiltonian cycles in balanced bipartite graphs. However, when $k \geq 3$ a k-partite graph is not necessarily balanced. We determine some minimum degree thresholds for Hamiltonian cycles in 'not-too-unbalanced' k-partite graphs which are asymptotically tight. We use stability techniques to show that a graph obeying the degree conditions is either a robust expander, or else has a Hamiltonian cycle directly. (Received February 03, 2017)

1127-05-217 **Hoi Huu Nguyen***, 13169 E Crosset Hill dr, Pickerington, OH 43147. *Eigenvalue repulsion and eigenvector delocalization in adjacency matrices of random graphs.*

We will establish a repulsion estimate for the number of eigenvalues inside an extremely small interval for the adjacency matrix of random Erdos-Renyi graph. We will also show that with extremely high probability the eigenvectors cannot be localized along any direction. (Received February 04, 2017)

1127-05-220 **Cara Monical** (`cmonica2@illinois.edu`), 1409 W. Green Street, Urbana, IL 61801, **Neriman Tokcan** (`tokcan2@illinois.edu`), 1409. W. Green Street, Urbana, IL 61801, and **Alexander Yong*** (`ayong@illinois.edu`), 1409. W. Green Street, Urbana, IL 61801. *Newton Polytopes in Algebraic Combinatorics.*

A polynomial has *saturated Newton polytope* (SNP) if every lattice point of the convex hull of its exponent vectors corresponds to a monomial. While generically rare, it holds for Schur polynomials. We study the Newton polytopes and observe many instances of SNP for polynomials studied in Macdonald and Schubert polynomial theory. In particular, we introduce the *Schubitope* by explicit inequalities. This is a certain generalization of the permutahedron. We conjecture that for *Rothe diagrams* this is the Newton polytope of a Schubert polynomial whereas for *skyline diagrams* it is the Newton polytope of a key polynomial. We expect that the Schubitope has an Ehrhart polynomial with nonnegative coefficients. (Received February 04, 2017)

1127-05-221 **Brian Drake*** (`drakebr@gvsu.edu`), A-2-178 Mackinac Hall, 1 Campus Drive, Allendale, MI 49401. *Lattices of generalized Frobenius partitions.* Preliminary report.

Integer partitions have a natural generalization to two-rowed arrays called generalized Frobenius partitions or F-partitions. These were introduced by Andrews in 1982 and have been well studied from a number theoretic perspective. In this talk we show that F-partitions form an infinite family of lattices generalizing Young's lattice. Paths in these lattices correspond to generalizations of Young tableaux, and current work includes investigating formulae such an analogue of the hook length formula. (Received February 04, 2017)

1127-05-241 **Amy Grady** and **Svetlana Poznanović*** (spoznan@clemson.edu). *Mahonian - Stirling pairs of combinatorial statistics for labeled forests.*

Björner and Wachs defined a major index for labeled plane forests and showed that it has the same distribution as the number of inversions. This can be viewed as a generalization of the classical result for permutations. In this talk I will discuss a few other natural statistics on labeled forests. Specifically, I will introduce the notions of bottom-to-top maxima, cyclic bottom-to-top maxima, sorting index, and cycle minima. These statistics are such that the pairs (inv, Bt-max), (sor, Cyc), and (maj, Cbt-max) are equidistributed. Even though our results extend the result of Björner and Wachs and further generalize results for permutations, the picture is not complete and I will discuss some current work on how to improve this. (Received February 04, 2017)

1127-05-242 **Jeffery J Boats*** (boatsjj@udmercy.edu), Chair, UDM Dept. Math-CS, 4001 W. McNichols Road, Detroit, MI 48221-3038. *Expected Value for Routable Disjoint Paths Given Random Terminal Selections.*

The k-Disjoint Path Problem has been studied for a variety of graphs: determine k, the largest number which, for any starting vertices s_1,s_2,...,s_k and any corresponding ending vertices t_1,t_2,...,t_k in graph G, it can be guaranteed that vertex-disjoint paths can be routed, connecting the (s_i, t_i) pairs. The guarantee of k disjoint paths in a network guarantees faster communications by avoiding queuing. But often, more than k disjoint paths can be simultaneously routed, depending on the selection of the (s_i, t_i) pairs and properties of G.

This talk introduces the concept of the pansophy of a graph G – the expected value for the number of disjoint paths which can be simultaneously routed in G given random selections of (s_i, t_i) pairs. The object is to create a mechanism for evaluating the efficiency of algorithms which aim to route communications within a network without queuing. Care is taken is defining terms and discussing how they relate to algorithmic performance. The pansophies of several simple graphs are then combinatorially computed as demonstrations. (Received February 04, 2017)

1127-05-245 **Rafael S. González D'León*** (rafaeldleon@uky.edu), University of Kentucky, Lexington, KY 40506. *The γ-coefficients of the tree Eulerian polynomial.*

We consider the generating polynomial $\mathcal{T}_n(t)$ of the number of rooted trees on the set $\{1, 2, \ldots, n\}$ counted by the number of descending edges (a parent with a greater label than a child). This polynomial is an extension of the descent generating polynomial of the set of permutations of a totally ordered n-set, known as the Eulerian polynomial. We show how this extension shares some of the properties of the classical one. In particular it has palindromic coefficients and hence it can be expressed in the the basis $\left\{t^i(1+t)^{n-1-2i} \mid 0 \leq i \leq \lfloor \frac{n-1}{2} \rfloor\right\}$, known as the γ-basis. We show that $\mathcal{T}_n(t)$ has nonnegative γ-coefficients and we present various combinatorial interpretations for them. (Received February 05, 2017)

1127-05-247 **John Shareshian*** (shareshi@math.wustl.edu) and **Michelle L Wachs**. *Chromatic symmetric functions and regular semisimple Hessenberg varieties.*

A Hessenberg vector is a weakly increasing sequence $m = (m_1, \ldots, m_n)$ of integers satisfying $i \leq m_i \leq n$ for all i. The graph G_m has vertex set $[n]$, and an edge ij for each $1 \leq i < j \leq m_i$. Given an $n \times n$ complex matrix s, the Hessenberg variety $V(m, s)$ is the subvariety of the flag variety consisting of all full flags $0 < V_1 < \ldots < V_n = \mathbb{C}^n$ satisfying $sV_i \leq V_{m_i}$ for all i.

When the matrix s is regular semisimple, the cohomology of $V(m, s)$ admits an interesting representation of the symmetric group S_n. Brosnan and Chow proved a conjecture of Shareshian and Wachs, thus showing that (after tensoring with the sign character) the Frobenius characteristic of the given representation is (a refinement of) Stanley's chromatic symmetric function for G_m. (Another proof was given by Guay-Paquet.) This opens the door for a geometric attack on a conjecture of Stanley and Stembridge, which says that the chromatic symmetric function of G_m is a nonnegative integer combination of elementary symmetric functions. (Received February 05, 2017)

1127-05-251 **Mingfang Huang**, **Michael Santana*** (santanmi@gvsu.edu) and **Gexin Yu**. *Strong edge-coloring graphs with maximum degree four.* Preliminary report.

A strong edge-coloring of a graph is a coloring of the edges such that each color class forms an induced matching. In 1985, Erdős and Nešetřil conjectured that every graph with maximum degree Δ has a strong edge-coloring using at most $\frac{5}{4}\Delta^2$ if Δ is even, and at most $\frac{5}{4}\Delta^2 - \frac{1}{2}\Delta + \frac{1}{4}$ if Δ is odd. While this conjecture has been the impetus for a great deal of work in strong edge-colorings, only one nontrivial case (for graphs of maximum degree three) has been verified, due to Anderson, and independently, Horák, Qing, and Trotter. In 2006, Cranston showed that 22 colors suffice for graphs with maximum degree four. In this talk, we will present our recent work that shows 21 colors suffice, extending this to multigraphs with maximum degree four. (Received February 05, 2017)

1127-05-253 **John Shareshian*** (shareshi@math.wustl.edu) and **Michelle L Wachs** (wachs@math.miami.edu). *Identities involving Eulerian numbers and binomial coefficients.*

Chung, Graham and Knuth proved in several ways the identity

$$\sum_{m=1}^{r+s} \binom{r+s}{m} a_{m,r-1} = \sum_{m=1}^{r+s} \binom{r+s}{m} a_{m,s-1}, \tag{1}$$

where $a_{m,j}$ is the number of permutations in S_m with j descents. A q-analogue of this identity was proved by Chung-Graham and by Han-Lin-Zeng. We proved a symmetric function identity, which upon stable principal specialization becomes the q-analogue just mentioned.

I will discuss various aspects of our work, including a geometric proof of our identity, γ-positivity of certain polynomials, and some other identities involving Eulerian numbers and binomial coefficients. (Received February 05, 2017)

1127-05-255 **Neal Bushaw*** (neal@asu.edu), **Andrzej Czygrinow** and **Jangwon Yie**. *The Even Cycle Spectrum of Dense Graphs.*

Faudree, Gould, Jacobson and Magnant conjectured that any two connected graph with minimum degree at least d contains even cycles of at least $d-1$ different lengths; if the graph is non-bipartite, then it should also contain odd cycles of at least d different lengths. We prove a very strong form of this conjecture in the case of bipartite, dense graphs. This is joint work with Andrzej Czygrinow and Jangwon Yie. (Received February 05, 2017)

1127-05-258 **Erik Walsberg***, 606 E. Elm Street, Urbana, IL 61802. *Model-theoretically tame first order expansions of the ordered additive group of real numbers.*

We describe the consequences that model theoretic tameness assumptions on first order expansions of $(\mathbb{R}, <, +)$ have on the geometry and topology of definable subsets of $\mathbb{R}^n$. (Received February 05, 2017)

1127-05-260 **Laura Escobar*** (lescobar@illinois.edu), 1409 W. Green Street, Urbana, IL 61801, and **Oliver Pechenik**, **Bridget Eileen Tenner** and **Alexander Yong**. *Rhombic tilings and Bott-Samelson varieties.*

Elnitsky gave an elegant bijection between rhombic tilings of 2n-gons and commutation classes of reduced words in the symmetric group on n letters. We explain a natural connection between Elnitsky's and Magyar's construction of the Bott-Samelson resolution of Schubert varieties. This suggests using tilings to encapsulate Bott-Samelson data and indicates a geometric perspective on Elnitsky's combinatorics. We also extend this construction by assigning desingularizations to the zonotopal tilings considered by Tenner. (Received February 05, 2017)

1127-05-263 **Michael Ferrara**, **Bill Kay**, **Lucas Kramer** and **Ryan R. Martin*** (rymartin@iastate.edu), Department of Mathematics, 396 Carver Hall, 411 Morrill Road, Ames, IA 50010-2014, and **Ben Reiniger**, **Heather Smith** and **Eric Sullivan**. *The Saturation Number of Induced Subposets of the Boolean Lattice.*

Given a poset $\mathcal{P}$, a family $\mathcal{F}$ of points in the Boolean lattice is said to be $\mathcal{P}$-saturated if (1) $\mathcal{F}$ contains no copy of $\mathcal{P}$ as a subposet and (2) every strict superset of $\mathcal{F}$ contains a copy of $\mathcal{P}$ as a subposet. The maximum size of a $\mathcal{P}$-saturated subposet is denoted by $\mathrm{La}(n, \mathcal{P})$, which has been studied for a number of choices of $\mathcal{P}$.

Here, we are interested in $\mathrm{sat}(n, \mathcal{P})$, the size of the smallest family in $\mathcal{B}_n$ which is $\mathcal{P}$-saturated. This notion was introduced by Gerbner et al. (2013), and parallels the deep literature on the saturation function for graphs.

In particular, we introduce and study the concept of saturation for induced subposets. As opposed to induced saturation in graphs, the above definition of saturation for posets extends naturally to the induced setting. We give several exact results and a number of bounds on the induced saturation number for several small posets. We also use a transformation to the biclique cover problem to prove a logarithmic lower bound for a rich infinite family of target posets. (Received February 05, 2017)

1127-05-272 **Yue Cai** (ycai@math.tamu.edu), Texas A&M University, Department of Mathematics, College Station, TX 77843, **Richard Ehrenborg** (richard.ehrenborg@uky.edu), University of Kentucky, Department of Mathematics, Lexington, KY 40506, and **Margaret Readdy*** (margaret.readdy@uky.edu), University of Kentucky, Department of Mathematics, Lexington, KY 40506. *q-Stirling identities revisited.*

We give combinatorial proofs of q-Stirling identities using restricted growth words. This includes a poset theoretic proof of Carlitz's identity, a new proof of the q-Frobenius identity of Garsia and Remmel and of Ehrenborg's Hankel q-Stirling determinantal identity. We also develop a two parameter generalization to unify identities of Mercier and include a symmetric function version. (Received February 06, 2017)

1127-05-273 **Steve Butler*** (butler@iastate.edu). *Recovering permutations over a deletion channel.* Preliminary report.

A d-deletion channel $\mathcal{C}$ will take a sent message, remove up to d symbols, and then contract the resulting message before delivery. We consider the problem of finding a permutation σ acting on $[n]$ so that for any message M with n distinct symbols if $\mathcal{C}(M)$ and $\mathcal{C}(\sigma(M))$ collectively contain all n symbols, then M can be determined. Forbidden structures in σ are established in terms of existence of cycles in an auxiliary graph. We show for permutations which are sufficiently spreading, avoiding these structures is sufficient to be able to reconstruct. (Received February 05, 2017)

1127-05-276 **Bolor Turmunkh*** (turmunk2@illinois.edu), 3214 W Altgeld Street, unit 2, Chicago, IL 60647. *Nakajima's (q,t)-characters of Kirillov-Reshetikhin modules as quantum cluster variables.*

T-systems form mutation relations in certain cluster algebras. In this talk, we will show that Nakajima's t-deformed T-system of type A_r forms a quantum mutation relation in a quantum cluster algebra. (Received February 06, 2017)

1127-05-279 **Andrew Wagner*** (awagn011@uottawa.ca). *Stitched Together: Finding an Euler Tour in Triple Systems.*

An *Euler tour* in a hypergraph is a closed walk that traverses every edge exactly once. A *triple system* of order n and index λ, denoted $\mathrm{TS}(n, \lambda)$, is a 3-uniform hypergraph in which every pair of vertices lie together exactly λ edges.

In this talk, we will discuss the proof that all triple systems with at least two edges admit an Euler tour.

This presentation is based on joint work with Mateja Šajna. (Received February 06, 2017)

1127-05-285 **Anton Bernshteyn*** (bernsht2@illinois.edu) and **Alexandr Kostochka**. *Sharp Dirac's Theorem for DP-Critical Graphs.*

Correspondence coloring, or DP-coloring, is a generalization of list coloring introduced recently by Dvořák and Postle. The subject of this talk is a version of Dirac's theorem on the minimum number of edges in critical graphs in the framework of DP-colorings. A corollary of this result is a solution to the problem, posed by Kostochka and Stiebitz, of classifying list-critical graphs that satisfy Dirac's bound with equality. (Received February 06, 2017)

1127-05-294 **Hemanshu Kaul*** (kaul@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616, and **Jeffrey Mudrock**. *Criticality, List Color Function, and Chromatic-choosable Cartesian Products of Graphs.*

The list chromatic number of the Cartesian product of graphs is not well understood. The best result is by Borowiecki, Jendrol, Kral, & Miskuf (2006) who proved that the list chromatic number of the Cartesian product of two graphs can be bounded in terms of the list chromatic number and the coloring number of the factors, implying a bound exponential in the list chromatic number of the factors.

We show how the knowledge of the list color function (list coloring analogue of the chromatic polynomial) can be applied to list coloring of Cartesian products whose one factor is a strong k-chromatic choosable graph. We introduce the notion of strongly chromatic choosable graphs, that includes odd cycles, cliques, many more infinite families of graphs, and the join of a clique with any other such graph, as a strict generalization of the notion of strong critical graphs (Stiebitz, Tuza & Voigt, 2008). This leads to improved bounds on choosability of Cartesian product of certain large classes of graphs and to classes of chromatic-choosable Cartesian products of graphs. (Received February 06, 2017)

1127-05-302 **Michelle Delcourt*** (delcour2@illinois.edu), 1409 W Green St., Champaign, IL 61801. *Intersecting Families of Permutations.*

Enumerating families of combinatorial objects with given properties and describing the typical structure of these objects are fundamental problems in extremal combinatorics. In this talk, we will investigate intersecting families of discrete structures in various settings, determining their typical structure as the size of the underlying ground set tends to infinity. Our new approach outlines a general framework for a number of similar problems; in particular, we prove analogous results for hypergraphs, permutations, and vector spaces using the same technique. This is joint work with Jozsef Balogh, Shagnik Das, Hong Liu, and Maryam Sharifzadeh. (Received February 06, 2017)

1127-05-310 **Christin Bibby*** (cbibby2@uwo.ca). *Combinatorics and stability of arrangements.* Preliminary report.

We consider sequences of linear, toric, and elliptic arrangements when the cohomology of the complement is representation stable, and we study the combinatorics (intersection poset) as a key ingredient of the stability. Examples include arrangements arising from root systems, in which case the combinatorics can be described using labelled partitions. (Received February 06, 2017)

1127-05-312 **Csaba Biro***, Department of Mathematics, University of Louisville, and **E Bonnet**, **D Marx**, **T Miltzow** and **P Rzazewski**. *Coloring units disk graphs is probably quite hard.*

Many classical hard algorithmic problems on graphs, like coloring, clique number, or the Hamiltonian cycle problem can be sped up for planar graphs resulting in algorithms of time complexity $2^{O(\sqrt{n})}$. We study the coloring problem of unit disk intersection graphs, where the number of colors is part of the input. We conclude that, assuming the Exponential Time Hypothesis, no such speedup is possible. In fact we prove a series of lower bounds depending on further restrictions on the number of colors. Generalizations for other shapes and higher dimensions were also achieved. (Received February 06, 2017)

1127-05-316 **Csaba Biro***, Department of Mathematics, University of Louisville, and **Aaron Hill**. *Random walk with varying step size.* Preliminary report.

A well-known classical theorem of Polya states that one- and two-dimensional symmetric random walks are recurrent, while in larger dimension, they are transient. We study a different type of random walk, in which the step size may change with certain probability determined by a sequence. Our main result shows that the recurrence of the walk exhibits a phase transition type behavior. (Received February 06, 2017)

1127-05-319 **Michael Anastos*** (manastos@andrew.cmu.edu), Carnegie Mellon University, Wean Hall 6113, 5000 Forbes Avenue, Pittsburgh, PA 15213. *Coloring directed Hamilton cycles online.*

Consider a directed analogue of the random graph process on n vertices, whereby the $m = n(n-1)$ directed edges are ordered uniformly at random and revealed one at a time, giving a nested sequence of directed graphs $D_0, D_1, ..., D_m$. Let T_q be the smallest index such that every vertex in D_{T_q} has both in-degree and out-degree at least q. It is known that w.h.p. D_{T_q} is the first digraph of the process that has q edge-disjoint Hamilton cycles and hence a $[q]$ edge coloring that yields a Hamilton cycle in each color. We show that this coloring can be constructed online. That is, consider an online coloring process in which each newly appearing edge of D_i is colored irrevocably with one of q colors. We present a randomized coloring algorithm yielding a Hamilton cycle in D_T in all q colors. Joint work with Joseph Briggs. (Received February 06, 2017)

1127-05-324 **Daniel Johnston**, **Mark Kayll** and **Cory Palmer*** (cory.palmer@umontana.edu). *Deranged Matchings.* Preliminary report.

The number of derangements of an n-element set can be realized as the number of perfect matchings in a complete bipartite graph $K_{n,n}$ with a perfect matching removed. For large n, this value is approximately $n!/e$. A related problem is the number of perfect matchings in the complete graph K_{2n} with a perfect matching removed. For large n, this value is approximately $(2n-1)!!/\sqrt{e}$. In this talk we discuss a common generalization of these parameters by investigating the number of perfect matchings in certain k-partite graphs. (Received February 06, 2017)

1127-05-327 **Zdeněk Dvořák** and **Bernard Lidický*** (lidicky@iastate.edu). *Independent sets near the lower bound in bounded degree graphs.*

By Brook's Theorem, every n-vertex graph of maximum degree at most $\Delta \geq 3$ and clique number at most Δ is Δ-colorable, and thus it has an independent set of size at least n/Δ. We give an approximate characterization of graphs with independence number close to this bound, and use it to show that the problem of deciding whether such a graph has an indepdendent set of size at least $n/\Delta + k$ has a kernel of size $O(k)$. (Received February 06, 2017)

1127-05-334 **Richard Ehrenborg*** (richard.ehrenborg@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506, and **Dustin Hedmark** (dustin.hedmark@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *On filters of the partition lattice.*

For a filter F of integer compositions of n, we construct the filter $\Pi^*(F)$ of the partition lattice Π_n. We obtain the homology groups for the associated order complex $\Delta(\Pi^*(F))$. Our results extend work of Calderbank, Hanlon and Robinson, and Wachs on the d-divisible partition lattice and work by Ehrenborg and Jung. Our main theorem applies to a plethora of examples, including filters associated to integer knapsack partitions and filters generated by all partitions having block sizes a or b. We also obtain the reduced homology groups of the filter generated by all partitions having block sizes belonging to the arithmetic progression $a, a+d, \ldots, a+(a-1)\cdot d$, extending work of Browdy. (Received February 06, 2017)

1127-05-337 **Hao Huang*** (hao.huang@emory.edu), Atlanta, GA 30322, and **Noga Alon** and **Tom Bohman**. *Biclique partition number of random graphs.*

The biclique partition number $bp(G)$ is the minimum number of complete bipartite graphs needed to partition the edges of a graph G. It is not hard to see that $bp(G) \leq n - \alpha(G)$, where $\alpha(G)$ is the independence number. Erdős conjectured that for the random graph $G = G(n, 0.5)$, $bp(G) = n - \alpha(G)$ with high probability. In this talk I will discuss some recent progress and and remaining challenges in this area, and show that actually there exists an absolute constant $c > 0$ such that for $G = G(n, 0.5)$, $bp(G) \leq n - (1+c)\alpha(G)$ with high probability. This is joint work with Noga Alon and Tom Bohman. (Received February 06, 2017)

1127-05-342 **Kevin Milans*** (milans@math.wvu.edu) and **Michael Wigal**. *Online coloring blowups of a known graph.* Preliminary report.

In the *G-coloring game of width w*, both G and w are known to the two players, who alternate turns. First, Spoiler places a new token at a vertex in G, and Algorithm responds by assigning a color to the new token. Algorithm must ensure that tokens on the same or adjacent vertices receive distinct colors. Spoiler must ensure that the token conflict graph (in which two tokens are adjacent if and only if their distance in G is at most 1) has chromatic number at most w. Algorithm wants to minimize the number of colors used, and Spoiler wants to force as many colors as possible. The *value* of the G-coloring game of width w, denoted $f_G(w)$, is the minimum number of colors needed in an optimal Algorithm strategy.

A graph G is *online-perfect* if $f_G(w) = w$. We give a forbidden induced subgraph characterization of the class of online-perfect graphs. When G is not online-perfect, determining $f_G(w)$ seems challenging; we establish $f_G(w)$ asymptotically for some (but not all) of the minimal graphs that are not online-perfect. The game is motivated by a natural online coloring problem on the real line which remains wide open. (Received February 06, 2017)

1127-05-348 **Karen Gunderson*** (karen.gunderson@umanitoba.ca), Department of Mathematics, University of Manitoba, 186 Dysart Road, Winnipeg, MB R3T 2N2, Canada. *Small percolating sets in bootstrap percolation.*

The r-neighbour bootstrap process is an update rule for the states of vertices in a graph where 'uninfected' vertices with at least r 'infected' neighbours become infected and a set of initially infected vertices is said to percolate if eventually all vertices are infected. While the focus is often on whether a randomly chosen set percolates, one can ask for the minimum size of a percolating set for a graph in such a process and which graph properties guarantee the existence of small percolating sets. I will present a new sharp result on minimum-degree conditions that guarantee small percolating sets. (Received February 06, 2017)

1127-05-351 **Jordan Almeter**, **Samet Demircan**, **Andrew Kallmeyer**, **Kevin G Milans*** (milans@math.wvu.edu) and **Robert Winslow**. *Graph 2-rankings.*

A *2-ranking* of a graph G is a proper coloring $f : V(G) \to [t]$ such that for each path uvw in G, either u and w have distinct colors or $f(v) > f(u) = f(w)$. A 2-ranking is intermediate in strength between a star coloring and a distance-2 coloring. The *2-ranking number of G*, denoted $\chi_2(G)$, is the minimum number of colors needed for a 2-ranking. A classical error-correcting code argument gives an optimal distance-2 coloring of the d-dimensional cube Q_d when d is one less than a power of two. We extend the argument to obtain $\chi_2'(Q_d) = d+1$ for all d.

The *edge 2-ranking number* of a graph G, denoted $\chi_2'(G)$, is the 2-ranking number of the line graph of G. It is also the least integer t such that the edges of G can be partitioned into matchings $M_1, \ldots, M_t$ such that M_k is an induced matching in the subgraph of G with edge set $\bigcup_{j \in [k]} M_j$. What is the edge 2-ranking number of $K_{m,n}$? We obtain an asymptotic result when m is fixed and $n \to \infty$. For the diagonal case, we show only that $\Omega(n \log n) \leq \chi_2'(K_{n,n}) \leq O(n^{\log_2 3})$. (Received February 07, 2017)

1127-05-360 **Deepak Bal*** (deepak.bal@montclair.edu), 1 Normal Ave., Montclair, NJ 07043, and **Patrick Bennett**. *Improved analysis of the Karp-Sipser algorithm on random graphs with a prescribed degree sequence.*

We analyze the performance of the Karp-Sipser matching algorithm on a graph chosen uniformly at random from the set of graphs having a prescribed degree sequence. We extend and improve a result of Bohman and Frieze, who showed that with high probability the algorithm outputs an almost perfect matching (i.e. a matching that saturates $n - o(n)$ vertices) when the degree sequence is log-concave. In particular, we improve the $o(n)$ term and prove that a more general condition on the degree sequence guarantees that the algorithm outputs an almost perfect matching with high probability. Our result applies to degree sequences that are 'very far' from being log-concave. (Received February 07, 2017)

1127-05-367 **Paul Horn**, **Pfender Florian*** (florian.pfender@ucdenver.edu) and **Michael Tait**. *Clique Degrees in Random Graphs.* Preliminary report.

One of the first theorems one may learn in graph theory is that every graph on at least two vertices contains two vertices of equal degrees. One can define the K_r-degree of a vertex as the number of K_rs that vertex lies in. Inspired by the previous theorem, we ask if a similar statement is true for K_r-degrees.

The answer is no, finding a graph with all different K_r-degrees is an interesting exercise. But is this outcome typical? To this end, we study the question for random graphs. (Received February 07, 2017)

1127-05-370 **Dustin G Hedmark*** (dustin.hedmark@gmail.com), 221 Loch Lomond Drive, Lexington, KY 40517. *Box Polynomials.*

We define the Box polynomial, $B_{m,n}(x)$, as the sum of $\prod_i (x + \lambda_i)$ over all partitions λ that fit in the m by n grid. We give interesting properties of the coefficients of of $B_{m,n}$ and also give properties of its roots, including asymptotics. This is joint work with Richard Ehrenborg and Cyrus Hettle, both of the University of Kentucky. (Received February 07, 2017)

1127-05-372 **Jeremy F Alm*** (alm.academic@gmail.com), Jacksonville, IL 62650, and **Keenan M L Mack**. *Robustness and vulnerability in correlated power-law networks.*

Many naturally occurring networks have a power-law degree distribution as well as a non-zero degree correlation. Despite this, most studies analyzing the robustness to random node-deletion and vulnerability to targeted node-deletion have concentrated only on power-law degree distribution and ignored degree correlation. In this talk, we consider the effect that degree-correlation has on robustness and vulnerability in scale-free networks. We found that networks with positive degree-correlation are more vulnerable to random node-deletion than to targeted deletion methods that utilize knowledge of initial node-degree only. Targeted deletion sufficiently alters the topology of the network to render this method less effective than uniform random methods unless changes in topology are accounted for. (Received February 07, 2017)

1127-05-374 **Russ Woodroofe*** (rwoodroofe@math.msstate.edu). *Arrangements and the independence polynomial.* Preliminary report.

I'll show how to construct a subspace arrangement which encodes the independence polynomial of a graph G. I'll discuss possible applications to unimodality questions. (Received February 07, 2017)

1127-05-375 **Yuliang Ji**, **Jie Ma**, **Juan Yan** and **Xingxing Yu***, School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *On judicious bipartitions of graphs.*

Bollobás and Scott conjectured that every graph G has a balanced bipartite spanning subgraph H such that for each $v \in V(G)$, $d_H(v) \geq (d_G(v) - 1)/2$. In this paper, we show that every graphic sequence has a realization for which this Bollobás-Scott conjecture holds, confirming a conjecture of Hartke and Seacrest. On the other hand, we use an infinite family of graphs to illustrate that $\lfloor (d_G(v) - 1)/2 \rfloor$ (rather than $(d_G(v) - 1)/2$) may have been the intended lower bound by Bollobás and Scott. We also study bipartitions V_1, V_2 of graphs with a fixed number of edges. We provide a (best possible) upper bound on $e(V_1)^\lambda + e(V_2)^\lambda$ for any real $\lambda \geq 1$ (the case $\lambda = 2$ is a question of Scott) and answer a question of Scott on $\max\{e(V_1), e(V_2)\}$. (Received February 07, 2017)

1127-05-383 **Arthur L. Gershon*** (arthur.gershon@case.edu). *Counting StArrs: Enumerating the Number of Aligned Strip Arrangements on Rectangular Regions in the Square Lattice.*

We generalize the classical problem of counting the number of ways to place non-overlapping 1×2 strips (commonly called *dominoes* or *dimers*) on rectangular regions in the square lattice, or *chessboards.* We consider instead placements of $1 \times k$ strips of any positive integer length k, and we also take into account how the strips are aligned within the chessboard. These generalized arrangements are what we call *aligned strip arrangements, or aligned StArrs.* StArrs correspond to models of bonds among particles, and thus their study (and enumeration) is of a broad scientific interest. Using the transfer matrix method, we prove a general formula allowing one to compute generating functions for various aligned StArr families on chessboards of fixed width. We apply this general method to StArrs that are *restricted* to at most one horizontal strip in each row and at most one vertical strip in each column. Such StArrs correspond to eight-vertex models of statistical physics, and are therefore of particular interest. The structure of the transfer matrices in this case allows us to compute not only generating functions for certain widths, but corresponding exact formulas, and hence an asymptotic formula for all fixed widths. (Received February 07, 2017)

1127-05-393 **Yong-Yeol Ahn*** (yyahn@iu.edu), 919 E 10th Street, Bloomington, IN 47408, **James P Bagrow** (james.bagrow@uvm.edu), Farrell Hall, room 212, University of Vermont, Burlington, VT 05405, **Sune Lehmann** (slj@imm.dtu.dk), Technical University of Denmark Building 321, DK-2800 Kgs., Lyngby, Denmark, **Alexander Gates** (ajgates@umail.iu.edu), Indiana University, Bloomington, IN 47408, and **Ian Wood** (ibwood@umail.iu.edu), Bloomington, IN 47408. *Discovering and Comparing Clusters in Networks.*

Network, or graph, is a unifying framework to study many complex systems in nature. Theories and techniques developed for a network can be readily applied to other systems; Networks from completely different systems often share similar characteristics that allow transfer of insights from one system to another. One of such common characteristics is clustering. Networks tend to exhibit dense subgraphs that correspond to important structural and functional units. Thus, discovering and understanding such clusters is a crucial step in network analysis. In this talk, I will first discuss distinguishing aspects of network clustering and introduce a method for discovering strongly overlapping clusters in networks. I will then explain general issues in comparing clusterings and introduce a new method to compare clusterings and reveal insights into clusterings. (Received February 07, 2017)

1127-05-399 **Po-Shen Loh*** (ploh@cmu.edu), **Michael Tait** and **Craig Timmons**. *Induced Turán numbers.*

The classical Kővári-Sós-Turán theorem states that if G is an n-vertex graph with no copy of $K_{s,t}$ as a subgraph, then the number of edges in G is at most $O(n^{2-1/s})$. We prove that if one forbids $K_{s,t}$ as an *induced* subgraph, and also forbids *any* fixed graph H as a (not necessarily induced) subgraph, the same asymptotic upper bound still holds, with different constant factors. This introduces a nontrivial angle from which to generalize Turán theory to induced forbidden subgraphs, which this paper explores. Along the way, we derive a nontrivial upper bound on the number of cliques of fixed order in a K_r-free graph with no induced copy of $K_{s,t}$. This result is an induced analog of a recent theorem of Alon and Shikhelman and is of independent interest. (Received February 07, 2017)

1127-05-409 **Mihai Ciucu***, Department of Mathematics, Indiana University, 831 East 3rd St, Rawles Hall, Bloomington, IN 47405. *Title: Lozenge tilings with gaps in a 90 degree wedge domain with mixed boundary conditions.*

Abstract: We consider a triangular gap of side two in a 90 degree angle on the triangular lattice with mixed boundary conditions: a constrained, zig-zag boundary along one side, and a free lattice line boundary along the other. We study the interaction of the gap with the corner as the rest of the angle is completely filled with lozenges. We show that the resulting correlation is governed by the product of the distances between the gap and its three images in the sides of the angle. This provides evidence for a unified way of understanding the interaction of gaps with the boundary under mixed boundary conditions, which we present as a conjecture. Our conjecture is phrased in terms of the steady state heat flow problem in a uniform block of material in which there are a finite number of heat sources and sinks. This new physical analogy is equivalent in the bulk to the electrostatic analogy we developed in previous work, but arises as the correct one for the correlation with the boundary.

The starting point for our analysis is an exact formula we prove for the number of lozenge tilings of certain trapezoidal regions with mixed boundary conditions, which is equivalent to a new, multi-parameter generalization of a classical plane partition enumeration problem. (Received February 08, 2017)

1127-05-410 **Aba Mbirika**, Department of Mathematics, 105 Garfield Avenue, Eau Claire, WI 54701, and **Julianna Tymoczko***, Department of Mathematics and Statistics, Smith College, Northampton, MA 01063. *Representation stability of Springer fibers.*

Springer fibers are subvarieties of the flag variety parametrized by partitions. They arise naturally in geometric representation theory; their cohomology naturally carries the action of a symmetric group action called the Springer representation. We show that Springer representations are representation stable. More precisely, for any increasing sequence of Young diagrams, the corresponding Springer representations form a graded co-FI-module of finite type. (Received February 08, 2017)

11 ► Number theory

1127-11-246 **Karol Koziol***, 40 St. George Street, Toronto, Ontario M5S 2E4, Canada. *Projective dimensions of simple Iwahori-Hecke modules in characteristic p.*

A classical result of Bernstein implies that the category of smooth complex representations of a split p-adic reductive group has finite global dimension, and thus the associated complex Iwahori-Hecke algebra also has finite global dimension. In contrast, recent work of Ollivier-Schneider shows that the (pro-p-)Iwahori-Hecke $\mathbb{F}_p$-algebra of a split p-adic reductive group has infinite global dimension (at least generically). We will build on some of these results to give a classification of simple Hecke modules (in characteristic p) of finite projective dimension. (Received February 05, 2017)

1127-11-261 **Mojtaba Moniri*** (m-moniri@wiu.edu). *Approximate closed formulas for (the g-inverse of) binary lengths of a Wolfram sequence.*

For a sequence c of approximate multiplication by $\frac{3}{2}$, namely $x_{n+1} = \lfloor \frac{3}{2} x_n \rfloor$, with $x_1 = 2$, the binary lengths s of the terms of c and the generalized inverse $r(m) = \min\{k | s(k) \geq m\}$ of s are considered. We prove that if c is never a power of 2 beyond the third position, then r is Sturmian there $\lfloor \frac{m}{\log_2(\frac{3}{2})} + \gamma \rfloor - 1$ with its inhomogeneity γ expressible via an Odlyzko-Wilf constant. In any case we show that on a set of n's with density between 0.9027 to 0.9028, $r_m = \lfloor \frac{m}{\log_2(\frac{3}{2})} \rfloor - 1$ and on an exception set of density between 0.0972 to 0.0973, $r_m = \lfloor \frac{m}{\log_2(\frac{3}{2})} \rfloor$. For the sequence s itself, we show that on a set of n's with density between 0.8869 to 0.8870, $s_n = \lfloor n \log_2(\frac{3}{2}) \rfloor + 1$ and on an exception set of density between 0.1130 to 0.1131, $s_n = \lfloor n \log_2(\frac{3}{2}) \rfloor + 2$. A similar conditional closed formula is obtained for s in the style of the one for the sequence r. (Received February 05, 2017)

1127-11-265 **Florin P Boca*** (fboca@illinois.edu), Urbana, IL 61801, and **Maksym Radziwill** (maksym.radziwill@mcgill.ca), Montreal, Quebec H3A 0B9, Canada. *Moments and Distribution of Eigenvalues in Large Sieve Matrices.*

The classical large sieve inequality in number theory provides an upper bound estimate for the largest eigenvalue of the N by N matrix A^*A, where A is a Vandermonde type matrix defined by roots of unity of order at most Q (a.k.a. Farey fractions of order Q). This talk will discuss some aspects concerning the behavior of the eigenvalues of these matrices when $N \sim cQ^2$, with $Q \to \infty$ and $c > 0$ constant. In particular, we establish asymptotic formulas for their moments of all orders, proving as a corollary the existence of a limiting distribution as a function of c, and answering in the affirmative a problem of Olivier Ramaré. (Received February 05, 2017)

1127-11-275 **George Pappas** and **Haoran Wang*** (wanghaoran@math.msu.edu). *On the mod p cohomology of Lubin-Tate space.*

We calculate the action of pro-p-Iwahori-Hecke algebra on the mod p cohomology of Lubin-Tate space. We also discuss the relation with mod p local Langlands correspondence for $GL_2(F)$, where F is a finite extension of Q_p. (Received February 06, 2017)

1127-11-323 **Preston Wake*** (wake@math.ucla.edu), UCLA Mathematics Department, Box 951555, Los Angeles, CA 90095, and **Carl Wang Erickson**. *Pseudorepresentations, Massey products, and the Eisenstein ideal.* Preliminary report.

In his landmark 1976 paper "Modular curves and the Eisenstein ideal", Mazur studied congruences modulo p between cusp forms and an Eisenstein series of weight 2 and prime level N. He proved a great deal about these congruences, but also posed a number of questions: how big is the space of cusp forms that are congruent to the Eisenstein series? How big is the extension generated by their coefficients? In joint work with Carl Wang Erickson, we give an answer to these questions using the deformation theory of Galois pseudorepresentations. The answer is intimately related to the algebraic number theoretic interactions between the primes N and p, and is given in terms of cup products (and Massey products) in Galois cohomology. (Received February 06, 2017)

1127-11-333 **Lue Pan***, Fine Hall, Washington Road, Princeton, NJ 08540. *First covering of Drinfel'd upper half plane and Banach representations of* $\mathrm{GL}_2(\mathbb{Q}_p)$.

We construct some admissible Banach representations of $\mathrm{GL}_2(\mathbb{Q}_p)$ that conjecturally should correspond to some 2-dimensional tamely ramified, potentially Barsotti-Tate representations of $G_{\mathbb{Q}_p}$ via the p-adic local Langlands correspondence. To achieve this, we generalize Breuil's work in the semi-stable case and work on the first covering of Drinfel'd upper half plane. (Received February 06, 2017)

1127-11-341 **Bao V Le Hung*** (lhvietbao@gmail.com), 5734 S University Ave, Chicago, IL 60637, and **Daniel Le**, **Brandon Levin** and **Stefano Morra**. *Recent progress on Serre weight conjectures.* Preliminary report.

Abstract: I will discuss some recent results on Serre weight conjectures in dimension >2, based on the study of certain tame type deformation rings. This is joint work with (various subsets of) D. Le, B. Levin and S. Morra. (Received February 06, 2017)

1127-11-344 **Charlotte Chan*** (charchan@umich.edu), 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *Semi-infinite Deligne–Lusztig varieties and the unramified Jacquet–Langlands correspondence.*

In 1979, Lusztig proposed a conjectural analogue of Deligne–Lusztig varieties for p-adic groups G which we call "semi-infinite." These varieties carry commuting actions by G and an unramified maximal torus T. We show that when G is a division algebra, the homology of these infinite-dimensional varieties is very nicely behaved: the T-eigenspaces are concentrated in a single degree and give rise to irreducible supercuspidal G-representations when the T-action is sufficiently generic. This verifies Lusztig's conjecture in this setting, and along the way, we prove two conjectures of Boyarchenko in full generality. Finally, we use geometric trace formulas to prove that semi-infinite Deligne–Lusztig varieties induce a cohomological realization of the (unramified) Jacquet–Langlands correspondence. (Received February 06, 2017)

1127-11-388 **Trevor Hyde*** (tghyde@umich.edu), 609 Lawrence St Apt 4, Ann Arbor, MI 48104. *Polynomial Splitting Measures and the Cohomology of the Pure Braid Group.*

Let $\mathbb{F}_q$ be a finite field. If $f(x)$ is a monic, squarefree, degree n polynomial over $\mathbb{F}_q$, then the degrees of its irreducible factors partition n; we call this partition the *factorization type* of $f(x)$. For any given partition λ of n one may ask, for a random monic, squarefree, degree n polynomial over $\mathbb{F}_q$, what is the probability that $f(x)$ has factorization type λ? The answer for each λ is a Laurent polynomial of q called the q-splitting measure. We show that the coefficients of the q-splitting measure are given by characters of the symmetric group associated to certain S_n-submodules of the cohomology of the pure braid group.

This talk is based on joint work with Jeffrey C. Lagarias. (Received February 07, 2017)

13 ► Commutative rings and algebras

1127-13-14 **Sunil K Chebolu*** (schebol@ilstu.edu) and **Keir Lockridge**. *Recent Progress on Fuchs' Problem.*

More than 50 years ago, Laszlo Fuchs asked which abelian groups can be the group of units of a commutative ring. The problem can also be asked for various classes of nonabelian groups. Though progress has been made, the question remains open. We provide answer to this question in the case of indecomposable abelian groups, dihedral groups, and quaternion groups. Some of this work is based on papers arXiv:1505.03508 and arXiv:1607.00687 (Received November 06, 2016)

1127-13-74 **Laura Ghezzi*** (lghezzi@citytech.cuny.edu). *Invariants of Cohen-Macaulay rings associated to their canonical ideals.*

The purpose of this work (joint with Shiro Goto, Jooyoun Hong and Wolmer Vasconcelos) is to introduce new invariants of Cohen-Macaulay local rings. Our focus is the class of Cohen-Macaulay local rings that admit a canonical ideal. Attached to each such ring R with a canonical ideal C, there are integers–the type of R, the reduction number of C–that provide valuable metrics to express the deviation of R from being a Gorenstein ring. We enlarge this list with other integers–the roots of R and several canonical degrees. In this talk we will define and focus on the (basic) canonical degree. (Received January 22, 2017)

1127-13-155 **Chris Fraser***, chfraser@iupui.edu. *Braid group symmetries of Grassmannian cluster algebras.*

We define an action of the k-strand braid group on the set of cluster variables for the Grassmannian $\mathrm{Gr}(k,n)$, whenever k divides n. The action sends clusters to clusters, preserving the underlying quivers, defining a homomorphism from the braid group to the cluster modular group for $\mathrm{Gr}(k,n)$. Then we apply our results to the Grassmannian $\mathrm{Gr}(3,9)$. We prove the $n=9$ case of a conjecture of Fomin-Pylyavskyy describing the cluster combinatorics for $\mathrm{Gr}(3,n)$, in terms of Kuperberg's basis of non-elliptic webs. (Received February 01, 2017)

1127-13-158 **Hema Srinivasan*** (srinivasanh@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, **Sabine El Khoury** (se24@aub.edu.lb), Beirut, Lebanon, and **A V Jayanthan**, Chennai, India. *Inverse systems,Hilbert Function and μ - generic Artin Algebras.*

Suppose R is a polynomial ring in n variables and I is a homogeneous ideal of height n in R so that R/I is an Artin Algebra. Let $\mu(I)$ denote the minimum number of generators for I. If the Hilbert function of R/I is of the form $(1, n, \binom{n}{2} + 1, \ldots, 1 + \binom{n}{2}, n, 1)$ and further I_2, the ideal generated by the n quadratic generators of I has height 1, then we show that there is an upper bound for the number of generators of I in terms of n and a height $n-1$ Gorenstein ideal J contained in I. We say an ideal I is μ generic if $\mu(I)$ has this upper bound. We give some criterion when this is achieved and some consequences for the unimodality of Hilbert functions for a class of co-dimension three Artin algebras. (Received February 01, 2017)

1127-13-171 **Hiroki Matsui*** (m14037f@math.nagoya-u.ac.jp), Furo-cho, Chikusa-ku, Nagoya-shi, Aichi-ken 464-8061, Japan. *Balmer spectra of right bounded derived categories of commutative noetherian rings.*

This talk is based on joint work with Ryo Takahashi.

Let R be a commutative noetherian ring. Denote by $D^-(R)$ the derived category of cochain complexes X of finitely generated R-modules such that $H^i(X) = 0$ for $i >> 0$. Then this category $D^-(R)$ has the structure of tensor triangulated category by the derived tensor product $\otimes^L_R$. By this tensor triangulated structure, we can consider ideals of $D^-(R)$ (i.e., thick subcategory closed under action of $\otimes^L_R$).

First topic of my talk is classification of ideals of $D^-(R)$ which are generated by bounded complexes (we call these ideals “compact ideals”). To do this, we show and use the generalized version of Hopkins-Neeman's smash nilpotence theorem. Second topic is the structure of the Balmer spectrum $SpcD^-(R)$ which is the set of prime ideals of $D^-(R)$. We construct a pair of maps between the Balmer spectrum $SpcD^-(R)$ and the Zariski spectrum $SpecR$ and investigate their topological properties. If time permits, we give a counter example to the Balmer's conjecture, as an application of our classification theorem of ideals. (Received February 02, 2017)

1127-13-185 **Linquan Ma*** (lquanma@math.utah.edu), 155 S 1400 E, Salt Lake City, UT 84112, and **Karl Schwede** and **Kazuma Shimomoto**. *Deformation of F-injectivity.* Preliminary report.

A local ring is called F-injective if the natural Frobenius action on the local cohomology modules supported at the maximal ideal is injective. This is the (conjectured) characterisitic p>0 analog of Du Bois singularities in characteristic zero. A natural and interesting question asks whether F-injectivity deform, and this is supported by the fact that Du Bois singularities deform. In this talk we introduce and study a surjectivity condition on local cohomology, which is motivated by Du Bois singularities, and we use it to show that singularities of dense F-injecitive type deform. The talk is based on joint work with Karl Schwede and Kazuma Shimomoto. (Received February 02, 2017)

1127-13-257 **Sean Sather-Wagstaff*** (ssather@clemson.edu). *Derived categories and associated primes of derived local cohomology.* Preliminary report.

A fundamental idea in homological algebra is to consider a complex of R-modules as a single object to be acted on and studied as a whole, rather than as a combination of separate pieces. For instance, this allows one to study the modules $\mathrm{Ext}^i_R(M, N)$ by studying any of the complexes that give rise to these modules. In this talk, I will motivate and sketch the construction of the derived category, where much of this type of work takes place. I will also discuss a derived-category variant of a question of Huneke about the finiteness of the set of associated primes of local cohomology modules. (Received February 05, 2017)

1127-13-286 **Michael K Brown**, **Claudia Miller*** (clamille@syr.edu), **Peder Thompson** and **Mark E Walker**. *Adams operations for matrix factorizations and a conjecture of Dao and Kurano.*

Using an idea of Atiyah from 1966, we develop Adams operations on the Grothendieck groups of perfect complexes with support and of matrix factorizations using cyclic group actions on tensors powers. In the former setting, Gillet and Soule developed these using the Dold-Kan correspondence and used them to solve Serre's Vanishing Conjecture in mixed characteristic (also proved independently by P. Roberts using localized Chern characters). Their approach cannot be used in the setting of matrix factorizations, so we use Atiyah's approach, avoiding simplicial theory altogether.

As an application, we prove a conjecture of Dao and Kurano on the vanishing of Hochster's theta pairing for pairs of modules over an isolated hypersurface singularity in the remaining open case of mixed characteristic. Our proof is analogous to that of Gillet and Soule for the vanishing of Serre's intersection multiplicity. (Received February 06, 2017)

1127-13-293 **Olgur Celikbas** and **Greg Piepmeyer*** (pggreg@gmail.com). *Tensor products and Serre's condition.*

This talk examines recovery of Serre's (S_n) condition on the finitely generated factors of a tensor product from assumption of Serre's (S_n) condition on the tensor product. The setting is a complete intersection, and an assumption is that higher Tor modules between the factors vanish. This is the setting pioneered by Huneke and Wiegand, and extended by us a few years ago. Under these conditions, we improve the existing theorem to the point that reflexivity of the tensor product implies reflexivity of each factor, and similarly, torsionless tensor products imply each factor is torsionless. The work reexamines our earlier proof (which, for instance, only achieved reflexivity for one factor), and in fact, via an inductive argument recovers Serre's condition for each factor from Serre's condition on the tensor product. (Received February 06, 2017)

1127-13-296 **Ananthnarayan Hariharan*** (ananth@math.iitb.ac.in) and **Rajiv Kumar**. *Betti Tables of Modules over Standard Graded Rings.*

In this talk, we look at various aspects of Betti tables of modules over standard graded algebras over a field, and extend some results that are known over polynomial rings. In particular, we will see properties of modules with pure resolutions, and modules which span extremal rays, and see some applications. (Received February 06, 2017)

1127-13-358 **Oana Veliche*** (o.veliche@northeastern.edu), 360 Hungtington Avenue, Boston, MA 02115, and **Lars W. Christensen** and **Jerzy Weyman**. *Codepth 3 Artinian Algebras of Type Two.* Preliminary report.

A complete local ring (R, m, k) of embedding codepth 3 has a minimal free resolution of length 3 over a regular local ring Q. This resolution carries a differential graded algebra structure, which induces a unique graded-commutative algebra structure on the Tor algebra $\mathrm{Tor}_*^Q(R, k)$. The possible structures were identified by Weyman (1989) and by Avramov, Kustin, and Miller (1988). The talk, based on work in collaboration with L.W. Christensen and J. Weyman, will discuss the Tor algebra structures that can be realized by compressed, in particular generic, artinian local rings of type 2, and a question whether certain classes of perfect ideals of codepth 3 are licci. (Received February 07, 2017)

14 ► Algebraic geometry

1127-14-58 **Andrew Wilson Snowden*** (asnowden@umich.edu), 530 Church St, Math Department, Ann Arbor, MI 48109. *Topological noetherianity for cubic polynomials.*

I will talk about recent joint work with Harm Derksen and Rob Eggermont in which we show that the space $\mathrm{Sym}^3(\mathbf{C}^\infty)$ is topologically noetherian with respect to the action of GL_∞. This result is the first piece of progress towards showing that twisted commutative algebras generated in degrees greater than 2 are noetherian. It also has applications to certain uniformity problems in commutative algebra. (Received January 15, 2017)

1127-14-85 **Alexander Varchenko*** (anv@email.unc.edu). *Elliptic dynamical quantum group $E_{\tau,h}(gl_2)$ and elliptic equivariant cohomology of the cotangent bundles of Grassmannians.*

The torus T equivariant elliptic cohomology defines a functor $Ell_T : \{T-\text{spaces } X\} \to \{\text{schemes}\}$. For example, for the cotangent bundle of a Grassmannian the scheme $Ell_T(T^*Gr(k,n))$ is some explicitly given sub-scheme of $S^kE \times S^{n-k}E \times E^n \times E^2$ with coordinates $t_1, \dots, t_k, s_1, \dots, s_{n-k}, z_1, \dots, z_n, h, \lambda$, where t_i, s_j correspond to the Chern roots of the two standard vector bundles over the Grassmannian, z, y correspond to the torus parameters, λ is the dynamical parameter also called the Kähler parameter, and E is an elliptic curve.

I will define a class of line bundles on the scheme $\cup_{k=0}^n Ell_T(T^*Gr(k,n))$ such that the operator algebra of the elliptic dynamical quantum group $E_{\tau,h}(gl_2)$ will act on sections of those line bundles (a generator of the operator algebra will send a section of such a line bundle to a section of possibly another line bundle). That construction is an analog of the Yangian $Y(gl_2)$ action on the direct sum $\oplus_{k=0}^n H_T^*(T^*Gr(k,n))$ of equivariant cohomology.

This is a joint work with G.Felder and R.Rimanyi. (Received January 24, 2017)

1127-14-116 **Weiyan Chen*** (chen@math.uchicago.edu), Mathematics Department, University of Chicago, 5734 S. University Ave., Chicago, IL 60637. *Analytic Number Theory for 0-cycles.*

I will talk about some results about the asymptotic "prime factorization" of effective 0-cycles on varieties over finite fields, which were inspired by the work of Church-Ellenberg-Farb relating representation stability and arithmetic statistics. (Received February 07, 2017)

1127-14-167 **Gabino González-Diez*** (gabino.gonzalez@uam.es) and **Andrei Jaikin-Zapirain**. *The effect of Galois action on the topology of complex algebraic varieties.*

A combination of Hodge theory and Serre's GAGA principle implies that many topological invariants of complex projective varieties, such as Betti numbers and Chern classes, remain invariant under Galois action. Nevertheless, in 1964 Serre constructed examples of projective varieties X and Galois elements $\sigma \in Gal(\overline{\mathbb{Q}}/\mathbb{Q})$ such that X and its conjugate variety X^σ have non-isomorphic fundamental groups, and so they are not homeomorphic. Further particular instances of this phenomenon have been discovered since them. The result I would like to present is the following:

For every $\sigma \in Gal(\overline{\mathbb{Q}}/\mathbb{Q})$ different from the identity or the complex conjugation there is a complex surface S defined over a number field such that the fundamental groups $\pi_1(S)$ and $\pi_1(S^\sigma)$ are non-isomorphic (although their profinite completions $\pi_1^{alg}(S)$ and $\pi_1^{alg}(S^\sigma)$ are).

This is joint work with Andrei Jaikin-Zapirain. (Received February 02, 2017)

1127-14-268 **Rohini Ramadas*** (ramadas@umich.edu). *Dynamics on the moduli space $\mathcal{M}_{0,n}$.*

The moduli space $\mathcal{M}_{0,n}$ parametrizes all ways of labeling n distinct points on the Riemann sphere $\mathbb{P}^1$, up to Möbius tranformations. Let $\mathcal{H}$ be a Hurwitz space parametrizing holomorphic maps, with prescribed branching, from one n-marked $\mathbb{P}^1$ to another. $\mathcal{H}$ admits two different maps to $\mathcal{M}_{0,n}$: a "target" map π_t and a "source" map π_s. Since π_t is a covering map, $\pi_s \circ \pi_t^{-1}$ is a multi-valued map – a Hurwitz correspondence – from $\mathcal{M}_{0,n}$ to itself. Hurwitz correspondences arise through work of Koch in topology and Teichmüller theory through Thurston's topological characterization of rational functions on $\mathbb{P}^1$. I will discuss their dynamics via numerical invariants called dynamical degrees. (Received February 05, 2017)

1127-14-282 **Robert Silversmith*** (rsilvers@umich.edu). *A mirror theorem for* $\mathrm{Sym}^d(\mathbb{P}^r)$.

Through 3 general points and 6 general lines in $\mathbb{P}^3$, there are exactly 190 twisted cubics; 190 is a Gromov-Witten invariant of $\mathbb{P}^3$. Mirror symmetry is a conjecture about the structure of all Gromov-Witten invariants of a smooth complex variety (or orbifold). The conjecture is known for toric orbifolds and some of their complete intersections. We prove it in the case of the nontoric orbifold $\mathrm{Sym}^d(\mathbb{P}^r)$. This orbifold is of particular interest because when $r = 2$, its Gromov-Witten invariants are conjecturally related to those of the Hilbert scheme $\mathrm{Hilb}^d(\mathbb{P}^2)$. (Received February 06, 2017)

15 ► Linear and multilinear algebra; matrix theory

1127-15-239 **Joseph H Tien*** (tien.20@osu.edu), Department of Mathematics, Columbus, OH 43210. *Disease spread on networks: integrating structure and dynamics through a generalized inverse.*

A fundamental issue for understanding disease dynamics on networks is how network structure and node characteristics combine to influence disease spread. I will discuss a generalized inverse, called the absorption inverse, that arises naturally in this context. The absorption inverse is connected to transient random walks on the graph, and can be used to derive a distance metric, centrality measures, and community detection algorithms that integrate both structure and dynamics. I will describe some of these measures, together with implications for disease dynamics. This is joint work with Karly Jacobsen. (Received February 04, 2017)

16 ► Associative rings and algebras

1127-16-37 **Eric G Ramos*** (eramos@math.wisc.edu). *The Local Cohomology of FI-modules.*

Much of the work in homological invariants of FI-modules has been concerned with properties of certain right exact functors. One reason for this is that the category of finitely generated FI-modules over a Noetherian ring very rarely has sufficiently many injectives. In this talk we consider the (left exact) torsion functor on the category of finitely generated FI-modules, and show that its derived functors exist. Properties of these derived functors, which we call the local cohomology functors, can be used to repove well known theorems relating to the stable range of a module. This is joint work with Liping Li (Received January 06, 2017)

1127-16-90 **Natasha Rozhkovskaya*** (rozhkovs@math.ksu.edu), Department of Mathematics, 138 Cardwell Hall, Manhattan, KS 66506, and **Naihuan Jing**. *Generating functions for generalized symmetric functions and their interpretation through vertex operators.*

The framework of the boson-fermion correspondence gives rise to the vertex operator realization of classical Schur functions. This setting motivated us to describe in a similar unified way generating functions for several analogues of symmetric functions, they are interpreted as a result of successive application of vertex operators to a vacuum vector. The talk is based on the joint work with N.Jing. (Received January 25, 2017)

1127-16-346 **John D Wiltshire-Gordon*** (jwiltshiregordon@gmail.com). *Specht polytopes and Matroidification.*

We present an analog of "categorification" which we call "matroidification" and explain the relationship to the theory of FI-modules. The real matroidification of the Specht module is a polytope that carries an action of the symmetric group and naturally inhabits an irreducible representation.

This talk relies on joint work with Alexander Woo, Magdalena Zajaczkowska, and Megan Maguire. (Received February 06, 2017)

1127-16-397 **Jonas T. Hartwig*** (jth@iastate.edu). *Noncommutative Kleinian fiber products and vertex models.*

This talk is about a recent connection between (higher spin) six-vertex configurations on a square lattice with semi-periodic twisted boundary conditions and noncommutative deformations of certain fiber products of two type A Kleinian singularities. Examples include quotients of the enveloping algebra of the affine Lie algebra $A_1^{(1)}$ and a finite W-algebra of $\mathfrak{sl}_4$. I will discuss some interesting features of their representation theory, in particular how the center as well as simple objects of the category of weight modules can be directly described from the six-vertex configuration. I will also present a combinatorial description of the signature of the unique (possibly indefinite) invariant inner product on simple weight modules in terms of certain eight-vertex configurations induced by the original six-vertex configuration. (Received February 07, 2017)

17 ► Nonassociative rings and algebras

1127-17-131 **Iana I. Anguelova*** (anguelovai@cofc.edu). *The CKP and DKP hierarchies and their bosonizations.* Preliminary report.

The BKP and CKP hierarchies were introduced by Date, Jimbo, Kashiwara and Miwa as reductions of the KP hierarchy, with DKP related to the BKP. Although the bosonization of the BKP hierarchy has been known for some time, this is not the case for the CKP and DKP hierarchies. In this talk I will discuss the bosonization of type D, as well as the two different bosonizations of the CKP hierarchy, particularly the second bosonization via an untwisted Heisenberg algebra. I will also discuss the issue of solutions to those hierarchies. (Received January 30, 2017)

1127-17-269 **Michael Reeks*** (mar3nf@virginia.edu) and **Can Oguz**. *Trace of the twisted Heisenberg algebra.*

Categorification is a process by which structures can be lifted to higher categorical levels, often revealing new information. The original structure can be recovered through an inverse process, decategorification. Decategorification is typically accomplished by taking the Grothendieck group. Several recent works have shown that an alternative decategorification functor, the trace (or zeroth Hochschild homology), can reveal additional rich algebraic structures. In this talk, we shall describe the trace of a categorification of the twisted Heisenberg algebra and connect it to a certain infinite dimensional Lie algebra known as a W-algebra. (Received February 05, 2017)

1127-17-303 **Darlayne Addabbo***, 1409 West Green Street, Urbana, IL 61801. *Q-systems and Generalizations in Representation Theory.*

In this talk, we will define tau-functions given as matrix elements for the action of $\widehat{GL_n}$ on n-component fermionic Fock space. We will show that, in the $n = 2$ case, these tau-functions satisfy the $A_{\infty/2}$ Q-system. Since Q-systems are of interest in many places in mathematics, for example in representation theory and in combinatorics, it is natural to expect that the difference relations satisfied by tau-functions for $n > 2$ are also interesting. Here, we will discuss the difference relations for the general n case and the progress we have made in analyzing these systems of equations within the context of other areas of mathematics. If time permits, a generalization of this work will be discussed. (Joint with Maarten Bergvelt) (Received February 06, 2017)

1127-17-308 **Weiqiang Wang*** (ww9c@virginia.edu). *Divided powers arising from quantum symmetric pairs.*

A theory of canonical bases arising from quantum symmetric pairs has recently been developed by Bao and Wang, generalizing the canonical bases of Lusztig and Kashiwara. We shall describe the rich q-combinatorics of the new divided powers (which are the simplest new canonical basis elements) in $sl(2)$ case. In this case, these divided powers are also known to admit geometric interpretation. This is based in part on joint work with Collin Berman (undergraduate at Virginia), and also on earlier works with Huanchen Bao (IAS), Yiqiang Li (Buffalo). (Received February 06, 2017)

1127-17-390 **Ben L. Cox*** (coxbl@cofc.edu), Charleston, SC 29401. *On the universal central extension of certain Krichever-Novikov algebras.*

We will describe results on the center of the universal central extension of certain Krichever-Novikov algebras. In particular we will describe how various families of classical and non-classical orthogonal polynomials appear. We will also provide certain new identities of elliptic integrals. This material we will covered was obtained in joint work with V. Futorny, J. Tirao, M. S. Im, X. Gu, R. Luo, and K. Zhao. (Received February 07, 2017)

1127-17-391 **Kang Lu*** (lukang@iupui.edu), Department of Mathematical Sciences LD 270, 402 N Blackford St, Indianapolis, IN 46202. *On the Gaudin model and self-dual Grassmannian.*

We derive explicit formulas for solutions of the Bethe ansatz equations of the Gaudin model associated to the tensor product of one arbitrary finite-dimensional irreducible module and one vector representation for all simple Lie algebras of classical type. We use this result to show that the Bethe ansatz is complete in any tensor product where all but one factor are vector representations and the evaluation parameters are generic.

We shall also talk about the self-dual Grassmannian. The self-dual Grassmannian is a subset of Grassmannian related to the study of Gaudin model in types B and C. It has a remarkable stratification-like structure.

This is a joint work with E. Mukhin and A. Varchenko. (Received February 07, 2017)

18 ► Category theory; homological algebra

1127-18-170 **Alexei Davydov*** (davydov@ohio.edu), Morton Hall, Ohio University, Athens, OH 45701. *Lagrangian correspondences between group-theoretical modular categories.*

Group-theoretical modular categories is a class of modular categories for which Lagrangian algebras (or physical modular invariants) can be described effectively (in group-theoretical terms). This description is useful for applications in conformal field theory, allowing classification of full CFTs with given chiral halves being holomorphic orbifolds. In condensed matter physics it can be used to classify possible boson condensations. It also provides ways of studying braided equivalences between group-theoretical modular categories. The class of modular categories can be used to provide examples of counter-intuitive behaviour of modular invariants: multiple physical realisations of a given numerical modular invariant, non-physicality of some permutation modular invariants. The talk will try to give an overview of known results and open problems. (Received February 02, 2017)

1127-18-199 **Marcel Bischoff*** (marcel.bischoff@vanderbilt.edu). *Realizability of Tambara-Yamagami Categories by Conformal Nets.*

Chiral conformal field theory can be axiomatized by so-called conformal nets. Tambara-Yamagami categories are a certain class of $\mathbb{Z}/2\mathbb{Z}$-graded extensions of the category of G-graded vector spaces. Assuming that G is odd, I will show how all equivalence classes of Tambara-Yamagami categories and their doubles are realized as the category of (twisted) representation of conformal nets. (Received February 03, 2017)

1127-18-224 **Vladimir Turaev*** (vturaev@yahoo.com), 831 E Third st, Bloomington, IN 47405-7106. *Phylogenetic precategories.* Preliminary report.

I will present an axiomatic approach to evolution and phylogenetics based on the concept of a phylogenetic precategory. No preliminary knowledge of phylogenetics is required. (Received February 04, 2017)

1127-18-229 **Noah Snyder*** (nsnyder@gmail.com), **Scott Morrison** and **Emily Peters**. *Trivalent Categories.*

We give a skein theoretic classification of tensor categories generated by a "trivalent vertex." That is we study a category $\mathcal{C}$ with an object X and a map $X \otimes X \to X$. Some of the examples that appear are quantum SO_3, quantum G_2, and some fusion categories related to the Haagerup subfactor. Our main techniques are a new approach to finding skein relations which can be easily automated using Gröbner bases, and evaluation algorithms which use the discharging method developed in the proof of the 4-color theorem. (Received February 04, 2017)

1127-18-237 **Alexei Davydov** and **Darren A. Simmons*** (ds207206@ohio.edu). *Third Cohomology and Fusion Categories.*

We apply the theory of pointed fusion categories and categorical groups to reinterpret the third cohomology group of an arbitrary finite Abelian group L in terms of Lagrangian extensions A of L. (Received February 04, 2017)

1127-18-289 **Paul Gustafson*** (pgustafs@math.tamu.edu). *Computing quantum mapping class group representations with Haskell.* Preliminary report.

Stringnet is a Haskell library for computing mapping class group representations from the Turaev-Viro-Barrett-Westbury (TVBW) construction. Its main ingredients are (i) Kirillov's description of the TVBW representation space as a space of embedded, colored graphs modulo local moves, (ii) calculation of local moves for a set of mapping class group generators, and (iii) representation of the relevant categorical data in Haskell's type system. In this talk, I will outline *Stringnet*'s development and walk through the calculation of a braid group representation from a Tambara-Yamagami category. I will also explain how the *Stringnet* library relates to the Property F conjecture. (Received February 06, 2017)

1127-18-340 **Rohit Nagpal*** (nagpal@math.uchicago.edu). *Generic representations of the finite general linear groups.*

Let F be a finite field of characteristic p and K be a commutative ring. A functor V from F-vector spaces to K-modules encodes a sequence $(V_n)_{n\geq 0}$ where V_n is a $GL_n(F)$ representation over K. The category of such functors, which we call VA-modules, behaves very differently depending on whether p is invertible in K. We will discuss a recent result of Nick Kuhn that proves that the category of VA-modules is of Krull dimension 0 when K is a field of characteristic different from p. We will also discuss conjectures and known results in the case when the characteristic of K is p and some related results in other categories. (Received February 06, 2017)

1127-18-345 **Yu Tsumura*** (tsumura.2@osu.edu), 231 W. 18th Ave., MW 400, Columbus, OH 43210, and **Thomas Kerler** and **Yilong Wang**. *The coend and the dihedral type subcategory of a metaplectic category.*

A metaplectic modular category is a unitary modular category with the same fusion rules as $\mathrm{SO}(N)_2$ for some odd $N > 1$. A metaplectic category contains a subfusion category $\mathcal{D}$ whose fusion rules are the same as the representation of the dihedral group of order $2N$.

A key ingredient to construct topological invariants from a modular category is the coend. The coend of $\mathrm{SO}(N)_2$ is a braided Hopf algebra that is in fact an object in the subcategory $\mathcal{D}$. In the talk, I talk about our research on the subcategory $\mathcal{D}$ and the coend. This is a joint work with Thomas Kerler and Yilong Wang. (Received February 06, 2017)

1127-18-401 **Daniel Barter**, **Corey Jones** and **Henry Tucker***, 9500 Gilman Drive #0112, La Jolla, CA. *Invariant rigidity properties from eigenvalues of rotations and braids in spherical fusion categories.*

Using the generalized categorical Frobenius-Schur indicators for semisimple spherical categories we have established formulas for the multiplicities of eigenvalues of generalized rotation operators. In particular, this implies for a finite depth planar algebra, the entire collection of rotation eigenvalues can be computed from the fusion rules and the traces of rotation at finitely many depths. If the category is also braided these formulas yield the multiplicities of eigenvalues for a large class of braids in the associated braid group representations. This provides the eigenvalue multiplicities for braids in terms of just the S and T matrices in the case where the category is modular. (Received February 07, 2017)

19 ► K-theory

1127-19-5 **Wolfgang Lück** (wolfgang.lueck@him.uni-bonn.de), **Holger Reich** (holger.reich@fu-berlin.de), **John Rognes** (rognes@math.uio.no) and **Marco Varisco*** (mvarisco@albany.edu). *Assembly maps for topological cyclic homology.*

I will present the results of [arXiv:1607.03557], in which we use assembly maps to study the topological cyclic homology of group algebras. For any finite group, we prove that the assembly map for the family of cyclic subgroups is an isomorphism on homotopy groups. For infinite groups, we establish pro-isomorphism, split injectivity, and rational injectivity results, as well as counterexamples to injectivity and surjectivity. In particular, for hyperbolic groups and for virtually finitely generated abelian groups, we show that the assembly map for the family of virtually cyclic subgroups is split injective but in general not surjective. (Received September 12, 2016)

1127-19-111 **Kiyonori Gomi*** (kgomi@math.shinshu-u.ac.jp), 3-1-1 Asahi, Matsumoto, Nagano 390-8621, Japan. *K-theory, gapped quantum system and C-symmetric indefinite metric space.*

Since Kitaev's work about the periodic table, topological K-theory has been recognized as a useful tool for classifications of gapped quantum systems such as topological insulators. Usually, such a quantum system is described by a self-adjoint operator acting on a Hilbert space, and the inner product of a Hilbert space is positive definite. However, some meta-materials are described by operators on a Hilbert space which are self-adjoint with respect to an indefinite inner product. An example is a photonic crystal, though is a classical system.

The spectra of a self-adjoint operator on a Hilbert space with indefinite metric are generally not real, whereas the reality of the spectral seems to be essential to descriptions of physical systems. A way to ensure the positivity of the spectra is to impose a so-called C-symmetry.

The introduction of C-symmetry allows us to formulate a K-theory which serves as a tool for classifications of gapped systems described by self-adjoint operators on Hilbert spaces with possibly indefinite inner product. Further, this K-theory can be interpreted as a K-theory introduced by Freed and Moore. I will talk about these results obtained in a joint work with Giuseppe de Nittis. (Received January 28, 2017)

1127-19-363 **Michael Keogh*** (mkkeogh@wayne.edu), 2625 Walnut, Dearborn, MI 48124. *Connection between Connective K-Theory and Number Theory.*

Computations of complex connective K-theory of certain metacyclic groups by Bruner and Greenlees have shown a link between Euler classes of connective K-theory and cyclotomic units in the corresponding field extensions. We will discuss this general relationship and some specific computations of particular interest. (Received February 07, 2017)

20 ► Group theory and generalizations

1127-20-68 **Andrew Putman**, **Steven V Sam*** (svs@math.wisc.edu) and **Andrew Snowden**. *Stability in the homology of unipotent groups.*

Let R be a commutative ring whose additive group is finitely generated. We show that the homology of the group of $n \times n$ upper-triangular matrices with entries in R has polynomial growth in n when considered with field coefficients. More generally, we show that it is a finitely generated functor for the category of ordered sets and injections. Time permitting, I will also discuss how this can action can be upgraded to one over a q-deformation of the category FI of finite sets and injections. (Received January 20, 2017)

1127-20-184 **Joseph Ricci*** (ricci@math.ucsb.edu) and **Zhenghan Wang** (zhenghwa@math.ucsb.edu). *Congruence subgroups from representation of the three-strand braid group.*

Ng and Schauenburg proved that the kernel of a $(2+1)$-dimensional topological quantum field theory representation of $\mathrm{SL}(2,\mathbb{Z})$ is a congruence subgroup. Motivated by their result, we explore when the kernel of an irreducible representation of the braid group B_3 with finite image enjoys a congruence subgroup property. In particular, we show that in dimensions two and three, when the projective order of the image of the braid generator σ_1 is between 2 and 5 the kernel projects onto a congruence subgroup of $\mathrm{PSL}(2,\mathbb{Z})$ and compute its level. However, we prove for three dimensional representations, the projective order is not enough to decide the congruence property. In particular, for each odd integer $\ell \geq 3$ we construct a pair of non-congruence subgroups associated with three-dimensional irreducible representations having finite image and σ_1 mapping to a matrix with projective order 2ℓ. Our technique uses classification results of low dimensional braid group representations, and the Fricke-Wohlfarht theorem in number theory. (Received February 02, 2017)

1127-20-227 **Sheila Sundaram*** (shsund@comcast.net). *On the Schur-positivity of sums of power-sums.* Preliminary report.

We show that the multiplicity-free sum of power-sum symmetric functions indexed by partitions λ whose parts are all powers of a fixed prime q, is Schur-positive. We give a precise description of the associated symmetric group representations.

A famous result of Thrall states that the regular representation of the symmetric group S_n decomposes into a sum of symmetric powers of the representation afforded by the free Lie algebra. By contrast, our work leads to a decomposition of the regular representation as a sum of *exterior* powers of modules related to the Lie representation of S_n. (Received February 04, 2017)

1127-20-230 **Andrew Kimball*** (amkimball1@math.tamu.edu). *Representations of the Necklace Braid Group.*

The Necklace Braid group (NB_n) is the identified with the fundamental group of the configuration space of n unlinked oriented circles that are linked to another oriented circle. We look at representations of this group. (Received February 04, 2017)

1127-20-231 **Nate Harman*** (nharman@mit.edu). *Cross-characteristic representation stability.*

We prove a stability result for certain sequences of representations over fields of different characteristics. As a corollary, we show that the stably periodic mod p homology of configuration spaces admits a description that is in a sense uniform in p, for all but finitely many primes. (Received February 04, 2017)

1127-20-354 **Siu-Hung Ng*** (rng@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Fusion square root of the sum of self-dual simple objects.*

There is no nontrivial self-dual simple object in any integral fusion category with odd dimension or Frobenius-Schur exponent. However, nontrivial self-dual simple objects exist in any non-integral modular tensor category. It has been shown by Gannon that the sum of the self-dual primary fields has a fusion square root in any rational conformal field theory with an odd order T-matrix. In this talk, we discuss a more general version of this result for modular tensor categories. (Received February 07, 2017)

1127-20-369 **Peter Patzt*** (peter.patzt@gmail.com). *Representation stability for filtrations of Torelli groups.*

We show, finitely generated rational $\mathsf{VIC}_{\mathbb{Q}}$–modules and $\mathsf{SI}_{\mathbb{Q}}$–modules are uniformly representation stable and all their submodules are finitely generated. We use this to prove two conjectures of Church and Farb, which state that the quotients of the lower central series of the Torelli subgroups of $\mathrm{Aut}(F_n)$ and $\mathrm{Mod}(\Sigma_{g,1})$ are uniformly representation stable as sequences of representations of the general linear groups and the symplectic groups, respectively. Furthermore we prove an analogous statement for their Johnson filtrations. (Received February 07, 2017)

22 ► *Topological groups, Lie groups*

1127-22-213 **Dubravka Ban*** (dban@siu.edu), Department of Mathematics, Southern Illinois University, Carbondale, IL 62901. *Basic properties of Iwasawa modules corresponding to p-adic principal series representations.* Preliminary report.

We use the structure theory of p-adic reductive groups to study the continuous principal series over p-adic fields. Our approach is based on the duality theory of Schneider and Teitelbaum and the corresponding Iwasawa modules. (Received February 03, 2017)

1127-22-379 **Ivan Contreras*** (icontrer@illinois.edu), 1409 W Green St, Urbana, IL 61801, and **Nicolas Martinez**, Carrera 30 # 45-03, Bogota, Colombia. *Topological field theories and poly-Poisson structures.* Preliminary report.

Following the integration procedure from Lie algebras to Lie groups via the path space construction (Lie's third theorem), we propose an integration of Poly-Poisson structures, a higher order generalization of Poisson manifolds, via two dimensional topological field theories. In this talk we introduce the notion of Poly-Poisson and poly-symplectic structures and we highlight the path space construction giving rise to poly-symplectic groupoids as the integration. (Received February 07, 2017)

26 ► Real functions

1127-26-240 **Amalia Culiuc*** (amalia@math.gatech.edu), **Robert Kesler** (rkesler6@gatech.edu) and **Michael Lacey** (lacey@math.gatech.edu). *Sparse bounds for the discrete cubic Hilbert transform.*

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

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

We prove that there exists $r < 2$ such that H_3 is dominated by an (r,r) sparse form. This is the first result of this type concerning discrete harmonic analytic operators and it immediately implies new weighted inequalities. (Received February 04, 2017)

30 ► Functions of a complex variable

1127-30-41 **Boris Hanin*** (bhanin@mit.edu). *Pairing between zeros and critical points of random polynomials.*

Consider a polynomial $p_N(z)$ in one complex variable. The Gauss-Lucas Theorem says that the critical points of p_N lie inside the convex hull of its zeros. But how are critical points actually distributed inside the convex hull if p_N is chosen at random? The purpose of this talk is to explain that in fact each critical point of p_N typically comes paired with a single zero. The distance between a critical point and its paired zero is on the order of N^{-1}, which is much smaller than the typical $N^{-1/2}$ spacing between order of N independently selected points on the sphere. In the first part of my talk, I will give a heuristic interpretation for this pairing by relating zeros and critical points to electrostatics on the Riemann sphere. In the second part, I explain what rigorous theorems are now available and state a few open problems. (Received January 07, 2017)

31 ► Potential theory

1127-31-80 **thomas bloom*** (bloom@math.toronto.edu), 40 St Georege St., Toronto, Ontario M5S2E4, Canada. *Large deviation for certain ensembles related to Hermitian random matrices.*

We present a method, using potential theory, to obtain a large deviation principle for the empirical measure of a random point in certain ensembles. In addition to Hermitian random matrix ensembles the method applies to Nikishin or biorthogonal ensembles and also ensembles based on Riesz potentials. A common feature of these ensembles is a related energy functional. The rate function of the large deviation is given in terms of the energy functional. This is joint work with N.Levenberg, F.Wielonsky and V. Totik. (Received January 23, 2017)

32 ► Several complex variables and analytic spaces

1127-32-38 **Jeffrey Diller*** (diller.1@nd.edu) and **Roland Roeder**. *Typical dynamics of plane rational maps with equal dynamical degrees.*

Let f be a plane rational with algebraic and topological degrees equal and larger than one. We explain in this talk that it is fairly common that f admits exactly two ergodic measures of maximal entropy, one of saddle and one of repelling type. Moreover, neither measure is supported in an algebraic curve, and f is 'fully two dimensional' in the sense that it does not preserve any singular holomorphic foliation. (Received January 06, 2017)

1127-32-73 **Dan Coman*** (dcoman@syr.edu), Department of Mathematics, 215 Carnegie Bldg, Syracuse University, Syracuse, NY 13244-1150. *Equidistribution results for big line bundles.*

We show that normalized currents of integration along the common zeros of random m-tuples of sections of powers of m singular Hermitian big line bundles on a compact Kähler manifold distribute asymptotically to the wedge product of the curvature currents of the metrics. As an application, we give sufficient conditions ensuring that the wedge product of the curvature currents of m singular Hermitian big line bundles can be approximated by analytic cycles. The results are joined with George Marinescu and Viêt-Anh Nguyên. (Received January 22, 2017)

1127-32-87 **Steve Zelditch*** (zelditch@math.northwestern.edu), Evanston, IL 60208, and **Pen Zhou** (pengzhou@math.northwestern.edu), Evanston, IL 60208. *Interface asymptotics and partial Bergman kernels.*

Partial Bergman kernels are orthogonal projections onto subspaces S_k of the space $H^0(M, L^k)$ of holomorphic sections of powers of an ample line bundle L with respect to an inner product. The problem of finding asymptotics of partial Bergman kernels arises in probabilistic complex geometry, in Kaehler geometry and in physics (quantum Hall effect), all for different reasons. Shiffman-Z studied random polynomials with spectra in a fixed Newton polytope, which is a special case in the toric setting. It was generalized by Ross-Singer, who first proved Gaussian interface asymptotics for certain S^1 invariant Kaehler manifolds. Peng Zhou and I generalized that and gave new proofs for all S^1 invariant Kaehler manifolds, and then generalized it further to subspaces S_k defined by spectral theory of Toeplitz operators. The asymptotics of the partial density of states determine the distribution of zeros of random sections drawn from the subspaces. (Received January 24, 2017)

1127-32-94 **Steve Zelditch**, 2033 Sheridan Rd, Evanston, IL 60208, and **Peng Zhou*** (pengzhou@math.northwestern.edu), 2033 Sheridan Rd, Evanston, IL 60208. *Zeros of random sections in S^1-equivariant line bundles.*

Let (L, h) be an positive hermitian line bundle over a compact Kahler manifold $(M, \omega = Ric(h))$, with an holomorphic Hamiltonian S^1-action acting on M and L, corresponding to the Hamiltonian $H : M \to \mathbb{R}$. For any interval $I = [a, b]$ in the image $H(M)$, and any positive integer k, we define a subspace $\mathcal{S}_{I,k} \subset H^0(M, L^k)$ spanned by S^1-equivariant sections whose weights lie in the interval $k[a, b]$. This talk is about the zero loci for random sections in $\mathcal{S}_{I,k}$, and their different behaviors in the 'allowed region' $A = H^{-1}([a, b])$ and the 'forbidden region' $F = M \backslash A$. (Received January 25, 2017)

1127-32-335 **Greg Knese*** (geknese@wustl.edu), One Brookings Dr, Dept of Math, CB 1146, St. Louis, MO 63130. *Saturated polynomials and extreme points.* Preliminary report.

We will discuss an interesting class of polynomials in two variables, namely those with no zeros in the bidisk, finitely many zeros on the two-torus, and as many zeros on the two-torus as possible (given that there are finitely many such zeros). It turns out they have an interesting characterization in terms of integrability and sums of squares decompositions. We also discuss a connection of these polynomials to the problem of characterizing the extreme points in the space of analytic functions on the polydisk with positive real part. (Received February 06, 2017)

34 ► Ordinary differential equations

1127-34-72 **Zhilan Feng*** (fengz@purdue.edu), 150 N. University Street, Department of Mathematics, Purdue University, West Lafayette, IN 47907, and **Yiqiang Zheng**, **Nancy Hernandez-Ceron**, **Henry Zhao**, **John Glasser** and **Andrew Hill**. *Mathematical models of Ebola—Consequences of underlying assumptions.*

Mathematical models have been used to study Ebola disease transmission dynamics and control for the recent epidemics in West Africa. Many of the models used in these studies are based on the model of Legrand et al. (Epidemiol. Infec., 2007), and most failed to accurately project the outbreak's course. Although there could be many reasons for this, including incomplete and unreliable data on Ebola epidemiology and lack of empirical data on how disease-control measures quantitatively affect Ebola transmission, we examine the underlying assumptions of the Legrand model, and provide alternate formulations that are simpler and provide additional information regarding the epidemiology of Ebola during an outbreak. We developed three models with different assumptions about disease stage durations, one of which simplifies to the Legrand model while the others have more realistic distributions. Control and basic reproduction numbers for all three models are derived and shown to provide threshold conditions for outbreak control and prevention. (Received January 22, 2017)

1127-34-266 **Komi Segno Messan*** (kmessan@asu.edu), SAL MCMSC, Arizona State University, Tempe, AZ 85287-3901, **Gloria DeGrandi-Hoffman**, Tucson, AZ 85719, **Carlos Castillo-Chavez**, SAL MCMSC, Arizona State University, tempe, AZ 85287-3901, and **Yun Kang** (yun.kang@asu.edu), Mesa, AZ 85212. *Migration effects on population dynamics of the honeybee-mite interactions.*

Honeybees are an amazing and highly beneficial insect species that play important roles in undisturbed and agricultural ecosystems. Unfortunately, honeybees are increasingly threatened by numerous factors, most notably the parasitic varroa mite (*Varroa destructor* Anderson and Trueman). A recent field study showed that migrations of migration of mites into hives on foraging bees' greatly contributes to the rapid growth of mite populations in colonies, and increases the mortality of honeybee. Motivated by this, we propose a simple two-patch honeybee-Varroa model to explore how foraging behavior of honeybees in the presence of Varroa mite infestations affect the population dynamics of honeybees and mites, respectively. Our analytical and numerical studies reveal the dynamical outcomes of migration including: (a) Under proper conditions, high rates of mite migration could save one honeybee colony from collapsing. (b) Intermediate migration rate could generate multiple locally stable honeybee-mite coexistence equilibria. (c) An increase in migration rate causes a growth of the varroa population, which in return has a negative feedback on the colony population. Our results provide novel insights on the effects of foraging and Varroa migration on colony survival. (Received February 06, 2017)

1127-34-349 **Bruce Pell*** (pell1@stolaf.edu), **Yang Kuang**, **Gerardo Chowell** and **Cecile Viboud**. *Using phenomenological models for forecasting the 2015 Ebola challenge.*

The rising number of novel pathogens threatening the human population has motivated the development of mathematical modeling for forecasting the trajectory and size of epidemics. In this talk, we'll summarize the real-time forecasting results of the logistic equation during the 2015 Ebola Challenge focused on predicting synthetic data derived from a detailed individual-based model of Ebola transmission dynamics and control. In addition, we systematically compare the logistic growth model and a recently introduced generalized Richards model (GRM) that captures a range of early epidemic growth profiles ranging from sub-exponential to exponential growth. We assess the performance of each model for estimating the reproduction number, generate short-term forecasts of the epidemic trajectory and predict the final epidemic size. Our findings further support the consideration of transmission models that incorporate flexible early epidemic growth profiles in the forecasting toolkit. (Received February 07, 2017)

35 ► Partial differential equations

1127-35-24 **Stefan Steinerberger*** (stefan.steinerberger@gmail.com), New Haven, CT 06511. *Going with the flow: parabolic techniques applied to elliptic problems.*

I will survey how heat flow techniques can be applied to study Laplacian eigenfunctions. Topics discussed will include regularity and geometry of nodal domains, inradius estimates (including a refinement of the bound of E. Lieb), stochastic techniques for bounding the first eigenvalue (Donsker-Varadhan) and applications on graphs. Partially joint work with Jianfeng Lu (Duke) and Manas Rachh (Yale). (Received January 02, 2017)

1127-35-25 **Zhaosheng Feng*** (zhaosheng.feng@utrgv.edu), University of Texas-Rio Grande Valley, Edinburg, TX 78539. *Wave solutions to Kuramoto-Sivashinsky Equation.*

In this talk, we are concerned with the Kuramoto-Sivashinsky equation which occupies a prominent position in describing physical processes in unstable systems. By means of the Lie symmetry reduction method and the Preller-Singer procedure, we show that there exist nontrivial bounded solitary wave solutions under certain parametric conditions. Numerical simulations of wave phenomena are illustrated, which provide us rich dynamic information and are in agreement with our theoretical analysis. (Received January 02, 2017)

1127-35-33 **Steve Zelditch*** (zelditch@math.northwestern.edu), Department of Mathematics, Northwestern University, Lunt Hall, Evanston, IL 60208, and **Boris Hanin** and **Peng Zhou**. *Nodal sets of eigenfunctions around interfaces.*

Interfaces arise in the spectral theory of Laplacians or Schrodinger operators as caustics or boundaries. For instance the unit sphere in $\mathbb{R}^d$ is a caustic for the isotropic harmonic oscillator, separating $\mathbb{R}^d$ into allowed and forbidden regions. Nodal sets of eigenfunctions transition from the usual h^{-1} density inside the allowed region to sparse in the forbidden region. There is a small region around the caustic where an Airy type transition occurs. The boundary of the unit ball is also a caustic for Dirichlet/Neumann eigenfunctions of the Laplacian in the exterior of the unit ball. My talk is about joint results with B. Hanin and P. Zhou on the scaling behavior of nodal sets around each type of interface. (Received January 05, 2017)

1127-35-47 **Jianliang Qian**, **Hung Vinh Tran*** (hung@math.wisc.edu) and **Yifeng Yu**. *Min-max formulas and other properties of certain classes of nonconvex effective Hamiltonians.*

We present the first attempt to systematically study properties of the effective Hamiltonian arising in the periodic homogenization of some coercive but nonconvex Hamilton-Jacobi equations. Firstly, we introduce a new and robust decomposition method to obtain min-max formulas for a class of nonconvex effective Hamiltonians. Secondly, we analytically and numerically investigate other related interesting phenomena, such as "quasi-convexification" and breakdown of symmetry. Some conjectures and problems are also proposed. (Received January 12, 2017)

1127-35-48 **Hongjie Dong*** (hongjie_dong@brown.edu), 182 George Street, Providence, RI 02912, and **Hong Zhang** (hong_zhang@brown.edu), 182 George St, Providence, RI 02912. *Schauder and Dini type estimates for nonlocal fully nonlinear elliptic and parabolic equations.*

In 1934, J. Schauder first established by now well-known Schauder estimates for linear elliptic equations, which became an indispensable tool in the theory of partial differential equations. For fully nonlinear concave elliptic equations, such result was obtained by M. V. Safonov in 1988, following the seminal work of L. C. Evans and N. V. Krylov in early 1980s. I will present some recent work on Schauder estimates for a class of concave fully nonlinear nonlocal elliptic and parabolic equations with rough and non-symmetric kernels, where the data are allowed to be bounded and measurable. A further Dini type estimate will also be discussed. (Received January 12, 2017)

1127-35-53 **Zhongwei Shen*** (zshen2@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506, and **Jinping Zhuge** (jinping.zhuge@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *Boundary Layers in Periodic Homogenization of Neumann Problems.*

This talk is concerned with a family of second-order elliptic systems in divergence form with rapidly oscillating periodic coefficients. We initiate the study of homogenization and boundary layers for Neumann problems with first-order oscillating boundary data. We identify the homogenized system and establish the sharp rate of convergence in L^2 in dimension three or higher. Sharp regularity estimates are also obtained for the homogenized boundary data in both Dirichlet and Neumann problems. The results are used to establish a higher-order convergence rate for Neumann problems with non-oscillating data. (Received January 12, 2017)

1127-35-56 **Keith Promislow*** (kpromisl@math.msu.edu), Department of Mathematics, C212 Wells Hall, East Lansing, MI 48824, and **Qiliang Wu** (qwu@math.msu.edu), Department of Mathematics, East Lansing, MI 48824. *Competitive evolution of multicomponent amphiphilic bilayer networks.*

Many biological applications, in particular the endoplasmic reticulum, are comprised of a collections of amphiphilic lipids that encode distinct morphological preferences. We present a fourth order free energy whose mass-preserving gradient flows engender a center-stable reduction that couples geometric flow of the underlying membrane shape to phase separation of lipid types upon the surface of the membrane. We discuss applications to physical systems, and present an analysis of a minimal model that high-lights the complexity of the underlying dynamics, including a possible infinite dimensional 'quenched flow' that represents a slow motion to long-wave periodic modulations of bilayer composition. (Received January 15, 2017)

1127-35-63 **Jiahong Wu*** (jiahong.wu@okstate.edu), Department of Mathematics, 401 Mathematical Sciences, Stillwater, OK 74078. *Fluid dynamics equations with fractional partial dissipation.*

There have been considerable recent developments on fluid dynamics equations with partial or fractional dissipation. These partial differential equations (PDEs) are not only mathematically important but also physically relevant. This talk focuses on fundamental mathematical problems on several such PDEs with fractional partial dissipation including the 3D Navier-Stokes, the 2D Boussinesq and the 2D MHD equations with fractional partial dissipation. When there is only fractional partial dissipation, classical tools such as the maximal regularity estimates for the heat operator no longer apply. New techniques have been developed to fully exploit the regularization effects of such incomplete dissipation. We present several global regularity results based on these techniques. (Received January 18, 2017)

1127-35-65 **Nguyen Lam*** (nlam@math.ubc.ca), 1984 Mathematics Road, Vancouver, V6T 1Z2, Canada. *A note on Hardy inequalities.*

In this talk, we discuss the classical Hardy inequalities. Since these inequalities have no optimizers, it is a natural question whether the inequality can be improved by adding a suitable positive term to the left hand side. We survey some results in this direction and present some improvements for a class of the Hardy inequalities. (Received January 19, 2017)

1127-35-69 **Chenchen Mou** (muchenchen@math.ucla.edu), Department of Mathematics, UCLA, Los Angeles, CA 90095, and **Andrzej Swiech*** (swiech@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332.
Aleksandrov-Bakelman-Pucci maximum principle for a class of uniformly elliptic and parabolic integro-PDE.

We will discuss two versions of Aleksandrov-Bakelman-Pucci maximum principles for integro-PDE of Hamilton-Jacobi-Bellman type whose PDE parts are either uniformly elliptic or uniformly parabolic. One version uses slightly different notions of the elliptic and parabolic upper contact sets and is proved by arguments similar to those for the classical ABP maximum principles for elliptic and parabolic PDE. The other version is applicable to a wider class of integrability exponents and its proof is obtained by an infinite iteration procedure involving solutions of Pucci extremal equations. (Received January 21, 2017)

1127-35-78 **Olivier Goubet*** (olivier.goubet@u-picardie.fr), LAMFA CNRS UMR 7352, Université de Picardie, 33 rue Saint-Leu, 80039 Amiens, France, and **Imen Manoubi**. *A water wave model with a non local viscous dispersive term.*

We study the water wave model with a nonlocal viscous term

$$u_t + u_x + \beta u_{xxx} + \frac{\sqrt{\nu}}{\sqrt{\pi}} \frac{\partial}{\partial t} \int_0^t \frac{u(s)}{\sqrt{t-s}} ds + uu_x = \nu u_{xx},$$

where $\frac{1}{\sqrt{\pi}} \frac{\partial}{\partial t} \int_0^t \frac{u(s)}{\sqrt{t-s}} ds$ is the Riemann-Liouville half-order derivative. Here x belongs to $I\!R$ and $\nu > 0, \beta$ are parameters. We study the initial value problem and the decay rate of solutions to the equilibrium. We follow here the references below.

References

[1] I. Manoubi, Theoretical and numerical analysis of the decay rate of solutions to a water wave model with a nonlocal viscous dispersive term with Riemann-Liouville half derivative, *DCDS serie B*, **19**, (2014), n 9, 2837–2863.

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(Received January 23, 2017)

1127-35-81 **Mickael Chekroun** and **Eunhee Park***, 831 East 3rd St, Bloomington, IN 47405, and **Roger Temam**. *The Stampacchia maximum principle for stochastic partial differential equations and applications.*

Stochastic partial differential equations (SPDEs) are considered, linear and nonlinear, for which we establish comparison theorems for the solutions, or positivity results a.e., and a.s., for suitable data. Comparison theorems for SPDEs are available in the literature. The originality of our approach is that it is based on the use of truncations, following the Stampacchia approach to maximum principle. We believe that our method, which does not rely too much on probability considerations, is simpler than the existing approaches and to a certain extent, more directly applicable to concrete situations. Among the applications, boundedness results and positivity results are respectively proved for the solutions of a stochastic Boussinesq temperature equation, and of reaction-diffusion equations perturbed by a non-Lipschitz nonlinear noise. Stabilization results to a Chafee-Infante equation perturbed by a nonlinear noise are also derived. (Received January 23, 2017)

1127-35-84 **Patrick Guidotti** and **Yuanzhen Shao*** (shao92@purdue.edu), 150 N. University Street, West Lafayette, IN 47907. *Wellposedness of a Nonlocal Nonlinear Diffusion Equation of Image Processing.*

In this talk, we will establish the wellposedness of a degenerate regularization of the well-known Perona-Malik equation in noise reduction for discontinuous initial data. We will also show the (exponential) asymptotic stability of stationary solutions. (Received January 23, 2017)

1127-35-97 **Ihsan Topaloglu*** (iatopaloglu@vcu.edu), Virginia Commonwealth University, Richmond, VA. *Height-constrained nonlocal interaction energies and their gradient flows.*

Height-constrained nonlocal interaction energies and congested aggregation models, which formally can be considered as gradient flows of these energies, have recently appeared not only in models of collective behavior such as biological swarming and pedestrian crowd motion but also in simple nonlocal geometric shape optimization problems. In these models the inclusion of a height constraint on admissible functions poses significant challenges both analytically and numerically. In order to overcome these we consider a regularization of the energies by including a highly degenerate diffusion term and approximate the height-constrained model by the unconstrained ones. Justifying our approach analytically in the context of Γ-convergence we implement this scheme numerically in two dimension, and compute gradient flows via particle approximations. This is a joint project with Katy Craig. (Received January 26, 2017)

1127-35-103 **Qingshan Chen*** (qsc@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634. *The barotropic quasi-geostrophic equation under a free surface.*

When the length scale of the flow is on the same order of the Rossby deformation radius, the classical rigid-lid assumption is no longer valid, the impact of the free surface deformation on the the vorticity field is no longer negligible, and therefore it has to be accounted for in the model. In this talk, we present some new results concerning the well-posedness of the barotropic quasi-geostrophic equation under a free surface. Both simply connected domains and domains with holes representing above-surface islands will be considered. The connection of the QG model to other more complex and more realistic models will also be discussed. (Received January 26, 2017)

1127-35-104 **Ratnasingham Shivaji**, **Inbo Sim** and **Byungjae Son*** (b_son@uncg.edu), 830 West Market Street, Apt 623, Greensboro, NC 27401. *Uniqueness results for classes of semipositone p-Laplacian problems.*

We consider steady state reaction diffusion equations on the exterior of a ball, namely, boundary value problems of the form:

$$\begin{cases} -\Delta_p u = \lambda K(|x|)f(u) & \text{in } \Omega_E, \\ Bu = 0 & \text{on } |x| = r_0, \\ u \to 0 & \text{when } |x| \to \infty, \end{cases}$$

where $\Delta_p z := \operatorname{div}(|\nabla z|^{p-2}\nabla z)$, $1 < p < n$, $\lambda > 0$, $\Omega_E := \{x \in \mathbb{R}^n \mid |x| > r_0 > 0\}$ and the boundary operator B is either $Bu \equiv u$ or $Bu \equiv \frac{\partial u}{\partial y} + c(u)u$ where $c \in C((0,\infty),(0,\infty))$ and $\frac{\partial u}{\partial \eta}$ is the outward normal derivative of u on $|x| = r_0$. Here the weight function $K \in C^1([r_0,\infty),(0,\infty))$ satisfies $\lim_{r\to\infty} K(r) = 0$, and the reaction term $f \in C^1[0,\infty)$ is strictly increasing and satisfies $f(0) < 0$, $\lim_{s\to\infty} f(s) = \infty$, $\lim_{s\to\infty} \frac{f(s)}{s^{p-1}} = 0$ and $\frac{f(s)}{s^q}$ is nonincreasing on $[a,\infty)$ for some $a > 0$ and $q \in (0, p-1)$. We establish uniqueness results for positive radial solutions for $\lambda \gg 1$. (Received January 26, 2017)

1127-35-108 **Jun Kitagawa*** (kitagawa@math.msu.edu) and **Robert J McCann**. *Free singularities in optimal transport.*

On $\mathbb{R}^n$, with the choice of cost function given by Euclidean distance squared, an optimal transport map from a connected set to a disconnected set must have discontinuous points. In this talk I will discuss finer structure of this set of "free singularities." Specifically, if the connected components of the support of the target measure are suitably separated by hyperplanes, this singular set will consist of DC (difference of convex) hypersurfaces of appropriate codimensions. We prove this result via a non-smooth implicit function theorem for convex functions, which is of independent interest. Time permitting, I will also talk about another application of this implicit function theorem, in a stability result for singular sets. (Received January 26, 2017)

1127-35-117 **Qinfeng Li**, 150 N. University Street, West Lafayette, IN 40907, and **Changyou Wang*** (wang2482@purdue.edu), 150 N. University Street, West Lafayette, IN 40907. *A minimizing problem involving nematic liquid crystal droplets.* Preliminary report.

In this talk, we will describe an energy minimizing problem arising from seeking the optimal configurations of a class of nematic liquid crystal droplets. More precisely, the general problem seeks a pair (Ω, u) that minimizes the energy functional:

$$E(u,\Omega) = \int_\Omega |\nabla u|^2 + \mu \int_{\partial\Omega} f(x, u(x)\cdot\nu(x))\, d\sigma,$$

among all open set Ω within the unit ball of $\mathbf{R}^3$, with a fixed volume, and $u \in H^1(\Omega, S^2)$. Here $f(\cdot,\cdot) : \mathbf{R}^3 \times \mathbf{R}$ is a suitable nonnegative function, which is given.

While the existence of minimizers remains open in the full generality, there has been some partial progress when Ω is assumed to be convex. In this talk, I will discuss some results for Ω that are not necessarily convex. This is a joint work with Qinfeng Li. (Received January 28, 2017)

1127-35-119 **Gui-Qiang G Chen**, **Mikhail Feldman*** (feldman@math.wisc.edu) and **Wei Xiang**. *Uniqueness for shock reflection problem.*

We discuss shock reflection problem for compressible gas dynamics, von Neumann conjectures on transition between regular and Mach reflections, and existence of regular reflection solutions for potential flow equation. Then we will talk about recent results on uniqueness of regular reflection solutions for potential flow equation in a natural class of self-similar solutions. The approach is to reduce the shock reflection problem to a free boundary problem for a nonlinear elliptic equation, and prove uniqueness for that problem by a version of method of continuity. (Received January 29, 2017)

1127-35-120 **Katy Craig**, **Inwon Kim** and **Yao Yao*** (yaoyao@math.gatech.edu). *Congested aggregation via Newtonian interaction.*

In this talk, we consider a congested aggregation model that describes the evolution of a density through the competing effects of nonlocal Newtonian attraction and a hard density constraint. It is formulated as the Wasserstein gradient flow of an interaction energy, with a penalization to enforce the density constraint. From this perspective, the problem can be seen as a slow diffusion limit of the Keller-Segel equation with degenerate diffusion. We focus on the patch dynamics where the initial data is a characteristic function, and show that the solution remains a patch for all time, and its boundary evolution is given by a Hele-Shaw type free boundary problem. In addition, in two dimensions, we show that all patch solutions will converge to a disk as the time goes to infinity with certain convergence rate. (Received January 29, 2017)

1127-35-121 **Panagiotis E Souganidis*** (souganidis@math.uchicago.edu), 5734 S University Ave, Chicago, IL 60637. *Junction problems for Hamilton-Jacobi and second-order equations.* Preliminary report.

I will discuss viscosity solutions for "junction"-type Hamilton-Jacobi and fully nonlinear second order equations with nonconvex coercive Hamiltonians in one space dimension and study its well-posedness, stability and approximation properties. I will also show that viscosity approximations either select the state-constraint solution or have a unique limit, and we introduce another type of approximation by fattening the domain. This is joint work with Pierre-Louis Lions. (Received January 29, 2017)

1127-35-123 **Andrew Lorent** and **Guanying Peng*** (penggg@ucmail.uc.edu), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221. *Regularity of the Eikonal equation with two vanishing entropies.*

We study regularity of solutions to the Eikonal equation $|\nabla u| = 1$ a.e. in a bounded simply-connected two dimensional domain. With the help of two vanishing entropies, we prove that solutions of the Eikonal equation are locally Lipschitz continuous, except at a locally finite set of points in the domain. The motivation of our problem comes from the zero energy state of the Aviles-Giga functional in connection with the theory of smectic liquid crystals and thin film blisters. Our results for the first time use only two entropies to characterize regularity properties in this direction. This is joint work with Andrew Lorent at the University of Cincinnati. (Received January 29, 2017)

1127-35-124 **Sze-Bi Hsu** and **King-Yeung Lam*** (lam.184@math.ohio-state.edu), Department of Mathematics, The Ohio State University, Columbus, OH 43210, and **Feng-Bin Wang**. *Analysis of a PDE Model of Phytoplankton with Ratio Dependence.*

We study a PDE system modeling the growth of a single population consuming two forms of inorganic carbon in an unstirred chemostat. The resource uptake rate depends on the internal carbon storage and introduces a ratio dependence in the model. We first discuss the appropriate space for existence of solution that is motivated by the underlying biology. We will then proceed to apply a recent generalization of Krein-Rutman Theorem involving two different positive cones, due to Mallet-Paret and Nussbaum, to determine the threshold phenomena regarding persistence and extinction. This is joint work with Feng-Bin Wang (Chang Gung University, Taiwan) and Sze-Bi Hsu (National Tsing-Hua University, Taiwan). (Received January 29, 2017)

1127-35-126 **HAO JIA*** (jiahao@math.ias.edu), NJ 08540. *Channel of energy inequality for small energy wave maps and applications.*

We apply a recent channel of energy inequality for outgoing waves to the study of energy critical wave maps. More precisely, we show that energy concentration near null cone is not possible, and the wave map has a universal profile approaching blow up time for small blow up wave maps. Joint work with T. Duyckaerts, C. Kenig, F. Merle. (Received January 30, 2017)

1127-35-129 **E. N. Barron** and **R R Jensen*** (rjensen@luc.edu). *Envelope solutions of 1st and 2nd order pdes with u dependence.*

General envelope methods are introduced which may be used to embed equations with u dependence into equations without solution dependence. Furthermore these methods present a rigorous way to consider so-called nodal solutions. That is, if $w(t, x, z)$ is the viscosity solution of some pde, the nodal solution of an associated pde is a function $u(t, x)$ so that $w(t, x, u(t, x)) = 0$. Examples will be given to first and second order pdes such as those arising in optimal control, differential games, minimal time problems, scalar conservation laws, geometric type equations, and forward-backward stochastic control (Received January 30, 2017)

1127-35-132 **Stan Alama*** (alama@mcmaster.ca), Department of Mathematics & Statistics, McMaster University, Hamilton, ON L8S 4K1, Canada, and **Lia Bronsard** and **Ihsan Topaloglu**. *Minimizers of an isoperimetric problem with confinement.*

We identify the Γ-limit of an energy related to nanoparticle/block copolymer blends, in a limit of a large number of nanoparticles occupying a vanishingly small volume in the copolymer sample. The limiting energy consists of two terms: the perimeter of the interface separating the phases and a confinement term representing the effect of the nanoparticles, which attract one of the two stable phases. Our interest is in studying how the confinement term affects the phase transition morphology. We prove that local minimizers of the limiting energy admit regular phase boundaries and derive the first and second variations of the limiting energy functional. Finally we discuss possible critical and minimizing patterns in two dimensions and how these patterns vary from global minimizers of the purely local isoperimetric problem. (Received January 30, 2017)

1127-35-133 **Stan Alama** and **Lia Bronsard*** (bronsard@mcmaster.ca), Department of Mathematics & Statistics, McMaster University, Hamilton, ON L8S 4K1, Canada, and **Rustum Choksi** and **Ihsan A Topaloglu**. *Droplet phase in a nonlocal isoperimetric problem under confinement.*

We address small volume fraction asymptotic properties of a nonlocal isoperimetric functional with a confinement term, derived as the sharp interface limit of a variational model for self-assembly of diblock copolymers under confinement by nanoparticle inclusion. We introduce a small parameter η to represent the size of the domains of the minority phase, and study the resulting droplet regime as $\eta \to 0$. A key role is played by a parameter M which gives the total volume of the droplets at order η^3 and its relation to existence and non-existence of minimizers to a nonlocal isoperimetric functional on $\mathbb{R}^3$. For large values of M, the minority phase splits into several droplets at an intermediate scale $\eta^{1/3}$, while for small M minimizers form a single droplet converging to the maximum of the confinement density. (Received January 30, 2017)

1127-35-136 **Thomas Backing** and **Donatella Danielli*** (dgarofal@purdue.edu), Department of Mathematics, West Lafayette, IN 47907, and **Rohit Jain**. *Regularity results for a penalized boundary obstacle problem.*

In this talk we will discuss the optimal regularity of solutions and the regularity of the free boundary for a two-penalty boundary obstacle problem modeling fluid flow through a permeable membrane. (Received January 31, 2017)

1127-35-138 **Patricia Bauman*** (bauman@math.purdue.edu) and **Daniel Phillips**. *Properties of Eigenvalues for Minimizers to Landau-de Gennes energies in Two and Three Space Dimensions.*

We present results on properties of minimizers of Landau-de Gennes energies defined on tensor-valued functions in two- or three- dimensional domains that are constrained to symmetric 3 x 3 matrices with eigenvalues in [-1/3, 2/3]. It is shown that under mild assumptions, the eigenvalues for minimizers stay strictly between the values of -1/3 and 2/3 which are considered to be unphysical. (Received January 31, 2017)

1127-35-139 **Lidia Mrad** (lmrad@math.arizona.edu) and **Daniel Phillips*** (phillips@purdue.edu). *Dynamic Analysis of Chevron Structures in Liquid Crystal Cells.*

If a surface stabilized ferroelectric liquid crystal cell is cooled from the smectic-A to the smectic-C phase its layers thin causing V-shaped (chevron like) defects to form. These create an energy barrier that can prevent switching between equilibrium patterns. We examine a gradient flow for a mesoscopic Chen-Lubensky energy $\mathcal{F}(\psi, \mathbf{n})$ that allows the order parameter to vanish so that the energy barrier does not diverge if the layer thickness becomes small. (Received January 31, 2017)

1127-35-145 **Heng Li***, Department of Mathematics, University of Louisville, Louisville, KY 40292, **Yongzhi Xu**, Department of Mathematics, University of Louisville, Louisville, KY , and **Jianrong Zhou**, Department of Mathematics, Foshan University, Peoples Rep of China. *A free boundary problem arising from DCIS mathematical model.*

Ductal carcinoma in situ – a special cancer – is confined within the breast ductal only. We derive the mathematical ductal carcinoma in situ model in a form of a nonlinear parabolic equation with initial, boundary, and free boundary conditions. Existence, uniqueness, and stability of problem are proved. Algorithm and illustrative examples are included to demonstrate the validity and applicability of the technique. (Received February 01, 2017)

1127-35-151 **Andrew Comech*** (comech@math.tamu.edu), Mathematics Department, Texas A&M University, Mailstop TAMU3368, College Station, TX 77843-3368, and **Nabile Boussaid** (nabile.boussaid@univ-fcomte.fr), Laboratoire de Mathématiques, Université de Franche-Comté, 16 route de Gray, Besançon, France. *Stability of solitary waves in the nonlinear Dirac equation.* Preliminary report.

We consider the point spectrum of non-selfadjoint Dirac operators which arise as linearizations at solitary wave solutions to the nonlinear Dirac equation. We prove that in the nonrelativistic limit ($\omega \lesssim m$) the solitary waves in the Dirac equation with scalar-type self-interaction ("Soler model") are spectrally stable when the nonlinearity is "NLS-charge-critical" or subcritical (but not too small). (Received February 01, 2017)

1127-35-154 **Roza Aceska*** (raceska@bsu.edu), Muncie, IN 47304, and **Alessandro Arsie** and **Ramesh Karki**. *Approximation of Solutions of non-linear PDEs from finitely many samples.* Preliminary report.

We show how to reconstruct optimally the solution of certain non-linear PDEs in a suitable Sobolev class, using a finite set of measurements. In particular, we show that for our classes of PDEs the optimal sampling does not depend on the spectrum of the operators involved, but just on the order of the PDE. We also tackle the same problem in the case in which the coefficients of the PDEs depend explicitly on time, thus generating a non-autonomous dynamical system. We discuss the possibility of using a variation of our approach to deal with some nonlinear integro-differential equations or non-linear PDEs that are C-integrable. (Received February 01, 2017)

1127-35-164 **Jiancheng Lyu**, **Jack Xin** and **Yifeng Yu***, Department of Math, UC Irvine, Irvine, CA 92697-3875. *Curvature effects on the shear flow.*

It is known in the combustion community that curvature effects in general slow down flame propagation, which is, however, very hard to be established rigorously. As a preliminary step, I will talk about how to prove this for shear flows under the well known G-equaiton model. How burning velocity depends on the diffusivity will also be discussed. This is based on a joint work with Jiancheng Lyv and Jack Xin. (Received February 01, 2017)

1127-35-169 **Gautam Iyer** and **Daniel Spirn*** (spirn@math.umn.edu), School of Mathematics, 206 Church St. S.E., Minneapolis, MN 55455. *Model for vortex nucleation in superconductors.*

We will discuss questions related to the dynamic transition between local and global minimizers in the Ginzburg-Landau theory of superconductivity. We derive a heuristic equation governing the dynamics of vortices that are close to the boundary and of dipoles with small inter vortex separation. We then consider a small random perturbation of this equation and study the asymptotic regime under which vortices nucleate. (Received February 02, 2017)

1127-35-176 **Marius Beceanu** and **Michael Goldberg*** (goldbeml@ucmail.uc.edu). *Pointwise bounds for the three-dimensional wave propagator.* Preliminary report.

The wave equation in $\mathbb{R}^3$ is subject to a number of "reversed Strichartz" estimates in which solutions are integrated over a time interval and the resulting function is bounded in $L^p(\mathbb{R}^3)$. One elementary bound in this spirit is that the kernel $K(t,x,y)$ of the sine propagator $\frac{\sin(t\sqrt{-\Delta})}{\sqrt{-\Delta}}$ satisfies $\int_{\mathbb{R}} |K(x,y,t)|\,dt = (4\pi|x-y|)^{-1}$.

We examine the analogous propagator $\frac{\sin(t\sqrt{H})}{\sqrt{H}}P_{ac}(H)$ for operators $H = -\Delta + V$, with the potential V belonging to the Kato-norm closure of test functions. It is already known that many L^p bounds are preserved by such perturbations. We show that the stronger pointwise bound $\int_{\mathbb{R}} |K(x,y,t)|\,dt \le C|x-y|^{-1}$ is preserved as well. It appears that pointwise bounds for other spectral multipliers follow as a natural consequence. (Received February 02, 2017)

1127-35-189 **Hongwei Gao*** (hwgao@math.ucla.edu), Department of Mathematics, University of California, Los Angeles, Los Angeles, CA 90095. *Some observations on homogenization of certain non-convex Hamilton-Jacobi equations.*

In this talk, we will discuss some observations regarding to the homogenization of certain non-convex Hamilton-Jacobi equations. (Received February 02, 2017)

1127-35-195 **Burak Erdogan**, **William Green** and **Ebru Toprak*** (toprak2@illinois.edu). *Dispersive estimate for Dirac operators in dimension three with obstruction at threshold energies.*

We investigate $L^1 \to L^\infty$ dispersive estimates for the three dimensional Dirac operator with potential; $H = -i\alpha\cdot\nabla + m\beta + V(x)$, where $\alpha = (\alpha_1, \alpha_2, \alpha_3)$ and β are Pauli spin matrices. We also classify the structure of obstructions at the thresholds of the essential spectrum as being composed of a two dimensional space of resonances and finitely many eigenfunctions. We show that the following low-energy estimate

$$\left\| e^{-itH} P_{ac}(H)\chi(H) - \langle t\rangle^{-\frac{1}{2}} K_t \right\|_{L^1\to L^\infty} \lesssim \langle t\rangle^{-\frac{3}{2}}$$

holds where K_t is time dependent operator with finite rank and satisfying $\sup_t \|K_t\|_{L^1\to L^\infty} \lesssim 1$. (Received February 05, 2017)

1127-35-196 **Emanuel Indrei*** (eindrei@purdue.edu). *Dynamics of uniformly elliptic free boundary problems in higher dimensions.*

The tangential touch problem for uniformly elliptic fully nonlinear operators involves understanding the dynamics of how free boundaries generated by solutions of nonlinear PDEs associated to such operators intersect fixed boundaries. Recent progress has been made in showing that the intersection occurs non-transversally in two dimensions. We discuss partial results in higher dimensions as well as some applications. (Received February 03, 2017)

1127-35-198 **Jae Min Lee*** (jlee10@gradcenter.cuny.edu), Department of Mathematics, The Graduate Center, CUNY, 365 Fifth Avenue, New York, NY 10016, and **Stephen C. Preston** (stephen.preston@brooklyn.cuny.edu), Room 1156, Ingersoll Hall, 2900 Bedford Avenue, Brooklyn, NY 11210. *Local Well-posedness of the Camassa-Holm equation on the real line.*

In this paper we prove the local well-posedness of the Camassa-Holm equation on the real line in the space of continuously differentiable diffeomorphisms with an appropriate decaying condition. This work was motivated by G. Misiolek who proved the same result for the Camassa-Holm equation on the periodic domain. We use the Lagrangian approach and rewrite the equation as an ODE on the Banach space. Then by using the standard ODE technique, we prove existence and uniqueness. Finally, we show the continuous depdendence of the solution on the initial data by using the topological group property of the diffeomorphism group.

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arXiv link: https://arxiv.org/abs/1612.00921 This paper was submitted to 'Discrete and Continuous Dynamical Systems - A' on December 2016 and was accepted for publication. (Received February 03, 2017)

1127-35-202 **Xiulan Lai** and **Xingfu Zou*** (xzou@uwo.ca), Department of Applied Mathematics, University of Western Ontario, London, Ontario Nx5 0K1, Canada. *Modeling the repulsion effect on superinfecting virions by infected cells.*

In this talk, we present some results on modeling the repulsion effect of superinfecting virion by infected cells. The mathematical model is described by a system of reaction diffusion equation, in which the diffusion of virus depends not only on its concentration gradient but also on the concentration of infected cells. The basic reproduction number, linear stability of steady states, spreading speed, and existence of traveling wave solutions for the model are discussed. It is shown that viruses spread more rapidly with the repulsion effect of infected cells on superinfecting virions, than with random diffusion only. For our model, the spreading speed of free virus is not consistent with the minimal traveling wave speed. With our general model, numerical computations of the spreading speed shows that the repulsion of superinfecting virion promotes the spread of virus, which confirms, not only qualitatively but also quantitatively, the experimental result of Doceul et al. (Science, 2010) (Received February 03, 2017)

1127-35-222 **Boris Hanin*** (bhanin@mti.edu) and **Yaiza Canzani**. *Scaling Limit of Spectral Projector for the Laplacian on a Compact Riemannian Manifold.*

Let (M,g) be a compact smooth Riemannian manifold. I will give some new off-diagonal estimates for the remainder in the pointwise Weyl Law. A corollary is that, when rescaled around a non self-focal point, the kernel of the spectral projector of the Laplacian onto the frequency interval (lambda,lambda+1] has a universal scaling limit as lambda goes to infinity (depending only on the dimension of M). This is joint work with Y. Canzani. (Received February 04, 2017)

1127-35-226 **Jan Prüss**, jan.pruess@mathematik.uni-halle.de, and **Gieri Simonett***, gieri.simonett@vanderbilt.edu. *On the Muskat flow.*

Of concern is the motion of two fluids separated by a free interface in a porous medium, where the velocities are given by Darcy's law. We consider the case with and without phase transition. It is shown that the resulting models can be understood as purely geometric evolution laws, where the motion of the separating interface depends in a non-local way on the mean curvature. It turns out that the models are volume preserving and surface area reducing, the latter property giving rise to a Lyapunov function. We show well-posedness of the

models, characterize all equilibria, and study the dynamic stability of the equilibria. Lastly, we show that solutions which do not develop singularities exist globally and converge exponentially fast to an equilibrium. (Received February 04, 2017)

1127-35-228 **Alaa Haj Ali*** (ep3983@wayne.edu), Department of Mathematics, Wayne State University, 656 W. Kirby, 1150 FAB, Detroit, MI 48202, and **Peiyong Wang** (pywang@math.wayne.edu), Department of Mathematics, Wayne State University, 656 W. Kirby, 1150 FAB, Detroit, MI 48202. *Radial Symmetry Of A Nonlinear Elliptic Differential Or Integral Equation Over A Ring.* Preliminary report.

In this talk, I will talk about a joint work with P. Wang on the symmetry of a solution of a differential or integro-equation of the form $Lu = f(u)$ over a ring. Such a problem is known to not bear uniqueness, and even worse the radial monotonicity of a solution is absent. To my best knowledge, existing results, whether employing the moving plane method or not, treat only radially monotone solutions with restriction of the function f such as being increasing. We incorporated a new idea into the moving plane method so that the symmetry of a solution of a broader class of equations can be proved. Not only our result is new. The method we use is original and seems to work for more problems. I will just explain it for the Laplacian and its integro counterpart, the fractional Laplacian. (Received February 04, 2017)

1127-35-232 **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 indicated. (Received February 04, 2017)

1127-35-254 **William M Feldman*** (feldman@math.uchicago.edu). *Liquid Drops on a Rough Surface.*

I will discuss the problem of determining the minimal energy shape of a liquid droplet resting on a rough solid surface. The shape of a liquid drop on a solid is strongly affected by the micro-structure of the surface on which it rests, where the surface inhomogeneity arises through varying chemical composition and surface roughness. I will explain a macroscopic regularity theory for the free boundary which allows to study homogenization, and more delicate properties like the size of the boundary layer induced by the surface roughness.

The talk is based on joint work with Inwon Kim. (Received February 05, 2017)

1127-35-259 **L. Korobenko***, lyudmila@sas.upenn.edu, and **C. Rios**, **E. Sawyer** and **R. Shen**. *Sharp local boundedness in the infinitely degenerate regime via DeGiorgi iteration.*

I will talk about local boundedness and maximum principles for weak solutions to certain infinitely degenerate elliptic divergence form equations. We have previously shown local boundedness and continuity of weak solutions for certain classes of degeneracies in 2 and 3 dimensions, using Moser iteration scheme. Application of Moser iteration imposed a restriction on the type of degeneracy that is allowed. On the other hand, there is a counter example in three dimensions which shows that for very degenerate equations there exist unbounded week solutions. The boundedness result we obtained was not sharp, and it was not known if weak solutions are bounded for a big class of degeneracies, which we called a "Moser gap". Using the truncation method of DeGiorgi iteration we prove local boundedness in the gap left open by Moser iteration. This result is therefore sharp in dimensions $n \geq 3$. (Received February 05, 2017)

1127-35-284 **Alan E Lindsay*** (a.lindsay@nd.edu), Department of Applied and Computational Math, 153 Hurley Hall, South Bend, IN 46556. *Regularized post-contact dynamics of elastic-electrostatic deflections.*

In this talk I will discuss the problem of two elastic beams deflecting in an electric field. The beams are held opposite so that they will come into physical contact, if the electric field is strong enough. This contact is manifested as a singularity in the governing PDEs. We introduce a regularized model which is globally well-posed and permits dynamics through the singularity. The post contact dynamics are analyzed with numerical and perturbation methods and detailed interfacial dynamical laws are established and validated. We find new stable equilibrium states which raises the potential for bistability in the system. Estimates on the bistable parameter range are found by means of detailed singular perturbation analysis. (Received February 06, 2017)

1127-35-292 **M. Burak Erdogan*** (berdogan@illinois.edu), **T Burak Gurel** and **Nikolaos Tzirakis**. *Smoothing estimates for nonlinear Schrodinger equation.*

We discuss recent smoothing estimates for the cubic NLS and fractional cubic NLS equations on the torus and on the real line. (Received February 06, 2017)

1127-35-305 **Gro Hovhannisyan**, **Oliver Ruff*** (oruff@kent.edu) and **Zijing Zhang**. *Higher-dimensional Darboux transformations.*

The classical one-dimensional Darboux transformation, intertwining two second-order partial differential operators, has many applications in the study of nonlinear dynamic equations, particularly in the generation of multi-soliton solutions. We discuss an n-dimensional generalization and apply it to some specific higher-dimensional examples. (Received February 06, 2017)

1127-35-329 **Changbing Hu*** (changbing.hu@louisville.edu), Natural Science Building 328, University of Louisville, Louisville, KY 40292. *Point-wise estimates of semigroup generated by nonlocal dispersal operators and its applications in biology.* Preliminary report.

In this talk we introduce some techniques to estimate the semi-group generated by some nonlocal operators, which have been studied extensively in recent years. The major tools for our results are the Fourier and inverse Fourier transforms. These estimates are used to study some non-local differential models which describe the growth and spread of a species under a shifting habitat, physically caused by the climate change. Also these point-wise estimates have their own interest in the study of nonlocal differential equations. (Received February 06, 2017)

1127-35-330 **Truyen Nguyen*** (tn8@uakron.edu), 302 Buchtel Common, Akron, OH 44325. *Calderón-Zygmund estimates for quasilinear elliptic equations.*

We study quasilinear elliptic systems of the form $\operatorname{div}\mathbf{A}(x,u,\nabla u) = \operatorname{div}\mathbf{F}(x)$ with $\mathbf{A}$ being possibly discontinuous in the x variable. In this talk, we will discuss some results concerning local integrability of gradients of weak solutions to the equation. For scalar case, we derive interior L^q gradient estimates of Calderón-Zygmund type for bounded weak solutions. Similar gradient estimates are also established for solutions of systems in regions which are away from the singular set. The dependence of the principal part on the u variable made it difficult to perform any scaling analysis and we handle it by using a perturbation argument together with a two-parameter scaling technique. This is based on joint works with Tuoc Phan and with Phuoc-Tai Nguyen. (Received February 06, 2017)

1127-35-332 **Ning Ju*** (ning.ju@okstate.edu), Department of Mathematics, 401 Mathematical Sciences, Oklahoma State University, Stillwater, OK 74078. *Long-Time Dynamics for 3D Viscous Primitive Equations.*

Recent results on long-time dynamics for solutions of the 3D viscous Primitive Equations will be discussed. The main focus is on finiteness of the dimensions of the global attractor. (Received February 06, 2017)

1127-35-338 **Arshak Petrosyan***, Department of Mathematics, Purdue University, West Lafayette, IN 47907, and **Andrew Zeller**, Department of Mathematics, Purdue University, West Lafayette, IN 47907. *Signorini problem for parabolic equations with variable coefficients.*

We will talk about some recent results on the Signorini problem for parabolic equations with variable coefficients, including the optimal regularity of the solutions and the regularity of a part of the free boundary. Our approach is based on establishing the boundedness and continuity of the time derivative, thus effectively reducing the problem to the known results in the elliptic case. (Received February 06, 2017)

1127-35-353 **Igor Kukavica**, LA, CA 90007, and **Fei Wang*** (wang828@usc.edu) and **Mohammed Ziane**. *Persistence of regularity for solutions of the Boussinesq equations in Sobolev spaces.*

We address the global regularity of solutions to the Boussinesq equations with zero diffusivity in two spatial dimensions. Previously, the persistence in the space $H^{1+s}(\mathbb{R}^2)\times H^s(\mathbb{R}^2)$ for all $s\geq 0$ has been obtained. In this paper we address the persistence in general Sobolev spaces, establishing the local persistence on a time interval which is almost independent of the size of the initial data. Namely, we prove that if $(u_0,\rho_0)\in W^{1+s,q}(\mathbb{R}^2)\times W^{s,q}(\mathbb{R}^2)$ for $s\in(0,1)$ and $q\in[2,\infty)$, then the solution $(u(t),\rho(t))$ of the Boussinesq system stays in $W^{1+s,q}(\mathbb{R}^2)\times W^{s,q}(\mathbb{R}^2)$ for $t\in[0,T^*]$, where T^* depends logarithmically on the size of initial data. Furthermore, we prove the global persistence in the space $W^{1+s,q}(\mathbb{R}^2)\times W^{s,q}(\mathbb{R}^2)$ for the initial data with compact support. (Received February 07, 2017)

1127-35-380 **tej ghoul**, Saadyiat Island, Abu Dhabi, United Arab Emirates, **slim ibrahim*** (`ibrahims@uvic.ca`), Department of Mathematics, University of Victoria, Victoria, Canada, and **Shengyi Shen** (`g.spiritblue@gmail.com`), Department of Mathematics, Victoria, v8v3n9, Canada. *On the two-fluid model.* Preliminary report.

Consider a full ionized plasma consisting of two species of particles, i.e. ions and electrons. For plasma, in general collisions of ions and electrons are infrequent. However, the magnetic field makes them move together so that the plasma behaves like fluid. In this talk, we study a two-fluid model of charged incompressible fluids. After we review the well-posedness of the Cauchy problem, we study the stability and the rate of decay of small solutions. This is a join work with T. Ghoul and S. Shen (Received February 07, 2017)

1127-35-392 **Gregory Berkolaiko***, Department of Mathematics, Texas A&M University, MS 3368, College Station, TX 77843-3368. *From stability of nodal partitions on manifolds to nodal statistics on quantum graphs.*

The question of which partitions on manifolds correspond to the nodal sets of eigenfunctions gave rise to a plethora of interesting connections. We will review our recent results ranging from the stability of manifold partitions to the connection between nodal count and stability of eigenvalues under magnetic perturbation to the application of the latter to understanding statistics of nodal count for eigenfunctions of quantum graphs.

Based on join projects with L. Alon, R. Band, P. Kuchment and U. Smilasnky. (Received February 07, 2017)

37 ▶ Dynamical systems and ergodic theory

1127-37-100 **Mrinal K Roychowdhury*** (`mrinal.roychowdhury@utrgv.edu`), School of Mathematical and Statistical Scienc, University of Texas Rio Grande Valley, 1201 West University Drive, Edinburg, TX 78539. *Optimal Quantization.*

Let $\mathbb{R}^d$ denote the d-dimensional Euclidean space, $\|\cdot\|$ denote the Euclidean norm on $\mathbb{R}^d$ for any $d \geq 1$, and $n \in \mathbb{N}$. Then, the nth *quantization error* for a Borel probability measure P on $\mathbb{R}^d$ is defined by

$$V_n := V_n(P) = \inf\Big\{\int \min_{a\in\alpha} \|x-a\|^2 dP(x) : \alpha \subset \mathbb{R}^d, \ \text{card}(\alpha) \leq n\Big\},$$

where the infimum is taken over all subsets α of $\mathbb{R}^d$ with $\text{card}(\alpha) \leq n$. If $\int \|x\|^2 dP(x) < \infty$ then there is some set α for which the infimum is achieved. Such a set α for which the infimum occurs and contains no more than n points is called an *optimal set of n-means*, or *optimal set of n-quantizers*. Recently, we have determined the optimal sets of n-means and nth quantization error for some singular and nonsingular continuous probability measures. I will talk about it. (Received January 26, 2017)

1127-37-141 **PATRICK De Leenheer** (`iitmmanu@gmail.com`), Auburn Hill, MI 48326, **Anushaya Mohapatra***, amohapatra@oakland.edu, and **Haley Ohma** and **Dave Lytle**. *THE PUZZLE OF PARTIAL MIGRATION: ADAPTIVE DYNAMICS PERSPECTIVES.*

The phenomenon of partial migration is exhibited by populations in which some individuals migrate between habitats during their lifetime, but others do not. First, using an adaptive dynamics approach, we show that partial migration can be explained on the basis of negative density dependence in the per capita fertilities alone, provided that this density dependence is attenuated for increasing abundances of the subtypes that make up the population. We present an exact formula for the optimal proportion of migrants which is expressed in terms of the vital rates of migrant and non-migrant subtypes only. We show that this allocation strategy is both an evolutionary stable strategy (ESS) as well as a convergence stable strategy (CSS).

Secondly, we use an evolutionary game theory approach, and confirm, once again, that partial migration can be attributed to negative density dependence alone. In this context, the result holds even when density dependence is not attenuated. In this case, the optimal allocation strategy towards migrants is the same as the ESS stemming from the analysis based on the adaptive dynamics. (Received January 31, 2017)

1127-37-204 **Walter Parry***, walter.parry@emich.edu. *Computations for nearly Euclidean Thurston maps.* Preliminary report.

A nearly Euclidean Thurston (NET) map is an orientation-preserving finite branched cover from the 2-sphere to itself such that each critical point of the map is simple and its postcritical set has exactly four points. These maps are the simplest Thurston maps with nontrivial Teichmüller spaces and hyperbolic orbifolds. They are accessible, yet they exhibit many interesting properties. The focus of this talk will be on the computer program NETmap, which takes as input NET map presentations and outputs a wealth of information about the presented maps. (Received February 03, 2017)

1127-37-210 **William J Floyd*** (floyd@math.vt.edu), Dept of Mathematics, 460 McBryde Hall, Virginia Tech, 225 Stanger St, Blacksburg, VA 24061-0123, and **Kevin M Pilgrim** and **Walter R Parry**. *Dynamic portraits for nearly Euclidean Thurston maps.* Preliminary report.

A nearly Euclidean Thurston (NET) map is a branched map from the 2-sphere to itself such that there are exactly four postcritical points and every critical point is simple. I'll discuss the classification of dynamic portraits for NET maps and an algorithm to compute a NET map representative for each dynamic portrait. For the NET maps website, www.math.vt.edu/netmaps, this algorithm was used to compute NET map presentations for the 10,626 dynamic portraits of NET maps of degree at most 40. (Received February 03, 2017)

1127-37-250 **Dzmitry Dudko***, Institute for Mathematical Sciences, Mathematics Department, Stony Brook University, Stony Brook, NY 11794-3651, and **Laurent Bartholdi**. *Decidability of Thurston equivalence.*

We consider Thurston maps: branched self-coverings of the sphere, and prove that the Thurston equivalence problem between them (conjugacy combined with isotopy relative to the critical orbits) is decidable. In the talk we will compare Thurston maps with surface homeomorphisms; to illustrate the difference, we produce a Thurston map with infinitely generated centralizer –while centralizers of homeomorphisms are always finitely generated. (Received February 05, 2017)

1127-37-298 **Kathryn A Lindsey*** (klindsey@math.uchicago.edu). *3-D shapes associated to polynomial Julia sets.*

Any planar "shape" P can be embedded isometrically as part of a convex surface S in $\mathbb{R}^3$ such that the boundary of P is the support of the curvature of S. In particular, if P is a connected filled Julia set of a polynomial, this can be done so that the curvature distribution of the convex surface is proportional to the measure of maximal entropy on the Julia set. What would the associated convex subset of $\mathbb{R}^3$ look like? What can it tell us about the dynamics of the polynomial? This talk is based on joint work with Laura DeMarco. (Received February 06, 2017)

1127-37-306 **Volodymyr Nekrashevych*** (nekrash@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843-3368. *Rigidity of groups associated with dynamical systems.* Preliminary report.

We will discuss various rigidity results giving conditions when groups associated with dynamical systems (like iterated monodromy groups, topological full groups, analogs of Higman-Thompson groups, etc.) uniquely determine the dynamical system. (Received February 06, 2017)

1127-37-309 **Sarah C. Koch*** (kochsc@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Postcritical sets in complex dynamics.*

In complex dynamics, we are typically interested in iterating a rational map f on the Riemann sphere and studying the orbits of different points under iteration. The orbits of the critical points of f play a very important role in this process. For example, if $f_c(z) = z^2 + c$ possesses an attracting periodic cycle in $\mathbb{C}$, then the critical point $z_0 = 0$ is necessarily attracted to it under iteration. Furthermore, the *filled Julia set* of f_c is connected if and only if the orbit of the critical point is bounded.

The *postcritical set* of a rational map f, denoted P_f, is the union of the orbits of the critical values of f (recall that the critical values of f are precisely the images of the critical points of f). The map f is said to be *postcritically finite* if P_f is finite. In this talk, we study the subsets of the Riemann sphere that arise as P_f for some postcritically finite rational map f. We employ a variety of results to explore this problem, ranging from Belyi's celebrated theorem, to analytic techniques used in the proof of Thurston's topological characterization of rational maps, a central result in the subject.

This talk is based on joint work with L. DeMarco and C. McMullen. (Received February 06, 2017)

1127-37-314 **Jan-Li Lin*** (janlin@math.northwestern.edu). *On the arithmetic dynamics of monomial maps.*

I will introduce several conjectures in arithmetic dynamics, including Silverman's conjectures for height growth, Moredell-Lang conjecture, and Manin-Mumford conjecture. These conjectures are difficult in general. For monomial maps on the algebraic tori, these conjectures are true. With a little help from toric geometry, we can generalize the results to monomial maps on toric varieties. (Received February 06, 2017)

1127-37-357 **Holly C Krieger*** (hkrieger@dpmms.cam.ac.uk), University of Cambridge, Cambridge, CB3 0WB, United Kingdom. *A spectral gap for the Thurston pullback map of an unbounded family.* Preliminary report.

Work of Buff-Epstein-Koch suggests a connection between the boundedness of a collection of PCF maps in moduli space and the existence of a spectral gap for the corresponding collection of Thurston pullback maps. I will discuss this question in the example of the family of quadratic rational maps satisfying the critical relation $f^2(c_1) = c_2$. In this family, there is a sequence of PCF maps which are unbounded in moduli space, but which have a spectral gap for the Thurston pullback maps. (Received February 07, 2017)

1127-37-368 **Mary Elizabeth Wilkerson*** (mwilkerso@coastal.edu), Mathematics and Statistics Department, Coastal Carolina University, PO Box 261954, Conway, SC 29528-6054. *Obtaining rational maps from quadratic matings using Thurston's algorithm.*

Results of Lei, Rees, and Shishikura give a fast parameter test to determine when the mating of two postcritically finite quadratic polynomials is a rational map. We build upon the Medusa algorithm to present an iterative method that utilizes finite subdivision rules and Thurston's algorithm to approximate this rational map. We discuss the theoretical basis for the algorithm, issues concerning implementation, and examples generated with this technique. (Received February 07, 2017)

1127-37-381 **Zhiqiang Li*** (lizq@math.stonybrook.edu). *Prime orbit theorems and rational maps.*

Periodic orbits play an important role in the study of dynamical systems. In resemblance to the classical Prime Number Theorem in number theory and its relation to the Riemann Hypothesis, it is a natural problem to investigate precise asymptotes for the number of (primitive) periodic orbits as well as the error terms. Such results, known as Prime Orbit Theorems, have been established in many dynamical systems thanks to the works of W. Parry, M. Pollicott, V. Baladi, D. Dolgopyat, C. Liverani, L. Stoyanov, G. A. Margulis, A. Avila, S. Gouëzel, J. C. Yoccoz, M. Tsujii, and many others.

In this talk, we are going to introduce a brief history of such results, focusing mainly on the works of F. Naud, H. Oh, and D. Winter on hyperbolic rational maps. We are going to discuss the main ideas used to obtain such results. If time permits, we are going to discuss how to extend such results to a class of non-hyperbolic rational maps known as (rational) expanding Thurston maps. This is a joint work with T. Zheng. (Received February 07, 2017)

1127-37-384 **Gregory A. Kelsey*** (gkelsey@bellarmine.edu) and **Russell Lodge**. *Subhyperbolicity and twists of quadratic Thurston maps with four postcritical points.*

We extend the methods of Bartholdi-Nekrashevych's solution of the twisted rabbit problem from polynomials of degree two with four postcritical points to all such rational maps. Through specific choices of how we set up the self-similar machinery, we simplify the calculations of the action by twists. Showing these actions are subhyperbolic gives an algorithmic solution to the twisted rabbit problem for these non-polynomial maps and allows us to enumerate all quadratic Thurston maps with four postcritical points. This work is joint with R. Lodge. (Received February 07, 2017)

1127-37-387 **Russell Lodge*** (russell.lodge@stonybrook.edu), Institute for Mathematical Sciences, 100 Nicolls Rd, and **Gregory Kelsey**. *An enumeration of quadratic Thurston maps with few postcritical points.*

Bartholdi and Nekrashevych's celebrated solution to the twisted rabbit problem has led to a flourishing interaction between self-similar group theory and holomorphic dynamics. I will characterize some important combinatorial structures for iterated rational maps in terms of group theory, and show how these group-theoretic invariants can be used to enumerate postcritically finite quadratic branched covers with four or fewer postcritical points. There are further implications for the dynamics of W. Thurston's pullback map on Teichmueller space, and I will partially answer a conjecture on the global dynamics of (homotopy classes of) multicurves under pullback by a postcritically finite rational map. (Received February 07, 2017)

1127-37-408 **Rodrigo Pérez***, 402 N Blackford st, LD-224R, Indianapolis, IN 46202. *Siegel's combinatorial garden.* Preliminary report.

We will review the original proof of existence of Siegel disks, and uncover the rich combinatorial structure in the linearization equation, which is at the heart of the argument. (Received February 08, 2017)

1127-37-413 **Tanya Firsova***, 138 Cardwell Hall, Manhattan, KS 66506. *Non-contractibility of deformation spaces.*

Deformation spaces were introduced by Adam Epstein and were used to prove transversality between dynamically interesting loci. He asked if deformation spaces are always contractible. We give a simple geometric condition that ensures that a deformation space is not contractible and conclude non-contractibility of a class of deformation spaces. This is a joint work with Jeremy Kahn and Nikita Selinger. (Received February 08, 2017)

41 ► Approximations and expansions

1127-41-95 **Aaron M. Yeager*** (aaron.yeager@okstate.edu), 913 S. Orchard Street, Stillwater, OK 74074, and **Maxim L. Yattselev**, Department of Mathematical Sciences, 402 North Blackford Street, Indianapolis, IN 46202. *Zeros of Real Random Polynomials Spanned by OPUC.*

Let $\{\varphi_i\}_{i=0}^{\infty}$ be a sequence of orthonormal polynomials on the unit circle with respect to a probability measure μ. We study zero distribution of random linear combinations of the form

$$P_n(z) = \sum_{i=0}^{n-1} \eta_i \varphi_i(z),$$

where $\eta_0, \ldots, \eta_{n-1}$ are i.i.d. standard Gaussian variables. We use the Christoffel-Darboux formula to simplify the density functions provided by Vanderbei for the expected number real and complex of zeros of P_n. From these expressions, under the assumption that μ is in the Nevai class, we deduce the limiting value of these density functions away from the unit circle. Under the mere assumption that μ is doubling on subarcs of the unit circle centered at 1 and -1, we show that the expected number of real zeros of P_n is at most

$$(2/\pi) \log n + O(1),$$

and that equality holds when μ is in the Szegő-Bernstein class. We conclude with providing discrepancy results that estimate the expected number of complex zeros of P_n in shrinking neighborhoods of compact subsets of the unit circle. (Received January 25, 2017)

42 ► Fourier analysis

1127-42-52 **Ji Li**, **Rob Rahm*** (robertrahm@gmail.com) and **Brett Wick**. *Fractional Integral Operators Associated to Schrodinger Operators.*

Consider the Schrödinger operator $Lf(x) = -\Delta f(x) + V(x)f(x)$. We investigate weighted inequalities for the fractional integral operator $I_\alpha = (L)^{-\alpha/2}$. More precisely, let $0 < \alpha < n$ and $1/p - 1/q = \alpha/n$, we would like to estimate the operator norm of I_α as an operator from $L^p(w^p)$ to $L^q(w^q)$ in terms of a fractional Muckenhoupt condition adapted to L. I_α has better decay properties than the classical fractional integral operator but is highly "non-local"; this is one of the obstructions to establishing the weighted estimate. (Received January 13, 2017)

1127-42-60 **Jose Manuel Conde-Alonso**, **Amalia Culiuc** and **Francesco Di Plinio*** (francesco.diplinio@virginia.edu), Department of Mathematics, University of Virginia, Kerchof Hall, Box 400137, Charlottesville, VA 22904, and **Yumeng Ou**. *A sparse domination principle for rough singular integrals.*

Singular integral operators, which are a priori signed and non-local, can be dominated in norm, pointwise, or dually, by sparse averaging operators, which are in contrast positive and localized. The most striking consequence is that weighted norm inequalities for the singular integral follow from the corresponding, rather immediate estimates for the averaging operators. In this talk, we prove that bilinear forms associated to the rough homogeneous singular integrals

$$T_\Omega f(x) = \text{p.v.} \int_{\mathbb{R}^d} f(x-y)\Omega\left(\tfrac{y}{|y|}\right) \frac{\mathrm{d}y}{|y|^d}$$

where $\Omega \in L^q(S^{d-1})$ has vanishing average and $1 < q \leq \infty$, and to Bochner-Riesz means at the critical index in $\mathbb{R}^d$ are dominated by sparse forms involving $(1, p)$ averages. Our domination theorems entail as a corollary new sharp quantitative A_p-weighted estimates, extending previous results of Hytönen-Roncal-Tapiola for T_Ω and answering a conjecture of Perez, Roncal and Rivera-Rios. Our results follow from a new abstract sparse domination principle which does not rely on weak endpoint estimates for maximal truncations. (Received January 17, 2017)

1127-42-86 **Ciprian Demeter*** (demeterc@indiana.edu). *Decouplings and applications: a journey from continuous to discrete.*

I will talk about how a theory in Fourier Analysis recently developed in collaboration with Jean Bourgain has led to interesting discoveries in Number Theory and Partial Differential Equations. (Received January 24, 2017)

1127-42-88 **Jarod Hart** and **Virginia Naibo*** (vnaibo@math.ksu.edu), Kansas State University, Mathematics Department, 138 Cardwell Hall, Manhattan, KS 66506. *On certain commutator estimates for vector fields.*

We present a unifying approach for proving certain commutator estimates for smooth, not-necessarily divergence-free vector fields and implement it in the scales of weighted Triebel-Lizorkin and Besov spaces and variable exponent Triebel-Lizorkin and Besov spaces. Such commutator estimates are motivated by the study of well-posedness results for some models in incompressible fluid mechanics. (Received January 25, 2017)

1127-42-105 **Jarod V. Hart**, **Rodolfo H. Torres** and **Xinfeng Wu*** (wuxf@ku.edu). *Smoothing properties of bilinear operators and Leibniz-type rules in Lebesgue and mixed Lebesgue spaces.*

We prove that bilinear fractional integral operators and similar multipliers are smoothing in the sense that they improve the regularity of functions. We also treat bilinear singular multiplier operators which preserve regularity and obtain several Leibniz-type rules in the contexts of Lebesgue and mixed Lebesgue spaces. (Received January 26, 2017)

1127-42-216 **Jongchon Kim*** (jkim@math.wisc.edu). *Some remarks on Fourier restriction estimates.*

The Fourier restriction problem, raised by Stein in the 1960's, is a hard open problem in harmonic analysis. Recently, Guth made some progress on this problem using polynomial partitioning, a divide and conquer technique developed by Guth and Katz for some problems in incidence geometry. In this talk, we introduce the restriction problem and the polynomial partitioning method. In addition, we present some new $L^p \to L^q$ estimates for the Fourier restriction operator for the paraboloid. The refinements rely on some important results of Guth used to obtain $L^p \to L^p$ estimates. (Received February 04, 2017)

1127-42-281 **Adam Osękowski**, **Leonid Slavin*** (leonid.slavin@uc.edu) and **Vasily Vasyunin**. *The* BMO $\to$ BLO *norm of the dyadic maximal operator.* Preliminary report.

We construct the Bellman functions for the action of the dyadic maximal operator M (or a more general operator on trees) from BMO($\mathbb{R}^n$) to BLO. These functions solve a Monge–Ampere PDE on a non-convex planar domain, exhibit fairly sophisticated geometric structure, and explicitly depend on dimension (eccentricity of the tree). However, surprisingly, the actual BMO $\to$ BLO norm of M is dimension-free: it equals 1 for all n. A similar phenomenon is observed in related formulations, such as the action of M between weight classes and on A_p-weighted L^p. (Received February 06, 2017)

1127-42-287 **Seungly Oh*** (seungly.oh@wne.edu), 24 Blacksmith Rd., Wilbraham, MA 01095, and **Loukas Grafakos**. *Kato-Ponce inequalities and various extensions.*

In this talk, we will discuss Kato-Ponce inequality, which is also known as "Fractional Leibniz Rule." We will examine a few extensions of this classical inequality by the speaker and Loukas Grafakos. We will also mention subsequent extensions and a few unsettled problems. (Received February 06, 2017)

1127-42-313 **Chandan Biswas*** (cbiswas@wisc.edu), 480 Lincoln Dr, Van Vleck Hall, Madison, WI 53706. *On extremals for a certain convolution operator.*

The operator defined by convolution with the affine arc length measure on the moment curve parametrized by $h(t) = (t, t^2, ..., t^d)$ is a bounded operator from L^p to L^q if $(\frac{1}{p}, \frac{1}{q})$ lies on the line segment joining the points $\left(\frac{2}{d+1}, \frac{2(d-1)}{d(d+1)}\right)$ and $\left(1 - \frac{2(d-1)}{d(d+1)}, 1 - \frac{2}{d+1}\right)$. We prove that there exist functions which extremize the associated inequality and any extremizing sequence is pre compact modulo the action of the symmetry group when $\left(\frac{1}{p}, \frac{1}{q}\right)$ is an interior point. We also establish a relation between extremizers for T at the end point and the extremizers of the Xray transform restricted to the moment curve. Our proof is based on the ideas of Christ on convolution with the surface measure on the paraboloid. (Received February 06, 2017)

1127-42-356 **José Manuel Conde Alonso*** (jconde@mat.uab.cat), Departament de Matèmatiques, Facultat de Ciències, Universitat Autònoma de Barcelona, 08193 Cerdanyola, Barcelona, Spain. *A sparse domination principle for rough (and non-rough) singular integrals.*

In this talk, we will show that bilinear forms associated to dyadic shifts, or to the rough homogeneous singular integrals

$$T_\Omega f(x) = \text{p.v.} \int_{\mathbb{R}^d} f(x-y)\Omega\left(\tfrac{y}{|y|}\right) \frac{dy}{|y|^d}$$

where $\Omega \in L^q(S^{d-1})$ has vanishing average and $1 < q \leq \infty$, and to Bochner-Riesz means at the critical index in $\mathbb{R}^d$ are dominated by sparse forms involving $(1,p)$ averages. This domination is stronger than the weak-L^1 estimates for T_Ω and for Bochner-Riesz means, respectively due to Seeger and Christ. Our domination theorems imply new sharp quantitative A_p-weighted estimates for Bochner-Riesz means and for homogeneous singular integrals with unbounded angular part. Our results follow from a new abstract sparse domination principle which does not rely on weak endpoint estimates for maximal truncations.
Based on joint work with A. Culiuc, F. di Plinio, and Y. Ou, and on previous work by A. Culiuc, F. di Plinio, and Y. Ou. (Received February 07, 2017)

46 ► Functional analysis

1127-46-50 **Costel Peligrad*** (costel.peligrad@uc.edu), University of Cincinnati, Department of Mathematical Sciences, Cincinnati, OH 45221-0025. *A solution of the maximality problem for one parameter dynamical systems.*

We prove a maximality theorem for one-parameter dynamical systems including multiplier one-parameter dynamical systems. Our main result is new even for one-parameter actions on commutative multiplier algebras including the algebra of bounded continuous functions on the set of real numbers acted upon by translations. The methods we develop and use in our characterization of maximality include harmonic analysis, topological vector spaces and operator algebra techniques. (Received January 12, 2017)

1127-46-150 **Alexandru Aleman**, **Michael Hartz** and **John E. McCarthy***, Dept. of Mathematics, Washington University, 1, Brookings Drive, St. Louis, MO 63130, and **Stefan Richter**. *The Smirnov class for complete Pick kernels.*

The Smirnov class for a Hilbert function space H can be defined as the set of ratios f/g, where f and g are multipliers, and g is cyclic. If H is the Hardy space, this gives the classical Smirnov class for the disk. I will talk about the Smirnov class of spaces with the complete Pick property. (Received February 01, 2017)

1127-46-180 **Alexandru Aleman**, **Michael Hartz*** (mphartz@wustl.edu), **John E. McCarthy** and **Stefan Richter**. *Interpolating sequences in complete Pick spaces.*

A classical theorem of Carleson characterizes sequences in the unit disc which are interpolating for H^∞. Bishop and Marshall–Sundberg established an analogue of Carleson's theorem for the multiplier algebra of the Dirichlet space. I will talk about a generalization of these results to multiplier algebras of complete Pick spaces, which applies in particular to the Drury-Arveson space. This is joint work with Alexandru Aleman, John McCarthy and Stefan Richter. (Received February 02, 2017)

1127-46-200 **Meredith Sargent*** (meredithsargent@wustl.edu). *A Boundary Version of Carlson's Theorem.*

In 1913, Bohr observed that Dirichlet series on the positive half plane can be connected to power series on the infinite polydisk. In the modern viewpoint, we use this observation to think of any vertical line in the half plane as an ergodic flow on the polytorus: in fact, Carlson's theorem about integrals in the mean of Dirichlet series can be interpreted in this way. Of particular interest is the imaginary axis because it connects to convergence questions on the boundary of the polydisk. In this talk, we explore integrals in the mean along the imaginary axis and how they connect to norms of power series on the polydisk. (Received February 03, 2017)

1127-46-223 **Dan Li*** (li1863@math.purdue.edu), 150 N Unversity St., West Lafayette, IN 47907, and **Ralph M Kaufmann** and **Birgit Wehefritz-Kaufmann**. *Noncommutative topological $\mathbb{Z}_2$ invariant.* Preliminary report.

Topological insulators are time reversal symmetry protected topological order, we will give some background on the topological $\mathbb{Z}_2$ invariant, which characterizes time reversal invariant topological insulators. In a disordered system, noncommutative geometry provides a practical methodology, and in this talk, we will give a noncommutative generalization of the classical topological $\mathbb{Z}_2$ invariant. (Received February 04, 2017)

1127-46-290 **Andre Henriques** and **David Penneys*** (penneys.2@osu.edu). *Commutants of multifusion categories.*

A bicommutant category is a higher categorical analog of a von Neumann algebra due to Andre Henriques. In joint work, we constructed the first examples coming from unitary fusion categories, and proved the analog of the finite dimensional von Neumann bicommutant theorem. Recently, Henriques constructed examples arising from conformal nets which had been announced previously.

In this talk, I'll discuss the commutant categories of multifusion categories. We prove that two Morita equivalent unitary fusion categories have equivalent commutant categories. This categorifies the well-known result according to which the commutants of two Morita equivalent finite dimensional von Neumann algebras embedded in $B(H)$ for H separable and infinite dimensional are isomorphic. As an application of this theorem, we show that every unitary $k \times k$ multifusion category gives an example of a bicommutant category in $\mathrm{Bim}(R^{\oplus k})$. (Received February 06, 2017)

1127-46-331 **Ryan K Tully-Doyle*** (rtullydo@gmail.com), 13 Murray St, Hampton, VA 23651-1024. *Schur functions on the bidisk and differentiability in terms of Hilbert space operators.*

The Schur functions in two variables are the holomorphic maps from the complex unit bidisk $\mathbb{D}^2$ into the unit disk $\mathbb{D}$. We characterize the differential behavior of a Schur function φ at a boundary singularity $\tau \in \mathbb{T}^2$ in terms of the structure of an associated contractive operator Y on a Hilbert space $\mathcal{H}$ arising from an Agler model. (Received February 06, 2017)

1127-46-339 **Terry A Loring*** (loring@math.unm.edu), Department of Mathematics & Statistics, MSC01 1115, Albuquerque, NM 87131-0001. *Emergent topology for insulators.* Preliminary report.

Many insulators can be modeled by a Hamiltonian that allows local hopping between lattice sites in $\mathbb{R}^d$. Typically these lattice sites form a crystalline lattice, but more recently models have involved quasicrystalline lattices or random points. In all cases, the essential information is in the d position observables, which are unbounded and commute pairwise, and the bounded, self-adjoint Hamiltonian that almost commutes with position and is gapped.

The joint Clifford spectrum of these $d+1$ observables is a closed subset of $\mathbb{R}^{d+1}$. Experience with commuting matrices and the much-studied pseudosectrum of a non-normal matrix will tend to suggest that this joint Clifford spectrum will have uninteresting topology. In the case of topological insulators, however, K-theory arises naturally and forces the joint Clifford spectrum to have homology at least as rich as that of a d-sphere.

The mathematics here is closely recent to work on emergent geometry in string theory. (Received February 06, 2017)

1127-46-359 **Hari Bercovici*** (bercovic@indiana.edu), Mathematics Department, Indiana University, Bloomington, IN 47405. *Noncommutative functions in the study of random matrices.* Preliminary report.

It is known that large independent ensembles of random matrices are asymptotically free (relative to the expected value of the normalized trace). This allows the application of the subordination functions appearing in free probability to such matrices. We will explain how this works in the calculation of the spectral distribution of a polynomial in two random matrices, using subordination as well as a linearization of the polynomial. The new results we present come from joint work with Serban Belinschi and Mireille Capitaine. (Received February 07, 2017)

47 ► Operator theory

1127-47-98 **Hakim Boumaza*** (boumaza@math.univ-paris13.fr), 99, avenue J.B. Clément, 93430 Villetaneuse, France, and **Olivier Lafitte** (olafitte@iu.edu), Visiting Professor, Math Department, Rawles Hall, Indiana University, 831 East 3rd Street, Bloomington, IN 47405. *The band spectrum of the periodic Airy-Schrödinger operator on the real line.*

We introduce the periodic Airy-Schrödinger operator and we study its band spectrum. This is an example of an explicitly solvable model with a periodic potential which is not differentiable at its minima and maxima. We define a semiclassical regime in which the results are stated for a fixed value of the semiclassical parameter and are thus estimates instead of asymptotic results. We prove that there exists a sequence of explicit constants, which are zeroes of classical functions, giving upper bounds of the semiclassical parameter for which the spectral bands are in the semiclassical regime. We completely determine the behaviour of the edges of the first spectral band with respect to the semiclassical parameter. Then, we investigate the spectral bands and gaps situated in the range of the potential. We prove precise estimates on the widths of these spectral bands and these spectral gaps and we determine an upper bound on the integrated spectral density in this range. Finally, in the semiclassical regime, we get estimates of the edges of every spectral bands and thus of the widths of every spectral bands and spectral gaps. (Received January 27, 2017)

1127-47-102 **Karl-Mikael Perfekt*** (kperfekt@utk.edu) and **Alexander Pushnitski**. *Helson matrices: Boundedness, moment problems, and finite rank.*

A Helson matrix (also known as a multiplicative Hankel matrix), is an infinite matrix of the form $M(\alpha) = \{\alpha(nm)\}_{n,m=1}^{\infty}$, where α is a sequence of complex numbers. As linear operators on $\ell^2(\mathbb{N})$, Helson matrices generalize Hankel matrices $\{\beta(j+k)\}_{j,k=0}^{\infty}$.

Helson initiated the study of their boundedness, but the theory has not yielded a characterization. However, when a Helson matrix is positive semidefinite it may be realized as the moment sequence of a measure μ on $\mathbb{R}^{\infty}$, assuming that α does not grow too fast. This gives a description of the bounded non-negative Helson matrices in terms of Carleson measures for the Hardy space of countably many variables.

We have also completely determined the spectrum of the model example of a Helson matrix: the multiplicative Hilbert matrix. Furthermore, we characterized the Helson matrices of finite rank, giving an analogue of Kronecker's theorem in this context. (Received January 26, 2017)

1127-47-125 **Derek Thompson*** (theycallmedt@gmail.com). *Complex symmetric composition operators on the Hardy Space.*

An operator is complex symmetric if there exists a conjugate-linear, isometric involution J such that $T^* = JTJ$. The investigation into which composition operators and weighted composition operators have this property began in 2011 with a paper by Hammond and Garcia, after which very few unweighted examples were found. Through work by the speaker, Narayan, Sievewright and others, we show that if φ is linear-fractional, then there are exactly three cases when C_φ is complex symmetric. We conclude with suggested avenues for further study. (Received January 29, 2017)

1127-47-137 **Katie Spurrier Quertermous*** (querteks@jmu.edu), Dept of Mathematics and Statistics, MSC 1911, James Madison University, Harrisonburg, VA 22807. *Composition C*-algebras Induced by Linear-fractional Non-automorphism Self-maps of the Unit Disk.*

If φ is an analytic self-map of the unit disk $\mathbb{D}$, then the composition operator $C_\varphi : f \to f \circ \varphi$ is a bounded operator on the Hardy space $H^2(\mathbb{D})$. We are particularly interested in composition operators induced by linear-fractional self-maps of $\mathbb{D}$. Several authors have investigated the structures of C*-algebras generated by these operators and either the unilateral shift or the ideal of compact operators on $H^2(\mathbb{D})$. For non-automorphism self-maps of the disk, these structure results have required restrictions on the behavior of the inducing maps on the unit circle. In this talk, we relax these restrictions and investigate the structures of C*-algebras generated by the ideal of compact operators and arbitrary finite collections of composition operators induced by linear-fractional, non-automorphism self-maps of $\mathbb{D}$. (Received January 31, 2017)

1127-47-146 **Raphael Clouatre*** (raphael.clouatre@umanitoba.ca) and **Ken Davidson** (krdavids@uwaterloo.ca). *Purity of absolutely continuous constrained commuting row contractions.*

A Hilbert space contraction T is said to be *constrained* (or *of class* C_0) if it is absolutely continuous and the associated Sz.-Nagy–Foias H^∞-functional calculus has non-trivial kernel. The structure of such contractions is rather well-understood due to work of Sz.-Nagy, Foias, Bercovici and others, who developed flexible functional models. It is known that a constrained contraction must be pure: its minimal isometric coextension does not have a unitary summand. This is a basic ingredient of the aforementioned structure theory, and the purpose of this talk is to discuss a multivariate generalization of this fact. We show that it holds for a constrained absolutely continuous commuting row contraction T, provided that the ideal of functions which annihilate T has a sufficiently small zero set on the sphere. We also discuss some examples that illustrate the difficulties inherent to the higher dimensional setting. This is based on joint work with Ken Davidson. (Received February 01, 2017)

1127-47-214 **Dan Timotin*** (dan.timotin@imar.ro). *A preorder relation for contractions.*

An order relation for contractions on a Hilbert space can be introduced by stating that $A \prec B$ if and only if A is unitarily equivalent to the restriction of B to an invariant subspace. We discuss the equivalence classes associated to this relation, and identify cases in which they coincide with classes of unitary equivalence. The results extend those for completely nonunitary partial isometries obtained by Garcia, Martin, and Ross. (Received February 03, 2017)

1127-47-233 **Brittney R. Miller*** (`bmiller@coe.edu`). *The Kernel of the Adjoint of a Composition Operator with Rational Symbol on the Hardy Space.*

For a rational symbol φ mapping $\mathbb{D}$ to $\mathbb{D}$, the composition operator C_φ acts on the Hardy space by $C_\varphi f = f \circ \varphi$. If φ is not univalent, then the kernel of the adjoint C_φ^* is infinite dimensional. In this talk, we will investigate functions in the kernel of C_φ^*. Using the explicit formula for the adjoint C_φ^* given by Hammond, Moorhouse, and Robbins, we will characterize the functions in the kernel of C_φ^* for a particular class of rational symbols. (Received February 04, 2017)

1127-47-271 **Benjamin P Russo***, benjamin.russo@uconn.edu, and **Joel Rosenfeld**, joelar@ufl.edu. *A Generalization of the Fock Space.* Preliminary report.

In this talk we will introduce a generalized Fock space which uses the Mittag-Leffler function as its reproducing kernel. This space has been featured in the development of a finite difference method. However, it has yet to be investigated as a space of entire functions. We will discuss some preliminary results in comparison to the Fock space and potential applications. This is joint work with Joel Rosenfeld. (Received February 05, 2017)

1127-47-317 **Matthew Fleeman*** (`matthew_fleeman@baylor.edu`) and **Constanze Liaw**. *Preliminary findings on hyponormal operators on the Bergman space with non-harmonic symbol.* Preliminary report.

The Toeplitz operator acting on the Bergman space $A^2(\mathbb{D})$, with symbol φ is given by $T_\varphi f = P(\varphi f)$, where P is the projection from $L^2(\mathbb{D})$ onto the Bergman space. In this talk we will present some history on the study of hyponormal Toeplitz operators acting on $A^2(\mathbb{D})$, as well as give some results for when φ is a non-harmonic polynomial. (Received February 06, 2017)

1127-47-318 **Stefan Richter*** (`richter@math.utk.edu`). *Multipliers for Holomorphic Besov spaces of the ball of $\mathbb{C}^d$.* Preliminary report.

The Drury-Arveson space H^2_d is a space of analytic functions on the unit ball $\mathbb{B}_d$ of $\mathbb{C}^d$. It is at the cross-roads of multi-variable operator theory and function theory. It is important for the dilation theory of tuples of commuting operators associated with $\mathbb{B}_d$, its reproducing kernel has the complete Nevanlinna-Pick property, and it is one among a family of weighted holomorphic Besov spaces.

In this talk I plan to discuss some aspects of the emerging function theory of these spaces. (Received February 06, 2017)

1127-47-328 **Marie-Jose Saad*** (`mariejose@wustl.edu`). *Weak Factorization of the Hardy space $H^p(\mathbb{R}^n)$ in the multilinear setting, for $\frac{n}{n+1} < p < 1$.*

In 1976, Coifman, Rochberg and Weiss presented a weak factorization result of the Hardy Space $H^1(\mathbb{R}^n)$ through commutators. In 1981, Uchiyama proved a factorization of $H^p(\mathbb{R}^n)$ in the space of homogeneous type, for $p < 1$. In this talk, we extend Uchiyama's method and provide a proof of the weak factorization of $H^p(\mathbb{R}^n)$ in the multilinear setting, for $\frac{n}{n+1} < p < 1$. As an application, we obtain a characterization of the boundedness of the commutator $[b, T]$ from $L^{r_1}(\mathbb{R}^n)$ x ... x $L^{r_m}(\mathbb{R}^n)$ to $L^{q'}(\mathbb{R}^n)$, where $b \in \mathrm{Lip}_\alpha(\mathbb{R}^n)$, and $\frac{\alpha}{n} = \frac{1}{p} - 1$. (Received February 06, 2017)

1127-47-343 **Michael T Jury*** (`mjury@ufl.edu`) and **Robert T.W. Martin** (`rtwmartin@gmail.com`). *Extremal multipliers of the Drury-Arveson space.*

We consider a family of multipliers on the Drury-Arveson space H^2_d which we call *quasi-extreme.* To each contractive multiplier b is associated a de Branges-Rovnyak space $\mathcal{H}(b)$ with kernel

$$k^b(z, w) = \frac{1 - b(z)b(w)^*}{1 - zw^*}$$

In one variable, the theory of $\mathcal{H}(b)$ spaces splits into two streams, depending on whether or not b is an extreme point of the unit ball of $H^\infty(\mathbb{D})$. We show that there is an analogous splitting in the Drury-Arveson case, between the quasi-extreme and non-quasi-extreme cases. We give a number of equivalent characterizations of quasi-extremity, and prove that if b is quasi-extreme then b is an extreme point of the unit ball of the multiplier algebra of H^2_d. (Received February 06, 2017)

1127-47-361 **Robert Wolf*** (robert.wolf@uky.edu), 270 Malabu Drive, Lexington, KY 40502, and **Peter Hislop**. *Compactness of Isoresonant Potentials.* Preliminary report.

Brüning considered sets of isospectral Schrödinger operators with smooth real potential on a compact manifold of dimension 3. He showed the set of potentials associated to an isospectral set is compact in the C^∞ topology by relating the spectrum to the trace of the heat semi-group.

Similarly, we can consider the resonances of Schrödinger operators with real valued potentials on $\mathbb{R}^3$ whose support lies inside a ball of fixed radius that generate the same resonances as some fixed Schrödinger operator, an "isoresonant" set of potentials. Using the Poisson formula to relate the resonances to the trace of the wave group, we can show that this "isoresonant" set of potentials is also compact the C^∞ topology. (Received February 07, 2017)

49 ► Calculus of variations and optimal control; optimization

1127-49-42 **Chong Wang*** (chongwang@gwu.edu), 532 20TH ST NW, Apt 705, Washington, DC 20006, and **Yanxiang Zhao** and **Xiaofeng Ren**. *Pattern Formation – on the modeling of multi-constituent inhibitory systems.*

Skin pigmentation, animal coats and block copolymers, which can be considered as multi-constituent inhibitory systems, are all around us. Theoretical analysis and numerical simulation of multi-constituent inhibitory systems will be provided here. An inhibitory system is studied as a nonlocal geometric variational problem. The free energy of the system is the sum of two terms: the total size of the interfaces separating the constituents, and a longer ranging interaction energy that inhibits micro-domains from unlimited growth. We establish that in different parameter ranges there are corresponding assemblies of certain patterns that exist as the stationary sets of the free energy functional. Numerically, a diffusive interface model is proposed here to study the dynamics. To reduce the computational complexity, a reduced FFT-based fast algorithm is also discussed here. (Received January 08, 2017)

1127-49-93 **Tadele Mengesha*** (mengesha@utk.edu). *Variational limit of some convex nonlocal functionals.*

This talk is on the mathematical analysis of a certain class of nonlocal systems that are derived from a nonlocal model in continuum mechanics. The system is made up of coupled integral equations. I will briefly discuss their derivation and then show well poshness of the problem via basic variational analysis. Along the way, we will study associated energy spaces and establish connections with classical function spaces. By taking limit of certain parameters, we establish the convergence of a sequence of nonlocal energies to a limiting local (gradient-based) energy via Gamma convergence. As a special case the classical Navier-Lame potential energy will be realized as a limit of these nonlocal energy offering a rigorous connection between the nonlocal model to classical mechanics for small uniform strain. (Received January 25, 2017)

1127-49-99 **Alpár R. Mészáros*** (alpar@math.ucla.edu). *Mean Field Games with density constraints.*

The theory of Mean Field Games (MFG) was initiated by J.-M. Lasry and P.-L. Lions roughly 10 years ago. In its simplest form an MFG system can be written in terms of a coupled system of a Hamilton-Jacobi and a continuity equation. The first equation describes the evolution of the value function of a typical agent, while the second one characterizes the evolution of the agents' density.

We study a variational MFG model, where we impose a density constraint. From the modeling point of view, imposing this new constraint means that we are aiming to avoid congestion among the agents. A weak solution of the system contains an extra term, an additional price imposed on the saturated zones.

Our model shares some common features with the variational models of incompressible Euler equations à la Brenier. In particular, the additional price appearing in the saturated zones corresponds to the pressure field from these models. The techniques to study the regularity ($L^2_{loc,t}BV_x$) of the pressure field (developed by Y. Brenier and later by L. Ambrosio and A. Figalli) can be used in our context as well to obtain the same regularity for the additional price. The talk will be based on a joint work with P. Cardaliaguet (Paris Dauphine) and F. Santambrogio (Paris-Sud, Orsay). (Received January 26, 2017)

1127-49-197 **Tiziana Giorgi*** (tgiorgi@nmsu.edu), **Carlos J García-Cervera** and **Sookyung Joo**. *Analysis of Landau-de Gennes functionals for the $B_{1RevTilted}$ phase of bent-core liquid crystals.*

The $B_{1\mathrm{RevTilted}}$ is a columnar phase proper of bent-core molecule liquid crystals in which is possible to reorient the spontaneous polarization by applying an electric field. Experiments indicate that the reorientation can be achieved by either a rotation around the smectic cone or the molecular axis or a combination of both. We present a Gamma-convergence result for an energy introduced in the physics literature to model these experiments, and a comparison with a similar functional also used to study bent-core liquid crystals. (Received February 03, 2017)

1127-49-350 **Jochen Denzler*** (denzler@math.utk.edu), Dept of Mathematics, Ayres Hall, 1403 Circle Dr, Knoxville, TN 37996-1320. *The Oval Problem and Its Euler-Lagrange Equation.* Preliminary report.

The problem to minimize the principal eigenvalue of a Schrödinger operator $-d^2/ds^2+\kappa^2$ (with κ the curvature) on a loop of fixed length, as a function of the geometry of the loop, has been known as the Oval Problem. Existence and regularity of a solution (which are nontrivial due to a lack of compactness and coercivity) have been proved in prior work. The Euler-Lagrange equation for the problem seems rather daunting, and a proof for the conjectured family of minimizers has been elusive for over a decade. Nevertheless, the EL equation of the problem displays some intriguing structure that gives rise to insight (including an abundance of non-minimal critical points). I will elaborate on some details of this structure. This is a preliminary report on work in progress. (Received February 07, 2017)

51 ► Geometry

1127-51-173 **Maxime Fortier Bourque***, Department of Mathematics, 40 St. George Street, Toronto, Ontario M5S 2E4, Canada. *Searching for convex sets in Teichmüller space.*

It is an open question of Howard Masur whether the convex hull of 3 points in Teichmüller space is always compact. Indeed, very few convex sets are known. For example, metric balls are not necessarily convex. In an attempt to explore Masur's question, I will discuss an algorithm for computing extremal length, Teichmüller distance, and geodesics in some low-dimensional Teichmüller spaces. (Received February 02, 2017)

1127-51-186 **Bach Nguyen***, Louisiana State University, Department of Mathematics, 303 Lockett Hall, Baton Rouge, LA 70803, and **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 02, 2017)

52 ► Convex and discrete geometry

1127-52-115 **Robert Davis*** (davisr@math.msu.edu), 619 Red Cedar Rd., Michigan State University, East Lansing, MI 48824, and **Bruce Sagan**. *Pattern-avoiding Birkhoff polytopes and an application of Gröbner basis techniques.*

The Birkhoff polytope B_n is the convex hull of all $n \times n$ permutation matrices, and is a long-studied polytope related to many areas of mathematics. This talk will discuss a generalization which considers subpolytopes $B_n(\Pi)$ of B_n whose vertices correspond to permutations avoiding a given set of patterns Π. We will pay special attention to $B_n(132, 312)$ due to its relationship with certain EL-shellable posets, shifted standard Young tableaux, and (P, ω)-partitions. We will see how Gröbner basis techniques allow us to identify a regular, unimodular triangulation of $B_n(132, 312)$, which in turn allows us to compute explicit formluas for its normalized volume and its Ehrhart h^*-vector. (Received January 28, 2017)

53 ► Differential geometry

1127-53-403 **Benjamin Schmidt** (schmidt@math.msu.edu), Michigan State University, Department of Mathematics, East Lansing, MI 48824, and **Craig Sutton*** (craig.j.sutton@dartmouth.edu), Dartmouth College, Department of Mathematics, Hanover, NH 03755. *Detecting the Moments of Inertia of a Molecule via its Rotational Spectrum.* Preliminary report.

Spectral geometry has connections with the field of spectroscopy where one is interested in recovering the structure and composition of a molecule or compound from various spectral data. We demonstrate that the moments of inertia of a molecule can be recovered from its rotational spectrum. Geometrically speaking this means that the isometry classes of left-invariant metrics on SO(3) can be mutually distinguished via their spectra. In fact, they can be distinguished by their first four heat invariants. More generally, we demonstrate that among compact homogeneous three-manifolds a non-trivial isospectral pair must consist of spherical three-manifolds possessing non-isomorphic cyclic fundamental groups and each is equipped with a so-called Type I metric: at present, no such isospectral pairs exist in the literature. (Received February 07, 2017)

54 ► General topology

1127-54-39 **Ahmad Rafiqi*** (ar776@cornell.edu), 310 Malott Hall Cornell University, Ithaca, NY 14853. *Constructing pseudo-Anosov maps with given dilatations, and computing the Teichmuller polynomial.* Preliminary report.

Dilatations, or 'stretch factors', are a real numerical invariant associated to pseudo-Anosov self-homeomorphisms of a compact surface. These numbers turn out to be algebraic units and are biPerron. Given a biPerron algebraic unit λ (satisfying additional properties) we construct a surface and a self-homeomorphism of this surface with λ as dilatation.

The mapping torus of such a homeomorphism gives us a compact 3-manifold M (possibly with boundary) that fibers over the circle. The fiber is an element $[S] \in H_2(M, \partial M; \mathbb{Z}) \simeq H^1(M; \mathbb{Z})$. If the first cohomology of M is at least of rank 2, there are infinitely many other fibrations of M over the circle, and the Teichmuller polynomial encodes the dilatations of the monodromies of these other fibrations. We explain how to compute this polynomial. Part of this work was done in collaboration with Hyungryul Baik and Chenxi Wu. (Received January 30, 2017)

55 ► Algebraic topology

1127-55-4 **Jacobson Blomquist**, **Michael Ching** and **John E. Harper***, harper.903@math.osu.edu. *Iterated Suspension Spaces and an Integral Analog of Quillen's Rational Homotopy Theorem.*

In his landmark 1969 Annals paper, Quillen showed that the rational homotopy type of a simply connected space could be detected at the level of its singular rational chains, and furthermore, that rational chains fit into a derived equivalence with cocommutative dg coalgebras over the rationals, after restricting to 1-connected objects. In 1977 Sullivan subsequently proved the analogous result in the case of rational cochains and commutative dg algebras over the rationals. Since then topologists have worked on attempting to establish analogous results for finite fields (Kriz, Goerss, Mandell), and more recently some partial results have been established in the integral chains case (Mandell, Karoubi). Nevertheless, establishing that integral chains fit into a derived equivalence has proved resistant to all attacks. In this talk I will outline how we recently resolved, in the affirmative, the integral chains problem. If time permits, I will also describe how we recently resolved the problem of establishing a recognition principle for iterated suspension spaces, dual to the celebrated iterated loop spaces work of May and Beck. This is joint work with J. Blomquist and M. Ching. (Received September 12, 2016)

1127-55-8 **Zhen Huan*** (huan2@illinois.edu). *Quasi-elliptic cohomology.*

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

formulation of global stable homotopy theory that contains quasi-elliptic cohomology. (Received September 14, 2016)

1127-55-13 **Jon Carlson** and **Sunil K Chebolu***, Department of Mathematics, Illinois State University, Normal, IL 61761, and **Jan Minac**. *A Strong Generating Hypothesis for the Stable Module Category.*

Generating Hypothesis is a famous conjecture in homotopy theory due to Peter Freyd from 1965 which states that a map between finite spectra that induces the zero map on stable homotopy groups is null homotopic. Although this original conjecture is still unsolved, in the intervening years the corresponding conjecture in other triangulated categories including derived categories of rings and stable module category of a group algebra has been solved. In recent joint work with Jon Carlson and Jan Minac we formulated a strong form of this conjecture and solved it for the stable module category of a group algebra. This work has led to a new characterization of groups with periodic cohomology and related results on the finite generation problem for Tate cohomology. I will present an overview of this work which is based on arXiv:1509.02845. (Received November 06, 2016)

1127-55-15 **Niles Johnson*** (niles@math.osu.edu). *A 2-categorical group completion.* Preliminary report.

We discuss a 2-categorical construction generalizing Quillen's $S^{-1}S$. This provides a group-completion for 2-dimensional symmetric monoidal algebra which models topological group-completion. We apply this to prove the 2-dimensional stable homotopy hypothesis. This work is joint with N. Gurski and A. Osorno. (Received November 07, 2016)

1127-55-16 **Prasit Bhattacharya*** (pbhattac@nd.edu), 5634 Osage Lake Dr, Apt 2A, Mishawaka, IN 46545. *A very nice type 2 spectrum.*

Finite 2-local complex with 192 periodic v_2-self-map were known to exist, e.g. $M(1,4)$ and A_1, which leads to the question whether there exist 2-local finite complex with v_2-periodicity less than 192. In a joint work with P.Egger we answer this question by producing a finite 2-local spectrum Z which admits a 6-periodic v_2-self-map. The spectrum Z has some special properties, among which the most notable one is, $tmf \wedge Z \simeq k(2)$. We also give a complete calculation of the homotopy groups of its $K(2)$-localization. Moreover, because of the property mentioned above, the v_2-periodic part of E_2-page of tmf-based Adams spectral sequence can be computed as well, thereby providing a new gadget to attack the Telescope Conjecture at height 2 prime 2. Time permitting, we will discuss possible future applications that the spectrum Z may have. (Received November 11, 2016)

1127-55-17 **Bertrand Guillou*** (bertguillou@uky.edu), **Daniel Isaksen**, **Michael Hill** and **Douglas Ravenel**. *From motivic to equivariant homotopy groups - a worked example.* Preliminary report.

The realization of a motivic space defined over the reals inherits an action of Z/2Z, the Galois group. This realization functor allows for information to pass back and forth between the motivic and equivariant worlds. I will discuss one example: an equivariant Adams spectral sequence computation for ko, taking the simpler motivic computation as input. (Received November 11, 2016)

1127-55-18 **Xing Gu*** (xgu21@uic.edu), University of Illinois at Chicago, Mathematics & Comp Sci MC 249, 851 S. Morgan St., Chicago, IL 60607-7045. *On the Cohomology of the Classifying Space of PU_n.*

I will introduce a Leray-Serre spectral sequence converging to the integral cohomology ring $H^*(\mathbf{B}PU_n;\mathbb{Z})$ for any $n > 1$, where $\mathbf{B}PU_n$ is the classifying space of the projective unitary group of order n. I will show how to use this spectral sequence to determine the ring structure of $H^*(\mathbf{B}PU_n;\mathbb{Z})$ up to degree 10, for any $n > 1$, and obtain some of its p-local information, for any prime p. (Received December 04, 2016)

1127-55-19 **Kristine Bauer**, **Brenda Johnson**, **Christina Osborne*** (cdo5bv@virginia.edu), **Emily Riehl** and **Amelia Tebbe**. *Directional derivatives and higher order chain rules for abelian functor calculus.*

One of the most fundamental tools in calculus is the chain rule for functions. Huang, Marcantognini, and Young developed the notion of taking higher order directional derivatives, which has a corresponding higher order iterated directional derivative chain rule. When Johnson and McCarthy established abelian functor calculus, they constructed the chain rule for functors which is analogous to the directional derivative when $n = 1$. In joint work with Bauer, Johnson, Riehl, and Tebbe, we defined an analogue of the iterated directional derivative and provided an inductive proof of the analogue to the HMY chain rule. Our initial investigation of this result involved a concrete computation of the case when $n = 2$, which will be presented in this talk. (Received December 20, 2016)

1127-55-20 **Yifei Zhu*** (zyf@umn.edu). *Toward calculating unstable higher-periodic homotopy types.*
The rational homotopy theory of Quillen and Sullivan identifies homotopy types of topological spaces with differential graded commutative (co)algebras, and with differential graded Lie algebras, after inverting primes. Given any non-negative integer n, we can instead invert certain v_n*-self maps* and seek algebraic models for the resulting unstable v_n*-periodic* homotopy types. I'll explain why this is a natural and useful generalization of the classical story, and how a version of it has been achieved through Goodwillie calculus in recent work of Behrens and Rezk. I'll then explain my work on its applications to calculating unstable homotopy types in the case of $n = 2$. A key tool is power operations in Morava E-theory. (Received December 22, 2016)

1127-55-21 **Mentor Stafa*** (mstafa@iupui.edu). *The topology of some representation spaces.*
Spaces of group homomorphisms $Hom(\pi, G)$ from a discrete group to a Lie group have been studied in various contexts. We study the space of pairwise commuting n-tuples, i.e. π is free abelian of rank n, in a compact and connected Lie group G, from the topological viewpoint. We will describe a way to stabilize spaces of homomorphisms by introducing an infinite dimensional topological space, reminiscent of a Stiefel variety, that assembles the spaces of commuting tuples into a single space. Hilbert-Poincare series will be also described, in addition to other properties. (Received December 26, 2016)

1127-55-22 **Nima Rasekh*** (rasekh2@illinois.edu), Altgeld Hall, 1409 W. Green Street, URBANA, IL 61801. *Composition Fibrations: How Base Change can preserve Equivalences of Higher Categories.*
There are various models of higher categories, each of which comes with its own strengths and weaknesses. Two of the most famous models are quasi-categories and complete Segal spaces. Despite their many strengths, one of their weaknesses is the fact that these two models are not right proper, meaning that base change along fibrations does not preserve equivalences. Thus, we might ask ourselves which maps will preserve equivalences. The goal of this talk is to introduce a new class of maps, composition fibrations, that satisfies the desired property stated above. After introducing its key features, I will discuss some relevant examples and show how it leads to interesting implications. If time permits, I will also sketch out a proof on why composition fibrations preserve equivalences. (Received December 27, 2016)

1127-55-23 **Gabe Angelini-Knoll*** (gabriel.angelini-knoll@wayne.edu) and **Andrew Salch**. *Loday constructions in functor categories.*
The Loday construction in spectra produces interesting invariants such as topological Hochschild homology and its "higher order" variations. The construction is sufficiently general to be applied in the setting of general symmetric monoidal model categories satisfying mild assumptions. For example, the Loday construction can be defined for functor categories using the Day convolution symmetric monoidal product. I will describe how a specific case of this construction produces a spectral sequence in higher order topological Hochschild homology of a filtered commutative ring spectrum. New concrete calculations can be done by this method, for example, I compute topological Hochschild homology of the connective cover of the K(1)-local sphere. (Received December 27, 2016)

1127-55-26 **Cary L Malkiewich*** (cmalkiew@illinois.edu), 1409 W Green St, Urbana, IL 61801. *Periodic orbits and topological restriction homology.* Preliminary report.
This talk is about an emerging connection between algebraic K-theory and free loop spaces on the one hand, and periodic orbits of continuous dynamical systems on the other. The centerpiece is a construction in equivariant stable homotopy theory called the "nth power trace," which relies on the equivariant norm construction of Hill, Hopkins, and Ravenel. This trace is a refinement of the Lefschetz zeta function of a map f, which detects not just fixed points but also periodic orbits of f. The applications so far include the resolution of a conjecture of Klein and Williams, and a new approach for the computation of transfer maps in algebraic K-theory. These projects are joint work with John Lind and Kate Ponto. (Received January 03, 2017)

1127-55-27 **Thomas M. Fiore*** (tmfiore@umich.edu). *Approximation in K-theory for Waldhausen Quasicategories.*
Waldhausen's Approximation Theorem from 1985 gives a sufficient criteria for an exact functor to induce a level-wise equivalence of Waldhausen K-theory spectra. This talk is about an analogous version in the setting of quasicategories: if an exact functor F satisfies Waldhausen's App 1 and App 2, and the domain admits certain colimits, then F induces a level-wise equivalence in Waldhausen K-theory. As a corollary, if F is an exact

functor of Waldhausen quasicategories and induces an equivalence of homotopy categories, and all morphisms of the domain are cofibrations, then F induces a level-wise equivalence in Waldhausen K-theory. The main technical result to prove this is a Pre-Approximation Theorem that does not require Waldhausen structures. Namely, if F is a functor between quasicategories that reflects equivalences, every morphism $Fa \to b$ factors as $(equiv) \circ Ff$, the functor of homotopy categories hoF is essentially surjective and full on isos, and the domain of F admits certain colimits preserved by F, then F induces an equivalence of maximal Kan subcomplexes. (Received January 04, 2017)

1127-55-30 **Zachery Lindsey*** (`zalindse@indiana.edu`). *Localization of Quasicategories with Calculi of Right Fractions.*

Working in the model of quasicategories, we define a generalization of a calculus of right fractions for a relative quasicategory $(\mathcal{C}, \mathcal{W})$. We also show that a marked version of $\mathrm{Ex}(\mathcal{C})$ models the localization $\mathcal{C}[[\mathcal{W}^{-1}]]$, and when the pair $(\mathcal{C}, \mathcal{W})$ admits a calculus of right fractions, then this marked Ex construction is already a quasicategory. Hence the usual models of mapping spaces in a quasicategory can be readily applied to compute the mapping spaces in $\mathcal{C}[[\mathcal{W}^{-1}]]$ in this case. (Received January 04, 2017)

1127-55-32 **Carolyn Yarnall*** (`carolyn.yarnall@uky.edu`). *Slices, Suspensions, and Connectivity.*

The equivariant slice filtration is an analogue of the Postnikov tower for G-spectra. However, since nontrivial representation spheres are used to construct the slice tower, we have a different notion of connectivity and thus, some of the nice properties of the Postnikov tower do not hold in this setting. In this talk, after recalling the construction and basic properties of the slice tower, we will discuss a new way of determining slices by looking at equivariant connectivity and provide specific examples of slice towers of suspensions of certain Eilenberg-MacLane spectra. (Received January 04, 2017)

1127-55-114 **Philip Tosteson*** (`ptoste@umich.edu`). *Representation Stability for Singular Configuration Spaces.*

We introduce an analog of the Totaro spectral sequence that converges to the cohomology of $\mathrm{Conf}_n X$ for any Hausdorff space X, and use it to extend representation stability of cohomology to a topological spaces that are not manifolds, but that are in some sense ≥ 2 dimensional. (Received January 28, 2017)

1127-55-153 **Kate Ponto*** (`kate.ponto@uky.edu`), 715 Patterson Office Tower, Department of Mathematics, Lexington, KY 40508. *Refinements of fixed point invariants and refinements of the symmetric monodial trace.*

Classical fixed point invariants start with detecting fixed points of the identity map (up to homotopy) via the Euler characteristic. The Euler characteristic generalizes to the Lefschetz number and then to the Reidemeister trace. These invariants capture all of the interesting information about fixed points (up to homotopy), but they also have interesting further refinements.

The Lefschetz number and Reidemeister trace are examples of the trace in symmetric monodial categories or bicategories and this structure captures many of the fundamental results about the invariants. I will describe how the categorical traces generalize to match the interesting topological refinements.

This work is joint with Cary Malkiewich. (Received February 01, 2017)

1127-55-178 **Anna Marie Bohmann**, **Teena Gerhardt*** (`teena@math.msu.edu`), **Amalie Hogenhaven**, **Brooke Shipley** and **Stephanie Ziegenhagen**. *Computational Tools for Topological coHochschild Homology.*

The theory of Hochschild homology for algebras has a topological analogue, topological Hochschild homology (THH). For coalgebras, there is an algebraic theory dual to Hochschild homology, called coHochschild homology. In recent work, Hess and Shipley defined a topological version of coHochschild homology (coTHH) for coalgebra spectra. In this talk I will introduce this theory of coTHH, discuss computational tools to study coTHH, and present some computational results. This work is joint with Bohmann, Hogenhaven, Shipley, and Ziegenhagen. (Received February 02, 2017)

1127-55-311 **Megan Maguire*** (`mmaguire2@math.wisc.edu`). *Cohomology algebras of configuration spaces.* Preliminary report.

For a manifold X with finite-dimensional cohomology, we know that the cohomology algebra of each unordered configuration space of X is finitely generated, but can we say something stronger about their generators? More precisely, does there exist a D (depending only on X) so that the cohomology algebra of each unordered configuration space of X can be generated in degree at most D? We will answer this question in some cases. (Received February 06, 2017)

1127-55-321 **Amin Saied*** (amin.saied@gmail.com), 205A W Court St, Ithaca, NY 14850. *On the homology of $Aut(F_n)$ and $Out(F_n)$ with certain twisted coefficients.*

This is joint work with Martin Kassabov and Jim Conant, who constructed an action of $\mathrm{Aut}(F_n)$ on $H^{\otimes n}$ where H is a cocommutative Hopf algebra, and who introduced a related representation of $\mathrm{Out}(F_n)$. We study certain coefficients $c_{\lambda,\mu}$ arising from a filtration of these representations and discover stability patterns among them akin to representation stability. This construction is related to the study of the Johnson cokernel when H is the tensor algebra, and to the abelianisation of Kontsevich's Lie Lie algebra when H is the symmetric algebra. (Received February 06, 2017)

1127-55-347 **Jeremy Miller**, **Peter Patzt** and **Jennifer C. H. Wilson***, jchw@stanford.edu. *Stability in the second homology of Torelli groups.*

In this talk, I will describe stability results for two families of groups, the Torelli groups of automorphisms of free groups, and (respectively) the Torelli groups of mapping class groups of surfaces with one boundary component. Specifically, I will explain the following statement: the degree-2 integer homology groups of these Torelli groups are *centrally stable* when viewed as representations of $\mathrm{GL}_n(\mathbb{Z})$ and (respectively) $\mathrm{Sp}_{2n}(\mathbb{Z})$. This project uses a framework developed by Putman, Church–Ellenberg–Farb, and Putman–Sam. It is work in progress, joint with Jeremy Miller and Peter Patzt. (Received February 06, 2017)

57 ► Manifolds and cell complexes

1127-57-148 **Zhenghan Wang*** (zhenghwa@microsoft.com), 2237 CNSI Bldg. Microsoft Station Q, UC Santa Barbara, Santa Barbara, CA 93106. *A remark on the volume conjecture.* Preliminary report.

The volume conjecture is inspired by 3D quantum gravity, which is some unitary irrational TQFT. I will remark on possible rational versions of a volume conjecture. (Received February 01, 2017)

1127-57-152 **Thomas Kerler*** (kerler.2@osu.edu) and **Qi Chen**. *Integrality and Gauge Dependence of Hennings TQFTs.*

We provide an overview of our construction of integral TQFTs over a general commutative ring, k, starting from a finite Hopf algebra over k which is Frobenius and double balanced. The examples of Borel parts of Lusztig's small quantum groups for all simple Lie types and k given by the cyclotomic integers are discussed. An explicit isomophism between TQFTs that stem from ribbon Hopf algebras related by a gauge twist in the sense of Drinfeld is established. Applications to specific situations are outlined. (To appear in Journal of Pure and Applied Algebra). (Received February 01, 2017)

1127-57-225 **Vladimir Turaev*** (vturaev@yahoo.com), 831 E 3rd St, Bloomington, IN 47405-7106. *Homotopy Quantum Field Theory.*

I will survey Homotopy Quantum Field Theory following mainly my joint papers with Alexis Virelizier. (Received February 04, 2017)

1127-57-277 **Wade Bloomquist*** (bloomquist@math.ucsb.edu) and **Zhenghan Wang**. *Asymptotic Faithfulness of Skein Quantum $SU(3)$ Representations.*

We generalize the asymptotic faithfulness of the skein quantum $SU(2)$ representations of mapping class groups of orientable surfaces to skein $SU(3)$. This skein construction yields a different underlying modular tensor category compared to the Reshetikin-Turaev ones coming from quantum groups or geometric quantization, and so yields a different mapping class group representation. (Received February 06, 2017)

1127-57-300 **Helen Wong*** (hwong@carleton.edu), 1 North College St, Northfield, MN 55057, and **Francis Bonahon**. *Representations of the Kauffman Bracket Skein Algebra.*

The Kauffman bracket skein algebra of a surface was originally defined as a generalization of the Jones polynomial, and a representation of the skein algebra plays an important role in the Witten-Reshetikhin-Turaev quantum field theory. In this talk, we survey recent results related to the construction and classification of representations of the Kauffman bracket skein algebra. (Received February 06, 2017)

58 ► Global analysis, analysis on manifolds

1127-58-28 **Liviu I Nicolaescu*** (lnicolae@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Random functions and spectral geometry.*

On a given closed Riemann manifold (M,g) we consider random functions described as sums of certain random series of eigenfunctions of the rescaled metric $\hbar^{-2}g$. As $\hbar \to 0$ this random function approaches the white noise. We investigate the asymptotic behavior as $\hbar \to 0$ of several quantities associated to this random function and explain how to completely recover the geometry of (M,g) from these probabilistic asymptotics. (Received January 04, 2017)

1127-58-57 **Alexandre Girouard*** (alexandre.girouard@mat.ulaval.ca), Département de mathématiques, Pavillon Alexandre-Vachon, 1045, av. de la Médecine, Québec, Québec G1V 0A6, Canada, **Bruno Colbois**, Neuchâtel, Switzerland, and **Ahmad El Soufi**, Tours, France. *Compact manifolds with fixed boundary and large Steklov eigenvalues.*

Let (M,g) be a compact Riemannian manifold with boundary. Let $b>0$ be the number of connected components of its boundary. For manifolds of dimension ≥ 3, we prove that for $j=b+1$ it is possible to obtain an arbitrarily large Steklov eigenvalue $\sigma_j(M,e^{\delta}g)$ using a conformal perturbation $\delta \in C^{\infty}(M)$ which is supported in a thin neighbourhood of the boundary, with $\delta=0$ on the boundary. For $j \leq b$, it is also possible to obtain arbitrarily large eigenvalues, but the conformal factor must spread throughout the interior of M. We also prove that it is possible to obtain large eigenvalues while keeping different boundary components arbitrarily close to each others, by constructing a convenient Riemannian submersion. (Received January 15, 2017)

1127-58-179 **David Borthwick*** (davidb@mathcs.emory.edu), Dept. of Mathematics and CS, 400 Dowman Dr., Atlanta, GA 30306. *Distribution of Resonances for Hyperbolic Surfaces.*

For hyperbolic surfces of infinite area, the appropriate generalization of the eigenvalue spectrum is the resonance set, the set of poles of the resolvent of a meromoprhic continuation of the Laplacian. We will introduce the notion of resonances and discuss recent progress that has been made in understanding the distribution of resonances. (Received February 02, 2017)

1127-58-193 **Dubi Kelmer*** (dubi.kelmer@bc.edu), Department of Mathematics, Maloney Hall Boston College, Chestnut Hill, MA 02467. *On the spectrum and length spectrum of hyperbolic manifolds.*

There is a close relation between the eigenvalues of the Laplace-Beltrami operator of a Riemannian manifold and the set of lengths of its closed geodesics. Moreover, from these spectra one can extract additional geometric properties of the manifolds. In my talk I will describe some new and old results of this type. In particular, I will discuss the question of how much information can be obtained when we have only partial information on the spectrum. (Received February 03, 2017)

1127-58-270 **Teresa Arias-Marco**, **Emily Dryden** and **Carolyn Gordon***, csgordon@dartmouth.edu, and **Asma Hassannezhad**, **Allie Ray** and **Elizabeth Stanhope**. *Spectral geometry of the Steklov problem on orbifolds.*

We consider how the geometry and topology of a compact Riemannian orbifold with boundary relates to its Steklov spectrum, i.e., to the spectrum of the Dirichlet-to-Neumann operator. In two dimensions, motivated by work of A. Girouard, L. Parnovski, I. Polterovich and D. Sher in the manifold setting, we compute the precise asymptotics of the Steklov spectrum in terms of only boundary data. As a consequence, we prove that the Steklov spectrum detects the presence and number of orbifold singularities on the boundary of an orbisurface and it detects the number each of smooth and singular boundary components. Moreover, we find that the Steklov spectrum also determines the lengths of the boundary components modulo an equivalence relation, and we show by examples that this result is the best possible. We give examples showing that the Steklov spectrum does *not* detect the presence of interior singularities nor does it determine the orbifold Euler characteristic. In fact, a flat disk is Steklov isospectral to a cone. (Received February 05, 2017)

1127-58-280 **Gabe Khan*** (khan.375@osu.edu), 218 W 18th Ave, Columbus, OH 43210. *Estimates on the Principle Eigenvalue of a Hermitian Manifold.* Preliminary report.

A natural geometric invariant on a Riemannian manifold is the spectrum of the Laplacian. In this talk, we consider a compact Hermitian manifold M and study the principle eigenvalue of the complex Laplacian on M. A natural question is to estimate the principle eigenvalue using the Hermitian and Riemannian geometry. We also show that, under some special conditions, we can establish estimates solely from the Riemannian geometry independent of the choice of complex structure. This provides an example of the connection between the complex and Riemannian geometry of a Hermitian manifold. This connection has manifested itself in many different theorems that show that under certain curvature conditions a Riemannian metric admits no complex structure. However, for our work, we assume that the metric admits some complex structure but try to establish results that are independent of the choice of complex structure. (Received February 06, 2017)

1127-58-400 **Brian Benson*** (babenson@ksu.edu), **Ivan Blank** and **Jeremy LeCrone**. *Mean Value Theorems for the Laplace-Beltrami Operator.* Preliminary report.

We have proven a mean value theorem for the Laplace-Beltrami operator. In this talk, we will discuss how this mean value theorem relates to those previously established in the literature. Further, we will discuss our developments of some of the introductory theory of the obstacle (free boundary) problem on Riemannian manifolds which we used to prove our result. (Received February 07, 2017)

60 ► *Probability theory and stochastic processes*

1127-60-9 **Martial Longla*** (mlongla@olemiss.edu). *Remarks on limit theorems for reversible Markov processes and their linear functions.*

We propose some backward-forward martingale decompositions for functions of reversible Markov chains. These decompositions are used to prove the functional Central limit theorem for reversible Markov chains with asymptotically linear variance of partial sums. We also provide a proof of the equivalence between asymptotic linearity of the variance and convergence of the integral of $1/(1-t)$ with respect to the associated spectral measure ρ. We show a result on uniform integrability of the supremum of the average sum of squares of martingale differences. We also study the asymptotic behavior of linear processes having as innovations mean zero square integrable functions of stationary reversible Markov chains. We include in our study the long range dependence case. We apply this study to several cases of reversible stationary Markov chains that arise in regression estimation. (Received September 16, 2016)

1127-60-10 **Richard C Bradley*** (bradleyr@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405. *On mixing properties of reversible Markov chains.*

This talk will discuss an example, from R.C. Bradley [*New Zealand J. Math.* 45 (2015) 71-87], of a strictly stationary, countable-state, reversible Markov chain that satisfies the ρ-mixing condition (and hence also geometric ergodicity) but fails to satisfy ρ^*-mixing (the "interlaced" variant of ρ-mixing in which the two index sets can be "interlaced" instead of being restricted to "past" and "future"). In this example, the "mixing rate" for ρ-mixing (and absolute regularity and even information regularity) can be made "arbitrarily fast exponential", and the entropy of the marginal distribution can be made arbitrarily small. (Received September 18, 2016)

1127-60-34 **Liviu I Nicolaescu*** (lnicolae@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *A stochastic Gauss-Bonnet-Chern theorem.*

We investigate Gaussian ensembles of random sections of an oriented real vector bundle E over a compact oriented manifold M. We first show that this ensemble naturally defines a metric on E and a connection compatible with this metric. We next prove that the expectation of the random current defined by the zero locus of such a random section is equal, as a current, to the Euler form of E canonically determined by the above metric and connection. (Received January 05, 2017)

1127-60-35 **Richard C. Bardley** and **Cristina Tone*** (cristina.tone@louisville.edu). *A Central Limit Theorem for Non-stationary Strongly Mixing Random Fields.*

A central limit theorem is introduced for sequences of random fields that satisfy a Lindeberg condition and uniformly satisfy both strong mixing and an upper bound less than 1 on $\rho'(\cdot, 1)$, in the absence of stationarity. There is no requirement of either a mixing rate assumption or the existence of moments of order higher than two. The additional assumption of a uniform upper bound less than 1 for $\rho'(\cdot, 1)$, cannot simply be deleted altogether from the theorem, even in the case of strict stationarity. For the case $d = 1$, that can be seen from any (finite-variance) strictly stationary, strongly mixing counterexample to the CLT such that the rate of growth of the variances of the partial sums is at least linear; see Bradley (1), Theorem 10.25 and Chapters 30-33. Our main theorem extends certain central limit theorems of Peligrad (2) involving "arrays of random sequences".

(1) Bradley, R.C.,*Introduction to Strong Mixing Conditions*, vol. 1, 2, and 3. Kendrick Press, Heber City (Utah) (2007)

(2) Peligrad, M., *On the asymptotic normality of sequences of weak dependent random variables*, J. Theor. Probab. 9, 703-715 (1996). (Received January 05, 2017)

1127-60-36 **Pavel Bleher**, **Yushi Homma** and **Roland Roeder*** (rroeder@math.iupui.edu). *Two-Point Correlation Functions and Universality for the Zeros of Systems of $SO(n+1)$-invariant Gaussian Random Polynomials.*

We study the two-point correlation functions for the zeroes of systems of SO(n+1)-invariant Gaussian random polynomials on $\mathbb{RP}^n$ and systems of isom($\mathbb{R}^n$)-invariant Gaussian analytic functions. Our result reflects the same "repelling," "neutral," and "attracting" short-distance asymptotic behavior, depending on the dimension, as was discovered in the complex case by Bleher, Shiffman, and Zelditch. For systems of the isom($\mathbb{R}^n$)-invariant Gaussian analytic functions we also obtain a fast decay of correlations at long distances.

We then prove that the correlation function for the isom($\mathbb{R}^n$)-invariant Gaussian analytic functions is "universal," describing the scaling limit of the correlation function for the restriction of systems of the $SO(k+1)$-invariant Gaussian random polynomials to any n-dimensional C^2 sub manifold $M \subset \mathbb{RP}^n$. This provides a real counterpart to the universality results that were proved in the complex case by Bleher, Shiffman, and Zelditch. (Our techniques also apply to the complex case, proving a special case of the universality results of Bleher, Shiffman, and Zelditch.) (Received January 06, 2017)

1127-60-40 **Christopher Dean Sinclair** and **Maxim L. Yattselev*** (maxyatts@iupui.edu). *Root statistics of random polynomials with bounded Mahler measure.*

The Mahler measure of a polynomial is a measure of complexity formed by taking the modulus of the leading coefficient times the modulus of the product of its roots outside the unit circle. The roots of a real degree N polynomial chosen uniformly from the set of polynomials of Mahler measure at most 1 yields a Pfaffian point process on the complex plane. When N is large, with probability tending to 1, the roots tend to the unit circle. In this talk, the asymptotics of the scaled kernel in a neighborhood of a point on the unit circle will be described. (Received January 06, 2017)

1127-60-43 **Erkan Nane*** (ezn0001@auburn.edu). *Analysis of space-time fractional stochastic partial differential equations.*

Stochastic partial differential equations and random fields have been used as successful models in various areas of applied mathematics, statistical mechanics, theoretical physics, theoretical neuroscience, theory of complex chemical reactions, fluid dynamics, hydrology, cosmology, mathematical finance, and other scientific areas.

In this talk I will consider non-linear space-time fractional stochastic heat type equations. These time fractional stochastic heat type equations are attractive models that might be used to model phenomenon with random effects with thermal memory. In this talk, I will discuss: (i) Existence an uniqueness of solutions and existence of a continuous version of the solution; (ii) absolute moments of the solutions of this equation grows exponentially; and (iii) intermittency fronts. Our results are significant extensions of those in recent papers by Foodun, Liu, Omaba (Preprint, 2014); Foondun and Khoshnevisan(Electron. J. Probab., 2009, and Conus and Khoshnevisan (Probab. Theory Related Fields, 2012).

These results are our recent joint work with Jebessa B Mijena, Mohammud Foondun, Sunday Asogwa and Guerngar Ngartelbaye. (Received January 09, 2017)

1127-60-46 **Juan Carlos Escanciano*** (jescanci@indiana.edu), 3568 East Bryn Mawr Drive, Bloomington, IN 47401. *Persistence in Nonlinear Time Series: A Nonparametric Approach.*

Traditional measures of persistence in time series are typically based on correlations or periodograms. These are adequate in many circumstances but in others, like those implied by nonlinearity and/or non-Gaussianity, might be inappropriate. In the present paper we show that nonlinear persistence can be characterized by nonparametric cumulative measures of dependence, we propose estimates for these measures and establish their limiting properties. Additionally, we employ our measures to analyze the nonlinear persistence properties of some international stock market indices, where we find an ubiquitous nonlinear persistence in conditional variance that is not accounted for by popular parametric models or by classical linear measures of persistence. This finding has important economic implications in, e.g., asset pricing and hedging. Conditional variance persistence in bull and bear markets is also analyzed and compared.

Keywords and Phrases: Conditional mean; Nonlinear time series; Nonlinear persistence; Nonlinear correlograms; Persistence in variance; Bull and bear markets. (Received January 11, 2017)

1127-60-51 **Indranil SenGupta*** (indranil.sengupta@ndsu.edu), Department of Mathematics, North Dakota State University, NDSU Dept # 2750, Minard Hall 408, Fargo, ND 58108-6050.
Generalized Barndorff-Nielsen and Shephard model with applications in financial swaps.

In this presentation, a class of generalized Barndorff-Nielsen and Shephard model will be investigated from the viewpoint of derivative asset analysis. It will be shown that such models can be effectively used for arbitrage free pricing of volatility, variance, and covariance swaps. One of the major challenges in arbitrage free pricing of swap is to obtain an accurate pricing expression which can be used with good computational accuracy. In this presentation various approximate expressions will be obtained for the pricing of volatility, variance, and covariance swaps. (Received January 12, 2017)

1127-60-54 **Chunfeng Huang*** (huang48@indiana.edu), **Haimeng Zhang**, **Scott Robeson** and **Jacob Shields**. *Intrinsic random functions on the sphere.*

Spatial stochastic processes that are modeled over the entire Earth's surface require statistical approaches that directly consider the spherical domain. We extend the notion of intrinsic random functions to model non-stationary processes on the sphere and show that low-frequency truncation plays an essential role. The developments can be presented through the theory of reproducing kernel Hilbert space. In addition, the link between universal kriging and splines is carefully investigated, whereby we show that thin-plate splines are non-applicable for surface fitting on the sphere. (Received January 13, 2017)

1127-60-59 **Elena Kosygina** and **Jonathon Peterson*** (peterson@purdue.edu), 150 N University St, West Lafayette, IN 47907. *Functional limit laws for recurrent excited random walks.*

Excited random walks (also called cookie random walks) are a model for self-interacting random motion where the transition probabilities are dependent on the local time at the current location. While self-interacting random walks are typically very difficult to study, many results for (one-dimensional) excited random walks are remarkably explicit. In particular, one can easily (by hand) calculate a parameter of the model that will determine many features of the random walk: recurrence/transience, non-zero limiting speed, limiting distributions and more.

In this talk I will discuss functional limit laws for one-dimensional excited random walks that are recurrent. For certain values of the parameters in the model the random walks under diffusive scaling converge to a "Brownian motion perturbed at its extremum." This was known previously for the case of excited random walks with boundedly many cookies per site, but we are able to generalize this to excited random walks with periodic cookie stacks. In this more general case, it is much less clear why perturbed Brownian motion should be the correct scaling limit. (Received January 16, 2017)

1127-60-66 **M Denker*** (denker@math.psu.edu). *Occupation times for fractal Gaussian noise.*

We discuss occupation times for a special long range dependent Gaussian process: the discrete time fractional Brownian motion with Hurst prameter $3/4<H<1$. Topics are: relation to Mittag-Leffler distribution,conditional local limit theorems and infinite ergodic theory. This is joint work with Xiaofei Zheng. (Received January 19, 2017)

1127-60-67 **José Enrique Figueroa-López** (figueroa@math.wustl.edu), One Brookings Drive, St. Louis, MO 63130-4899, **Ruoting Gong*** (rgong2@iit.edu), 10 West 32nd Street, Chicago, IL 60616, and **Matthew Lorig** (mlorig@uw.edu), 4182 W Stevens Way NE, Seattle, WA 98195-3925. *Short-Time Asymptotics for Options on Leveraged ETFs under Exponential Lévy Models with Local Volatility.*

In this talk, we consider the small-time asymptotics of options on a Leveraged Exchange-Traded Fund (LETF) when the underlying Exchange Traded Fund (ETF) exhibits both local volatility and Lévy jumps of either finite or infinite activity. We show that leverage modifies the drift, volatility, jump intensity, and jump distribution of an LETF in addition to inducing the possibility of default, even when the underlying ETF price remains strictly positive. Our main results are closed-form expressions for the leading order terms of off-the-money European call and put LETF option prices, near expiration, with explicit error bounds. These results, in turn, suggest a method to hedge off-the-money LETF options near expiration using options on the underlying ETF. Finally, we derive a second-order expansion for the implied volatility of an off-the-money LETF option and show both analytically and numerically how this is affected by leverage. (Received January 20, 2017)

1127-60-83 **Dan Pirjol*** (`dpirjol@gmail.com`), 225 St Pauls Avenue, apt 17H, Jersey City, NJ 07306, and **Lingjiong Zhu** (`ling@cims.nyu.edu`), Department of Mathematics, Florida State University, Tallahassee, FL. *Infinite sums of the geometric Brownian motion and generalizations.*

The infinite sum of a geometric Brownian motion (gBM) sampled on a sequence of uniformly spaced times appears in problems of theoretical probability, actuarial science and mathematical finance. For example this appears when considering the present value of a perpetuity: a fixed recurring payment made in perpetuity from an initial deposit of stock, assumed to follow a geometric Brownian motion. The talk studies the distributional properties of the infinite sum of the gBM. This can be characterized as the stationary distribution of a linear stochastic recursion. Tail asymptotics are derived, and the distribution is found numerically by solving an integral equation. Similar results are obtained for the sum of the gBM with a geometrically distributed stopping time. The results can be generalized further by replacing the gBM with an exponential Levy process. (Received January 23, 2017)

1127-60-92 **Samy Tindel*** (`stindel@purdue.edu`), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907. *Rate of convergence to equilibrium for fractional driven stochastic differential equations with rough multiplicative noise.* Preliminary report.

In this talk we wish to give an account on the problem of the rate of convergence to equilibrium for ergodic stochastic differential equations driven by a fractional Brownian motion with Hurst parameter $H \in (1/3, 1)$ and multiplicative noise component σ. When σ is constant and for every $H \in (0, 1)$, it was proved by Hairer that, under some mean-reverting assumptions, such a process converges to its equilibrium at a rate of order $t^{-\alpha}$ where $\alpha \in (0, 1)$ (depending on H). In this talk, we will show how to extend this result to a multiplicative noise in an irregular situation. We will mainly focus on the general mechanism one should adopt in this context with long range dependence, and we will show how to construct the coupling we need for our purposes. (Received January 25, 2017)

1127-60-109 **Ewain Gwynne*** (`ewain@mit.edu`) and **Jason Miller**. *Convergence of the self-avoiding walk on random quadrangulations to $SLE_{8/3}$ on $\sqrt{8/3}$-Liouville quantum gravity.*

We prove that a uniform infinite quadrangulation of the half-plane decorated by a chordal self-avoiding walk (SAW) converges in the scaling limit to $\mathrm{SLE}_{8/3}$ on an independent $\sqrt{8/3}$-Liouville quantum gravity surface, which can equivalently be described as the metric gluing of two independent Brownian half-planes identified along their positive boundary rays. The topology of convergence is the local Gromov-Hausdorff-Prokhorov-uniform topology, the natural generalization of the local Gromov-Hausdorff topology to curve-decorated metric measure spaces. The proof of the scaling limit result uses only the theory of random planar maps and does not make direct use of SLE or LQG. Based on joint work with Jason Miller https://arxiv.org/abs/1608.00956. (Received January 27, 2017)

1127-60-130 **Robin Pemantle*** (`pemantle@math.upenn.edu`), 209 South 33rd Street, Philadelphia, PA 19104. *Zeros of random polynomials and their derivatives.*

Consider a random polynomial or power series f. Its zero set Z is a point process in the complex plane. An obvious and much studied question is to describe of the law of Z. In this talk I consider a rather different model where f is obtained from g by differentiating once or more, with the zeros of g following some simple law. The goal is now to understand how the zeros evolve. In one step, there is little change. In many steps, for a model with zeros of constant density on the real line, the zeros approach an evenly spaced lattice. (Received January 30, 2017)

1127-60-142 **L Weakley*** (`llnguyen@iu.edu`). *Strictly stationary, N-tuplewise independent counterexamples to the Central Limit Theorem.*

For an arbitrary integer $N \geq 2$, we construct a strictly stationary, N-tuplewise independent sequence of (nondegenerate bounded) random variables that is mixing in the ergodic-theoretic sense and such that the Central Limit Theorem fails to hold. This construction was given by L. Weakley [Ph.D. Dissertation, Indiana University, 2013]. It is an adaptation of a construction from a paper by Bradley and Pruss [*Stochastic Processes and Their Applications*,**119**, 2009] of a strictly stationary, N-tuplewise independent, ergodic sequence of (nondegenerate bounded) random variables such that the Central Limit Theorem fails to hold. (Received February 03, 2017)

1127-60-149 **Magda Peligrad*** (peligrm@ucmail.uc.edu), Department of Mathematical Sciences, PoBox 210015, Cincinnati, OH 45221-0025, and **Na Zhang**. *Central limit theorem for discrete double Fourier series of random fields.* Preliminary report.

The talk is motivated by the properties surrounding the spectral density of a process and of a random field. We start by presenting a characterization of the spectral density in function of projection operators on sub-sigma fields. We also point out that the limiting distribution of the real and the imaginary part of the Fourier transform of a stationary random field is almost surely an independent vector with Gaussian marginal distributions, whose variance is, up to a constant, the field's spectral density. The dependence structure of the random field is general and we do not impose any conditions on the speed of convergence to zero of the covariances, or smoothness of the spectral density. The only condition required is that the variables are adapted to a partially commuting filtration and are regular in some sense. The results go beyond the Bernoulli fields and apply to both short range and long range dependence. The method of proof is based on new probabilistic methods based on martingale approximations and also on borrowed tools from harmonic analysis. Several examples to linear, Volterra and Gaussian random fields will be presented. (Received February 01, 2017)

1127-60-160 **Panki Kim** and **Renming Song*** (rsong@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green St, Urbana, IL 61801, and **Zoran Vondracek**. *Potential theory of subordinate killed Brownian motions.*

Let W^D be a killed Brownian motion in a domain $D \subset \mathbb{R}^d$ and S an independent subordinator with Laplace exponent ϕ. The process Y^D defined by $Y^D_t = W^D_{S_t}$ is called a subordinate killed Brownian motion. It is a Hunt process with infinitesimal generator $-\phi(-\Delta|_D)$, where $\Delta|_D$ is the Dirichlet Laplacian. In this paper we study the potential theory of Y^D under a weak scaling condition on the derivative of ϕ. We first show that non-negative harmonic functions of Y^D satisfy the scale invariant Harnack inequality. Subsequently we prove two types of scale invariant boundary Harnack principles with explicit decay rates for non-negative harmonic functions of Y^D. The first boundary Harnack principle deals with a $C^{1,1}$ domain D and non-negative functions which are harmonic near the boundary of D, while the second one is for a more general domain D and non-negative functions which are harmonic near the boundary of an interior open subset of D. The obtained decay rates are not the same, reflecting different boundary and interior behaviors of Y^D. (Received February 01, 2017)

1127-60-161 **Xiaoqin Guo***, 150 N University St, West Lafayette, IN 47907, and **N Berger**, **J.-D. Deuschel** and **A. F Ramirez**. *Central limit theorems for random walks in balanced random environment.*

In this talk we will discuss random walks in a zero-drift ergodic random environment on Z^d which is allowed to be non-elliptic. We will obtain a condition of the quenched central limit theorem (QCLT) for non-elliptic environment, which generates all currently known conditions. We will also show that the limiting diffusion constants of the QCLT maybe random, if the ergodic environment is not mixing enough. This is a joint work with my coauthors Noam Berger, Jean-Dominique Deuschel and Alejandro Ramirez. (Received February 01, 2017)

1127-60-163 **Yimin Xiao*** (xiao@stt.msu.edu), Department of Statistics and Probability, Michigan State University, 619 Red Cedar Rd, East Lansing, MI 48824. *Fractal Properties of Operator Stable Lévy Processes.* Preliminary report.

It is known that operator (semi)-stable Lévy processes are operator (semi)-self-similar and their sample functions can generate various random fractals. By applying potential theory of multiparameter Lévy processes in Khoshnevisan and Xiao (2003, 2009), we determine the Hausdorff dimensions of the range, graph, and set of multiple points of a symmetric operator (semi) stable Lévy process $X = \{X(t), t \in \mathbb{R}_+\}$ in terms of the eigenvalues of its stability exponent.

This talk is based on joint works with D. Khoshnevisan, P. Kern, T. Luks, and M. M. Meerschaert. (Received February 01, 2017)

1127-60-166 **Lu Chen**, **Omar De la Cruz Cabrera** and **Oana Mocioalca*** (oana@math.kent.edu), Mathematics and Computer Science Building 233, Kent State University, Summit Street, Kent, OH 44242. *A Diffusion Model for Compositional Data.*

We present a class of stochastic processes in continuous time which take as values vectors with non-negative components adding up to 1, and show their use as models for compositions continuously changing in time. They are defined as solutions of a stochastic differential equation, in such a way that the invariant distribution is Dirichlet. The aggregation property of this distribution can be exploited to allow the study of compositions at different levels; for example, modeling the composition over time of a portfolio of stock shares at the sector, industry, or individual firm levels. We will discuss some aspects of inference for this model. (Received February 02, 2017)

1127-60-168 **Wei-Kuo Chen*** (wkchen@umn.edu), 127 Vincent Hall 206 Church St. SE, Minneapolis, MN 55455, and **Antonio Auffinger**, **Gilad Lerman** and **Madeline Handschy**. *The energy landscape of the Sherrington-Kirkpatrick model.*

The Sherrington-Kirkpatirck (SK) model is a mean-field spin glass introduced by theoretical physicists in order to explain the strange behavior of certain alloy, such as CuMn. Despite of its seemingly simple formulation, it was conjectured to possess a number of fruitful properties. This talk will be focused on the energy landscape of the SK model. First, we will present a formula for the maximal energy in Parisi's formulation. Second, we will give a description of the energy landscape by showing that near any given energy level between zero and maximal energy, there exist exponentially many equidistant spin configurations. Based on joint works with Auffinger, Handschy, and Lerman. (Received February 03, 2017)

1127-60-191 **Tao Pang*** (tpang@ncsu.edu) and **Katherine Varga**. *Portfolio Optimization for Assets with Stochastic Dividends and Stochastic Volatility.*

We consider a portfolio optimization model in which the risky asset has stochastic volatility and also produces stochastic dividends. The goal is to choose the optimal investment and consumption controls to maximize the investor's expected total discounted HARA utility. We derive the Hamilton-Jacobi-Bellman equation using the dynamic programming principle, and then establish the existence of solution using the subsolution-supersolution method. Finally, we verify that our solution is equal to the value function, and derive and verify the optimal investment and consumption controls. (Received February 02, 2017)

1127-60-192 **Herold G Dehling*** (herold.dehling@rub.de), Department of Mathematics, Ruhr-University Bochum, 44791 Bochum, Germany, and **Aeneas Rooch** and **Martin Wendler**. *Two-sample U-statistic processes for long-range dependent data.*

Motivated by some common change-point tests, we investigate the asymptotic distribution of the U-statistic process

$$U_n(t) = \sum_{i=1}^{[nt]} \sum_{j=[nt]+1}^{n} h(X_i, X_j),\ 0 \le t \le 1,$$

when the underlying data are long-range dependent. We present two approaches, one based on an expansion of the kernel $h(x, y)$ into Hermite polynomials, the other based on an empirical process representation of the U-statistic. Together, the two approaches cover a wide range of kernels, including all kernels commonly used in applications. (Received February 03, 2017)

1127-60-201 **Na Zhang*** (zhangn4@mail.uc.edu), University of Cincinnati, Department of Mathematical Sciences, PoBox 210025, Cincinnati, OH 45221-0025, and **Magda Peligrad**. *On the normal approximation for random fields via martingale methods.*

We present a central limit theorem for strictly stationary random fields under a sharp projective condition. The assumption was introduced in the setting of random variables by Maxwell and Woodroofe and for certain random fields by Wang and Woodroofe. Compared to the results of Wang and Woodroofe, our paper has double scope. First, to provide a central limit theorem under a generalized Maxwell-Woodroofe condition. Second, to use a more general filtration. Our results are relevant for analyzing some statistics based on repeated independent samples from a stationary process. The tools for proving these results consist of new theorems for triangular arrays of martingales differences, which have interest in themselves. We present applications of our result to linear random fields and nonlinear random fields of Volterra-type, which provide new central limit theorems for these structures. (Received February 03, 2017)

1127-60-203 **Dan Cheng*** (cheng.stats@gmail.com), 1108 Memorial Circle, Lubbock, TX 79409, and **Yimin Xiao**. *The expected Euler characteristic approximation for Gaussian vector fields.*

Let $\{(X(t), Y(s)) : t \in T, s \in S\}$ be an $\mathbb{R}^2$-valued, centered, unit-variance smooth Gaussian vector field, where T and S are rectangles in $\mathbb{R}^N$; and let $A_u = \{(t, s) \in T \times S : X(t) \ge u, Y(s) \ge u\}$ be the excursion set. It is shown that, as $u \to \infty$, the excursion probability $\mathbb{P}\{\sup_{t\in T} X(t) \ge u, \sup_{s\in S} Y(s) \ge u\}$ can be approximated by $\mathbb{E}\{\chi(A_u)\}$, the expected Euler characteristic of A_u, such that the error is super-exponentially small. This verifies the expected Euler characteristic heuristic for a large class of smooth Gaussian vector fields. (Received February 03, 2017)

1127-60-234 **Rafal Kulik***, 585 King Edward Avenue, Ottawa, ON K1N6N5, Canada. *Statistical Inference for Extremes of Long Memory Processes.*

In this talk I will review known results and present open problems related to statistical inference for extremes of regularly varying, long range dependent processes. I will discuss asymptotic behaviour of tail empirical processes and their functionals, with applications to estimation of the index of regular variation. The talk is based on a joint work with Philippe Soulier. (Received February 04, 2017)

1127-60-235 **Wai T Fan*** (louisfan@math.wisc.edu), 926 Eagle Heights, C, Madison, WI 53705. *Coupled stochastic reaction-diffusion equations on metric graphs.*

I will present some novel limiting objects including stochastic partial differential equations (SPDE) on metric graphs and coupled SPDE. These SPDE not only interpolate between interacting particle systems and PDE, but also quantify the source and the order of magnitude of stochasticity. Scaling limit theorems and novel duality formulas are obtained for these SPDE, which connect phenomena across scales and offer insights about the genealogies and the time-asymptotic properties of certain population dynamics. Based on recent collaborations with the Systems Biology group at UW-Madison and WID. (Received February 04, 2017)

1127-60-249 **Vladas Pipiras*** (pipiras@email.unc.edu), Department of Statistics & OR, CB# 3260, Hanes Hall, University of North Carolina, Chapel Hill, NC 27599, and **Stefanos Kechagias**. *Bivariate long-range dependent time series models with general phase.*

The focus of this talk is on bivariate (vector-valued) time series that exhibit long-range dependence (LRD) and, more specifically, on the so-called phase parameter, an important quantity that appears in the cross spectrum at the zero frequency and controls the asymmetry of the series at large time lags. Previously considered bivariate LRD models have necessarily special phase parameter values, and hence can be unsuitable to capture general LRD behavior in bivariate time series. In this talk, I will introduce several bivariate LRD models that allow for general phase, including a bivariate extension of the celebrated FARIMA class with a proposed set of identifiable parameters. I will indicate their connections to bivariate counterparts of fractional Brownian motion, and raise several open problems. Finally, I will also discuss maximum likelihood inference for the proposed models, and present an application to the annualized US inflation rates for goods and services. (Received February 05, 2017)

1127-60-256 **Lochana Siriwardena*** (siriwardenal@uindy.edu). *Generalized Stochastic Delay Models with Applications to Finance.* Preliminary report.

Stochastic models are very popular and play an important role in financial applications. Geometric Brownian motion has played a significant role in modeling stock prices in the Black-Scholes option-pricing model and Feller's square root process (generalized squared Bessel process) has been used to model short-term interest rates in the Cox–Ingersoll–Ross (CIR) model. These processes are related to Bessel processes via space-time transformations. In this talk, some generalizations of the above mentioned models would be presented. Two of the generalizations are based on the growth rate of the processes allowing functional coefficients that take the prior values of the process into account. The other generalization extends the CIR process with a logistic drift term. Existence and uniqueness will be discussed for the generalized models with non-linear drifts and non-Lipschitz diffusion terms. Boundary behavior and asymptotic properties of the models will also be discussed. (Received February 05, 2017)

1127-60-283 **Thomas Church*** (tfchurch@stanford.edu), **Jordan S. Ellenberg** and **Graham White**. *Exchangeable distributions on FI^{op}-sets.* Preliminary report.

We use the philosophy of FI-modules to generalize and strengthen classical theorems in probability on exchangeable distributions. An *exchangeable distribution* on an FI$^{\mathrm{op}}$-set Σ is an element $\mu \in \lim \mathbb{P}\Sigma_T$. We give a general structure theorem for such exchangeable distributions based on the degree of cogeneration of Σ, by describing certain concrete data conditional on which any exchangeable distribution is "i.i.d." Taking $\Sigma_T = 2^T$ this recovers de Finetti's theorem (every exchangeable random sequence is a mixture of i.i.d. sequences according to some Bayesian prior); for $\Sigma_T = \{\text{partitions of } T\}$, Kingman's theorem on random partitions; and for $\Sigma_T = 2^{\binom{T}{2}}$, the Aldous–Hoover theorem describing random graphs as mixtures of graphons. Compared with these classical results, the key advance is that the necessary data is given by concrete empirical statistics such as induced subgraph densities. (Received February 06, 2017)

1127-60-288 **Michael Damron**, **Jack Hanson** and **Philippe Sosoe*** (psosoe@cmsa.fas.harvard.edu), Cambridge, MA 02138. *New bounds on the chemical distance in 2D critical percolation.*

We consider the problem of estimating the length, in lattice spacings, of the shortest open connection between the two vertical sides of a square of side length N in critical percolation, when N tends to infinity. This is known as the chemical distance between the sides. Kesten and Zhang asked if this length is asymptotically negligible compared to the length of the "lowest crossing", whose length can be expressed in terms of arm exponents and thus calculated quite precisely on the hexagonal lattice. With M. Damron and J. Hanson, we answered this question in 2015. In this talk, we present improved estimates on the chemical distance, using a new iteration technique. (Received February 06, 2017)

1127-60-291 **Bin Wang**, **Ruodu Wang**, **Yi Shen** and **Jie Shen***, 200 University Ave W, Waterloo, ON N2L3G1, Canada. *Compatibility for Change of Measures.*

We study the compatibility for change of measures in this paper. More precisely, for a given set of probability measures on a probability space and a corresponding set of probability distributions on the real line, we develop sufficient and necessary conditions for the existence of a random variable, such that under each measure given on the probability space, the distribution of this random variable coincides with the corresponding distribution on the real line, respectively. It is shown that the compatibility of these two sets of measures holds if and only if the Radon-Nikodym derivatives of the measures, with respect to some reference measures, satisfy a convex order condition. Furthermore, the result can be extended to continuous stochastic processes. (Received February 06, 2017)

1127-60-315 **Gu Wang*** (gwang2@wpi.edu), Department of Mathematical Sciences, 100 Institute Road, Worcester, MA 01609, and **Paolo Guasoni**. *Consumption in Incomplete Markets.*

To overcome the intractability of consumption-investment problems in incomplete markets, this paper develops approximate solutions to the maximization of isoelastic utility from consumption with infinite horizon in a market where state variables follow a multivariate diffusion. After proving a general verification theorem that links the solution of the Hamilton-Jacobi-Bellman (HJB) equation to the value function and optimal consumption-investment policies, the paper develops point-wise upper and lower bounds of the value function, which have closed-form solutions in typical models and lead to approximate policies with an explicit bound on the certainty-equivalent loss. Further, the approximations correspond to sub- and super-solutions to the original HJB equation, and help establish the existence and the optimality of the solution to the original problem. (Received February 06, 2017)

1127-60-325 **Andrey Sarantsev*** (sarantsev@pstat.ucsb.edu), South Hall 5607A, University of California, Santa Barbara, CA 93106. *Infinite Systems of Competing Brownian Particles.*

Systems of Brownian particles with drift and diffusion coefficients depending on their current rank relative to other particles have recently attracted a lot of attention. In this talk, we survey some results on such infinite systems: stationary distributions, weak convergence, asymptotic behavior at large time. (Received February 06, 2017)

1127-60-326 **Andrey Sarantsev*** (sarantsev@pstat.ucsb.edu), South Hall 5607A, University of California, Santa Barbara, CA 93106. *Collisions of Brownian Particles.*

Three independent Brownian motions do not collide, but if they have rank-dependent diffusion coefficients, they might collide. We investigate this question for multiple Brownian particles. (Received February 06, 2017)

1127-60-355 **Alexandra Chronopoulou*** (achronop@illinois.edu), IL. *Estimating the correlation in a stochastic volatility model with LRD.*

We consider a stochastic differential equation (SDE) in which the diffusion coefficient is a function of the solution to a fractional SDE. We assume that the noises of these two equations are correlated, and we consider the problem of estimating their correlation structure using discrete-time, high-frequency observations. To this end, we propose a nonparametric estimator based on the quadratic co-variation of the two processes. Using Malliavin calculus techniques, we establish a Central Limit Theorem for the quadratic co-variation process, and based on this result, we derive the strong consistency and asymptotic distribution of the proposed estimator. We illustrate our results in a simulation example, as well in a financial application that is the motivation for this work: the estimation of leverage effects under a long-memory stochastic volatility model. (Received February 07, 2017)

1127-60-362 **Kiseop Lee***, 150 N. University St., Department of Statistics, Purdue University, West Lafayette, IN 47907. *INFORMED TRADERS' HEDGING WITH NEWS ARRIVALS.*

We study a hedging and pricing problem of a market with jumps, where both the jump size and the timing are affected by exclusive informa- tion available only to informed traders. The exclusive information process is a continuous time stochastic process, but affects the price process only at discrete times. This model is an extension of Lee and Song(2007), where the ex- clusive information affects only the jump timing, and Kang and Lee(2014), where the exclusive information affects only the jump size. We find the local risk minimization hedging strategy of informed traders. (Received February 07, 2017)

1127-60-365 **Eyal Lubetzky***, Courant Institute of Mathematical Sciences, New York University, 251 Mercer St, New York, NY 10012. *Random walks on Ramanujan graphs, complexes, and digraphs.*

We will discuss the sharp transition in the time it takes simple random walk on regular Ramanujan graphs to approach the uniform distribution (known as the cutoff phenomenon), and geometric consequences (such as typical distances between vertices) that this implies for such graphs. We will then discuss how these ideas can be extended to regular Ramanujan digraphs, and consequently, to any d-dimensional Ramanujan complexes for d>1 associated with a simple group, with analogous geometric implications for these objects.

Base on joint works with Y. Peres and with A. Lubotzky and O. Parzanchevski. (Received February 07, 2017)

1127-60-366 **Michael Woodroofe***, 1405 Maywood, Ann Arbor, MI 48103, and **Dalibor Volny**. *Quenched Central Limit Theorem for Linear Processes.*

For a linear process, $X_k = \sum_{j=0}^{\infty} a_j \epsilon_{k-j}$, where ϵ_j form a stationary sequence of martingale differences for which $E(\epsilon_j^2) < \infty$ and a_j are square sumable, let $S_n = X_1 + \cdots + X_n$, and observe that $S_n = \sum_{j=0}^{n} b_{n-j}\epsilon_j$, where $b_n = a_0 + \cdots + a_n$, so that $\sigma_n^2 := E(S_n^2) = (b_0^2 + \cdots + b_n^2)E(\epsilon_0^2)$. Ibragimov showed that if $\sigma_n \to \infty$ as $n \to \infty$, then the distribution of S_n/σ_n converges to the standard normal distribution. The condition $\sigma_n \to \infty$, only restricts the coefficients a_j, In the talk, I will present conditions under which the convergence is quenched (that is, the conditional distributions, given $\cdots \epsilon_1, \epsilon_0$ converge to the standard normal *w.p.one*. (Received February 07, 2017)

1127-60-377 **Ju-Yi Yen*** (ju-yi.yen@uc.edu), University of Cincinnati, Department of Mathematical Sciences, Cincinnati, OH 45221. *Excursion landscape.*

In this talk, we study the process obtained from a Brownian bridge after excising all the excursions below the waterline level which reach zero. Three variables of interest are the maximum of this process, the value where this maximum is attained, and the total length of the excursions which are excised. Our analysis relies on some interesting transformations connecting Brownian path fragments and the 3-dimensional Bessel process. (Received February 07, 2017)

1127-60-386 **Nina Holden*** (ninah@math.mit.edu). *Percolation-decorated triangulations and their relation with SLE and LQG.*

The Schramm-Loewner evolution (SLE) is a family of random fractal curves, which have been proven or conjectured to be the 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 study percolation-decorated RPM and their relation with SLE-decorated LQG. Based on a joint work with Olivier Bernardi and Xin Sun. (Received February 07, 2017)

1127-60-395 **Scott P Robertson*** (scottrob@bu.edu), Questrom School of Business, Boston University, Boston, MA 02215. *Optimal Investment, Indifference Pricing, and Dynamic Default Insurance for Defaultable Assets.* Preliminary report.

We consider the optimal investment problem when the traded asset may default. For an exponential investor, our goal is to explicitly compute both the indifference price for a defaultable bond, and a fair price for dynamic protection against default. For the latter problem, our work complements Sicar and Zariphopoulu (2007). We consider a factor model where asset returns, variances, correlations and default intensities are driven by a time-homogenous diffusion X. In addition to trading in the defaultable asset, the investor owns a non-traded asset whose terminal payoff depends upon the survival of the stock. We identify the certainty equivalent with a semi-linear degenerate elliptic partial differential equation, and under a mild integrability assumption on the market price of risk, we show the certainty equivalent is a classical solution. We also derive the indifference price for a defaultable bond, as well as a fair price for dynamic protection against default. Numerical examples highlight the relationship between the factor process, and both the indifference price and default insurance. In fact, we show the insurance protection does not coincide with the default intensity under the dual optimal measure. This is joint work with Tetsuya Ishikawa of Morgan Stanley. (Received February 07, 2017)

1127-60-398 **Andrey Sarantsev*** (sarantsev@pstat.ucsb.edu), South Hall 5607A, University of California, Santa Barbara, CA 93106, and **Ioannis Karatzas**. *Market Models with Splits and Mergers.*

Consider a model of a stock market: Each stock is represented by a positive stochastic process, jointly governed by a system of SDEs. We introduce splits and mergers in this model, so that the quantity of stocks is not constant. Under certain conditions, we show this model does not allow arbitrage. (Received February 07, 2017)

1127-60-406 **Jeremie Brieussel** and **Tianyi Zheng*** (tzheng2@math.ucsd.edu). *Speed of random walks on finitely generated groups and minimal growth of harmonic functions.*

We discuss a flexible construction of groups where the speed (rate of escape) of simple random walk can follow any sufficiently nice function between diffusive and linear. Minimal growth of non-constant harmonic functions on these groups are tightly related to the speed of the random walk. While in a variant of this construction, all harmonic functions of sub-exponential growth factor through a projection to a lamplighter $F \wr \mathbb{Z}$ with F finite. In particular we show that there exist groups on which all sub-linear harmonic functions are constant, while the speed of simple random walk can follow any prescribed super-diffusive function. (Received February 07, 2017)

1127-60-412 **Hyungbin Park*** (hpark@wpi.edu), Worcester, MA 01609. *Sensitivity analysis of long-term cash flows.*

This talk discusses a sensitivity analysis of long-term cash flows. The price of the cash flow at time zero is given by a pricing operator of a Markov diffusion acting on the cash flow function at the payoff time. We study the extent to which the price of the cash flow is affected by small perturbations of the underlying Markov diffusion. The main tool is Hansen-Scheinkman decomposition, which is a technique that expresses the cash flow in terms of the eigenvalue and eigenfunction of the pricing operator. By combining the results of Fournie et al. (1999), we conclude that the sensitivities of long-term cash flows can be represented via simple expressions in terms of the eigenvalue and the eigenfunction. (Received February 08, 2017)

1127-60-414 **Joseph Najnudel*** (joseph.najnudel@uc.edu), Department of Mathematical Sciences, University of Cincinnati, French Hall - 2815 Commons Way, Cincinnati, OH 45221. *On the extreme values of the Riemann zeta function on random intervals of the critical line.*

In a preprint recently submitted, we show that under the Riemann hypothesis, the supremum of the real and the imaginary parts of $\log \zeta(1/2+it)$ for $t \in [UT-h, UT+h]$ are in the interval $(1-\epsilon)\log\log T, (1+\epsilon)\log\log T]$ with probability tending to 1 when T goes to infinity, if U is uniformly distributed in $[0,1]$. For the real part, the result has been proven later by Arguin, Belius, Bourgade, Raziwill and Soundararajan without the Riemann hypothesis. However, until now, this hypothesis is still needed for the imaginary part. The result on imaginary part gives information on the fluctuations of the distribution on the zeros of the Riemann zeta function. (Received February 08, 2017)

62 ► Statistics

1127-62-31 **Shuyang Bai*** (bsy9142@uga.edu), Athens, GA 30606, and **Murad Taqqu** (murad@bu.edu), Boston, MA 02215. *Between-block dependence under long memory.*

For time series with long memory, inference through resampling is of particular importance, since the asymptotic distributions are often difficult to determine statistically. To establish the asymptotic validity of certain resampling procedures, it requires a fine understanding of the dependence between two finite blocks of the time series. We shall introduce some recent progress on this direction. (Received January 04, 2017)

1127-62-45 **Ba Chu*** (ba.chu@carleton.ca), Carleton University, C-870 Loeb Bldg., 1125 Colonel By Dr., Ottawa, Ontario K1S-5B6, Canada. *Composite Likelihood Estimation of Dynamic Panels with Group-Specific Heterogeneity and Spatially Dependent Errors.*

This paper proposes a dynamic panel data model with spatially dependent errors that allows for known or unknown group-specific patterns of slope heterogeneity. Analysis of this model is conducted in the framework of composite likelihood maximization. Unlike the traditional maximum likelihood paradigm the method of composite likelihood (CL) does not require a specification/estimation of the spatial variance-covariance matrix to obtain asymptotically unbiased feasible estimators. Moreover the proposed CL estimator is robust against some misspecification of the unobserved individual/group-specific fixed effects. Clustering and estimation of the parameters of interest involve a large-scale non-convex mixed-integer programming problem, which can then be solved via a new efficient approach developed based on DC (Difference-of-Convex functions) programming and the DCA (DC algorithm). Suppose that the number of time periods and the size of spatial domain grow simultaneously, asymptotic theory is derived for both cases where the covariates are stationary and nonstationary. An extensive Monte Carlo simulation is also provided to examine the finite-sample performance of the proposed estimator. (Received January 11, 2017)

1127-62-89 **Xuwen Zhu*** (xuwen.zhu@louisville.edu), 3700 Beaufort Lane, Louisville, KY 40207. *Assessment of variable contribution in model-based clustering through variation partition.*

Model-based clustering is a flexible grouping technique based on a mixture of fitted statistical distributions for data groups. In recent years, model-based clustering has grown to be more popular among practitioners with applications that can be found in numerous fields of study. However, there is limited literature devoted to developing diagnostic tools for obtained clustering solution. In this paper, a new method through variation decomposition is proposed for probabilistic assessing the contribution of variables to the partitioning of data groups. Positive and negative correlations between two variable contributions are investigated with developed visualization tool. The method demonstrates promising results on application to real-life datasets. (Received January 25, 2017)

1127-62-128 **Daniel J McDonald*** (dajmcdon@indiana.edu), **Cosma Rohilla Shalizi** and **Mark Schervish**. *Estimating beta-mixing coefficients via histograms.*

The literature on statistical learning for time series often assumes asymptotic independence or "mixing" of the data-generating process. These mixing assumptions are never tested, nor are there methods for estimating mixing coefficients from data. Additionally, for many common classes of processes (Markov processes, ARMA processes, etc.) general functional forms for various mixing rates are known, but not specific coefficients. We present the first estimator for beta-mixing coefficients based on a single stationary sample path and show that it is risk consistent. Since mixing rates depend on infinite-dimensional dependence, we use a Markov approximation based on only a finite memory length d. We present convergence rates for the Markov approximation and show that as $d \to \infty$, the Markov approximation converges to the true mixing coefficient. Our estimator is constructed using d-dimensional histogram density estimates. Allowing asymptotics in the bandwidth as well as the dimension, we prove L^1 concentration for the histogram as an intermediate step. Simulations wherein the mixing rates are calculable and a real-data example demonstrate our methodology. (Received January 30, 2017)

1127-62-174 **Giray Okten*** (okten@math.fsu.edu) and **David Mandel**. *Global Sensitivity Analysis and Model Robustness.*

Global sensitivity analysis is a widely used tool for modelers in sciences and engineering, however, it's use in financial modeling has been limited. I will discuss global sensitivity analysis based on Sobol' sensitivity indices, and a novel approach to quantify the robustness of a model using randomized sensitivity indices. I will present some applications to interest rate and weather derivative models. (Received February 02, 2017)

1127-62-183 **Rasitha R. Jayasekare***, Department of Mathematics and Actuarial Sc, Butler University, Indianapolis, IN 46208, **Ryan Gill**, Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Kiseop Lee**, Department of Statistics, Purdue University, West Lafayette, IN 47907. *Modeling the Changes in the Minimum Gasoline Price using a Threshold Auto Regressive Model.*

Threshold Auto Regressive (TAR) models have become popular in many financial and economic applications. A TAR model is applied to describe the changes in minimum gasoline price. Non linearity and the symmetry in the mean and the volatility of the minimum gasoline price change is also discussed. The model is tested with daily gasoline prices from Western Australia. (Received February 02, 2017)

1127-62-209 **Sonja Petrovic*** (sonja.petrovic@iit.edu), **Elizabeth Gross** and **Despina Stasi**. *Discrete methods for statistical network analysis.*

Sampling algorithms, hypergraph degree sequences, and polytopes play a crucial role in statistical analysis of network data. This talk will offer a brief overview of open problems in this area of discrete mathematics from the point of view of a particular family of statistical models for networks called exponential random graph models. The problems and underlying constructions are also related to well-known concepts in commutative algebra and graph-theoretic concepts in computer science. We outline a few lines of recent work that highlight the natural connection between these fields and unify them into some open problems. While these problems are often relevant in discrete mathematics in their own right, the emphasis here is on statistical relevance with the hope that these lines of research do not remain disjoint. and that they can be used to advance algebraic statistics theory and applied statistical tools for rigorous statistical analysis of networks. (Received February 03, 2017)

1127-62-301 **Ryan Gill***, 328 Natural Sciences Building, Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Rasitha Jayasekare** and **Kiseop Lee**. *Asymptotic properties of the MLE in a Poisson mixture model with applications.*

In this talk, results concerning weak consistency and asymptotic normality of the maximum likelihood estimator of the parameter vector for a Poisson mixture model are discussed. Asymptotic confidence intervals are derived based on the asymptotic normality and applied to tick-by-tick stock data to model changes in the price of a stock based on the size of a trade. (Received February 06, 2017)

1127-62-352 **Jose E. Figueroa-Lopez*** (figeroa@math.wustl.edu), Department of Mathematics, One Brookings Drive, St. Louis, MO 63130, and **Cecilia Mancini**. *Optimum Thresholding for Semimartingales with Levy Jumps under the mean-square error.* Preliminary report.

We consider a univariate semimartingale model for (the logarithm of) an asset price, containing Levy jumps having possibly infinite activity (IA). General conditions are known for the nonparametric threshold estimator of the integrated variance proposed in Mancini (2009) to be asymptotically consistent for the integrated volatility. However, the finite sample properties of the estimator can depend on the specific choice of the threshold. In this work, we aim at optimally selecting the threshold by minimizing either the estimation mean square error (MSE) or its conditional mean square error (cMSE). In both cases a parsimonious characterization of the optimum is established, which allows us to show that the optimal threshold sequence is proportional to the Levy's modulus of continuity of the underlying Brownian motion. Moreover, minimizing the cMSE enables us to propose a novel implementation scheme for the optimal threshold sequence. Monte Carlo simulations illustrate the superior performance of the proposed method. (Received February 07, 2017)

1127-62-411 **Omar De la Cruz Cabrera*** (odelacru@kent.edu), OH. *Sets of Hypotheses.* Preliminary report.

The analysis of high throughput data is often set up as a set of parallel hypothesis tests. The result is usually a list of "discoveries," together with a measure of significance. Often, this is regarded as a way to rank or prioritize promising hypotheses; in this case, the resources available for follow up studies might determine the number of discoveries (for which a false discovery rate can be reported).

This is fine, but not appropriate when we want to make inferences about sets of hypotheses. This occurs when we need to go further than individual hypotheses, by comparing the set of discoveries with pre-existing, annotated sets. We will sketch a general setup for inference about sets of hypothesis, with applications in the interpretation of high throughput studies and data integration. (Received February 08, 2017)

65 ► Numerical analysis

1127-65-82 **Emily Schaal*** (eeschaal@email.wm.edu), PO 8793, Williamsburg, VA 23187, and **Yu-Min Chung** (ychung@wm.edu), 200 Ukrop Way, Williamsburg, VA 23187. *Center Manifolds via Lyapunov-Perron.* Preliminary report.

The Lyapunov-Perron (L-P) operator is a theoretical method used to show the existence of the invariant manifold. In 2005, M.S. Jolly and R. Rosa presented an algorithm for solving systems with center manifolds based on discretizing the L-P operator. However, this discretization can be expensive to implement. We provide detailed proofs of the construction of the center manifold and its derivative by the L-P operator under the Jolly-Rosa framework. We present an algorithm based on a boundary value formulation of the operator. Importantly, the algorithm is simple and can be adopted by any generic scheme. We implement the algorithm, test it with a simple ODE example, and then test it by performing a center manifold reduction on a quasilinear elliptic PDE. We perform a bifurcation analysis on the full equation and compare it to the bifurcation analysis of the reduced equation. (Received January 23, 2017)

1127-65-206 **Daozhi Han*** (djhan@iu.edu), 831 E 3rd, Bloomington, IN 47405, **Wenbin Chen**, Shanghai, and **Xiaoming Wang**, Tallahassee, FL 32308. *On two-phase flows in karstic geometry.*

Multiphase flow phenomena are ubiquitous. In some applications such as flows in unconfined karst aquifers, karst oil reservoir, proton membrane exchange fuel cell, multiphase flows in conduits, and in porous media must be considered together. Geometric configurations that contain both conduit and porous media are termed karstic geometry. In this talk, we derive a diffuse interface model for two-phase flow in karstic geometry utilizing

Onsager's extremum principle. The model together with the interface boundary conditions satisfies a physically important energy law. Then, we present a novel decoupled unconditionally energy-stable numerical scheme for solving this diffuse interface model. (Received February 03, 2017)

1127-65-267 **Youngjoon Hong*** (`hongy@uic.edu`), 851 S Morgan St, Chicago, IL 60607, and **Jerry Bona**. *Numerical study of the generalized Korteweg-de Vries equations with oscillating nonlinearities and boundary conditions.*

Numerical studies of the supercritical transitional generalized Korteweg-de Vries equations (t-gKdV) posed with periodic boundary conditions and generalized Korteweg-de Vries (gKdV) equations in a finite domain are presented. To begin, we employ a class of the Fourier spectral methods to implement the solution to the initial value problem associated to the supercritical gKdV equations. Considering nonlinear time-oscillating nonlinearities, the blow-up patterns of the numerical solution are analyzed. In the presence of the boundaries and time-oscillating boundary conditions, the supercritical gKdV equations are studied in a finite domain. For numerical experiments, an accurate spectral collocation method and spectral element method are implemented and tested. As the boundary frequency parameter ω increases, we find that the periodic time-oscillating condition can disturb the blow-up solution. We provide numerical evidence that the numerical solutions remain stable with high frequencies on boundary data. This is joint work with Jerry Bona. (Received February 05, 2017)

1127-65-274 **Jie Shen*** (`shen7@purdue.edu`), Department of Mathematics, Purdue University, West Lafayette, IN 47907-2067. *Accurate spectral methods for a class of problems with singular solutions.*

The usual spectral methods will provide high-order accuracy for problems with smooth solutions. However, they may not work well for problems with singular solutions due to various facts such as corner singularities, non-matching boundary conditions, non-smooth coefficients.

If the form of the singular expansion for the solution is known, we develop a Muntz Galerkin method which is based on specially tuned Muntz polynomials to deal with the singular behaviors of the underlying problems, and show that it provide optimal error estimates. On the other hand, if the Muntz Galerkin method is not applicable or efficient, we present a new extended spectral-Galerkin method which allows us to split it into two separate problems: one is to find an approximation for the smooth part by a usual spectral method, the other is to determine an approximation to the singular part with k terms by solving a $k \times k$ system. So the new method is very easy to approximations for a class of singular problems.

We will present ample numerical results for a variety of problems with singular solutions, including fractional PDEs, to demonstrate the effectiveness of our approaches. (Received February 05, 2017)

68 ► Computer science

1127-68-304 **Xiaoran Yan***, 1001 E SR 45/46 Bypass, Bloomington, IN 47408, and **Shanghua Teng** and **Kristina Lerman**. *Z-Laplacian: a dynamical framework for community structures and centralities on networks.* Preliminary report.

In this work, we highlight the interplay between a dynamical process and the structure of the network on which it is defined. We start by examining the connections between random walks on graphs and node ranking and community detection algorithms. We introduce the Z-Laplacian framework for defining and characterizing an ensemble of dynamical processes which spans the space of all possible Z-matrices. We show that some traditional node centrality and clustering criterion are special cases under this framework.

Based on the Z-Laplacian framework, we will demonstrate how graph transformations can represent the flow of different dynamic processes on networks. We will show some empirical examples of how such transformations can be applied in real world problems, including modelling information diffusion over communication networks, brain connectome and scholarly collaboration networks. (Received February 06, 2017)

1127-68-396 **Maggie E. Habeeb*** (`habeeb@calu.edu`), 250 University Ave, #54, California, PA 15419. *A Verification Protocol using the Word Problem.*

Secret sharing schemes provide a method of distributing a secret among a group of participants. Typically a dealer distributes the shares to the participants, and is assumed to be honest. A secret sharing scheme using group presentations and the word problem was proposed by Habeeb, Kahrobaei and Shiplrain. Here we present a verification protocol to be used with the Habeeb-Kahrobaei-Shpilrain secret sharing scheme that allows participants to check if their shares are correct, solving the problem of a dishonest dealer. (Received February 07, 2017)

76 ► *Fluid mechanics*

1127-76-207 **Thomas E Carty*** (tcarty@bradley.edu), Bradley University, Department of Mathematics, Bradley Hall 445, Peoria, IL 61625. *Asymptotic analysis of elementary solutions of a Boltzmann-type equation and the concept of grossly determined solutions.*

In the early 1980's, Truesdell and Muncaster conjectured the existence of grossly determined solutions for the Boltzmann equation: a subclass of solutions which are determined at any given instant by the principle moments of the gas (mass density, velocity and temperature). Moreover, they conjectured that if one could find the general solutions to the Boltzmann, then the general solutions should evolve in time to the class of grossly determined solutions. In this talk we will show that the two conjectures hold for Cercignani's time-dependent slip-flow model Boltzmann for initial data of compact support under the Fourier transform. (Received February 03, 2017)

1127-76-385 **Guher Camliyurt*** (camliyur@usc.edu), 3620 S. Vermont Ave. Mathematics Department, Los Angeles, CA 90089, and **Igor Kukavica** (kukavica@usc.edu), 3620 S. Vermont Ave. Mathematics Department, Los Angeles, CA 90089. *The Lagrangian and Eulerian analyticity for the Euler equations.*

We revisit preservation of analyticity and Gevrey regularity for the Euler equation. We provide a result on preservation of Gevrey norm and analyticity in Lagrangian formulation and discuss the validity of the result in the Eulerian variables. (Received February 07, 2017)

81 ► *Quantum theory*

1127-81-70 **Yilong Wang*** (wang.3003@osu.edu), 412 Math Building, 231 West 18th Avenue, Columbus, OH 43210. *Integrality for $SO(p)_2$ TQFTs in genus 1.*

In this talk, we establish the integrality result for the genus 1 TQFT associated to $\mathrm{SO(p)}_2$ modular categories presenting an explicit change of basis formula. In addition, we will relate the SL(2, Z) representation to the Weil representation over finite fields. (Received January 22, 2017)

1127-81-157 **Barbara A Sanborn*** (bsanborn@antiochcollege.edu) and **Edwin C Ihrig**. *The uncertainty principle and the energy identity for holomorphic maps in geometric quantum mechanics.* Preliminary report.

The theory of geometric quantum mechanics describes a quantum system as a Hamiltonian dynamical system with a complex projective Hilbert space as its phase space, equipped with a Riemannian metric in addition to the symplectic structure characteristic of classical mechanics. This paper extends the geometric quantum theory to include aspects of the symplectic topology of the phase space by identifying the Robertson-Schrödinger uncertainty relation for pure quantum states as the energy identity in the theory of J-holomorphic curves. We define a map from a Riemann surface into the quantum phase space by using the vector fields generated by two quantum observables, and show that the Fubini-Study metric tensor pulls back by this map to the covariance matrix for the two observables. The uncertainty principle is represented as an equality that compares the map energy to the sum of the symplectic area of the map image and a positive definite term that vanishes when the map is holomorphic. Saturation of the Robertson-Schrödinger uncertainty inequality implies that the map is harmonic and its image is a minimal surface. In this case, the covariance term vanishes and the uncertainty product is a topological invariant. (Received February 01, 2017)

1127-81-159 **Yuan-Ming Lu*** (yuanming.lu@gmail.com), Department of Physics, The Ohio State University, 191 W Woodruff Ave, Columbus, OH 43210. *Lieb-Shcultz-Matthis Theorems for Symmetry Protected Topological Phases.* Preliminary report.

The Lieb-Schultz-Mattis (LSM) theorem and its descendants represent a class of powerful no-go theorems that rules out any short-range-entangled (SRE) symmetric ground state irrespective of the specific Hamiltonian, based only on certain microscopic inputs inlcuding the symmetry and Hilbert space of the quantum many-body system. Here we introduce and prove a new class of LSM-type theorems, where any symmetry-allowed SRE ground state must be a symmetry protected topological (SPT) phase with exotic edge/surface states. Topological insulators and topological superconductors are examples of SPT phases. These theorems provide new insights into numerical models and experimental realizations of SPT phases in interacting bosons and fermions. (Received February 01, 2017)

1127-81-175 **Zhengwei Liu*** (zhengweiliu@fas.harvard.edu), 17 Oxford Street, Cambridge, MA 02138. *The string Fourier transform on quons.*

In recent joint work with Arthur Jaffe and Alex Wozniakowski, we introduced quon 3D language for quantum information associated with a unitary modular tensor category (MTC). In joint work with Feng Xu, we proved that the string Fourier transform (SFT) on quons is the S matrix of the MTC. I will talk about string quons defined by strings in 3-manifolds. String quons include the Greenberger-Horne-Zeilinger (GHZ), Max, and 6j-symbol states. We obtain an algebraic identity for the MTC from each pair of string quons related by the SFT. The identity from the pair of GHZ and Max generalizes the Verlinde fomula. The pair of 6j-symbol states defines a new identity between 6j-symbols and the S matrix. (Received February 02, 2017)

1127-81-238 **Tianyuan Xu*** (tianyuan@uoregon.edu), Department of Mathematics, University of Oregon, Eugene, OR 97403. *Based rings attached to generators of Coxeter groups.*

The asymptotic Hecke algebra J of a Coxeter group W is an associative algebra constructed from the Hecke algebra of W by G. Lusztig. The algebra J naturally has the structure of a *based ring* and appears as the Grothendieck ring of a tensor category associated to W. We study subalgebras J_s of J corresponding to the simple reflections of W and discuss two results. First, we show that all *fusion rings* appearing in the form J_s are isomorphic to the odd part of a *Verlinde algebra* of the Lie group $SU(2)$. Second, we show that for suitable choices of Coxeter groups and simple reflections, the algebras J_s are isomorphic to certain *free fusion rings*; this connects J and its associated tensor category to certain *partition quantum groups* arising from operator algebra theory. (Received February 04, 2017)

1127-81-244 **Pavel Mnev*** (pmnev@nd.edu), 255 Hurley, Notre Dame, IN 46556. *Abelian and non-abelian BF theory on cobordisms endowed with cellular decomposition.*

We will present an example of a topological field theory living on cobordisms endowed with CW decomposition (this example corresponds to the so-called BF theory in its abelian and non-abelian variants), which satisfies the Batalin-Vilkovisky master equation, satisfies (a version of) Segal's gluing axiom w.r.t. concatenation of cobordisms and is compatible with cellular aggregations. In non-abelian case, the action functional of the theory is constructed out of local unimodular L-infinity algebras on cells; the partition function carries the information about the Reidemeister torsion, together with certain information pertaining to formal geometry of the moduli space of local systems. This theory provides an example of the BV-BFV programme for quantization of field theories on manifolds with boundary in cohomological formalism. This is a joint work with Alberto S. Cattaneo and Nicolai Reshetikhin. (Received February 05, 2017)

82 ▶ Statistical mechanics, structure of matter

1127-82-252 **Bruno Nachtergaele*** (bxn@math.ucdavis.edu), Department of Mathematics, University of California, Davis, Davis, CA 95616, and **Robert Sims** and **Amanda Young**. *Stability of Frustration-Free Ground States of Lattice Fermion Systems.*

We study frustration-free lattice Fermion systems with a non-vanishing spectral gap above one or more (infinite-volume) ground states. The ground states are called stable if arbitrary perturbations of the Hamiltonian that are uniformly small throughout the lattice have only a perturbative effect. In the past several years stability results have been obtained for quantum spin models of increasing generality aimed at applications to topological phases (most notably in work by Bravyi-Hastings-Michalakis and Michalakis-Zwolak). We present a recent extension to lattice Fermion models that may also exhibit spontaneously broken discrete symmetries. (Received February 05, 2017)

1127-82-307 **Rajinder Mavi**, 619 Red Cedar Road, East Lansing, MI 48824, and **Jeffrey Schenker*** (jeffrey@math.msu.edu), 619 Red Cedar Road, East Lansing, MI 48824. *Localization in the disordered Holstein model.*

The Holstein model (in the one particle sector) describes a lattice particle interacting with independent Harmonic oscillators at each site of the lattice. We consider this model with on site disorder in the particle potential. This is proposed a simple model in which it may be possible to test some ideas regarding multi/many-body localization. Provided the oscillator frequency is not too small and the hopping is weak, we are able to prove localization for the eigenfunctions, in particle position and in oscillator Fock space. Some open problems regarding the character of high energy eigenstates will be discussed. (Joint work with Rajinder Mavi.) (Received February 06, 2017)

91 ► Game theory, economics, social and behavioral sciences

1127-91-61 **Zachary Feinstein*** (zfeinstein@wustl.edu). *An Equilibrium Network Model for Financial Contagion with Illiquid Assets.*

In this talk we will consider an extension of the Eisenberg & Noe (2001) model of financial contagion to include fire sale externalities from multiple illiquid assets. By allowing for multiple illiquid assets, institutions may have a choice in how they delever in a fire sale. Mathematical results on existence and uniqueness of clearing payments and prices will be given. Special emphasis will be placed on a game theoretic equilibrium liquidation strategy. (Received January 17, 2017)

1127-91-62 **Dan Pirjol** and **Lingjiong Zhu*** (zhu@math.fsu.edu), 1017 Academic Way, Room 208, Tallahassee, FL 32306. *Short Maturity Asian Options in Local Volatility Models.*

We present a rigorous study of the short maturity asymptotics for Asian options with continuous-time averaging, under the assumption that the underlying asset follows a local volatility model. The asymptotics for out-of-the-money, in-the-money, and at-the-money cases are derived, considering both fixed strike and floating strike Asian options. The asymptotics for the out-of-the-money case involves a non-trivial variational problem which is solved completely. We present an analytical approximation for Asian options prices, and demonstrate good numerical agreement of the asymptotic results with the results of Monte Carlo simulations and benchmark test cases in the Black-Scholes model for option parameters relevant in practical applications. (Received January 17, 2017)

92 ► Biology and other natural sciences

1127-92-75 **Adam J Lonnberg*** (adamlonnberg@yahoo.com), 5555 Ironwood Dr., Newburgh, IN 47630, and **Pengcheng Xiao** (px3@evansville.edu). *A Modeling Study of the Hypothalamic-Pituitary-Adrenal (HPA) Axis Including Glucocorticoid Receptor (GR).* Preliminary report.

The human stress response is controlled largely by the hypothalamic pituitary adrenal (HPA) axis. Models predicting the levels of the hormones involved very often are not analytically solvable. Many of these models, such as Gupta et al. 2007, predict a bistability in this axis. Said bistability results in two steady states, a normal high-glucocorticoid receptor (GR) state, and an alternate low-GR steady state. In the current study, we are able to simplify the HPA axis model in order to solve it more easily while maintaining key features such as the bistability thereof. This model's equilibrium and characteristic polynomial are both more easily derived when compared with previous models, and the latter can be more easily analyzed via the Routh-Hurwitz criteria and its Sturm chain. Simulations run with this model exhibit oscillation, a feature found in many recent models to account for the circadian rhythms of this axis. (Received January 22, 2017)

1127-92-110 **Zachariah Sinkala*** (zachariah.sinkala@mtsu.edu), Department of Mathematical sciences, Murfreesboro, TN 37132, and **Richard Ewool**. *Global existence and convergence of solutions to a cross-diffusion Phenotypic Switching on Glioblastoma Growth and Invasion system.*

In this paper, we study brain tumor glioblastoma model, the system of reaction-diffusion equations, in the brain tissue. The system attempts to simulate the progression speed of a glioblastoma tumor at the macroscopic level. This is determined by two key factors: the cell proliferation rate and the cell migration speed. At the microscopic level, however, proliferation and migration appear to be mutually exclusive phenotypes, as indicated in vivo imaging data. Here, we develop a two coupled reaction-diffusion equations model to analyze how the phenotypic switching between proliferative and migratory states of individual cells affects the macroscopic growth of the tumor. We start by considering the asymptotical stability of equilibrium points to the associated system of ordinary differential equations type. Then, the global existence of solutions and the stability of equilibrium points to the system of coupled reaction-diffusion type are discussed. Finally, the existence of nonnegative classical global solutions to the system of coupled reaction-diffusion type is investigated, and the global asymptotic stability of unique positive equilibrium point of the system is proved by constructing Lyapunov functions. (Received January 27, 2017)

1127-92-134 **David Murrugarra*** (murrugarra@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *A Near-Optimal Control for Stochastic Gene Regulatory Networks.*

One of the ultimate goals of computational biology and bioinformatics is to develop control strategies to find efficient medical treatments. One step towards this goal is to develop methods for changing the state condition of a cell into a new desirable state. Using a stochastic modeling framework generalized from Boolean Networks, this talk discusses a computationally efficient method that determines sequential combinations of network perturbations (control actions), that induce the transition of a cell towards a new predefined state. The method requires a set of possible control actions as input, every element of this set represents the silencing of a gene (node) or a disruption of the interaction between two molecules (edge). An optimal control policy defined as the best intervention at each state of the system, can be obtained using theory of Markov decision processes. However, these algorithms are computationally prohibitive for models of tens of nodes. The proposed method generates a sequence of actions that approximates the optimal control policy with high probability and with a computational efficiency that does not depend on the size of the state space of the system. The methods are validated by using published models where control targets have been identified. (Received January 30, 2017)

1127-92-165 **Tracy Stepien*** (stepien@math.arizona.edu), Department of Mathematics, University of Arizona, Tucson, AZ, **Erica Rutter** (erutter@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC , and **Yang Kuang** (kuang@asu.edu), School of Mathematical & Statistical Sciences, Arizona State University, Tempe, AZ. *Traveling Wave Solutions of a Glioma Tumor Growth Model.* Preliminary report.

Glioblastoma multiforme is an aggressive brain tumor that is extremely fatal. Gliomas are characterized by both high amounts of cell proliferation as well as diffusivity, which make them impossible to remove with surgery alone. To gain insight on the mechanisms most responsible for tumor growth and the difficult task of forecasting future tumor behavior, we investigate a mathematical model in which tumor cell motility and cell proliferation are considered as separate processes. We explore the existence of traveling wave solutions and determine conditions for various wave front forms. We also examine the model's efficacy in fitting in vitro experimental data. (Received February 02, 2017)

1127-92-182 **garrett luther otto*** (garrett.otto@louisville.edu), 328 natural sciences bldg, university of louisville, louisville, KY 40292. *Spatially localized equilibrium solutions in integro-difference equations exhibiting Allee and over-compensation effects.*

Previous work in integro-difference equations, which considers Allee effect and over-compensation separately, has shown the existence of constant spreading speeds and traveling wave solutions. In our work, we demonstrate the existence of spatially localized equilibriums when Allee and over-compensation effects are combined. We show these equilibriums are robust in that they occupy a set of full measure in parameter space, and that these equilibria are compatible with the Uniform, Laplace, and Gaussian dispersal kernels. Our numerical work shows that perturbations of these equilibria lead to stable quasi-periodic distributions that are also strongly and persistently spatially localized. These surprising results demonstrate that under appropriate conditions patch like populations can arise entirely from endogenous mechanisms even in a homogeneous environment. (Received February 07, 2017)

1127-92-215 **Jimin Zhang** and **Junping Shi*** (jxshix@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23187, and **Xiaoyuan Chang**. *A mathematical model of interaction of pelagic algae, benthic algae and nutrients in an oligotrophic shallow aquatic ecosystem.*

A coupled system of ordinary differential equations and partial differential equations is proposed to describe the interaction of pelagic algae, benthic algae and one essential nutrient in an oligotrophic shallow aquatic ecosystem with ample supply of light. The existence, uniqueness and stability of non-negative steady states are shown, and these results characterize some threshold conditions for the regime shift. The influence of environmental parameters on algal biomass density is also considered, which is an important indicator of algal blooms. (Received February 04, 2017)

1127-92-219 **Jacopo Grilli**, **Gyorgy Barabas** and **Matthew J Michalska-Smith** (sallesina@uchicago.edu), Chicago, IL 60637, and **Stefano Allesina*** (sallesina@uchicago.edu), 1101 E 57th, Zoology Building 403A, Chicago, IL 60637. *Higher-order interactions stabilize dynamics in competitive network models.*

The difficulty of reconciling the staggering biodiversity found in tropical rainforests with classical theories of resource partitioning has led ecologists to explore neutral coexistence, in which all species have the same physiological parameters, and variations in species abundance arise from stochastic fluctuations. The debate on neutral theories has led ecologists to reconsider the foundations of the discipline. However, the strong assumption of equivalence among all species, and the high sensitivity of neutral models to slight perturbations of the parameters are still considered problematic.

Here we propose a theory of coexistence in which all species have different physiological rates, and interact with each other through a network of competitive interactions. We show that our models produce robust coexistence of many species even when parameters are drawn at random. Importantly, the dynamical stability of our models is due to higher-order interactions—interactions involving more than two species at a time. The existence of higher-order interactions has been debated in ecology for decades, but their role in shaping ecological communities is still understudied. Results show that higher-order interactions can have dramatic effects on the dynamics of ecological systems. (Received February 04, 2017)

1127-92-243 **Yanyu Xiao***, PO box 210025, French Hall west, Dept of Math. Sci, Univ. of, Cincinnati, OH 45221. *Investigation on the dynamics of a stage-structured model.*

In this work, we consider a stage-structured model incorporating the intra-competition at certain stage. We examine the rich dynamics of the delay system theoretically and numerically. (Received February 05, 2017)

1127-92-262 **Lauren M Smith-Ramesh*** (laurensmithramesh@gmail.com). *Food web network properties and the causes and consequences of species invasions.*

Past efforts to understand global patterns of species invasions have focused on the relationship between invasion and native biodiversity, based on the premise that more diverse communities will resist invasion because invaders will be more likely to encounter natural enemies in diverse communities. However, support for a diversity-invasibility relationship has been mixed. Theory suggests that food-web network properties, such as connectance or the distribution of interaction strengths within a food web, may yield key insights into which communities will be most susceptible to invasion. I present empirical case studies and literature syntheses showing that food web properties can predict habitat invasibility and invader impact from local to global scales. (Received February 05, 2017)

1127-92-295 **Rebecca A Everett**, Raleigh, NC 27695, **John D Nagy**, Scottsdale, AZ 85256, and **Yang Kuang*** (kuang@asu.edu), Tempe, AZ 85287. *Dynamics of an Ovarian Cancer Growth and Treatment Model with Time Delay.*

We present a delay differential equation model that describes ovarian tumor growth and tumor induced angiogenesis, subject to on and off anti-angiogenesis treatment. The tumor growth is governed by Droop's cell quota model, a well established mathematical expression developed in ecology. Here, the cell quota represents the intracellular concentration of necessary nutrients provided through blood supply. We present mathematical analysis of the model, including a detailed study of local and global stability of equilibria. The mathematical model can be employed to fit both on-treatment and off-treatment preclinical mice data using the same biologically relevant parameters. We also present an open mathematical question. (Received February 06, 2017)

1127-92-320 **Miguel Acevedo**, **T Trevor Caughlin**, **Kenny Lopiano**, **Olivia F Prosper*** (olivia.prosper@uky.edu) and **Nick Ruktanonchai**. *Spatial heterogeneity, host movement, and the transmission of mosquito-borne disease.*

The Ross-Macdonald framework, a suite of mathematical models for the transmission of mosquito-borne disease, made numerous simplifying assumptions including that transmission occurs in a homogeneous environment. Despite these assumptions, this modeling framework has been invaluable to the study of vector-borne disease and to informing public health policy. In recent years, more attention has been paid to the role of human movement in regions with spatially heterogeneous disease transmission. In this talk, I will introduce a metapopulation framework for vector-borne disease, based on the Ross-Maconald model, in which human movement connects discrete populations with different levels of malaria transmission. I will discuss properties of this model, compare these properties to the homogeneous case, and will discuss the implications for malaria control. Next, I will present some of the challenges that arise when linking this theoretical framework to a real-world problem. Finally, I will briefly discuss an approach developed to address one of these challenges, namely identifying the appropriate network structure for the metapopulation model, using either mobile phone or geographical data. (Received February 06, 2017)

1127-92-336 **Sharon Bewick**, **Phillip P.A. Staniczenko**, **Bingtuan Li*** (bing.li@louisville.edu), **David Karig** and **William F. Fagan**. *Invasion speeds in microbial systems with toxin production and quorum sensing.*

The theory of invasions and invasion speeds has traditionally been studied in macroscopic systems. Surprisingly, microbial invasions have received less attention. Although microbes share many of the features associated with competition between larger-bodied organisms, they also exhibit distinctive behaviors that require new mathematical treatments to fully understand invasions in microbial systems. We model bacterial invasion using a system of coupled partial differential equations. Our model considers a competitive system with diffusible toxins that, in some cases, are expressed in response to quorum sensing. We derive analytical approximations for invasion speeds in the limits of fast and slow toxin diffusion. Interestingly, we find that toxins should diffuse quickly when used offensively, but that there are two optimal strategies when toxin is used as a defense mechanism. Specifically, toxins should diffuse quickly when their killing efficacy is high, but should diffuse slowly when their killing efficacy is low. Our approach permits an explicit investigation of the properties of diffusible compounds used in non-local competition, and is relevant for microbial systems and select macroscopic taxa, such as plants and corals, that can interact through biochemicals. (Received February 06, 2017)

1127-92-364 **Keenan M.L. Mack*** (keenan.mack@mail.ic.edu) and **Jeremy F. Alm**. *Small network assembly and degree correlation.* Preliminary report.

In their landmark study, Barabási and Albert showed how preferential attachment could provide a first-principles algorithmic mechanism to explain the observed power-law degree distribution found in many naturally occurring networks. However, naturally occurring networks have other important characteristics, such as degree correlation, that cannot be explained by preferential attachment. Thus, developing a first-principles network assembly algorithm that can generate degree correlation while preserving the power-law degree distribution would be an important step towards understanding how real world networks are assembled. One of the artificialities of preferential attachment is that all links are permanent and added only to new individuals. By allowing connections to be broken and added throughout the assembly process, degree correlation can be generated. However, in doing so, the power-law distribution is necessarily eroded and replaced with a distribution that appears lognormal. While this mechanism cannot explain the degree correlation observed in many naturally occurring networks with a known power-law degree distribution, it seems likely to explain degree distribution and correlation in small social networks, such as face-to-face friendship networks. (Received February 07, 2017)

1127-92-402 **Changbing Hu**, **James D Johnson** and **Jiaxu Li*** (jiaxu.li@louisville.edu). *Modeling the distribution of insulin in pancreas.*

Maintenance of adequate pancreatic beta-cell mass, via suppression of programmed cell death and/or sustained proliferation is critical for the prevention or delay of diabetes mellitus. It is well established that insulin potently activates mitogenic and anti-apoptotic signaling cascades in cultured beta-cells. Furthermore, loss of beta-cell insulin receptors is sufficient to induce T2DM in animal models. However, it remains unclear whether the in vitro effect in human islets and the in vivo effects in mice can be applied to human physiology. The major obstacle to a complete understanding of the effects of insulin's feedback in human pancreas is the absence of technology to measure the concentrations of insulin inside of pancreas. To contextualize recent in vitro data, it is essential to know the local insulin concentration and distribution in pancreas. We formulate a novel mathematical model to investigate the distribution and concentration of insulin within pancreas using existing physiological data and islet imaging data. It is revealed that insulin concentration along pancreas increases nearly linearly in the fashion of increasing quicker in tail area but slower in head area. The factor of small diffusion with blood is negligible since the convection of blood flux dominates. (Received February 07, 2017)

97 ► Mathematics education

1127-97-143 **Teresa Hughes** and **James R. Valles, Jr.*** (jrvalles@pvamu.edu), Department of Mathematics, Prairie View A&M University, P. O. Box 519 – Mailstop 2225, Prairie View, TX 77446-0519. *Critical thinking through student-led error analysis in algebra.* Preliminary report.

A preponderance of mathematics instruction involves students watching examples, which are worked by an instructor, and then the students will complete similar exercises, essentially mimicking work and procedure. If students make errors in their work, then emphasis is placed on how to perform the work correctly and avoid the error(s) being made in the future.

This talk will introduce one method, developed by Teresa Hughes in the Cypress-Fairbanks ISD, for student-led identification of mistakes made in their own algebraic work. Students are shown how to code the work (e.g. Careless Mistake, Did not Understand the Question) as well as asked to provide an explanation of the error made. Students are then asked to provide a correction to the work. The increased participation among the students, as well as observed results, will be discussed. (Received January 31, 2017)

Abstracts of the 1128th Meeting.

00 ► General

1128-00-62 **Hossein Noorazar*** (hnoorazar@math.wsu.edu), 1630 NE VALLEY RD, L301, PULLMAN, WA 99163. *A energy-based interaction model for population opinion dynamics with topic coupling.*

We introduce a new, and quite general variational model for opinion dynamics based on pairwise interaction potentials and a range of opinion evolution protocols ranging from random interactions to global synchronous flows in the opinion state space. The model supports the concept of topic "coupling", allowing opinions held by individuals to be changed via indirect interaction with others on different subjects. Interaction topology is governed by a graph that determines interactions. Our model, which is really a family of variational models, has, as special cases, many of the previously established models for the opinion dynamics. After introducing the model, we study the dynamics of the special case in which the potential is either a tent function or a constructed bell-like curve. We find that even in these relatively simple potential function examples there emerges interesting behavior. We also present results of preliminary numerical explorations of the behavior of the model to motivate questions that can be explored analytically. (Received February 08, 2017)

1128-00-98 **Michael Dorff*** (mdorff@math.byu.edu). *PIC Math – a course for undergraduate students to do research on actual problems from industry.*

There are hundreds of jobs in industry for math students, and several recent reports list mathematician as one of the best careers. However, just graduating with a math degree is not enough to guarantee getting one of these jobs. In addition, many students and professors think that teaching is the main (or only) career option for someone who studies mathematics. How can students learn about these jobs and develop the skills they need in order to get a job in industry? In this talk, we will answer those questions and talk about the national PIC Math program that prepares students for nonacademic careers. The main component of PIC Math is a semester course in which students spend class time working in small groups on research problems from industry instead of listening to lectures. During the 2016-2017 academic year there are math departments at 65 different institutions with about 750 students participating in PIC Math courses throughout the U.S. (Received February 16, 2017)

1128-00-183 **Dominika W Dec**, **Claire Seibold*** (claire.seibold@umontana.edu) and **Emily Stone**. *Synaptic Plasticity in Excitatory and Inhibitory Hippocampal Neuron Circuit Dynamics.* Preliminary report.

Microcircuits of inhibitory and excitatory neurons in the hippocampus have been studied over the past 30 years because of their importance in creating neural spike rhythms that have been implicated in processes such as the consolidation of episodic memories. Models for these circuits range from extremely simple (coupled phase oscillators) to extremely complex (complete, spatially extended, biophysically correct representations of the cells in Neuron). Various complex phenomena have been observed and explained through these models, such as synchronization, phase precession and bursting. Here we consider how time dependent connectivity of these cells effects these phenomena by incorporating a model for short-term synaptic plasticity that we developed and parameterized (from whole cell experiments) for two specific interneuron-pyramidal cell connections. To make analysis possible, we use the maps to describe both the plasticity and spike timing in the circuit (inspired by the work of Ermentrout and Kopell, 1998). (Received February 25, 2017)

1128-00-214 **Jennifer B Webster*** (jenny.webster@pnnl.gov), 902 Battelle Boulevard, PO Box 999, MSIN K7-20, Richland, WA 99352, and **Stephen J Young** and **Patrick Mackey**. *Uncertainty in Community Detection.* Preliminary report.

Typical community detection algorithms designed by the mathematics and computer science communities either (A) assume perfect knowledge of the underlying graph or (B) are tuned to a particular dataset(s). When generalizing to other real-world data sets, we rarely have the choice of data or complete data sets. In this talk, we will discuss how incomplete knowledge of the underlying graph impacts the communities determined using modularity and present a set of metrics for describing differences among communities. PNNL Release Number: PNNL-SA-124237 (Received February 27, 2017)

1128-00-246 **Jason Portenoy*** (jporteno@uw.edu) and **Jevin D West** (jevinw@uw.edu). *The InfoMap Community Detection Algorithm: Techniques for Scaling to Very Large Networks.* Preliminary report.

Infomap is a community detection algorithm that uses compression of random walks to surface patterns and structure on a network. Using network dynamics, it is capable of partitioning graphs into the optimal number of hierarchically nested modules. Infomap has become widely adopted, finding use in industry settings and research labs around the world. While we have been able to scale this algorithm to large networks on the order of tens of millions of nodes, we have recently reached an upper limit when attempting to cluster the citation graph from Web of Science, which contains 219,963,473 nodes and 1,034,566,885 edges. We present our current progress in attempting to scale our algorithm, including making use of supercomputing clusters at the Pacific Northwest National Laboratory, and a parallelized version of the algorithm (GossipMap). (Received February 27, 2017)

1128-00-268 **Wei Li*** (wei.li@wsu.edu), 1630 NE VALLEY RD. K301, Pullman, 99163, and **Hongbo Dong** and **Haijun Li**. *Sparse model selection for high-dimensional vine copulas via penalized optimization.*

Vine Copula is a flexible graphical model to capture the dependence structure for high-dimensional continuously-valued random variables. It has been shown to be useful in many fields such as finance and risk management, especially when the usual Gaussian assumptions do not hold. We propose a method for model selection of high-dimensional vine copulas with certain structures, such as the sparsity (i.e., promote the number of independence copulas used). Motivated by the literature in sparse regression, the zero-norm penalty function is used in our context. We show that combined with the stepwise estimation method, optimization problems with the zero-norm penalty functions can be solved with little additional costs. We report comparisons between our proposed method and the state-of-the-art VineCopula package on simulated data. (Received February 28, 2017)

1128-00-301 **Mimi Tsuruga*** (mtsuruga@math.ucdavis.edu), UC Davis, One Shields Ave, Davis, CA 95616. *Topology of Data: A special topic.*

Applied topology is an area of research with many open problems whose popularity is markedly on the rise, especially in the context of data analysis. It is also a highly interdisciplinary field and can be appealing to researchers of varying backgrounds. To promote further development and research in this increasingly relevant field, we hope to tempt experts in our field to teach a special topics course at their home institutes.

In this talk, we present an example of a graduate level special topics course at UC Davis taught in Fall 2016. We discuss how applied topology can be introduced to students of a wide variety of disciplines. We will also present the final results from the students' group projects, which analyzed publicly available or generated data sets using techniques from topological data analysis. The data sets include biological data, video or image data, financial data, and time series data such as crime or weather. (Received February 28, 2017)

1128-00-311 **Michael Newsham*** (michael.newsham@wsu.edu). *Divergence, Permutations, and the Axiom of Choice: Exploring Cardinalities of Infinite Symmetric Groups.*

We provide motivation for the study of the permutation group on a finite set by providing introductory examples of its applications in algebraic contexts before generalizing the notion of the permutation group on finite sets to the infinite case. We use these permutation groups to draw connections between Hilbert's Grand Hotel and properties of conditionally convergent series in order to illustrate that the permutation group and power set of a countably infinite set have equal cardinalities. Finally, we discuss the importance of the axiom of choice in establishing that this result is true in general for infinite sets. (Received February 28, 2017)

01 ► History and biography

1128-01-233 **Jana Doppa*** (jana@eecs.wsu.edu), School of EECS, Pullman, WA 99163. *HC-Search: A Learning Framework for Search-based Structured Prediction.*

We are witnessing the rise of the "Big Data" paradigm, in which massive amounts of data (e.g., text, images, videos, speech) can be analyzed to make sense of the data, and to make useful predictions. To fully realize the promise of Big Data, we need automated systems that can transform structured inputs to structured outputs (e.g., resolving coreferences of entity and event mentions in a piece of text, interpreting a visual scene). Problems such as these are often referred to as structured prediction problems in the machine learning community. These prediction problems pose severe learning and inference challenges due to the huge number of possible outputs.

In this talk, I will introduce a new framework to solve these structured prediction problems called HC-Search. The problem of structured prediction is formulated as an explicit search process in the combinatorial space of outputs. The search seeks to optimize the cost function C using a heuristic H to guide the search. Both the cost function and the heuristic are learned from supervised data to minimize a given task loss function. I show that the HC-Search framework achieves state-of-the-art results in a wide range of structured prediction problems that arise in natural language processing and computer vision. (Received February 27, 2017)

03 ► Mathematical logic and foundations

1128-03-187 **Valentina Harizanov*** (harizanv@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *Structure of orders on structures.*

A magma is an algebraic structure with a single binary operation. A right order on a magma is a linear ordering of its domain, which is right-invariant with respect to the magma operation. We similarly define a left order and a bi-order on a magma. 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. Interesting computable magmas that are orderable come from algebra and knot theory and include quandles, free groups, fundamental groups of closed and oriented surfaces, finitely generated one-relator parafree groups, and right-angled Artin groups. For orderable magmas, their spaces of orders are compact and in some cases homeomorphic to the Cantor set. We further investigate Turing complexity of orders on computable orderable magmas. (Received February 26, 2017)

1128-03-217 **Tom Richmond*** (tom.richmond@wky.edu), Department of Mathematics, Western Kentucky University, 1906 College Heights Blvd., Bowling Green, KY 42101. *Introducing Research through a Computational Problem Solving Course.* Preliminary report.

A cross-listed Math and Computer Science course in Computational Problem Solving is offered at my institution. Students use Mathematica to discover and investigate patterns. The course has only a computer science course as prerequisite and Calculus I as a pre- or co-requisite. The course is required for students of Kentucky's Academy of Math and Sciences, which is located on our campus. The last half of the course is dedicated to open-ended student projects. We will discuss how this course promotes investigative discovery and introduces students to research methods. (Received February 27, 2017)

05 ► Combinatorics

1128-05-117 **Srikumar Ramalingam*** (srikumar@cs.utah.edu). *Efficient Minimization of Higher Order Submodular Functions using Monotonic Boolean Functions.*

Submodular function minimization is a key problem in computer vision and many other domains. While the general submodular solver has a high complexity, many vision problems are defined over specialized subclasses of submodular functions that can be written as the sum of submodular cost functions defined over cliques containing only a few variables. We develop an efficient algorithm for the minimization of this useful subclass of submodular functions. To do this, we define a novel mapping that transforms submodular functions of order k into quadratic ones. The main idea is to use auxiliary variables to model the higher order terms and the transformation is found using a linear program. In particular, we model the auxiliary variables as monotonic Boolean functions, allowing us to use as few auxiliary variables as possible. We show that the fourth order function requires only 2 auxiliary variables in contrast to 30 variables in existing methods. In the general case, we give an upper bound on the number or auxiliary variables required to transform a function of order k using Dedekind number, which is substantially lower than the current bound of 2^{2^k}.

This is a joint work with Chris Russell, Ľubor Ladický, and Philip H.S. Torr. https://arxiv.org/abs/1109.2304 (Received February 20, 2017)

1128-05-121 **Steve Butler*** (butler@iastate.edu). *Kemeny's constant and the normalized Laplacian.* Preliminary report.

Kemeny's constant is related to the mean transit time of a random walk. This can be computed in terms of the eigenvalues of the probability transition matrix, which is connected to the normalized Laplacian. Using tools for the normalized Laplacian we show how to compute this value for some families. (Received February 20, 2017)

1128-05-155 **Ewa Joanna Infeld*** (evainfeld@ryerson.ca), 350 Victoria Street, Toronto, ON M5B 2K3, Canada. *Iterated Local Anti-Transitivity Network.* Preliminary report.

In adversarial networks such as certain market graphs, nodes are adjacent if they are antagonists, negatively correlated stocks or exhibit opposing characteristics. Negative correlation is also studied in social networks, where anti-transitivity makes precise the adage "the enemy of my enemy is my friend." We present a simplified, deterministic model for negative correlation in complex networks called the Iterated Local Anti-Transitivity Network. It is a recursively generated graph with low clustering. At each time-step, for each existing node x, we create a clone x' and connect it to every node y that has existed at the previous step that was not in the neighbor set of x. We then recover several properties of this graph, including the degree distribution, average distance, cop number, and the clustering coefficient. This is joint work with A. Bonato, H. Pokhrel and P. Pralat. (Received February 23, 2017)

1128-05-162 **Laura Escobar*** (lescobar@illinois.edu), Urbana, IL 61801, and **Oliver Pechenik**, **Bridget Eileen Tenner** and **Alexander Yong**. *Rhombic tilings and Bott-Samelson varieties.*

Elnitsky gave an elegant bijection between rhombic tilings of 2n-gons and commutation classes of reduced words in the symmetric group on n letters. We explain a natural connection between Elnitsky's and Magyar's construction of the Bott-Samelson resolution of Schubert varieties. This suggests using tilings to encapsulate Bott-Samelson data and indicates a geometric perspective on Elnitsky's combinatorics. We also extend this construction by assigning desingularizations to the zonotopal tilings considered by Tenner. (Received February 24, 2017)

1128-05-184 **Danny Rorabaugh*** (rorabaugh@mast.queensu.ca), **Claude Tardif**, **David Wehlau** and **Imed Zaguia**. *Arc Graphs and Free Distributive Lattices.*

The arc graph $\delta(G)$ of a digraph G is the digraph with the set of arcs of G as vertex-set, where the arcs of $\delta(G)$ join consecutive arcs of G. In 1981, Poljak and Rödl characterised the chromatic number of $\delta(G)$ in terms of the chromatic number of G when G is symmetric (i.e., undirected). In contrast, directed graphs with equal chromatic numbers can have arc graphs with distinct chromatic numbers. Even though the arc graph of a symmetric graph is not symmetric, we show that the chromatic number of the iterated arc graph $\delta^k(G)$ still only depends on the chromatic number of G when G is symmetric. arXiv:1610.01259 [math.CO] (Received February 25, 2017)

1128-05-190 **Andrew Berget*** (andrew.berget@wwu.edu). *Simplicial complexes associated to matrix orbit closures.* Preliminary report.

Given an r-by-n matrix, one constructs the locally closed set of matrices that are obtained from it by performing row operations and scaling of columns in all possible ways. This is a *matrix orbit closure.* We will describe a conjectural Gröbner basis for the prime ideal of a matrix orbit closure whose initial ideal is a square free monomial ideal. Using computer algebra, we guess the structure of the associated simplicial complex in a large family of cases. (Received February 26, 2017)

1128-05-208 **Sinan G Aksoy*** (saksoy@ucsd.edu), **Tamara G Kolda** and **Ali Pinar**. *Measuring and modeling bipartite graphs with community structure.*

We propose a generative model for large-scale bipartite graphs which can be easily tuned to reproduce the characteristics of real-world networks. The characteristics we consider are the degree distributions and the metamorphosis coefficient. The metamorphosis coefficient, a bipartite analogue of the clustering coefficient, is the proportion of length three paths that participate in length four cycles. We further define edge, node, and degreewise metamorphosis coefficients, enabling a more detailed understanding of bipartite clustering. As demonstrated on several real-world data sets, our proposed bipartite block two-level Erdös-Rényi (BTER) model reproduces both the degree distributions as well as the degreewise metamorphosis coefficients. (Received February 27, 2017)

1128-05-229 **Tobias Hagge**, **Patrick Mackey**, **Kathleen Nowak**, **Carlos Ortize Marrero**, **Jenny Webster** and **Stephen J Young*** (stephen.young@pnnl.gov). *The Geometric Spectrum of Graphs.* Preliminary report.

Recently, Mendel and Naor, Dumitriu and Radcliffe, and Radcliffe and Williamson have begun the study of what could be termed the geometric Fiedler vector (or spectral gap) for graphs. Their principle observation is that the functional form associated with the graph can be expressed in terms of the distance function on $\mathbb{R}$. We give a partial structural characterization of when the geometric Fiedler vector can be extended to a geometric spectrum. Additionally, we provide applications of the geometric spectrum to community detection in graphs. This is joint work with Tobias Hagge, Patrick Mackey, Kathleen Nowak, Carlos Ortiz Marrero, and Jenny Webster. (Received February 27, 2017)

1128-05-244 **Mark Kempton*** (mkempton@cmsa.fas.harvard.edu). *Non-backtracking random walks and graph clustering.* Preliminary report.

Recently, operators related to non-backtracking random walks on graphs have been used to give improved spectral algorithms for graph clustering. These operators have interesting spectra that relate to the mixing of non-backtracking random walks. I will discuss spectral properties of non-backtracking random walks, and related results. (Received February 27, 2017)

1128-05-271 **Radmila Sazdanovic*** (rsazdan@ncsu.edu), Department of Mathematics, NC State University, PO Box 8205, Raleigh, NC 27695, and **Victor Summers**. *On the categorification of the magnitude of a graph.* Preliminary report.

In 2015 Richard Hepworth and Simon Willerton categorified the magnitude of a graph and posed some questions about the strength and properties of this homology theory. We settle some of these questions and offer further insights into magnitude homolog based on the combinatorial data of a graph. (Received February 28, 2017)

1128-05-273 **Alex Fink*** (a.fink@qmul.ac.uk), **David E Speyer** and **Alexander Woo**. *A Gröbner basis for the graph of the reciprocal plane.*

Two different-looking commutative algebraic ways to get the characteristic polynomial of a hyperplane arrangement appear in the literature: from the K-polynomial of the reciprocal plane (Orlik-Terao), and from the multidegree of the graph over this plane (Adiprasito-Huh-Katz). We give a Stanley-Reisner initial degeneration explaining why these two are not different after all. (Received February 28, 2017)

1128-05-308 **Shannon Overbay*** (overbay@gonzaga.edu), Gonzaga University, 502 E Boone Ave, Spokane, WA 99205. *Toroidal Zero-Divisor Graphs and Book Embeddings.*

An n book is formed by taking a line in 3-space (the spine) together with n half-planes (the pages) joined together at the spine. A graph is embedded in a book by placing the vertices along the spine and each edge on a single page of the book so that no two edges cross. The book thickness of a graph is the smallest n for which the graph has an n-book embedding. The zero-divisor graph of a commutative ring R is formed by taking the nonzero zero-divisors of R as the vertices and joining two vertices x and y with an edge if an only if $xy = 0$. Chiang-Hsieh, Smith, and Wang have classified all 90 non-isomorphic rings having zero-divisor graphs of genus at most one. We further categorize these graphs in terms of book thickness. (Received February 28, 2017)

1128-05-333 **Kenneth J. Prevot*** (prevot@msudenver.edu), Department of Mathematics, Metropolitan State University of Denver, Denver, CO 80217-3362. *Some Notes on the boundary operator on the n-cube.* Preliminary report.

Let $I^n = [0,1] \times [0,1] \times \ldots \times [0,1]$, the Cartesian product of n unit intervals, denote the standard n-cube. This paper discusses certain aspects of the boundary operator ∂ on I^n. A few basic formulas and some geometric results are presented with mention of relationships to elementary calculus and elementary number theory. This talk is expository in nature. (Received March 01, 2017)

06 ► Order, lattices, ordered algebraic structures

1128-06-218 **Trang T Ha*** (trangtha@gwu.edu), 17 E Centre St, Apt 3, Baltimore, MD 21202. *Topology and Computability of Orders on Some Algebraic Structures.*

We consider order relations on a magma, an algebraic structures with a binary operation that is not necessarily associative or commutative. The space of orders on a magma consists of all possible orders (of a certain kind) on the structure. We investigate the computational complexity and topological properties of the spaces of orders on a computable magma. We are able to represent these orders as infinite paths of a computable binary tree, while preserving their Turing degrees. We are especially interested in the cases when such collections of infinite paths do not have computable ones. (Received February 27, 2017)

08 ► General algebraic systems

1128-08-211 **Yuri Movsisyan***, Alex Manoogian 1, Yerevan State University, 0025 Yerevan, Armenia. *On the Belousov Variety.*

The concept of Belousov quasigroup is introduced and it is proved that the nontrivial Belousov quasigroup has at least five elements. The variety of Belousov quasigroups is a subvariety of the Mikado variety. The Belousov variety has a solvable word problem and is congruence-permutable. Every Belousov quasigroup of prime order is a simple algebra. To solution of the following problem is open: To which loops are Belousov quasigroups isotopic? (Received February 27, 2017)

11 ► Number theory

1128-11-10 **Jack Buttcane*** (buttcane@buffalo.edu), Mathematics Department, 244 Mathematics Building, Buffalo, NY 14260. *Higher weight on GL(3).*

Classical automorphic forms are generally attached to subgroups of $\Gamma = SL(2,\mathbb{Z})$ and are functions on

$$\Gamma\backslash\mathbb{H} = \Gamma\backslash PSL(2,\mathbb{R})/SO(2,\mathbb{R}).$$

They come in two flavors: holomorphic modular forms and (spherical or weight 0) Maass forms. These two types of automorphic forms are both special cases of Maass forms with weight, and they collectively generate a basis of $L^2(\Gamma\backslash PSL(2,\mathbb{R}))$. The spherical Maass forms have been generalized to subgroups of $SL(n,\mathbb{Z})$, and these are currently a popular topic of study, particularly on $SL(3,\mathbb{Z})$. This talk will describe the generalization to Maass forms with weight on $SL(3,\mathbb{Z})$, the new types of non-spherical forms that arise, and what is currently known about them. (Received September 22, 2016)

1128-11-26 **Wenzhi Luo*** (luo.43@osu.edu), 231 West 18th Avenue, Columbus, OH 43210. *On simultaneous non-vanishing of the central L-values.*

We derive a new quantitative result on the simultaneous non-vanishing of the central L-values twisted by quadratic characters, for pairs of holomorphic cuspidal Hecke eigenforms with large weight $2k$. (Received January 22, 2017)

1128-11-30 **Stephen Choi*** (schoia@sfu.ca), Simon Fraser University, Burnaby, B.C. V5A 6S1, Canada, and **Peter Cho-Ho Lam** (chohol@sfu.ca), Simon Fraser University, Burnaby, B.C. V5A 1S6, Canada. *Large Sieve Type Inequality for the Roots of Quadratic Congruence.*

In this talk, we discuss the proof of a large sieve type inequality for the roots of quadratic congruence: let D be a squarefree positive integer. For any complex numbers α_n, $0<\alpha<\beta$ and $J>1$, we have

$$\sum_{\alpha J<d\leq\beta J}\ \sum_{\nu^2+D\equiv 0 \pmod d}\left|\sum_{n\leq N}\alpha_n e^{2\pi i\nu n/d}\right|^2 \ll (\log J)^2(J+N)\sum_{n\leq N}|\alpha_n|^2.$$

The case of $D=1$ was proved by Fouvry and Iwaniec and they used this inequality to show that the number of primes p, of the form $p=x^2+y^2$ with integer x and prime y, is infinite. (This is a joint work with Peter Cho-Ho Lam) (Received January 26, 2017)

1128-11-51 **Chris Jennings-Shaffer** and **Holly Swisher***, swisherh@math.oregonstate.edu. *Mock modularity of a generalized rank for overpartitions.*

We investigate the modular properties of a new family of partition ranks for overpartitions, which gives both the Dyson overpartition rank and the M_2 overpartition rank as special cases. We show that the generating function for these overpartition ranks is the holomorphic part of a certain harmonic Maass form of weight $\frac{1}{2}$, and give precise transformation formulas for this Maass form along with a few rank generating function identities. This work is joint with Chris Jennings-Shaffer. (Received February 06, 2017)

1128-11-65 **Catherine M Hsu*** (cathyh@uoregon.edu). *Higher congruences between newforms and Eisenstein series of squarefree level.*

Let $p\geq 3$ be prime. For squarefree level $N>6$, we use a commutative algebra result of Berger, Klosin, and Kramer to bound the depth of Eisenstein congruences modulo p (from below) by the p-adic valuation of the numerator of $\frac{\varphi(N)}{24}$. We then show that if N has at least three prime factors and some prime $p\geq 5$ divides $\varphi(N)$, the Eisenstein ideal is not locally principal. Time-permitting, we will illustrate these results with explicit computations and give an interesting commutative algebra application related to Hilbert-Samuel multiplicities. (Received February 09, 2017)

1128-11-115 **Roman Holowinsky*** (holowinsky.1@osu.edu). *Applications of the Petersson trace formula as a delta-method.*

In this talk, we present some simplifications of the Petersson delta-method used by Ritabrata Munshi in his recent subconvexity results for Dirichlet character twists of GL(3) L-functions. We shall also explore other applications and demonstrate parallels between the classical delta-method and the Petersson delta-method. (Received February 20, 2017)

1128-11-159 **Steven J Miller*** (sjm1@williams.edu), 18 Hoxsey St, Williamstown, MA 01267. *Biases in Fourier Coefficients of Elliptic Curve L-functions.* Preliminary report.

We report on work in progress on lower-order biases in elliptic curve Fourier coefficients, and if time permits other families of L-functions. For non-CM families, Michel proved the second moment of the Fourier coefficents is $p^2 + O(p^{3/2})$. Cohomological arguments show that the lower order terms are of sizes $p^{3/2}, p, p^{1/2}$ and 1. In every case we are able to analyze, the largest lower order term in the second moment expansion that does not average to zero is on average negative. We prove this bias conjecture for several large classes of families, including families with rank and unusual distributions of functional equation signs. We also identify all lower order terms in large classes of families, shedding light on the arithmetic objects controlling these terms. The negative bias in these lower order terms has implications toward the excess rank conjecture and the behavior of zeros near the central point of elliptic curve L-functions. This work is joint with Megumi Asada, Eva Fourakis, Andrew Kwon, Blake Mackall, Karl Winsor and Kevin Yang. (Received February 24, 2017)

1128-11-164 **Igor Szczyrba*** (iszczyrba@yahoo.com), 2115 Genoa Ct, Loveland, CO 80538. *Asymptotic behavior of sequences generated by linear recurrences.* Preliminary report.

We introduce a necessary and sufficient criterion that allows to determine the existence and the values of ratio limits for sequences generated by arbitrary linear recurrences. (Received February 24, 2017)

1128-11-179 **Ralf Schmidt*** (rschmidt@math.ou.edu). *The multiplicity one theorem for paramodular forms.*

Classical modular forms enjoy the "strong multiplicity one" property, which states that a newform is determined by almost all of its Hecke eigenvalues. This was proved by Atkin and Lehner in 1970.

For higher rank modular forms, i.e., Siegel modular forms, the analogous theorem fails. In this talk we will explain why the strong multiplicity one property still holds for "paramodular forms", an important class of Siegel modular forms of degree 2. (Received February 24, 2017)

1128-11-198 **Brooks Roberts*** (brooksr@uidaho.edu) and **Ralf Schmidt**. *The structure of newforms in metaplectic representations.* Preliminary report.

The local analogues of modular forms of half-integral weight are certain vectors in irreducible genuine representations of the metaplectic group. As for GL(2) and GSp(4), these local vectors admit a new- and oldforms structure. However, in contrast to the case of GL(2) and GSp(4), there can be more than one newform, and in fact the number of newforms is the number of square classes with respect to which the representation admits a Whittaker model. In this talk we describe results about the structure of these newforms. (Received February 26, 2017)

1128-11-220 **Ameya Pitale*** (apitale@ou.edu). *Counter-examples to Ramanujan conjecture for GL(2,D) over a division quaternion algebra D.*

I will present joint work with Hiro-aki Narita, where we construct a Hecke-equivariant lifting from Maass cusp forms of level 2 to Maass cusp forms on 5-dim hyperbolic space. These lifts give rise to cuspidal automorphic representations of GL(2,D) over adeles of Q. These representations are CAP representations and violate the Generalized Ramanujan conjecture. The construction is very classical giving explicit formulas of Fourier coefficients (which look similar to the formulas of Saito-Kurokawa lifts) and the proof uses Maass' converse theorem. (Received February 27, 2017)

1128-11-256 **Riad Masri*** (masri@math.tamu.edu) and **Adrian Barquero-Sanchez**. *Effective nonvanishing of CM biquadratic L-functions.*

I will describe an effective nonvanishing theorem for L-functions associated to class group characters of CM biquadratic fields. The proof relies on an effective zero-free region for Hilbert modular Eisenstein series over real quadratic fields. (Received February 27, 2017)

1128-11-261 **Lillian Pierce**, **Caroline Turnage-Butterbaugh*** (ctb@math.duke.edu) and **Melanie Matchett Wood**. *Bounding ℓ-torsion in class groups.* Preliminary report.

Let K denote a number field of degree n, and for a fixed, positive integer ℓ, consider the ℓ-torsion subgroup of the class group of K. It is conjectured that the size of the this ℓ-torsion subgroup is very small (in an appropriate sense), relative to the absolute discriminant of the field K. In 2007, Ellenberg and Venkatesh proved a nontrivial bound (removing a power from the trivial bound) by assuming GRH. In this talk, we will discuss a method that recovers this bound for almost all members of certain families of fields, without assuming GRH. (Received February 28, 2017)

1128-11-272 **Jennifer Johnson-Leung*** (jenfns@uidaho.edu), Moscow, ID 83843. *Examples of Paramodular Surfaces.* Preliminary report.

The paramodular conjecture predicts that there is a bijective correspondence between isogeny classes of abelian surfaces of conductor N defined over the rational numbers with simple endomorphism ring and Siegel paramodular newforms with rational eigenvalues which are not in the span of the Gritsenko lifts. In this talk we will discuss several classes of examples which satisfy the paramodular conjecture. (Received February 28, 2017)

1128-11-292 **A. Folsom**, **S. Garthwaite**, **S.-Y. Kang**, **H. Swisher** and **S. Treneer*** (stephanie.treneer@wwu.edu), Department of Mathematics, Western Washington University, 516 High Street, Bellingham, WA 98225-9063. *Quantum mock modular forms arising from eta-theta functions.*

We consider mock modular forms whose shadows are both theta functions and eta-quotients (hereafter called eta-theta functions). Using Lemke Oliver's classification of all eta-theta functions, and methods of Zwegers, we construct mock modular forms from the eta-theta functions with even character, whose shadows are one of the six eta-theta functions with odd character. We then prove quantum modularity properties for one canonical choice of mock modular form corresponding to each of the six shadows. (Received February 28, 2017)

1128-11-353 **Caleb N Hunter*** (caleb.hunter@wallawalla.edu), PO Box 832, Eatonville, WA 98328. *Loops in a Generalized Collatz Mapping.* Preliminary report.

The focus of this exploration is a generalized form of the Collatz mapping. In particular the goal was to find patterns in the cycles formed by various starting rules in the Collatz mapping, as well as note any other interesting patterns. The two methods used to do so was to create a divisibility test capable of verifying whether a given path forms a valid cycle and also using a computer to help search for and categorize various cycles. (Received March 01, 2017)

13 ► *Commutative rings and algebras*

1128-13-36 **Jason M Lutz*** (lutzj@gonzaga.edu). *Homological characterizations of quasi-complete intersections.*

Let R be a commutative Noetherian ring and I and ideal of R. The homology of a Koszul complex associated with I is an invariant of I, and if this homology vanishes in positive degree, then I is said to be a *complete intersection.* If the homology exhibits the structure of an exterior algebra, then I is said to be a *quasi-complete intersection.* Using Tate's "adjunction of variables", we obtain an extension of the Koszul complex; a result of Blanco, Majadas, and Rodicio yields that I is a quasi-complete intersection if and only if the homology of this infinite complex vanishes in positive degree. Our main results characterize quasi-complete intersections as those ideals for which the homology of the associated Tate construction vanishes in a finite band of sufficient size. (Received January 31, 2017)

1128-13-44 **Weronika Buczyńska**, **Jarosław Buczyński**, **Johannes Kleppe** and **Zach Teitler*** (zteitler@member.ams.org). *Direct sum decomposability of forms.*

A polynomial is a direct sum if it can be written as a sum of two nonzero polynomials in some distinct sets of variables, up to a linear change of variables. We analyze criteria for a homogeneous polynomial to be decomposable as a direct sum in terms of the apolar ideal of the polynomial. We prove that the apolar ideal of a polynomial of degree d strictly depending on all variables has a minimal generator of degree d if and only if it is a limit of direct sums. This is joint work with Weronika Buczyńska, Jarosław Buczyński, and Johannes Kleppe. (Received February 04, 2017)

1128-13-46 **Luigi Ferraro*** (luigi.ferraro@huskers.unl.edu). *Modules with infinite regularity.*

Let R be the graded ring $k[x_1, \ldots, x_n]/I$ where I is an homogeneous ideal of the polynomial ring with the standard grading. If the Castelnuovo-Mumford regularity of k is infinite we are going to construct a class of modules with infinite regularity. If R is a complete intersection we will be able to construct a second class of modules with infinite regularity. (Received February 04, 2017)

1128-13-54 **Whitney I Liske*** (liske.2@nd.edu). *Rees Rings of Artinian Gorenstein 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 the 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 of 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 February 08, 2017)

1128-13-55 **Katharine Shultis*** (shultis@gonzaga.edu). *Systems of parameters and the Cohen-Macaulay property.*

Let R be a commutative, Noetherian, local ring and M a finitely generated R-module. Consider the module of homomorphisms $\mathrm{Hom}_R(R/\mathfrak{a}, M/\mathfrak{b}M)$ where $\mathfrak{b} \subseteq \mathfrak{a}$ are parameter ideals of M. When $M = R$ and R is Cohen-Macaulay, Rees showed that this module of homomorphisms is always isomorphic to $R/\mathfrak{a}$. Recently, K. Bahmanpour and R. Naghipour showed that if $\mathrm{Hom}_R(R/\mathfrak{a}, R/\mathfrak{b})$ is isomorphic to $R/\mathfrak{a}$ for *every* pair of parameter ideals $\mathfrak{b} \subseteq \mathfrak{a}$ then R is Cohen-Macaulay. In this talk, we will discuss the structure of $\mathrm{Hom}_R(R/\mathfrak{a}, M/\mathfrak{b}M)$ for general M, focusing on the case when $M = R$ and R is a quotient of a power series ring. (Received February 08, 2017)

1128-13-76 **J Hoffmeier*** (jhoff@nwmissouri.edu), **A Croll**, **R Dellaca**, **A Gupta**, **V Mukundan**, **D R Tracy**, **L M Sega**, **G Sosa** and **P Thompson**. *Detecting Koszulness from the algebra structure of Koszul homology.*

Let k be a field and R a standard graded k-algebra. We denote by H^R the homology algebra of the Koszul complex on a minimal system of generators of the irrelevant ideal of R. We discuss the relationship between the multiplicative structure of H^R and the property that R is a Koszul algebra. More generally, we work in the setting of local rings and show that certain conditions on the multiplicative structure of Koszul homology imply strong homological properties. (Received February 13, 2017)

1128-13-81 **Peder Thompson*** (peder.thompson@ttu.edu), Lubbock, TX 79409. *Cosupport computations for finitely generated modules over commutative noetherian rings.*

We will focus on computing the cosupport of finitely generated modules over commutative noetherian rings. After giving a method to detect cosupport in this setting, we will compute the cosupport of various rings and finitely generated modules. In particular, we will show that every countable commutative noetherian ring has full cosupport. We also will give a family of rings not having closed cosupport, providing a negative answer to a recent question of Sather-Wagstaff and Wicklein. (Received February 14, 2017)

1128-13-114 **Michael R DiPasquale*** (mdipasq@okstate.edu), 401 Math Sciences Building, Stillwater, OK 74078, and **Max Wakefield**. *Multi-derivations on the moduli of the X_3 arrangement.*

A central conjecture in the theory of hyperplane arrangements states that freeness of the module of derivations of a hyperplane arrangement is combinatorial (i.e. can be determined from its lattice of intersections). The main evidence for this conjecture is a celebrated result of Terao which implies that the exponents of a free arrangement are combinatorial. The corresponding statement is not true for multi-arrangements; there are simple examples due to Ziegler of free rank two multi-arrangements whose exponents are not combinatorial. In this talk we consider a non-free arrangement of rank three (the X_3 arrangement) and give a complete classification of free multiplicities for all arrangements in its moduli space. There are very few arrangements for which such a classification is known; this is the first such classification for a non-free arrangement or an arrangement with non-trivial moduli space. As a consequence, we have a simple example where freeness of a fixed multiplicity changes as we move through the moduli space. This is joint work with Max Wakefield. (Received February 19, 2017)

1128-13-130 **William J J Heinzer**, **Christel Rotthaus** and **Sylvia M Wiegand*** (swiegand1@unl.edu), Dept. of Mathematics, UNL, Lincoln, NE 68588-0130. *Construction of an Ogoma-like normal Noetherian non-catenary domain.* Preliminary report.

A Noetherian ring is "catenary" if every maximal nested chain of prime ideals between two prime ideals P and Q such that P is contained in Q has the same length. The first example of a non-catenary Noetherian ring was given by Nagata in the 1950s, but it was not integrally closed.

In 1980, Ogoma gave an example of a three-dimensional normal Noetherian local domain that is not catenary. He used a rather complicated construction using multi-ideal-adic completions. Ogoma's example also resolved—in the negative—the Chain Conjecture.

The present authors have been developing a procedure for building various examples of Noetherian and non-Noetherian rings using power series rings. This procedure yields a somewhat simpler "Ogoma-like" example with the properties of Ogoma's example. This example and many related topics are part of the authors' book in progress, "Integral Domains Inside Noetherian Power Series Rings: Constructions and Examples".

In this talk we present some of the theory, techniques, and features of the construction, and we show some of the properties of the Ogomo-like example. (Received February 21, 2017)

1128-13-132 **Irena Swanson*** (iswanson@reed.edu), 3203 SE Woodstock Blvd, Portland, OR 97202.
Associated primes of powers of ideals. Preliminary report.

Given an ideal I in a commutative Noetherian ring with identity, the set of associated primes of powers I^k of I varies with k and by a result of Brodmann eventually stabilizes. The numbers of elements can increase and decrease several times. This is a report on generating (prime) ideals with large increases. (Received February 22, 2017)

1128-13-139 **Jennifer Kenkel*** (jennifer.kenkel@gmail.com), UT. *Local Cohomology of Thickenings.* Preliminary report.

Let R be a standard graded polynomial ring that is finitely generated over a field, let $\mathfrak{m}$ be the homogeneous maximal ideal of R, and let I be a homogeneous prime ideal of R. Bhatt, Blickle, Lyubeznik, Singh and Zhang examined the local cohomology of R/I^t, as t goes to infinity, in characteristic 0. I will discuss their results, give a concrete example, and consider the same problem in positive characteristic. (Received February 22, 2017)

1128-13-169 **Susan Marie Cooper*** (susan.marie.cooper@ndsu.edu), Department of Mathematics, North Dakota State University, NDSU Dept # 2750, PO Box 6050, Fargo, ND 58108-6050.
The Difference Between Symbolic and Regular Powers: An Asymptotic Approach.

Understanding the difference between regular and symbolic powers of a homogeneous ideal is a significant problem, even for monomial ideals. One approach is to consider a special limit called the Waldschmidt constant which was first introduced as a way to estimate the lowest degree of a hypersurface vanishing at all the points of a variety to a given order. In this talk, we will give some interpretations of the Waldschmidt constant of a monomial ideal which allow us to determine this useful limit in a number of cases. This is joint work from two projects: the first with R. Embree, H. T. Hà, and A. Hoefel and the second with C. Bocci, E. Guardo, B. Harbourne, M. Janssen, U. Nagel, A. Seceleanu, A. Van Tuyl, and T. Vu. (Received February 24, 2017)

1128-13-175 **Craig Huneke**, **Srikanth Iyengar** and **Roger Wiegand*** (rwiegand1@unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130. *Rigid ideals in one-dimensional Gorenstein domains.* Preliminary report.

An R-module M is said to be *rigid* provided every self-extension of M splits, that is, $\mathrm{Ext}^1_R(M, M) = 0$. Suppose that R is a local Gorenstein domain of dimension one. In this context, there are no known examples of rigid ideals, except the obvious ones—principal ideals. We conjecture, at least when R is a complete intersection domain of dimension one, that rigid ideals must be principal. This is closely related to a conjecture (still open) from the early nineties, by Huneke and Wiegand: If M is a finitely generated module over a local domain (of any dimension), and if $M \otimes_R M^*$ (where $M^* = \mathrm{Hom}_R(M, R)$) is a maximal Cohen-Macaulay (MCM) module, then M must be free. (A finitely generated torsion-free module M over a one-dimensional local Gorenstein domain is rigid if and only if $M \otimes M^*$ is MCM (equivalently, torsion-free).)

In this talk I will report some positive results and also mention a place to look for possible counterexamples. (Received February 24, 2017)

1128-13-180 **John Myers*** (jmyers4@math.unl.edu). *Ext-algebras and minimal multiplicity.* Preliminary report.

If R is a commutative noetherian local ring with residue field k, then the graded vector space $\mathrm{Ext}^*_R(k, k)$ has a product giving it the structure of a graded k-algebra, which is called the Ext-algebra of R. In this talk we will explain how rings with minimal Hilbert-Samuel multiplicity can be detected by examining the structure of this algebra. (Received February 24, 2017)

1128-13-182 **Daniel Smolkin*** (smolkin@math.utah.edu). *Subadditivity formulas for test ideals.* Preliminary report.

Given a ring R of positive characteristic, an ideal $\mathfrak{a}$ in R, and a positive number t, one can construct what's called the *test ideal* of this data, denoted $\tau(\mathfrak{a}^t)$. This notion was introduced by Hara and Yoshida in 2003, based on work in tight closure by Hochster and Huneke, and it measures the singularities of R and $\mathfrak{a}$. Hara and Yoshida also showed that test ideals on regular rings obey a *subadditivity* formula, namely $\tau(\mathfrak{a}^s\mathfrak{b}^t) \subseteq \tau(\mathfrak{a}^s)\tau(\mathfrak{b}^t)$, and Takagi generalized this formula to the affine case. This formula has a number of important applications, such as bounding the growth of symbolic powers of ideals.

In this talk, I will discuss progress towards an improved subadditivity formula for non-regular rings using the formalism of Cartier algebras. Along the way, I will show some constructions for the toric case. (Received February 25, 2017)

1128-13-199 **Janet Page*** (jpage8@uic.edu). *The Frobenius Complexity of Hibi Rings.*

Cartier algebras and their duals, rings of Frobenius operators, have come up in the study of Frobenius splittings, which have been useful in many topics ranging from singularity theory in algebraic geometry to representation theory. When R is a local ring of characteristic $p > 0$, the Cartier algebra $\mathcal{C}(R)$, which is the ring of all potential Frobenius splittings of R, is dual to the ring of Frobenius operators (p^e-linear maps) on the injective hull of the residue field. This ring of Frobenius operators need not be finitely generated over R, which led Enescu and Yao to define Frobenius complexity as a measure of its non-finite generation. In their examples Frobenius complexity is not always even rational, but its limit as $p \to \infty$ is an integer. Few other examples have been computed. In this talk, I will discuss a method to compute limit Frobenius complexity for Hibi rings, which are a class of toric rings defined from finite posets. I will show that this computation can be read directly from the defining poset in nice cases. (Received February 26, 2017)

1128-13-204 **Patricia Jacobs Klein*** (triciajk@umich.edu). *Asymptotic behavior of certain Koszul cohomology modules.*

Let (R, m) be a local ring, M a finitely generated module over R, and $f_1, \dots, f_d$ a system of parameters on M. Lech's limit formula states that as $\min_i t_i \to \infty$

$$\frac{\ell(M/(f_1^{t_1}, \dots, f_d^{t_d})M)}{t_1 \cdots t_d} \longrightarrow e(f_1, \dots, f_d \mid M),$$

the multiplicity of $(f_1, \dots, f_d)$ on M. One may ask whether powers of a fixed sequence of parameters may be replaced by any sequence of parameter ideals I_n such that $I_n \subseteq m^n$. Recalling that the multiplicity may be realized as the alternating sum of the lengths of Koszul cohomology modules and that $H^n(f_1^{t_1}, \dots, f_d^{t_d} \mid M) \cong M/(f_1^{t_1}, \dots, f_d^{t_d})M$, we rewrite Lech's limit formula as follows

$$\frac{\sum_{j=0}^{n}(-1)^{n-j}\ell(H^i(f_1^{t_1}, \dots, f_d^{t_d}; M))}{\ell(H^n(f_1^{t_1}, \dots, f_d^{t_d}))} \longrightarrow 1.$$

From this point of view, it is also natural to ask in the case when $\dim M = \dim R = d$ for which $i < d$ we have $\ell(H^i(I_n; M))/\ell(R/I_nR) \to 0$. The main result is that when M is faithful, the M satisfying the condition that $\ell(H^i(I_n; M))/\ell(R/I_nR) \to 0$ for all $i < d$ and all parameter $I_n \subseteq m^n$ are exactly those M that are locally Cohen-Macaulay. (Received February 26, 2017)

1128-13-210 **Sean Sather-Wagstaff*** (ssather@clemson.edu) and **Jonathan Totushek**. *Complete intersection injective dimensions.* Preliminary report.

Complete intersection (CI) dimensions of modules over local rings model properties of modules over CI rings. In this talk, I will describe a new CI injective dimension and some of its properties. Like Avramov, Gasharov, and Peeva's CI-dimension, it is defined in terms of quasi-deformations, but using derived Hom in place of tensor product. (Received February 27, 2017)

1128-13-221 **Hannah Altmann*** (haltmann@morris.umn.edu), **Eloisa Grifo**, **Jonathan Montano**, **William Sanders** and **Thanh Vu**. *Lower Bounds on Projective Levels of Complexes.* Preliminary report.

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 February 27, 2017)

1128-13-324 **Thomas McKenzie*** (mckenzie@gonzaga.edu), 502 East Boone Avenue, Gonzaga University, Department of Mathematics, Spokane, WA 99258. *A Graph of Separable Polynomials.*

Assume R is a commutative ring with identity. A monic polynomial with coefficients in R is said to be separable if it is relatively prime to its formal derivative. We form a graph of separable polynomials and we consider the simplicial complex formed by the cliques of this graph. In the case where R has exactly one maximal ideal, we show that the set of separable polynomials forms a matroid. (Received February 28, 2017)

1128-13-356 **Gabriel E Sosa*** (gsosa@amherst.edu). *Toric rings arising from strongly stable sets of monomials with two generators.* Preliminary report.

A known result by DeNegri establishes that toric rings arising from principal strongly stable sets of monomials are Koszul normal domains. Conca has found examples of toric rings arising from strongly stable sets of monomials with three generators that are neither Koszul nor normal. We presents partial results regarding the Koszulness of toric rings arising from strongly stable sets of monomials with two generators. (Received March 01, 2017)

14 ► Algebraic geometry

1128-14-45 **Jarosław Buczyński**, **Kangjin Han**, **Massimiliano Mella** and **Zach Teitler*** (zteitler@member.ams.org). *Geometry of high rank loci.*

General $m \times n$ matrices have rank $\min\{m, n\}$, which is also the maximum possible rank. The loci of matrices of lower rank are well-studied. For more general notions of rank, such as tensor rank and Waring rank, once again loci of low rank points are well-known, namely, they are secant varieties. But high rank loci are almost completely mysterious.

We consider the loci of points with strictly greater than generic rank with respect to a projective variety X. This includes well-known notions of rank, such as tensor rank (when X is a Segre variety) and Waring rank (when X is a Veronese variety). We show nesting results, dimension bounds, and containment and non-containment results for high rank loci with respect to arbitrary varieties X. We improve upper bounds for rank with respect to any curve or homogeneous variety. In the case of Waring rank, we show that the locus of n-ary forms of maximal Waring rank has dimension at least $\binom{n+1}{2} - 1$. This is joint work with Jarosław Buczyński, Kangjin Han, and Massimiliano Mella. (Received February 04, 2017)

1128-14-61 **Vladyslav Oles*** (vladyslav.oles@gmail.com). *Finding fixed points of Boolean networks.*

It will be about a newly developed algorithm for finding fixed points of AND-NOT Boolean networks, which is equivalent to solving a system of equations, given by Boolean polynomials. Time complexity of the algorithm is proven to be $O(1,3562^N)$, compared to $O(2^N)$ of known tools from computational algebra. (Received February 08, 2017)

1128-14-101 **Saugata Basu**, **Antonio Lerario**, **Erik Lundberg** and **Chris Peterson*** (peterson@math.colostate.edu). *Computation, expectation, and symmetry for combinatorial problems in real algebraic geometry.*

A well known result in algebraic geometry asserts that 27 lines lie on a general cubic surface in $\mathbb{C}P^3$. From a homogeneous cubic polynomial in $\mathbb{C}[w, x, y, z]$ one can use elimination theory to determine a degree 27 homogeneous polynomial in two variables whose roots correspond to the 27 lines. If one starts with a homogeneous cubic polynomial in $\mathbb{R}[w, x, y, z]$ and again use elimination theory one obtains a degree 27 homogeneous polynomial in two variables with real coefficients. With probability one, it is known that this polynomial always has 3, 7, 15, or 27 real roots and that each of these cases occurs with positive probability. It is natural to ask for the expected number of real roots (i.e. the expected number of real lines on a general real cubic surface). Of course the answer depends on the probability distribution used to choose the cubic. We show that with respect to the Kostlan distribution (a particular O(4) invariant Gaussian distribution on the space of real cubic polynomials in four variables), one expects there to be $6\sqrt{2} - 3$ real lines. The goal of this talk is to present the key features that lead to this result. (Received February 16, 2017)

1128-14-126 **Andrew T Bydlon*** (bydlon@math.utah.edu). *Restriction of Test Ideals to Hypersurfaces.*

In positive characteristic commutative algebra and algebraic geometry, the test ideal $\tau(R, \mathfrak{a}^t)$ is an important invariant yielding important information about the severity of the singularities of R and $\mathfrak{a}$ simultaneously. In this talk, I demonstrate that the restriction of the test ideal to a general hypersurface is not in general equal to the the test ideal of the restriction, answering questions stemming from work of Hochster and Huneke. (Received February 21, 2017)

1128-14-128 **Adam Nyman*** (adam.nyman@wwu.edu). *Genus zero phenomena in noncommutative algebraic geometry.*

The notion of noncommutative $\mathbb{P}^1$-bundle was discovered and studied by M. Van den Bergh. Examples include noncommutative ruled surfaces, noncommutative Del Pezzo surfaces, and noncommutative curves of genus zero.

In this talk we describe necessary and sufficient conditions for an abelian category to be equivalent to a noncommutative $\mathbb{P}^1$-bundle over a pair of division rings. As a consequence, we show Piontkovski's nonnoetherian noncommutative projective lines are noncommutative $\mathbb{P}^1$-bundles. (Received February 21, 2017)

1128-14-149 **Praise Adeyemo*** (praise.adeyemo13@gmail.com), 222 College Street, Toronto, M5T 3J1, Canada, and **Frank Sottile**, College Station, TX. *COHOMOLOGICAL CONSEQUENCES OF THE PATTERN MAP.*

Billey and Braden defined maps on flag manifolds which are geometric counterpart of permutation patterns. A section of their pattern map is an embedding of the flag manifold of a Levi subgroup into the full flag manifold. We give two expressions for the induced map on cohomology. One is in terms of generators and the other is in terms of the Schubert basis. We show that the coefficients in the second expression are naturally Schubert structure constants and therefore positive. (Received February 23, 2017)

1128-14-193 **Joe Kileel*** (jkileel@math.berkeley.edu). *Using algebraic geometry for computer vision.*

In computer vision, 3D reconstruction is a fundamental task: starting from photographs of a world scene, taken by cameras with unknown positions and orientations, how can we best create a 3D model of that world scene? Algorithms that do this built Street View (Google) and are instrumental in autonomous robotics. In 2004, David Nister (Tesla) used Grobner bases to build a solver for robust reconstruction given just two photographs. This is a key routine in much larger-scale reconstructions today. In this talk, I will discuss reconstruction given three photographs, where efforts to replicate Nister have so far proven elusive. My approach relies on applied algebraic geometry. In particular, I shall introduce an algebraic variety whose points are 3x3x3 tensors in correspondence with configurations of three calibrated cameras. Special linear sections of this variety recover camera configurations from image data. The main result is the determination of the algebraic degree of minimal problems for this recovery. These comprise interesting enumerative geometry problems; the solution is by way of homotopy continuation calculations. (Received February 26, 2017)

1128-14-226 **Kyungyong Lee**, **Matthew R Mills*** (matthew.mills@huskers.unl.edu) and **Alexandra Seceleanu**. *Vanishing ideals for points from cluster algebras.*

Cluster algebras are a class of axiomatically defined commutative rings equipped with a distinguished set of generators (cluster variables) grouped into overlapping subsets (clusters) of the same finite cardinality. *A priori*, we know that cluster variables are multivariate rational functions, but by the Laurent Phenomenon we know that they are actually Laurent polynomials with positive integer coefficients. Therefore by evaluating these Laurent polynomials at one, each cluster gives rise to a point with positive integer coordinates. We study the vanishing ideal of these points to give polynomial invariants for affine quivers and cluster algebras. (Received February 27, 2017)

1128-14-227 **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 combinatorial objects to an algebraic variety. We are interested in computing 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 February 27, 2017)

1128-14-269 **James S. Wolper*** (wolpjame@isu.edu), Department of Mathematics and Statistics, Idaho State University, 921 S. 8th Ave., Mail Stop 8085, Pocatello, ID 83209-8085. *Periods of Prym Varieties.* Preliminary report.

David Mumford showed that a general Prym variety, constructed from an unramified double cover of an algebraic curve, is not a Jacobian, but those constructed from covers of hyperellitic curves are hyperelliptic Jacobians. Numerical experiments indicate that the arguments of periods of hyperelliptic curves cluster around a single value. This talk will explore the distribution of the periods of hyperelliptic Pryms from this perspective. (Received February 28, 2017)

15 ► Linear and multilinear algebra; matrix theory

1128-15-21 **Amy Ann Yielding*** (ayielding@eou.edu), **Ryan Blanchard**, **Joel Jacobs**, **Mico Murphy** and **Taylor Rhoton**. *Inertia Tables for Clique Galaxies.* Preliminary report.

In this talk we establish inertia tables for Cliques Galaxies. We also introduce the modified T-notation for describing these inertia tables. (Received January 20, 2017)

1128-15-31 **Mashael Albaidani*** (mashael.albaidani@wsu.edu), Pullman, WA 99163. *Properties of Nonnegative Matrices That are True for General Matrices.* Preliminary report.

In this talk we will explore properties established for nonnegative matrices that hold in a more general context. In particular, we show that if a matrix A has the property that $\mathrm{index}_0(A) \leq 1$, and g is a positive integer such that for all distinct eigenvalues λ and μ, it follows that $\lambda^g \neq \mu^g$, then there is a permutation matrix P such that PAP^{-1} and PA^gP^{-1} are in Frobenius normal form with the same block partitioning. (Received January 26, 2017)

1128-15-60 **Jillian Louise Glassett*** (jglassett@math.wsu.edu), jglassett@math.wsu.edu, and **Judith McDonald**. *Spectrally Arbitrary Zero-Nonzero Patterns over Rings with Unity.*

A zero-nonzero matrix pattern $\mathcal{A}$ is a square matrix with entries $\{0, *\}$. A $n \times n$ pattern $\mathcal{A}$ is spectrally arbitrary over a ring $\mathcal{R}$ if for each n-th degree monic polynomial $f(x) \in \mathcal{R}[x]$, there exist a matrix A over $\mathcal{R}$ with pattern $\mathcal{A}$ such that the characteristic polynomial $p_A(x) = f(x)$. A $n \times n$ pattern $\mathcal{A}$ is relaxed spectrally arbitrary over $\mathcal{R}$ if for each n-th degree monic polynomial $f(x) \in \mathcal{R}[x]$, there exist a matrix A over $\mathcal{R}$ with either pattern $\mathcal{A}$ or a subpattern of $\mathcal{A}$ such that the characteristic polynomial $p_A(x) = f(x)$. We consider whether a pattern $\mathcal{A}$ that is spectrally arbitrary over a ring $\mathcal{R}$ is spectrally arbitrary or relaxed spectrally arbitrary over another ring $\mathcal{S}$. In particular, we discovered that a pattern that is spectrally arbitrary over $\mathbb{Z}$ is relaxed spectrally arbitrary over $\mathbb{Z}_m$ for all m. We also determined the minimum number of $*$ entries to be spectrally arbitrary over $\mathbb{Z}$. (Received February 22, 2017)

1128-15-89 **David S Watkins*** (watkins@math.wsu.edu). *Fast, stable computation of the eigenvalues of unitary-plus-rank-one matrices, including companion matrices.*

We consider upper Hessenberg unitary-plus-rank-one matrices, that is, matrices of the form $A = \tilde{U} + \tilde{x}\tilde{y}^T$, where $\tilde{U}$ is unitary, and A is upper Hessenberg. This includes the class of Frobenius companion matrices, so methods for this type of matrix can be applied to the problem of finding the zeros of a polynomial.

The unitary-plus-rank-one structure is preserved by any method that performs unitary similarity transformations, including Francis's implicitly-shifted QR algorithm. We present a new implementation of Francis's algorithm that acts on a data structure that stores the matrix in $O(n)$ space and performs each iteration in $O(n)$ time. This is joint work with Jared Aurentz, Thomas Mach, and Raf Vandebril.

Ours is not the first fast algorithm that has been proposed for this problem, but it is the first that has been shown to be backward stable, and it is faster than other fast algorithms that have been proposed previously. (Received February 15, 2017)

1128-15-99 **Nathaniel Johnston** and **Steve Kirkland***, Department of Mathematics, University of Manitoba, Winnipeg, MB R3T 2N2, Canada, and **Sarah Plosker**, **Rebecca Storey** and **Xiaohong Zhang**. *Hadamard Diagonalizable Graphs and Perfect State Transfer.* Preliminary report.

Let G be a graph on vertices $1, \ldots, n$ with Laplacian matrix L. We say that there is perfect state transfer (PST) from vertex j to vertex k at time t_0 if the (j,k) entry of $exp(it_0L)$ has modulus 1. The interest in PST arises in connection with the transfer of information within a quantum computer. In this talk we focus on graphs whose Laplacian matrix is diagonalized by a Hadamard matrix. We provide a simple characterization for such graphs to have PST at time $\pi/2$, and produce a wide variety of new graphs that exhibit PST. (Received February 16, 2017)

1128-15-140 **Anne Greenbaum*** (greenbau@uw.edu), University of Washington, Applied Math Dept., Box 353925, Seattle, WA 98195. *A New Proof that Any Disk Containing the Numerical Range is a 2-Spectral Set.*

Let A be an n by n matrix and let $W(A) = \{\langle Aq, q\rangle \in \mathbb{C} : \|q\|_2 = 1\}$ denote its numerical range. In 1975, Okubo and Ando showed that if $W(A)$ is a subset of the unit disk $\mathbb{D}$, then $\mathbb{D}$ is a 2-spectral set for A; that is, for any polynomial p, $\|p(A)\| \leq 2\|p\|_{\mathbb{D}}$, where the norm on the left is the operator 2-norm, or, the largest singular value of $p(A)$, and $\|\cdot\|_{\mathbb{D}}$ on the right denotes the infinity norm: $\sup_{z\in\mathbb{D}} |p(z)|$. Crouzeix has conjectured that $W(A)$ itself is a 2-spectral set for A, and very recently Palencia and Crouzeix [https://arxiv.org/abs/1702.00668] were able to prove that $W(A)$ is a $(1+\sqrt{2})$-spectral set for A. We use the Palencia-Crouzeix result, along with a new result about the function $\hat{f}$ that maximizes $\|f(A)\|/\|f\|_{W(A)}$ over all f analytic in $W(A)$, to give a new proof that any disk containing $W(A)$ is a 2-spectral set for A. We discuss some classes of matrices for which the $1+\sqrt{2}$ bound in the Palencia-Crouzeix paper can be reduced to 2. (Received February 22, 2017)

1128-15-177 **Pietro Paparella*** (pietrop@uw.edu), 18115 Campus Way NE, Bothell, WA 98011. *A matricial view of the Karpelevič Theorem.*

The question of the exact region in the complex plane of the possible single eigenvalues of all n-by-n stochastic matrices was raised by Kolmogorov in 1937 and settled by Karpelevič in 1951 after a partial result by Dmitriev and Dynkin in 1946. The Karpelevič result is unwieldy, but a simplification was given by Djoković in 1990 and Ito in 1997. The Karpelevič region is determined by a set of boundary arcs each connecting consecutive roots of unity of order less than n.

However, noticeably absent in the Karpelevič theorem (and the above-mentioned works) are *realizing-matrices* (i.e., a matrix whose spectrum contains a given point) for points on these arcs. In this talk we show that each of these arcs is realized by a single, somewhat simple, parameterized stochastic matrix. Other observations are made about the nature of the arcs and several further questions are raised. The doubly stochastic analog of the Karpelevič region remains open, but a conjecture about it is amplified.

This is joint work with Charles R. Johnson. (Received February 24, 2017)

1128-15-194 **Michael Kasigwa*** (kasigwam@gmail.com), Department of Mathematics and Statistics, Washington State University, P.O. Box 643113, Pullman, WA 99164. *On Characterising Eventually Positive Linear Operators and Invariance.*

Notions in the theory of nonnegative matrices are generalized to cones with discussion of equivalances on transition from entrywise nonnegativity to a more general operator theoretic approach. Berman, Neumann and Stern (1989), showed that essential cone-nonnegativity of a real square matrix A and eventual exponential cone-nonnegativity are not equivalent for non-polyhedral cones. If A is an eventually nonnegative matrix and the index of zero, as an eigenvalue, is less than or equal to one, many of the combinatorial properties of A carry over to those of $A^m \geq 0, m > 0$, Carnochan and McDonald,(2002).In particular A and A^m have the same Frobenius normal form, a fact that was used to prove that eventual nonnegativity and eventual exponential nonnegativity of A are equivalent,Noutsos and Tsatsomeros,(2008).However such a generalization fails for eventual cone-nonnegativity and eventual exponential cone-nonnegativity. We conclude with a mention of work on inverse positivity of M-type matrices,Le and McDonald,(2006), recent work characterising eventual positivity of semigroups of linear operators using resolvent properties of the generator and Perron-Frobenius type conditions, Daners, Gl*ück* and Kennedy,(2016) and further work. (Received February 26, 2017)

1128-15-224 **Gerandy Brito***, Department of Mathematics., University of Washington, PoBox 354350, Seattle, WA 98195, and **Ioana Dumitriu** and **Kameron Harris**. *Spectral gap of random bipartite biregular graphs with application to clustering.*

We discuss how the study of the spectrum of the non backtracking operator can be used to understand clustering properties in networks with certain regularity properties. Our model is a natural extension of the Regular Stochastic Block Model introduced by the first two authors and coauthors. The results presented are of independent interest in the context of spectral theory of random graphs. Based on join work with Ioana Dumitriu and Kameron Harris. (Received February 27, 2017)

1128-15-237 **Thomas R Cameron*** (tcameron@collegeofidaho.edu). *On Descartes' rule of signs for matrix polynomials.*

Descartes' rule of signs, first described by René Descartes in 1637, provides an upper bound on the number of real positive roots of a polynomial scalar polynomial with real coefficients.

In this talk, we discuss a generalization of Descartes' rule of signs for matrix polynomials $P(\lambda)$ with Hermitian coefficients that are all either positive or negative definite. Specifically, we support our conjecture that the upper bound on the number of real positive eigenvalues $r(P)$ of such matrix polynomials satisfies

$$r(P) \leq ns(P) \quad \text{and} \quad r(P) = ns(P) \mod 2,$$

where $s(P)$ is the number of sign changes (alterations of positive and negative definite) between consecutive nonzero coefficients. (Received February 27, 2017)

1128-15-254 **Carlee Ann Walker*** (carlee.walker@wallawalla.edu), College Place, WA 99324.
Determination of Character Table for D_{3h} Point Group.

Chemists have long been interested in character tables to determine bonding tendencies and vibrational modes of molecular compounds. Here, special attention is given to borane, a molecule with the symmetries of a triangular prism. By considering conjugacy classes of the symmetric linear transformations of the molecule and the Great Orthogonality theorem, the irreducible representations of the character table can be found. Implications of these calculations are also explored. (Received February 27, 2017)

1128-15-286 **Hon Leung Lee*** (hllee@uw.edu). *Problems in Algebraic Vision.*

Reconstructing a three-dimensional world using two-dimensional images from multiple cameras is a fundamental problem in computer vision. We rewrite the existence of such reconstruction from two views as the existence of a common real solution of a bunch of linear equations and polynomial equations/inequalities. In this talk we discuss the recent progress of certifying the existence of such real solution. This is a joint work with Sameer Agarwal, Bernd Sturmfels and Rekha R. Thomas. (Received February 28, 2017)

1128-15-323 **Jerzy Kocik*** (jkocik@siu.edu), Department of Mathematics, Southern Illinois University, Carbondale, IL 62901. *Circles in configuration: from geometry to physics.* Preliminary report.

New and old results concerning the correspondence between the Minkowski space and the set of spheres in the Euclidean space will be reviewed. This will include certain intriguing analogies with formalisms native to theoretical physics and some outstanding problems. (Received February 28, 2017)

1128-15-326 **Jeffrey L Stuart*** (jeffrey.stuart@plu.edu), Department of Mathematics, Pacific Lutheran University, Tacoma, WA 98447. *Sign and ray patterns that allow k-potence.*

The sign (ray) pattern A is said to be sign (ray) k-potent for some positive integer k if $A^{k+1} = A$ as a sign (ray) pattern. We investigate which sign (ray) patterns allow k-potence. That is, if A is a sign pattern such that $A^{k+1} = A$, is there a real matrix B whose sign pattern is A such that $B^{k+1} = B$ as a real matrix. Likewise, if A is a ray pattern such that $A^{k+1} = A$, is there a complex matrix B whose ray pattern is A such that $B^{k+1} = B$ as a complex matrix. We present some new results and some open questions. (Received February 28, 2017)

1128-15-327 **Justin Dickinson Marks*** (justmarks@gmail.com). *Grassmann Manifold Means.*

Applications of geometric data analysis often involve producing collections of subspaces, such as illumination spaces for digital imagery. For a given collection of subspaces, a natural task is to find the mean of the collection. A robust suite of algorithms has been developed to generate mean representatives for a collection of subspaces of fixed dimension, or equivalently, a collection of points on a particular Grassmann manifold. These representatives include the flag mean, the normal mean, the projection mean, and the Karcher mean. We catalogue the types of means and present comparative heuristics for the suite of mean representatives. (Received February 28, 2017)

1128-15-335 **Amy Streifel*** (amystreifel@gmail.com). *Skew Adjacency Matrices of Cacti.*

What happens when we add the idea of directing the edges of a graph when looking at its adjacency matrix? One possible interpretation of this situation leads to the interesting world of skew adjacency matrices, and from them the skew characteristic polynomials and skew numbers of graphs. In this talk we look at the skew adjacency matrices of a specific family of graphs called cacti, and try to discover how many possible skew characteristic polynomials one can get from a single graph. (Received February 28, 2017)

1128-15-358 **Abbas Salemi Parizi*** (salemi@uk.ac.ir), Department of Applied Mathematics, Shahid Bahonar University of Kerman, Kerman, Iran, and **Faranges Kyanfar** (kyanfar@uk.ac.ir), Department of Applied Mathematics, Shahid Bahonar University of Kerman, Kerman, Iran. *ITERATIVE METHODS AND NUMERICAL RANGE OF MATRICES.*

The numerical range of $A \in M_n(\mathbb{C})$ is denoted by W(A) as follows: $W(A) = \{x^*Ax : x \in \mathbb{C}^n, \|x\| = 1\}$. This notion has applications to many different branches of pure and applied science and has a long and distinguished history. In this lecture we study the role of the numerical range and polynomial numerical hulls of matrices to stagnation and convergence rate of iterative (GMRES and DGMRES) methods. (Received March 01, 2017)

16 ► Associative rings and algebras

1128-16-37 **S. Paul Smith*** (smith@math.washington.edu), Department of Mathematics, University of Washington, Seattle, WA 98195-4350, and **Alex Chirvasitu**. *Some algebras having relations like the 4-dimensional Sklyanin algebras.*

(Joint work with Alex Chirvasitu) We discuss a 3-parameter family of associative algebras as in the title. They are graded and are generated by 4 elements subject to 6 quadratic relations. The motivation is a conjecture by Cho, Hong, and Lau, to the effect that a 2-parameter family of algebras that appeared in their work on homological mirror symmetry are 4-dimensional Sklyanin algebras. Only a 1-parameter sub-family of their algebras are Sklyanin algebras, but all of them belong to the 3-parameter family that is the focus of this talk. The members of this larger 3-parameter family that are not Sklyanin algebras differ from them in interesting ways. We discuss some of these differences. (Received February 01, 2017)

1128-16-42 **Jiafeng Lü**, **Sei-Qwon Oh** and **Xingting Wang*** (xingting@temple.edu), Department of Mathematics, Wachman Hall (038-16), 1805 N. Broad Street, Philadelphia, PA 19122-6094, and **Xianlan Yu**. *Enveloping algebras of double Poisson-Ore extensions.* Preliminary report.

In this talk, we prove that the Poisson enveloping algebra of a double Poisson-Ore extension is an iterated double Ore extension. As an application, properties that are preserved under iterated double Ore extensions are invariants of the Poisson enveloping algebra of a double Poisson-Ore extension. This is a joint work with Jiafeng Lü, Sei-Qwon Oh and Xiaolan Yu. (Received February 04, 2017)

1128-16-95 **Alexandru Chirvasitu*** (chirva@uw.edu), Department of Mathematics, Univerity of Washington, Seattle, WA 98195, and **S. Paul Smith** and **Michaela Vancliff**. *Families of quantum projective schemes.*

Quantum projective spaces are generally non-commutative graded algebras that in many ways resemble rings of polynomials and have good homological behavior. This makes them good candidates for what the homogeneous coordinate ring of a "quantum projective scheme" should be.

In this talk I will focus on the case of 3-dimensional non-commutative projective spaces (where the algebras in question have four generators and six quadratic relations). The intrinsic geometry of a quantum projective space can be probed by means of classical (i.e. commutative) schemes, analogous to grassmannians, parametrizing the "points" and "lines" in the respective quantum projective space.

The main result is that for nicely varying families of quantum $\mathbb{P}^3$ spaces the resulting families of classical schemes are flat. What this means is that various numerical invariants of the schemes in question are constant along the families, and hence there are strong numerical restrictions on what these schemes can look like. This helps in describing the varieties of lines in various quantum $\mathbb{P}^3$s, and sheds some light on our mostly conjectural understanding of the "generic" quantum projective three-space.

(joint w/ S. Paul Smith and Michaela Vancliff) (Received February 16, 2017)

1128-16-96 **Jason Gaddis*** (gaddisjd@wfu.edu). *Isomorphism problems in noncommutative algebra.*

Isomorphisms problems in ring theory have a long history with the Zariski Cancellation problem being among the most famous. There has been a flurry of activity in recent years in the study of isomorphism problems for noncommutative algebras. In this talk, I will discuss recent results on full and partial solutions to the isomorphism problem for quantum affine spaces, quantized Weyl algebras, and quantum matrix algebras. (Received February 16, 2017)

1128-16-97 **Robert Won*** (wonrj@wfu.edu), **Jason Gaddis**, **Ellen Kirkman** and **W. Frank Moore**. *Auslander's Theorem for permutation actions on noncommutative algebras.*

Let k be an algebraically closed field of characteristic zero. Let G be a small finite subgroup of $GL_n(k)$ acting linearly on $A = k[x_1, \ldots, x_n]$. Auslander's Theorem states that the skew group ring $A\#G$ is naturally isomorphic as a graded algebra to the endomorphism ring $\mathrm{End}_{A^G}(A)$. In recent work, Bao, He, and Zhang introduced a new invariant, called pertinency, associated to a Hopf algebra action on a k-algebra. They then use pertinency to prove Auslander's Theorem for several classes of noncommutative rings. In this talk, I will discuss ongoing work with Gaddis, Kirkman, and Moore in which we use pertinency to prove Auslander's Theorem for permutation actions on certain noncommutative rings. (Received February 16, 2017)

1128-16-118 **Manuel L. Reyes*** (reyes@bowdoin.edu), Department of Mathematics, Bowdoin College, 8600 College Station, Brunswick, ME 04011-8486, and **Daniel Rogalski**. *Twisted Calabi-Yau and Artin-Schelter regularity properties for locally finite algebras.*

It is known that a connected graded algebra is Artin-Schelter (AS) regular if and only if it is twisted Calabi-Yau (CY). While AS regular algebras are necessarily connected, a twisted CY algebra need not be. Thus we ask: for algebras that are graded but not necessarily connected, is the twisted CY property equivalent to a suitable analogue of the AS regular property? We give a positive answer, using a generalized AS regular property inspired by the work of Martinez-Villa, Minamoto, and Mori. We will also discuss properties of graded twisted CY algebras of dimension at most 2. (Received February 20, 2017)

1128-16-150 **Stephan Weispfenning*** (sweispfe@ucsd.edu). *Invariant Theory of Preprojective Algebras.* Preliminary report.

For a finite group acting on a polynomial ring, the Shephard-Todd-Chevalley Theorem proves that the fixed subring is isomorphic to a polynomial ring if and only if the group is generated by pseudo-reflections. In recent years, progress was made in work of Kirkman, Kuzmanovich, Zhang, and others to extend this result to regular algebras by expanding pseudo-reflections to quasi-reflections. Naturally, the question arises if the theory generalizes further to non-connected noncommutative algebras. Our objects of study will be preprojective algebras which are certain factor algebras of path algebras corresponding to extended Dynkin diagrams of type A, D or E. We will point out additional difficulties in establishing quasi-reflections using the trace, reveal situations which do not occur for regular algebras, as well as discuss what algebraic conditions we want the fixed ring to have. (Received February 23, 2017)

1128-16-165 **Elizabeth Wicks***, Department of Mathematics, Seattle, WA 98195. *Embeddings of derived categories.* Preliminary report.

We will investigate embeddings of derived categories and introduce the Frobenius-Perron dimension of a category. We will apply this theory to the derived category of finite dimensional representations of quivers. (Received February 24, 2017)

1128-16-167 **Ken A Brown** (ken.brown@glasgow.ac.uk), School of Mathematics and Statistics, University of Glasgow, Glasgow, G12 8QW, United Kingdom, and **Milen T Yakimov*** (yakimov@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Azumaya loci and discriminant ideals of PI algebras.*

We will present a theorem which establishes that under mild assumptions the zero set of the discriminant ideal of a prime polynomial identity (PI) algebra R coincides with the zero set of the modified discriminant ideal of R. Furthermore, the theorem proves that this set is precisely the complement of the Azumaya locus of R. This will be applied to classify the Azumaya loci of the mutiparameter quantized Weyl algebras at roots of unity. As another application, we prove that the zero set of the discriminant ideal of a prime PI algebra R coincides with the singular locus of the center of R, provided that the former has height at least 2, R has finite global dimension and is a Cohen-Macaulay module over its center. (Received February 24, 2017)

1128-16-192 **Daniel Rogalski*** (drogalski@ucsd.edu). *Noncommutative Projective Surfaces.*

Starting in the late 1980's, work of Artin, Schelter, Tate, Van den Bergh, and others laid the groundwork for a beautiful theory of the geometry of noncommutative graded algebras. This subject of noncommutative projective geometry has led to new insights into the structure of many important classes of algebras. We give an introduction to some of the main ideas of this area, and then survey some more recent results concerning the project to classify noncommutative projective surfaces. (Received February 26, 2017)

1128-16-245 **Ellen E. Kirkman*** (kirkman@wfu.edu), Dept of Mathematics and Statistics, Wake Forest University, Winston Salem, NC 27109, and **Jianmin Chen** and **James J. Zhang**. *Invariant subrings of noetherian graded down-up algebras under group coactions.*

Let $\Bbbk$ be a field of characteristic zero, $\mathbb{D} = \mathbb{D}(\alpha, \beta)$ be a noetherian down-up algebra that is graded by a finite group G, and $H = \mathrm{Hom}_{\Bbbk}(\Bbbk G, \Bbbk)$ be the $\Bbbk$-linear dual of the group algebra $\Bbbk G$. The fixed subring $\mathbb{D}^H$ under the Hopf algebra H can be identified with the identity component $\mathbb{D}_e$ under the G-grading. We prove that $\mathbb{D}$ is rigid in the sense that $\mathbb{D}^H$ is never AS regular (so $\mathbb{D}^H$ is not isomorphic to $\mathbb{D}$), and hence each $\mathbb{D}$ has no dual reflection group. Further, we prove that when the homological determinant of the H-action on $\mathbb{D}$ is trivial and H acts homogeneously on $\mathbb{D}$, Auslander's Theorem holds: the smash product $\mathbb{D}\#H$ is naturally isomorphic to $\mathrm{End}_{\mathbb{D}^H}(\mathbb{D})$, as $\Bbbk$-algebras. (Received February 27, 2017)

1128-16-257 **Jesse S. F. Levitt***, USC Dornsife, Department of Mathematics, 3620 S. Vermont Ave., KAP 104, Los Angeles, CA 90089, and **Milen Yakimov**. *Discriminants of Polynomial Identity Quantized Weyl Algebras.*

We present explicit formulas for the the discriminants of Polynomial Identity (PI) quantized Weyl algebras over a general class of central subalgebras along with several applications. Following a program proposed by Chan, Young and Zhang for investigating certain filtered PI algebras. We first classify the centers of PI quantized Weyl algebras, and examine the case where these algebras are then free over their centers. Two distinct approaches arise for calculating their discriminants, with one coming from deformation theory and Poisson geometry, while the other is based in the methods of quantum cluster algebras. Both formulations allow all such algebras to be classified and the discriminant is found to be both locally dominating and effective with applications to the automorphism and isomorphism problems for tensor products of these algebras. (Received February 27, 2017)

1128-16-263 **Siu-Hung Ng*** (rng@math.lsu.edu). *On some properties modular categories of odd dimension.*

A classical theorem of Burnside asserts that a finite group G has no nontrivial self-dual irreducible complex representation if and only if G has an odd order. This result has been recently generalized to integral fusion categories. However, there exists nontrivial self-dual simple object in a non-integral fusion category of odd dimension. In this talk, we will discuss a relation satisfied by the self-dual simple objects of a modular tensor category of odd dimension in terms of their Frobenius-Schur indicators. (Received February 28, 2017)

1128-16-298 **John E. Foster***, Department of Mathematics, 204 S College Ave, College Place, WA 99324. *Representations of the Quantum Double.* Preliminary report.

A good place to find representations of the quantum double $D(H)$ of a Hopf algebra H is in the $D(H)$-bimodule algebra $H \otimes C$, where C is the finite dual of H. Here we consider the case $H = U_q(\mathfrak{sl}_2)$ with generic q, and we give a presentation of the subalgebra of highest-weight vectors. (Received February 28, 2017)

1128-16-302 **Cris Negron*** (negronc@mit.edu). *Small quantum groups associated to Belavin-Drinfeld triples.*

I will introduce the small quantum group associated to a simple Lie algebra L. This is a finite dimensional Hopf algebra introduced by Lusztig in the 90's. Small quantum groups have a number of fantastic properties, from a categorical perspective. (For example, they is factorizable and ribbon.) I will explain how decorations of the Dynkin diagram for L lead to new (non-isomorphic) Hopf algebras with the same fantastic properties. I will also also explain how these new Hopf algebras reflect previous quantization constructions for Lie bialgebras and Poisson groups, and fit into recent ideas about classifying "twists" of the small quantum group. (Received February 28, 2017)

1128-16-304 **Rajesh S Kulkarni*** (kulkarni@math.msu.edu), Department of Mathematics, 619 Red Cedar Rd., East Lansing, MI 48824. *Graded and non-graded Clifford algebras and their homomorphic images.*

We discuss homomorphic images of graded and non-graded Clifford algebras and their homomorphic images. In particular, the period and index of such homomorphic images is of considerable interest. We study the special case graded Clifford algebras of generalized Hesse forms in detail. A part of this work is joint with Adam Chapman, Casey Machen and Charlotte Ure. (Received February 28, 2017)

1128-16-310 **Jonas T Hartwig*** (jth@iastate.edu). *Categories of modules over noncommutative Kleinian fiber products.* Preliminary report.

Six-vertex configurations on a square lattice with semi-periodic twisted boundary conditions turn out to parametrize noncommutative algebras which are deformations of certain fiber products of two type A Kleinian singularities. Examples of such algebras include quotients of the enveloping algebra of the affine Lie algebra $A_1^{(1)}$ and of a finite W-algebra related to $\mathfrak{sl}_4$. I will present some results in an ongoing study of the features of the category of weight modules over these algebras, including simple and indecomposable objects, and some results about extensions between simple objects. (Received February 28, 2017)

1128-16-316 **Sharon Henzler***, shenzler@zagmail.gonzaga.edu, and **Cameron Healy**, chealy@zagmail.gonzaga.edu. *Cluster algebras and their connection to triangulated n-gons and Coxeter groups.*

Although cluster algebras seem abstract at first glance and unrelated to the modern world of mathematics, today the theory of cluster algebras is connected to various fields of mathematics including coordinate rings of Grassmannians, quiver representations, Teichmuller theory, invariant theory, tropical calculus, Poisson geometry, etc. In this poster, we will introduce cluster algebras, give the definition of cluster algebra, explain the example of triangulation of an n-gon, make the connection with quiver mutations, and introduce and explain associahedrons. (Received February 28, 2017)

18 ► Category theory; homological algebra

1128-18-202 **Zbigniew Oziewicz*** (`oziewicz.zbigniew@gmail.com`), Universidad Nacional Autonoma de Mexico, Facultad de Estudios Superiores, 54714 Cuautitlan Izcalli, Mexico, Mexico, and **William Stewart Page**. *Algebra possesses eight bilinear forms - why for?* Preliminary report.

In monoidal category each operadic morphism is a vertex that possesses exterior arity-in-lines and arity-out-liines, like Conway's (n,m)-tangle without restriction for n=m, and allowing intersection at vertex. Duality, two-colors, allows connect in-line with out-line by simple curve of another color, and this define a trace: (n,m)-tangle —> (n-1,m-1)-tangle. This is analogous to Conway numerator or denumerator. We note that operad generated by (2,1)-algebra-tangle give rise exactly eight bilinear forms each as (2,0)-form-tangle. For associative algebra only four bilinear forms are independent. Our concern is a meaning and usefulness of these eight bilinear forms for each (2,1)-algebra-tangle not necessarily associative. This rise new, not equivalent, interpretation of the Frobenius algebra. (Received February 26, 2017)

1128-18-344 **Henry J Tucker***, UCSD, San Diego, CA 92093. *Modular subcategories of Drinfel'd centers of quadratic categories and their associated modular data.* Preliminary report.

Modular categories are braided tensor categories with non-degenerate braiding. From this data we can obtain the S and T matrices, the so-called modular data. It is known that the modular data for a pointed modular category (that is, those with all objects invertible under the tensor product) is given by the Weil representation associated to a bicharacter on the abelian group formed by the objects. It is conjectured that the modular data of the Drinfel'd centers for certain quadratic tensor categories (which are in some sense close to pointed categories) are given by a generalization of this representation. We will discuss some important examples of modular data exhibiting this phenomenon, and we will present preliminary work toward understanding these Drinfel'd centers when they factorize as a product of a pointed category and some other modular category. (Received February 28, 2017)

20 ► Group theory and generalizations

1128-20-207 **Larissa V. Sbitneva*** (`larissa@uaem.mx`), Universidad Autónoma del Estado de Morelos, Av.Universidad 1001, Col. Chamilpa, 62209 Cuernavaca, Morelos st, Mexico. *On the generalization of the Third Inverse Lie's Theorem for smooth loops.*

The generalizations of three direct and inverse Lie's Theorems for the smooth Bol and Moufang loops have been obtained by applying the original methods of Sophus Lie based on the differential equations (Lev V. Sabinin, Smooth Quasigroups and Loops, Kluwer Academic Publisher, 1999). Further generalizations of the above mentioned classes of loops lead to the smooth PL-loops. We will present the development of these classical methods to the special case when a non-singular PL-loop is related to the geometry of trans-symmetric spaces. For the general situation We will outline the possible approach concerned to the Third inverse theorem and to a similar problem for the theory of actions of smooth loops, initiated by L. Sabinin.

This talk is dedicated to the 85th Anniversary of Lev Sabinin, who developed the theory of smooth non-associative structures and its relation to differential geometry. (Received February 27, 2017)

26 ► Real functions

1128-26-70 **Henry Riely*** (`hriely@math.wsu.edu`). *Strengthening an inequality due to Chang, Wilson, and Wolff.*

In a 1985 paper by Chang, Wilson, and Wolff, it was shown that given a function $f : \mathbb{R} \supset I \to \mathbb{R}$, we have the following estimate

$$\langle e^{f-\langle f\rangle_I}\rangle_I \leq e^{\frac{1}{2}\|Sf\|_\infty^2}$$

where Sf is the martingale square function associated with f.

Inspired by a recent paper L. Slavin and A. Volberg, we explore the possibility of strengthening this estimate to the form

$$\langle e^{f-\langle f\rangle_I}\rangle_I \leq \langle e^{C(Sf)^2}\rangle_I$$

where C is come real constant. (Received February 26, 2017)

1128-26-172 **Paul Eloe** and **Tyler Masthay*** (tmasthay1@udayton.edu), 300 College Park, Dayton, OH 45469-2316. *A Compactness Criterion for Sets of Solutions of Fractional Differential Equations.*

In 1969, Keith Schrader and Lloyd Jackson proved an important compactness criterion for sets of solutions of third-order ordinary differential equations. To prove this theorem, a lemma is proved in order to obtain a fixed point of an integral operator defined on $C^2[a;b]$. We obtain an analogous fixed point for fractional differential equations of orders $2 < \alpha \leq 3$, and then obtain an analogous criterion for compactness of sets of solutions of fractional differential equations of orders $2 < \alpha \leq 3$. (Received February 24, 2017)

1128-26-334 **Daniel Gallab*** (dgallab@zagmail.gonzaga.edu), Gonzaga University, 502 E Boone Ave, Spokane, WA 99258. *Comparing the Growth Rates of $(ax)!$ and x^x.*

It is known that as x increases, that x^x eventually exceeds $x!$ without bound. It is also know that as x increases, $x!$ eventually exceeds a^x without bound, for any positive fixed value of a. However, it is much more difficult to compare the growth rates of $(ax)!$ and x^x. We will examine this problem and show that in the case where a is greater than one, that $(ax)!$ exceeds x^x without bound. (Received February 28, 2017)

28 ► Measure and integration

1128-28-4 **Laramie S Paxton*** (lpaxton@math.wsu.edu). *A Sequential Approach to the Henstock Integral.*

The theory of integration over $\mathbb{R}$ is rich with techniques as well as necessary and sufficient conditions under which integration can be performed. Of the many different types of integrals that have been developed since the days of Newton and Leibniz, one relative newcomer is that of the Henstock integral, aka the Henstock-Kurzweil integral, Generalized Riemann integral, or gauge integral, which was discovered independently by Henstock and Kurzweil in the mid-1950s. In this paper, we develop an alternative, sequential definition of the Henstock integral over closed intervals in $\mathbb{R}$ that we denote as the Sequential Henstock integral. We show its equivalence to the standard $\epsilon-\delta$ definition of the Henstock integral as well as to a Darboux definition and to a topological definition of the Henstock integral. We then prove the fundamental properties and theorems, including two convergence theorems, for the Sequential Henstock integral and offer several suggestions for further study. (Received September 18, 2016)

1128-28-25 **Kevin R. Vixie** and **Laramie S. Paxton*** (lpaxton@math.wsu.edu). *Cubical Coverings of sets in $\mathbb{R}^n$.*

Sets in $\mathbb{R}^n$ can be wildly unimaginable in their generality and abstractness, especially on their topological boundaries. Thus, mathematicians seek to develop methods to represent and characterize various classes of sets with more “friendly” sets, such as coverings. The focus of this work is on cubical coverings and what kinds of $\mathcal{L}^n$ or $\mathcal{H}^n$ bounds we can establish for these coverings in relation to their corresponding underlying sets as well as what assumptions are necessary. We first introduce and later explore three different representations of sets in $\mathbb{R}^n$: dyadic cubical coverings, Jones β numbers, and a new, "varifold-like" approach that we developed. We then present several inequalities for various classes of sets, including unions of balls, rectifiable sets with defined Minkowski content, and sets with “smooth” boundaries and positive reach. Lastly, we make a conjecture for a ratio of $\mathcal{H}^{n-1}$ boundary measures and pose further problems and questions for exploration with solutions to several. We note that we present old and new results with a view to illumination and exposition that we hope will motivate others to study these types of problems. (Received January 21, 2017)

1128-28-66 **Yunfeng Hu** (yunfeng.hu@wsu.edu), Department of Mathematics and Statistics, Washington State University, PO Box 643113, Pullman, WA 99163, and **Enrique Alvarado*** (ealvarado@math.wsu.edu), Enrique Alvarado, pullman, WA 99163. *On the Measure of a Cantor Set Packing in $\mathbb{R}$.*

Let T be a subset of $\mathbb{R}^n$, and let S and B be two subsets in $\mathbb{R}^n$ such that for any x in S, there exists an $r > 0$ for which $x + rT$ is a subset of B. How small (in measure) can B be be if we know the size of S?

Stein proved that if n is greater than or equal to 3 and T is a sphere centered at origin, then S having positive measure implies that B has positive measure. He showed this by using the spherical maximal operator. Later, Bourgain and Marstrand independently proved the result for $n = 2$.

However if $n = 1$ then the result is not true. We will show this by constructing a counterexample that involves the 1/3-Cantor set. (Received February 09, 2017)

1128-28-153 **Yunfeng Hu*** (`yunfeng.hu@wsu.edu`), 1630 NE Valley Rd, M106, Pullman, WA 99163, and **Mattew Hudelson**, **Bala krishnamoorthy**, **Altansuren Tumurbaatar** and **Kevin Vixie**. *Median Shapes.* Preliminary report.

In this talk, I will talk about median shapes, where the shapes are represented by currents and the distance is the flat norm. Under this setting, I will first verify the existence of medians and then prove some results for medians of currents with shared boundaries in codimension 1. At last, I will show an example for medians in codimension 2. (Received February 23, 2017)

30 ► Functions of a complex variable

1128-30-340 **Kourosh Tavakoli*** (`ktavakoli@okcu.edu`). *Interesting Examples of Iterated Holomorphic Function Systems.*

In this talk we investigate several examples of the compositions of infinitely many analytic complex functions from a domain in the plane into a subdomain. We study the limit behavior of these iterated function systems. (Received February 28, 2017)

31 ► Potential theory

1128-31-330 **Adebo James Sijuwade*** (`ajsijuwade@gmail.com`), 1401 NE Merman Dr. Apt. 104, Pullman, WA 99163. *Fractional calculus and applications of the Riesz Potential.*

In this exposition, we will take an alternative view on some standard interpretations of Calculus and explore fractional derivatives and integrals. These will lead into some foundations of Potential Theory wherein we will take a look at the Riesz potential and its applications in establishing embeddings. (Received February 28, 2017)

32 ► Several complex variables and analytic spaces

1128-32-13 **Debraj Chakrabarti*** (`chakr2d@cmich.edu`), Department of Mathematics, Central Michigan University, Mt Pleasant, MI 48859, and **Christine Laurent-Thiébaut** and **Mei-Chi Shaw**. *The $\overline{\partial}$-problem on annuli.*

An annulus is the domain between two pseudoconvex domains, the smaller of which, called the hole, is a relatively compact subset of the larger one. We show that the $\overline{\partial}$-operator from square integrable functions to square integrable $(0, 1)$-forms has closed range for various classes of piecewise smooth holes. This is then used to obtain new Sobolev estimates on the $\overline{\partial}$-problem on piecewise smooth domains. (Received November 28, 2016)

1128-32-15 **Bingyuan Liu*** (`bingyuan@ucr.edu`), 900 University Ave, Surge 275A, Riverside, CA 92521. *Geometric Analysis on the Diederich–Fornæss index.*

Geometric analysis in differential geometry is a powerful tool in Riemannian geometry. It has been used to solve many problems in Riemannian geometry. In the field of several complex variables, it was not the most popular weapon to attack questions. One of the reasons is that many problems in the several complex variables relates to some types of differential equations of complex-valued functions which is currently not well understood. In this talk, we consider problems in the Diederich–Fornæss index with a viewpoint of geometric analysis and see what we obtain. This talk includes a series results made by Krantz–Peloso–Liu and myself. (Received December 24, 2016)

1128-32-110 **Liwei Chen*** (`chen.1690@osu.edu`), 231 West 18th Avenue, Columbus, OH 43210. *The L^p estimate of an integral solution operator for $\bar{\partial}$ on the bidisk.*

By following the Cauchy-Fantappié formalism, we construct a generating form and obtain an integral solution operator for the $\bar{\partial}$ equation on the bidisk. Based on the integral representation, we study the L^p boundedness of the solution operator. (Received February 18, 2017)

1128-32-133 **Sivaguru Ravisankar** and **Yunus E. Zeytuncu*** (zeytuncu@umich.edu), 4901 Evergreen Road, Dearborn, MI 48128. *Friedrichs Operator on Pseudoconvex Domains in $\mathbb{C}^n$.*

Let Ω be a smooth bounded domain in $\mathbb{C}^n$ and let $L^2(\Omega)$ denote the space of square integrable functions on Ω with respect to the Lebesgue measure. We denote the subspace of holomorphic functions in $L^2(\Omega)$ by $A^2(\Omega)$ and the Bergman projection from $L^2(\Omega)$ to $A^2(\Omega)$ by $\mathbf{B}$.

The Friedrichs operator T is a conjugate linear mapping from $A^2(\Omega)$ onto itself, defined by $f \to \mathbf{B}(\overline{f})$. It was recently observed that this operator exhibits some additional smoothing properties under certain geometric assumptions on the domain. In this talk, after a quick review these results, we will prove that T is compact on any pseudoconvex domain without any further geometric conditions. We will also discuss some further implications of this observation. (Received February 22, 2017)

1128-32-136 **Andrew S Raich*** (araich@uark.edu), Department of Mathematical Sciences, 1 University of Arkansas, SCEN 327, Fayetteville, AR 72701. *Closed range of the Cauchy-Riemann operator on domains in $\mathbb{C}^n$.*

In this talk, I will discuss solvability of the Cauchy-Riemann, or $\bar{\partial}$, equation on domains in $\mathbb{C}^n$. I will talk about applications of the $\bar{\partial}$-problem and the reasons for the differences between solving the equation in one and several variables and the usefulness of working in L^2 (vs. the more classical spaces, e.g., C^∞). Solvability in several variables depends greatly on the geometry of the boundary of the domain, and I will conclude the talk with a discussion of most general geometric conditions that are known to imply solvability in L^2 on $(0,q)$-forms, and, time permitting, L^2-Sobolev spaces. (Received February 22, 2017)

1128-32-138 **Peter Ebenfelt*** (pebenfelt@ucsd.edu), Department of Mathematics, University of California San Diego, La Jolla, CA 92093. *The Bergman kernel and the obstruction function in strictly pseudoconvex domains in $\mathbb{C}^2$.* Preliminary report.

We will consider bounded strictly pseudoconvex domains Ω in $\mathbb{C}^2$. The obstruction function $b\eta_1$ on $\partial\Omega$ is the lowest order term in the singularity at the boundary of the Cheng-Yau solution to the Dirichlet problem for Fefferman's Monge-Ampere operator in Ω. By the work of Graham and Hirachi-Komatsu-Nakzawa, this function is also the restriction to the boundary of the log term in the Bergman and Szegő kernels in Ω. We shall discuss the condition $b\eta_1 = 0$ on $\partial\Omega$; in particular, if Ω also has transversal symmetry, then we will show that if $b\eta_1 = 0$ globally, then $\partial\Omega$ is locally spherical. We note that it is not true that $b\eta_1 = 0$ locally implies that $\partial\Omega$ is locally spherical. (Received February 22, 2017)

1128-32-191 **Aaron J Peterson*** (aaron.peterson@northwestern.edu), Department of Mathematics, Northwestern University, 2033 Sheridan Road, Evanston, IL 60208. *Uniform Large-Scale CR Control Geometry on Model Unbounded Pseudoconvex Domains in $\mathbb{C}^2$.*

Let $\Omega \subset \mathbb{C}^2$ be a weakly pseudoconvex finite-type domain with smooth boundary. We will discuss the Carnot-Carathéodory control geometry induced on bΩ by the real and imaginary parts of the CR vector field. After reviewing the local theory, we describe a framework for studying this geometry on a model class of unbounded domains. We will explore examples where the large-scale behavior of the control geometry is markedly different than the local behavior, and then present a characterization of the subclass of such domains for which the large-scale behavior of the control geometry is uniform. This is joint work with Ethan Dlugie. (Received February 26, 2017)

1128-32-200 **Séverine Biard** and **Emil Straube*** (straube@math.tamu.edu). *Estimates for the complex Green operator: symmetry.*

Let M be a pseudoconvex, oriented, bounded and closed CR–submanifold of $\mathbb{C}^n$ of hypersurface type, of CR–dimension $(m-1)$. We show that Sobolev estimates for the complex Green operator hold for (p,q)–forms if and only if they hold for $(m-p, m-1-q)$–forms. Symmetries of this type have been known to hold for compactness and subelliptic estimates. Sobolev estimates are more delicate in that certain error terms cannot be absorbed and so must be avoided. This is joint work with Séverine Biard. (Received February 26, 2017)

1128-32-223 **Andrew Zimmer*** (aazimmer@uchicago.edu). *Characterizing strongly pseudoconvex domains.*

In this talk I will describe some characterizations of strong pseudoconvexity which only use the intrinsic complex geometry of a domain. For instance, we show that for convex domains with $C^{2,\epsilon}$ boundary strong pseudoconvexity can be characterized in terms of the behavior of the squeezing function near the boundary, the behavior of the holomorphic sectional curvature of the Bergman metric near the boundary, or any other reasonable measure of the complex geometry. The first characterization gives a partial answer to a question of Fornæss and Wold. I will also describe the proofs which rely on estimating the "Lyapunov exponents" of the "geodesic flow" induced by the Kobayashi metric. (Received February 27, 2017)

1128-32-243 **Andrew S Raich*** (araich@uark.edu), Department of Mathematical Sciences, 1 University of Arkansas, SCEN 327, Fayetteville, AR 72701, and **Khanh Tran**. *The Kohn-Laplace equation on abstract CR manifolds: Global regularity.*

In this talk, I will outline recent joint work with Khanh Tran on the global regularity of the complex Green operator on abstract CR manifolds of hypersurface type. (Received February 27, 2017)

1128-32-251 **David E Barrett*** (barrett@umich.edu), Dept of Math 2074 East Hall, Ann Arbor, MI 48109-1043, and **Dusty Grundmeier**. *Projective dual CR structures.*

A strongly convex (or "strongly $\mathbb{C}$-convex") real hypersurface in $\mathbb{C}^n$ (or in complex projective space) inherits both the standard CR structure and a secondary "projective dual" structure.

The talk will examine various relations between the corresponding spaces of CR functions. Some of the results utilize dimension and/or symmetry conditions; in the particular case of circular domains in $\mathbb{C}^2$, consequences for certain pairs of one-dimensional complex structures will be set forth. (Received February 27, 2017)

1128-32-278 **Phillip S Harrington*** (psharrin@uark.edu), SCEN 336, 1 University of Arkansas, Fayetteville, AR 72704, and **Andrew S Raich**. *Unbounded $Z(q)$ Domains.*

The classic example of an unbounded strictly pseudoconvex domain is the Siegel Upper Half Space. Surprisingly, some critical estimates fail on this model example. In this talk, we will examine a class of unbounded domains with geometric properties that make them more amenable to analysis. (Received February 28, 2017)

1128-32-282 **Albert Boggess***, School of Mathematical and Statistical Scienc, Arizona State University, Tempe, AZ , and **Andrew Raich**, Fayetteville, AR. *Estimates on the Fundamental Solution to the Complex Green Operator in Higher Codimension.* Preliminary report.

The goal of this work (joint with Andy Raich, University of Arkansas) is to discuss recent progress on the estimates of the fundamental solution to the Kohn Laplacian (Box_b) in higher codimension. Unlike the hypersurface case, little is known about these estimates. In this talk, an explicit formula will be presented for the fundamental solution to Box_b for each of three "model" quadrics which have codimension two in C^4 and their estimates will be discussed. The kernel in one of these models is quite a bit more singular than the others and the estimates in this case have no known relationship to familiar metrics in geometry such as the Szego metric or sum of squares metric. (Received February 28, 2017)

1128-32-284 **Claudia Miller**, Department of Mathematics, 215 Carnegie Building, Syracuse University, Syracuse, NY 13244, and **Sophia Vassiliadou***, Department of Mathematics and Statistics, St. Mary's Hall, Georgetown University, Washington, DC 20057. *On torsion and cotorsion of differentials on certain complete intersection rings.*

I will discuss some results, old and new, on the vanishing/non-vanishing of torsion and cotorsion of Kahler differentials on certain complete intersection rings. Some geometric consequences of these results will also be discussed. This is joint work with Claudia Miller. (Received February 28, 2017)

34 ► *Ordinary differential equations*

1128-34-64 **Siamak Haghshenas** and **Mostafa Ghandehari***, ghandeha@uta.edu, and **Kambiz Alavi**. *Oscillation of Graphene Plates.* Preliminary report.

Newton's second law and Hooke's law are used to derive differential equation for the motion of graphene plates. separation of variables is used to integrate the non-linear differential equation. Integration involve elliptic integral. (Received February 09, 2017)

1128-34-69 **Youssef N Raffoul*** (yraffoul1@udayton.edu), 300 Coollege Park, Dayton, OH 45469-2316, and **Murat Adivar** and **Muhammad Islam**. *LARGE CONTRACTION AND EXISTENCE OF PERIODIC SOLUTIONS IN TOTALLY NONLINEAR DELAY DIFFERENTIAL EQUATIONS.*

In this talk we give a classification theorem providing sufficient conditions for an operator to be a large contraction. Then we use a modified version of Krasnoselskii's fixed point theorem and show that the nonlinear functional differential equation

$$x'(t) = -a(t)h(x(t)) + G(t, x(t - r(t))),$$

has a non-zero periodic solution and a positive periodic solution. (Received February 10, 2017)

1128-34-72 **Eric R Kaufmann*** (erkaufmann@ualr.edu), Department of Mathematics & Statistics, University of Arkansas Little Rock, 2801 S. University Ave, Little Rock, AR 72204. *Existence of solutions for a second order iterative boundary value problem.* Preliminary report.

We consider the existence of solutions to the second order iterative boundary value problem

$$x''(t) = f(t, x(t), x^{[2]}(t)).$$

with solutions satisfying the boundary conditions $x(a) = a$ and $x(b) = b$. Here $x^{[2]}(t) = x(x(t))$. We use the Schauder fixed point theorem to establish our main results. This is a preliminary report. (Received February 10, 2017)

1128-34-75 **Liancheng Wang*** (lwang5@kennesaw.edu), 1100 South Marietta Pkw, Marietta, GA 30060. *A Complete Analysis for a Differential Equation with Two Delays.*

In this research, we consider a general differential equation with two delays. The analysis for the stability, switch of the stability of the equilibrium, and the occurrence of Hopf bifurcation is carried out for all different parameter values. The stable regions along with the bifurcation curves in the plane of two delays are established. Numerical simulations are provided to confirm the theoretical results. (Received February 13, 2017)

1128-34-124 **Jeffery Thomas Neugebauer*** (jeffrey.neugebauer@eku.edu), Department of Mathematics and Statistics, 521 Lancaster Ave., 313 Wallace Building, Richmond, KY 40475. *A Singular Fractional Boundary Value Problem.*

For $\alpha \in (1, 2]$, the singular fractional boundary value problem $D^{\alpha}_{0+}x + f(t, x) = 0,\ 0 < t < 1$, satisfying the boundary conditions $x(0) = D^{\beta}_{0+}x(1) = 0$, where $\beta \in (0, \alpha - 1]$, and D^{α}_{0+} and D^{β}_{0+} are Riemann-Liouville derivatives of order α and β respectively, is considered. Here we assume $f(t, x)$ is singular at the value $x = 0$. Using fixed point methods, we show the existence of a positive solution of this boundary value problem. (Received February 21, 2017)

1128-34-156 **Tingxiu Wang*** (tingxiu.wang@tamuc.edu), 2600 S. Neal Street, Commerce, TX 75428. *Modeling the Financial Stock Market with Functional Differential Equations.* Preliminary report.

Technical analysis is popular in the financial stock market. Moving averages are commonly used in the technical analysis. Let $x(t)$ be the price of a stock. Based on the simple moving averages, we propose and study the following functional differential equations:

$$x'(t) = x(t) - x(t-1)$$
$$x'(t) = k\left(x(t) - \frac{1}{\alpha}\int_{t-\alpha}^{t} x(s)ds\right),$$

where k and $\alpha > 0$ are constants. (Received February 23, 2017)

1128-34-174 **Paul Eloe*** (peloe1@udayton.edu), Department of Mathematics, 300 College Park, Dayton, OH 45469-2316. *Fixed Point Methods and Boundary Value Problems at Resonance.*

Boundary value problems for nonlinear differential equations are at resonance if there exist nontrivial solutions to the associated linear problem. The shift method is a simple method to construct an equivalent nonlinear problem that is not at resonance. This talk surveys some recent work, two of which perform a shift that generates a Green's function that is positive on the interior of the domain and one that performs a shift to generate a Green's function that is negative on the interior of the domain. Different types of fixed point theorems are applied according to the sign of the Green's function. (Received February 24, 2017)

1128-34-276 **Bo Yang***, 1000 Chastain Road, Kennesaw, GA 30144. *Positive Solutions for a Fourth Order Boundary Value Problem.* Preliminary report.

We consider a boundary value problem for the fourth order beam equation. Some a priori estimates to positive solutions for the boundary-value problem are obtained. Sufficient conditions for the existence and nonexistence of positive solutions for the boundary value problem are established. (Received February 28, 2017)

1128-34-307 **Ernie Tsybulnik*** (etsybulnik@zagmail.gonzaga.edu), 502 E Boone Ave, Spokane, WA 99258. *Metapopulation Dynamics Incorporating an Allee Effect.*

We present the analysis of a metapopulation model for habitat destruction. The mathematical model includes an Allee effect, which is important in population dynamics and is driven by assumptions related to growth rates. We review the concept of Allee effect and distinguish between a strong versus weak effect. In our analysis, we present a bifurcation diagram which exhibits a critical threshold below which a population is predicted go extinct if the proportion of occupied patches falls below that threshold. (Received February 28, 2017)

35 ► Partial differential equations

1128-35-3 **Malgorzata Peszynska*** (mpesz@math.oregonstate.edu), Mathematics, Oregon State University, Corvallis, OR 97331. *Phase transitions in porous media: new applications and results.*

We discuss a model of methane evolution under deep ocean sediments in the hydrate zone and in the gas zone. The simplest model in the hydrate zone is a scalar nonlinear degenerate parabolic problem for which the nonlinearity is expressed as a parameter-dependent graph, and its well-posedness is obtained only in a very weak sense. We consider also new results in the gas zone and the transition between the hydrate and gas zones. The realistic models extend the scalar equations to a system modeling the transport not only of methane but also of salinity and energy. We will discuss numerical solutions which have been compared to experimental data obtained from geophysics collaborators. (Received September 15, 2016)

1128-35-12 **Hong-Ming Yin*** (hyin@wsu.edu), Department of Mathematics and Statistics, Washington State University, Pullman, WA 99164, **Xinfu Chen** (xinfu@pitt.edu), Department of Mathematics, University of Pittsburgh, Pittsburgh, PA 15260, and **Lihe Wang** (lihe-wang@uiowa.edu), Department of Mathematics, University of Iowa, Iowa City, IA 52242. *On a Cross-Diffusion System Modelling Vegetation Spots and Strips in a Semi-arid or Arid Landscape.* Preliminary report.

In this paper we study a model which describes the pattern formation of vegetation spots and strips in a semi-arid or arid landscape. The mathematical model consists of a nonlinear cross-diffusion system with evaporation and absorption sources. Global existence and uniqueness in classical sense for the system are established. Some asymptotic behaviors of the solution are derived for a linearized system. It is shown that the solution of linearized system is asymptotically stable near the steady-state solution. Moreover, we show that the Turing phenomenon occurs for the linearized cross-diffusion system and the cross-diffusion destabilizes the ecosystem.

This is a joint work with Professor Xinfu Chen at University of Pittsburgh and Professor Lihe Wang at University of Iowa. (Received November 19, 2016)

1128-35-16 **YUAN PEI*** (ypei4@unl.edu), 203 Avery Hall, Lincoln, NE 68588. *Data Assimilation on Geophysical and fluid dynamics.*

In this talk, we introduce some recent progress on the continuous data assimilation algorithm in geophysical and fluid dynamical models. In particular, we show the analysis of this algorithm for the two-dimensional magnetohydrodynamic equations, i.e., we prove that the interpolated solution converges to the reference solution in both L^2 and H^1 norms exponentially fast in time, one of which case is that we only need to interpolate for one component of the Elsässer variables. This is joint work with Animikh Biswas, Joshua Hudson, and Adam Larios. (Received January 01, 2017)

1128-35-29 **Haiyan Tian*** (haiyan.tian@usm.edu), 118 College Dr. # 5045, HATTIESBURG, MS 39406. *The method of approximate fundamental solutions for non-linear thermal explosions.*

The minimal solution of a steady-state blow-up problem is found using a numerical method that is based on the approximate particular solutions and approximate fundamental solutions. The numerical method is highly accurate and efficient. It needs neither domain discretization nor boundary discretization. Critical values of the Frank-Kamenetskii parameter are computed for two-dimensional problems with different geometrical boundaries. (Received January 25, 2017)

1128-35-39 **Fazel Hadadifard*** (f.hadadi@ku.edu). *On the global regularity of the 2D critical Boussinesq system with $\alpha > 2/3$.*

We examine the question for global regularity for the Boussinesq equation with critical fractional dissipation $(\alpha, \beta) : \alpha + \beta = 1$. The main result states that the system admits global regular solutions for all (reasonably) smooth and decaying data, as long as $\alpha > 2/3$. This improves upon some recent works.

The main new idea is the introduction of a new, second generation Hmidi-Keraani-Rousset type, change of variables, which further improves the linear derivative in temperature term in the vorticity equation. This approach is then complemented by new set of commutator estimates (in both negative and positive index Sobolev spaces!), which may be of independent interest. (Received February 02, 2017)

1128-35-41 **Xiaoqian Xu*** (xxu@math.cmu.edu), Providence, RI 02906, and **Alexander Kiselev** and **Gautam Iyer**. *Suppression of chemotactic explosion by mixing.*

Keller-Segel equation is one of the most studied PDE models of processes involving chemical attraction. However, solution of Keller-Segel equation can exhibit dramatic collapsing behavior, where the population density of bacteria concentrates positive mass in a measure zero region. In other words, there exist initial data leading to finite time blow up. In this talk, we will discuss the possible effects resulting from interaction of chemotactic and fluid transport processes, namely we will consider the Keller-Segel equation with additional advection term modeling ambient fluid flow. We will prove that the presence of fluid can prevent the singularity formation. We will discuss three classes of flows that have the explosion arresting property. Both classes are known as very efficient mixers. (Received February 03, 2017)

1128-35-48 **Jiahong Wu*** (jiahong.wu@okstate.edu), 401 Mathematical Sciences, Stillwater, OK 74078. *The 3D incompressible Navier-Stokes equations with partial hyperdissipation.*

The three-dimensional incompressible Navier-Stokes equations with the hyperdissipation $(-\Delta)^\gamma$ always possess global smooth solutions when $\gamma \geq \frac{5}{4}$. Tao and Barbato, Morandin and Romito made logarithmic reductions in the dissipation and still obtained the global regularity. This talk presents a very recent work on a different type of reduction in the dissipation and proves the global existence and uniqueness in the H^1-functional setting. (Received February 05, 2017)

1128-35-59 **Neelesh Tiruviluamala***, Dept. of Mathematics, USC, Los Angeles, CA 90033, and **James Ralston**. *A Grazing Beam.*

"We consider Friedlander's wave equation in two space dimensions in the half-space x>0 with the boundary condition u(x,y,t)=0 when x=0. For a Gaussian beam w(x,y,t;k) concentrated on a ray path that is tangent to x=0 at (x,y,t)=(0,0,0) we calculate the "reflected" wave z(x,y,t;k) in t>0 such that w(x,y,t;k)+z(x,y,t;k) satisfies Friedlander's wave equation and vanishes on x=0. These computations are done to leading order in k on the ray path.

The interaction of beams with boundaries has been studied for non-tangential beams and for beams gliding along the boundary. We undertook this calculation to see how a beam would change after it "grazed" a boundary." (Received February 08, 2017)

1128-35-78 **Sean Bassler*** (basslers@seattleu.edu), basslers@seattleu.edu, and **John Carter**. *The Viscous Dysthe equation with and without surface tension.*

We use the weakly viscous Euler equation to model water waves on infinitely deep water, with gravity, viscosity, and surface tension being the only forces considered. We derive the fourth-order viscous Dysthe equation with surface tension and the fifth-order viscous Dysthe equation without surface tension. We compare predictions from the model including surface tension with measurements from laboratory experiments. (Received February 15, 2017)

1128-35-86 **Tam Do**, **Alexander Kiselev**, **Lenya Ryzhik** and **Changhui Tan*** (ctan@rice.edu). *Global regularity for the fractional Euler alignment system.*

Euler alignment system arises from collective dynamics in mathematical biology. With a singular influence function, the system is closely related to fractional Burgers equation. It is well-known that in the supercritical case, solutions for fractional Burgers equation can lead to finite time blowup, as dissipation is too weak to compete with the nonlinear convection. In this talk, I will present a surprising result: the solution for fractional Euler alignment system is globally regular. I will discuss the mechanism that nonlinearity dynamically enhances dissipation which leads to global regularity. (Received February 14, 2017)

1128-35-87 **Alexis Drouot*** (alexis.drouot@gmail.com), Department of Mathematics, Evans Hall, Berkeley, CA 94720. *Eigenvalues for Schrödinger operators modelling high disorder.*

We study Schrödinger operators of the form $-\Delta_{\mathbb{R}^3} + q(x)$, $x \in \mathbb{R}^3$, where the potential q is the sum of a deterministic part q_0, and a random part q_1 that varies on a scale of order $N^{-1} \ll 1$. Such operators provide models for the diffusion of waves inside chaotic systems with small scale of heterogeneity. We prove that the eigenvalues (and the resonances) of $-\Delta + q$ converge to the eigenvalues (and the resonances) of $-\Delta + q_0$ in the limit $N \to \infty$. In the case of simple eigenvalues, we give a formula for the remainder term, which can be either deterministic or random, depending on the behavior of $\hat{q_1}(\xi)$ near $\xi = 0$. (Received February 15, 2017)

1128-35-94 **Joseph Nakao*** (nakaoj@seattleu.edu) and **Katie Oliveras** (oliveras@seattleu.edu). *Reconstructing the water-wave profile from pressure measurements in a moving body of water.*

A new method that recovers the water-wave surface elevation from pressure measurements at the bottom of the fluid is modified. Whereas any background fluid motion is typically ignored, the modified formulation includes the effects of a background current. By analyzing the structure of a nonlocal nonlinear partial differential equation for fluid motion known as Euler's Equations, a map relating the pressure and surface elevation is derived. From this new relationship, various asymptotic formulae are derived and then tested for accuracy using both numerical and experimental data. (Received February 15, 2017)

1128-35-103 **Mihaela Ifrim*** (ifrim@math.berkeley.edu) and **Daniel Ioan Tataru** (tataru@math.berkeley.edu). *Well-posedness and dispersive decay of small data solutions for the Benjamin-Ono equation.*

This talk represents a first step toward understanding the long time dynamics of solutions for the Benjamin-Ono equation. While this problem is known to be both completely integrable and globally well-posed in L2, much less seems to be known concerning its long time dynamics. Here, we prove that for small localized data the solutions have (nearly) dispersive dynamics almost globally in time. An additional objective is to revisit the L2 theory for the Benjamin-Ono equation and provide a simpler, self-contained approach. (Received February 17, 2017)

1128-35-129 **Vu Hoang*** (vu.hoang@rice.edu), 6100 Main Street, Houston, TX 77001. *Blowup for model equations of fluid mechanics.*

In this talk, I consider the 2D inviscid Boussinesq equations in vorticity form. It remains a challenge to decide if finite time blowup happens for smooth initial data or not. I introduce a model problem for the Boussinesq equations associated to the hyperbolic flow scenario for which we can show finite-time blowup (joint work with B. Orcan, M. Radosz,H. Yang). (Received February 21, 2017)

1128-35-142 **Daniel Ferguson*** (fergus23@seattleu.edu), **Katie Oliveras** (oliveras@seattleu.edu) and **Vishal Vasan** (vishal.vasan@icts.res.in). *A New Perspective of Steady Flow over Bathymetry.*

By modifying the work done in [1] we derive a relationship between the bathymetry, free-surface, and pressure at the bottom of a steady fluid flow. For example, given the shape of the bathymetry we recover both the pressure along the bathymetry as well as the shape of the free surface. We also derive an asymptotic relationship between the Fourier coefficients of the free surface and the Fourier coefficients of bathymetry. Recent work has been done to consider the effect of a corrective term to the ratio of the height to the period of the free surface. The models generated via this technique are contrasted with other models of steady flow over bathymetry namely the hydrostatic approximation model.

References

[1] K. L. Oliveras, V. Vasan, B. Deconinck, and D. Henderson, Recovering the Water-Wave Profile from Pressure Measurements, SIAM Journal on Applied Mathematics, **72:3** (2012), 897-918.
(Received February 22, 2017)

1128-35-151 **Ralph Showalter*** (show@math.oregonstate.edu) and **Dwight Holland**. *Visco-elastic Consolidation.*

We model a sedimentary basin as a saturated granular deforming porous medium of sand or silt consolidating due to its own weight and an overburden pressure. The porosity satisfies a degenerate PDE of pseudo-parabolic type for which we describe the existence and regularity of solutions. (Received February 23, 2017)

1128-35-163 **Victor Ivrii***, Department of Mathematics, University of Toronto, 40 St. George St., Toronto, ON M2N 4V4, Canada. *100 Years of Weyl's Law.*

In 1911-1912 Hermann Weyl published 2 papers (more followed) describing distribution of eigenvalues of Dirichlet Laplacian in the bounded domain. These were one of the first Weyl's publications and the new exciting field of mathematics has been created. I will discuss:

- Weyl's law with sharper remainder estimates (in particular, Weyl conjecture); - Generalized Weyl's law; - When generalized Weyl's law works and when it does not and how it should be modified; - What should be used instead of eigenvalue counting function when the spectrum is not necessarily discrete; - Weyl's law and Thomas-Fermi theory. (Received February 24, 2017)

1128-35-166 **Kazuo Yamazaki*** (kyamazak@ur.rochester.edu), Department of Mathematics, University of Rochester, Rochester, NY 14620. *Exponential convergence of the stochastic micropolar and magneto-micropolar fluid systems.*

The theory of micropolar fluids emphasizes the micro-structure of fluids by coupling the Navier-Stokes equations with micro-rotational velocity, and is widely viewed to be well fit, better than the Navier-Stokes equations, to describe fluids consisting of bar-like elements such as liquid crystals made up of dumbbell molecules or animal blood. Mathematically, the additional terms on the equations that govern the time evolution of the velocity and micro-rotational velocity vector fields are more singular than many other equations such as Benard or magnetic Benard problem, which creates challenging obstacles.

In this talk, I will describe some ergodicity results, precisely the existence of a unique invariant measure of micropolar and magneto-micropolar fluid systems. (Received February 24, 2017)

1128-35-171 **Peter Hintz** and **Andras Vasy***, Department of Mathematics, Bldg 380, 450 Serra Mall, Stanford, CA 94305-2125. *The stability of Kerr-de Sitter black holes.*

In this lecture, based on joint work with Peter Hintz, I will discuss Kerr-de Sitter black holes, which are rotating black holes in a universe with a positive cosmological constant, i.e. they are explicit solutions (in 3+1 dimensions) of Einstein's equations of general relativity. They are parameterized by their mass and angular momentum.

I will first discuss the geometry of these black holes as well as that of the underlying de Sitter space, and then talk about the stability question for these black holes in the initial value formulation. Namely, appropriately interpreted, Einstein's equations can be thought of as quasilinear wave equations, and then the question is if perturbations of the initial data produce solutions which are close to, and indeed asymptotic to, a Kerr-de Sitter black hole, typically with a different mass and angular momentum. In the second part of the talk I will discuss analytic aspects of the stability problem, in particular showing that Kerr-de Sitter black holes with small angular momentum are stable in this sense. (Received February 24, 2017)

1128-35-212 **Steve Zelditch*** (zelditch@math.northwestern.edu), Evanston, IL 60208, and **Boris Hanin**. *Interface asymptotics for spectral projections.*

Interfaces arise in spectral problems in several ways: For semi-classical Schrodinger operators at a fixed energy level, the interface in physical space is the caustic, i.e. the boundary between the allowed and forbidden regions. In phase space, the interface is at the energy surface. In boundary problems, the boundary is the interface. Spectral projections for the fixed energy level exhibit scaling asymptotics around the interface that we conjeture to be universal. For the isotropic harmonic oscillator, the scaling limit is a dimension-dependent Airy kernel which coincides with the Tracy-Widom Airy kernel in dimension 3. This is joint work with B. Hanin and P. Zhou (Received February 27, 2017)

1128-35-234 **Ben Bellis*** (benbellis1@gmail.com), 1417 Armacost Ave, Apt 14, Los Angeles, CA 90025. *Resolvent Estimates for Non-Self-Adjoint Semiclassical Schrödinger Operators.*

For self-adjoint operators, the spectral theorem provides a very powerful tool to estimate the norm of the resolvent, but there is no suitable analog in the non-self-adjoint case. This makes resolvent estimates for non-self-adjoint operators generally more difficult to attain. In this talk we provide a bit of background on estimating the resolvent for such operators in the semiclassical setting, and then outline a proof of one such estimate for a fairly broad class of non-self-adjoint Schödinger operators. (Received February 27, 2017)

1128-35-239 **Yaiza Canzani*** (canzani@email.unc.edu), 305 Phillips Hall CB #3250, University of North Carolina, Chapel Hill, NC 27599, and **John Toth**. *Averages of Laplace eigenfunctions over curves.*

In this talk we will discuss conditions on a sequence of Laplace eigenfunctions so that their averages over a given closed curve go to zero as their eigenvalues grow to infinity. We will also discuss the averages of the normal derivatives of the eigenfunctions along the curve. Everything will be done on smooth compact manifolds without boundary. The conditions needed to address these problems are on the defect measure associated to the sequence of eigenfunctions and on how this defect measure behaves near the given curve. This is joint work with John Toth. (Received February 27, 2017)

1128-35-249 **Hart F Smith*** (hfsmith@uw.edu), University of Washington, Box 354350, Seattle, WA 98195-4350. *On the trace of Schrödinger heat kernels and regularity of potentials.*

We consider the Schrödinger operator $-\Delta_{\mathrm{g}} + V$ on a complete Riemannian manifold (M, g), with a bounded real potential V of compact support, and establish a sharp equivalence between Sobolev regularity of V and the existence of finite-order asymptotic expansions as $t \to 0$ of the relative trace of the Schrödinger heat kernel.

Precisely, under the hypothesis $V \in L^\infty_{\text{comp}}(M)$ is real valued, then $V \in H^m(M)$ if and only if there are constants c_j so that

$$\operatorname{tr}\big(e^{-tP_V} - e^{-tP_0}\big) = (4\pi t)^{-\frac{n}{2}}\Big(c_1 t + c_2 t^2 + \cdots + c_{m+1} t^{m+1} + \mathcal{O}(t^{m+2})\Big).$$

As an application, we generalize a result of Sà Barreto and Zworski on the existence of resonances on compact metric perturbations of three-dimensional Euclidean space, to the case of bounded measurable potentials. (Received February 27, 2017)

1128-35-264 **Michael Hitrik***, Department of Mathematics, UCLA, Los Angeles, CA 90095-1555. *Spectra for non-self-adjoint operators and integrable dynamics.*

Non-self-adjoint operators appear in many settings, from kinetic theory and quantum mechanics to linearizations of equations of mathematical physics. The spectral analysis of such operators, while often notoriously difficult, reveals a wealth of new phenomena, compared with their self-adjoint counterparts. Spectra for non-self-adjoint operators display fascinating features, such as lattices of eigenvalues for operators of Kramers-Fokker-Planck type, say, and eigenvalues for operators with analytic coefficients in dimension one, concentrated to unions of curves in the complex spectral plane. In this talk, we shall discuss spectra for non-self-adjoint perturbations of self-adjoint operators in dimension two, under the assumption that the classical flow of the unperturbed part is completely integrable. We shall describe the role played by the flow-invariant Lagrangian tori of the completely integrable system, both Diophantine and rational, in the spectral analysis of the non-self-adjoint operators. The particular focus will be on the recent results on spectral contributions of rational tori, leading to eigenvalues having the form of the "legs in a spectral centipede". This talk is based on joint work with Johannes Sjöstrand. (Received February 28, 2017)

1128-35-267 **Radu Dascaliuc***, Department of Mathematics, Oregon State University, Corvallis, OR 97331-4605. *Multiplicative cascades approach to regularity: a case-study of the complex Burgers equation.*

The use of stochastic cascades to study the 3D Navier-Stokes equations (NSE) was originated by Le Jan and Sznitman in 1997. Under this approach, the mild solution in Fourier space is viewed as an expected value of a random variable over a stochastic process. As a result, the well-posedness is re-cast in terms of probabilistic analysis of a random process. More recently, this approach was used to connect the NSE uniqueness problem to the uniqueness of the self-similar solutions, suggesting that NSE regularity is closely connected to the natural scaling symmetries. To further illustrate the potential usefulness of such approach to study nonlinear evolution PDE, we will consider a much simpler case of complex Burgers equations, where explicit nature of probabilistic distributions allows us to prove existence and uniqueness of mild solutions in the widest invariant space, without smallness assumptions on the initial data. Moreover, our study of the associated cascade yielded several surprising results related to the long-time behavior of the solutions. We will conclude by discussing in which ways these results might be extended to the full NSE problem.

Based on the joint work with N. Michalowski, E. Thomann, and E. Waymire. (Received February 28, 2017)

1128-35-270 **Peter Hintz*** (phintz@berkeley.edu), Department of Mathematics, 805 Evans Hall, Berkeley, CA 94720, and **Maciej Zworski**. *Resonances for obstacles in hyperbolic space.*

We consider scattering by star-shaped obstacles in hyperbolic space and show that resonances satisfy a universal bound $\Im\lambda \leq -1/2$; in odd dimensions and for small obstacles with diameter ρ, we improve this to $\Im\lambda < -C/\rho$ for a universal constant C. Our proofs largely rely on the classical vector field approach of Morawetz. We also explain how to relate resonances for small obstacles to scattering resonances in Euclidean space. (Received February 28, 2017)

1128-35-277 **Irina Mitrea*** (imitrea@temple.edu), 1085 N. Broad Street, Wachman Hall, Philadelphia, PA 19122. *THE BMO-DIRICHLET PROBLEM FOR ELLIPTIC SYSTEMS IN THE UPPER-HALF SPACE.*

In this talk I will discuss the BMO-Dirichlet boundary value problem for homogeneous, second order, constant complex coefficient elliptic systems and show well-posedness in the class of functions for which the Littlewood-Paley measure associated with it is a Carleson measure in the upper-half space. This is joint work with J. Maria Martell, D. Mitrea, and M. Mitrea. (Received February 28, 2017)

1128-35-280 **Dean Baskin*** (dbaskin@math.tamu.edu). *The radiation field on conic manifolds.* Preliminary report.

In this talk I will describe recent joint work with Jeremy Marzuola describing the long-time behavior of the radiation field on product cones. We consider the wave equation on $\mathbb{R} \times X$, where X is a product cone equipped with the Riemannian metric $dr^2 + r^2 h$, where h is a Riemannian metric on the cross-section. We find asymptotic expansions for solutions of the wave equation in all asymptotic regimes and find the exponents seen in the expansion for the radiation field (the pattern seen by a distant observer); these exponents are precisely the resonances of a hyperbolic cone and can be computed explicitly. (Received February 28, 2017)

1128-35-287 **Angel Castro**, **Diego Cordoba** and **Javier Gomez-Serrano*** (jg27@math.princeton.edu), 610 Fine Hall, Washington Road, Princeton, NJ 08544. *Uniformly rotating smooth solutions for active scalars.*

Motivated by our previous results of global existence for active scalars in the patch setting, we are able to construct the first nontrivial family of global smooth solutions for the surface quasi-geostrophic (SQG) equations. These solutions rotate with uniform angular velocity both in time and space. We will outline the basic ingredients of the proof: bifurcation theory and computer-assisted estimates. Moreover, we will also discuss the case of uniformly rotating smooth solutions to the 2D incompressible Euler equations. Joint work with Angel Castro and Diego Cordoba. (Received February 28, 2017)

1128-35-290 **Hamid Hezari*** (hezari@math.uci.edu). *Equidistribution properties of toral eigenfunctions.*

In this talk we report some recent results (joint with Gabriel Riviere) on equidistribution properties of toral eigenfunctions. We will discuss small scale mass concentration and also equidistribution on hypersurfaces. (Received February 28, 2017)

1128-35-296 **Lizheng Tao***, 220 Surge, UC Riverside, Riverside, CA 92521. *Inviscid Limit Problem for Navier Stokes Equations with Fractional Laplacian.*

We will discuss some recent results in the inviscid limit problem for Navier-Stokes equations with fractional Laplacian in a domain. Some sufficient conditions will be given. (Received February 28, 2017)

1128-35-329 **Lyudmyla L. Barannyk*** (barannyk@uidaho.edu), 875 Perimeter Drive MS 1103, Brink Hall 317, Moscow, ID 83844-1103, and **John C. Crepeau** (crepeau@uidaho.edu), 875 Perimeter Drive MS 0902, Moscow, ID 83844-0902. *On the Stefan problem with internal heat generation in a cylinder.* Preliminary report.

We consider a problem of solid-liquid phase change driven by internal heat generation of the material in cylindrical coordinates. We incorporate the following assumptions: (1) the internal heat generation and the thermophysical properties of the materials are equal and constant in both the solid and liquid phases; (2) the material changes phase at only a single temperature; (3) there is no convection in the liquid phase; (4) we neglect the formation of the mushy zone so that there is a single, distinct interface $s(t)$ between the phases; finally, (5) there is no temperature variation circumferentially in the cylinder. Formulating problems for solid and liquid phases, which are non-homogeneous partial differential equations, we use the method of superposition to obtain steady-state and transient equations, which are then solved by the method of separation of variables. We show that the evolution of the phase change front $s(t)$ is governed by an ordinary differential equation. We solve the resulting equation numerically and compare solutions with the computational fluid dynamics (CFD) solutions. The relations between the interface, time and heat generation are analyzed. (Received February 28, 2017)

1128-35-332 **Kazuo Yamazaki*** (kyamazak@ur.rochester.edu), 1017 Hylan Hall, Department of Mathematics, University of Rochester, Rochester, NY 14627. *Recent Developments on the Component Reduction Results of Serrin-type Regularity Criterion for Equations Concerning Fluid.*

The question of whether the solution to the three-dimensional Navier-Stokes equations preserves its regularity for all time or experiences a finite-time blow-up remains one of the most challenging open problems in the research directions of analysis and partial differential equations. We review recent developments on the component reduction type results of Serrin-type regularity criterion for the equations of fluid, primarily the Navier-Stokes equations, and also list some remaining open problems. (Received February 28, 2017)

1128-35-346 **Juraj Földes**, **Susan Friedlander**, **Nathan Glatt-Holtz**, **Geordie Richards*** (geordie.richards@usu.edu) and **Jared Whitehead**. *Invariant measures and singular parameter limits for stochastic PDEs from fluid mechanics.*

We will discuss a technique for proving the weak convergence of invariant measures with respect to singular parameter limits for systems of stochastic PDEs from fluid mechanics. The crucial ingredients are a contraction property of the limiting dynamics relative to a Wasserstein metric, and the convergence of solutions in the singular parameter limit on finite time scales. Two physically motivated applications will be highlighted: the infinite

Prandtl number limit for a stochastic Boussinesq system, and the vanishing Rossby and Magnetic Reynolds number limit for stochastic MHD. This talk is based on joint works with Juraj Földes, Susan Friedlander, Nathan Glatt-Holtz and Jared Whitehead. (Received February 28, 2017)

1128-35-355 **Amael Le Squin*** (amael.lesquin@gmail.com). *Existence, unicity and positivity of the solution of an analytically tractable forest dynamics model.* Preliminary report.

We developed a spatially explicit and analytically tractable forest dynamics model with dispersion. Its aim is to predict changes in species distribution under climate change, taking into account dispersion and demographic parameters. Our forest model is based on the hypothesis of *perfect plasticity approximation* (Strigul et al. 2008) and uses the McKendrick–von Forster PDEs:

$$\frac{\partial N(s,x,t)}{\partial t} = -\frac{\partial G(s,s^*,t)\,N(s,x,t)}{\partial s} - \mu(s,s^*,t)N(s,x,t) \tag{1}$$

$$N(s_0,x,t) = \frac{1}{G(s_0,t)} \int_\Omega \mathcal{K}(x,y) \int_0^\infty N(s,y,t)F(s,t)\;ds\,dy \tag{2}$$

$$1 = \int_{s^*(x,t)}^\infty N(s,x,t)\mathcal{A}\big(s;s^*(x,t)\big)\,ds \tag{3}$$

The first equation is the dynamics of a cohort of size s at location x at time t. The second equation is a boundary condition and represent renewal. The last equation is a feedback function modifying the behaviour of individuals and defines a threshold s^* which required some conditions on $\mathcal{A}$ (tree crown area) and N to exist and being unique.

After presenting our model and discussing its meaning when adding space, we will focus on the existence, uniqueness and positivity of a weak solution. (Received March 01, 2017)

1128-35-357 **Gustavo Hoepfner***, Universidade Federal de Sao Carlos, Sao Carlos, Brazil, and **Andrew Seth Raich**. *Global L^q Gevrey Functions, Paley-Weiner Theorems, and the FBI Transform.*

I will explore the relationship of global L^q Gevrey classes with the FBI transform and the Fourier transform. In particular, we show that Salem's example of a positive, compactly supported Radon measure that is supported on a set of Hausdorff dimension α, $0 < \alpha < 1$, and whose Fourier transform is an element of $L^q(\mathbb{R})$ for $q > 2/\alpha$. is also in the global L^q Gevrey classes. (Received March 01, 2017)

37 ► Dynamical systems and ergodic theory

1128-37-20 **James R. Langenbrunner*** (jrl@lanl.gov), MS F644, LANL, Los Alamos, NM 87545, and **Hanna Makaruk** (hanna_m@lanl.gov), MS T080, LANL, Los Alamos, NM 87545. *Temperature dependence of nuclear fusion.* Preliminary report.

Nuclear deuterium fusion occurs as the second stage of the proton-proton chain reaction, supplying energy to Main Sequence stars. Deuterium-Tritium is also experimentally investigated at National Ignition Facility (US) and is going to be investigated at proposed High Power Laser Energy Research (HiPER, Europe) for a possibility of becoming an energy source on Earth. The rate of the fusion depends in a nonlinear way on the temperature. A mathematical model of this dependence is discussed. (Received January 13, 2017)

1128-37-170 **Hanna Makaruk*** (hanna_m@lanl.gov), MS T080, P-21, Los Alamos National Laboratory, Los Alamos, NM 87545, and **James R Langenbrunner** (jrl@lanl.gov), MS F644, XCP-8, Los Alamos National Laboratory, Los Alamos, NM 87545. *Reconstruction of a dynamical system from toy model experimental trajectories.* Preliminary report.

Semi empirical equation of the Deuterium-Deuterium and Deuterium-Tritium reactivity as a function of temperature is used to obtain a toy model of experimental data taken from a dynamical system. Under some conditions temperature can be assumed to be an unknown monotonic function of time. We are attempting to recreate the equation from the toy experimental trajectories, now as a function of time. We are also studying how modifying parameters changes trajectories of the system. (Received February 24, 2017)

39 ► Difference and functional equations

1128-39-109 **M N Islam*** (mislam1@udayton.edu), Department of Mathematics, University of Dayton, Dayton, OH 45458, and **J T Neugebauer**. *Asymptotically P-Periodic Solutions of a Quantum Volterra Integral Equation.* Preliminary report.

Abstract. In this paper, we study the existence of an asymptotically periodic solution of a Volterra integral equation on the time scale q^{N_0}, which we call a quantum Volterra integral equation. In the process, we study the existence of periodic solutions of an associated equation on the time scale $q^{\bar{Z}}$, which is an extension of q^{N_0}. We employ Schauder's fixed point theorem in the analysis. (Received February 18, 2017)

45 ► Integral equations

1128-45-43 **T. A. Burton*** (taburton@olypen.com), 732 Caroline St., Port Angeles, WA 98362.
Integro-differential Equations:Progressive Contractions.

First order integro-differential equations bear a special relation to fixed point theory. We will briefly describe how the new concept of "progressive contractions" works with "direct fixed point methods" to produce the following:

1. Lipschitz maps become contractions
2. The sum of two contractions can be a contraction even when the sum of the constants exceed 1
3. Continuous maps become compact maps. In particular:

a. Krasnoselskii's theorem on the sum of two operators can collapse into Schauder's theorem.

b. When the kernel is positive then Schaefer's theorem and a Liapunov function yield a unique global bounded solution. (Received February 04, 2017)

1128-45-71 **Colleen Margarita Kirk*** (ckirk@calpoly.edu) and **W. E. Olmstead**. *Local and Nonlocal Boundary Quenching in a Subdiffusive Medium.*

A mathematical model for boundary quenching in a subdiffusive medium is analyzed. The quenching effect is simulated by a nonlinear flux condition at the left boundary of a one- dimensional bar. The nonlinearity is allowed to depend upon either the local temperature of the boundary or a global average of temperature. The right boundary of the bar is subjected to either an insulation condition or a zero temperature condition. The model is analyzed by converting the original partial differential equation model into a nonlinear Volterra integral equation. A separate analysis is carried out for an extension of the model that includes the influence of advection. (Received February 10, 2017)

1128-45-137 **D. P. Dwiggins*** (ddwiggns@memphis.edu), 373 Dunn Hall, University of Memphis, Memphis, TN 38152. *Fixed Point Theory, Integral Equations, and Resolvents.*

During the Fall 2015 Southeastern sectional AMS meeting, conversations with our session attendees indicated an interest in learning more about how fixed point theory is used to investigate behavior of solutions to Volterra integral equations; this is a belated response to that request. After highlighting several basic approaches, including how some recently published results might be generalized, we will also briefly discuss how fixed point theory applies to the resolvent equation. This talk concludes with a presentation of final results from a study on approximating the resolvent using a convolution series. The main conclusion is that, in most cases of interest, it appears only the first two terms in this series are needed to determine the nature of the behavior of solutions. (Received February 22, 2017)

1128-45-242 **Keith Wojciechowski** and **Lynn Schreyer*** (lynn.schreyer@wsu.edu), Department of Mathematics and Statistics, Washington State University, PO Box 643113, Pullman, WA 99164-3113. *Modeling Swelling Polymers with a Nonlinear Volterra Partial Integrodifferential Equation.*

Using a methodical method called Hybrid Mixture Theory for porous materials, we derive a nonlinear Volterra partial integrodifferential equation (VPIDE) that models swelling polymers which can be used, for example, to model drug-delivery polymers (used for example in Aleve), expansive soils, soybeans, and biotissues. After solving the equation numerically using pseudospectral differentiation matrices in polar geometry in space and a method-of-lines approach in time, we show and interpret results for a variety of diffusion coefficients, permeability models, and parameters in order to study the model's behavior. (Received February 27, 2017)

46 ► Functional analysis

1128-46-77 **Maximillian Vaughn Hart*** (maximillian.hart@wsu.edu), 405 NE oak Street Apt. F, Pullman, WA 99613. *partial differentiation for composed linear functions in N dimensions.*

In this talk, I will explain how taking partial derivatives of composed linear functions can be solved using matrix algebra and gradients. (Received February 14, 2017)

47 ► Operator theory

1128-47-1 **Bo Zhang*** (bzhang@uncfsu.edu), Fayetteville State University, Department of Mathematics and Computer Scienc, 1200 Murchison Road, Fayetteville, NC 28301. *Stability by Schauder's Fixed Point Theorem for Nonlinear Delay and Fractional Differential Equations.* Preliminary report.

In this paper we first study a nonlinear scalar differential equation with variable delays

$$x' = -a(t)x^3(t) + b(t)x^3(t - r(t))$$

and give conditions to ensure that the zero solution is asymptotically stable by applying Schauder's Fixed Point Theorem. The paper is motivated by a number difficulties encountered in the study of this equation by means of Liapunov's direct method. We notice that most of these difficulties vanish when applying fixed point theory. While Liapunov's direct method usually asks pointwise conditions on the functions governing the system, the stability results we offer ask conditions of an averaging nature. Stability and asymptotic stability theorems are proved. The same technique is also applied to some nonlinear fractional differential equations of Caputo type with similar right-hand side functions. (Received August 12, 2016)

1128-47-82 **Waleed K. Al-Rawashdeh*** (walrawashdeh@mtech.edu), Montana Tech, Department of Mathematical Sciences, 1300 West Park Street, Butte, MT 59701. *Compact Weighted Composition Operators between Generalized Fock Spaces.*

Let ψ be an entire self-map of the n-dimensional Euclidean complex space $\mathbb{C}^n$ and u be an entire function on $\mathbb{C}^n$. A weighted composition operator induced by ψ with weight u is given by $(uC_\psi f)(z) = u(z)f(\psi(z))$, for $z \in \mathbb{C}^n$ and f is entire function on $\mathbb{C}^n$. In this talk, we characterize the boundedness and compactness of these operators act between $\mathcal{F}^p_\phi(\mathbb{C}^n)$ and $\mathcal{F}^q_\phi(\mathbb{C}^n)$ for $0 < p, q \leq \infty$. Moreover, we give estimates for the Fock-norm of $uC_\psi : \mathcal{F}^p_\phi \to \mathcal{F}^q_\phi$ when $0 < p, q < \infty$, and also when $p = \infty$ and $0 < q < \infty$. (Received February 14, 2017)

1128-47-188 **John R. Graef*** (john-graef@utc.edu), Department of Mathematics, University of Tennessee at Chattanooga, Chattanooga, TN 37403. *Some Multivalued Versions of Krasnosel'skii's Fixed Point Theorem.*

A well known fixed point theorem of Krasnosel'skii established the existence of a fixed point for the sum of two operators in the case where one is continuous and compact and the other is a contraction. Here we present some extensions of this result to mulivalued operators. (Received February 26, 2017)

49 ► Calculus of variations and optimal control; optimization

1128-49-32 **Humberto C Godinez*** (hgodinez@lanl.gov), Applied Mathematics and Plasma Physics, Mail Stop B284, Los Alamos, NM 87545, and **Nicholas W Hengartner** (nickh@lanl.gov), Mail Stop K710, Los Alamos, NM 87545. *Mode Reduction Methods for Data Assimilation: Subspace Projection using Koopman Operators.*

Data assimilation are methods that fuse observational data into model to improve the model forecast. These methods are widely used in several areas of science, including weather forecasting, hurricane forecasting, space weather, and subsurface flow, to name a few.

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 will derive an approximation to the eigenfunctions defined by the Koopman operator that represent the non-linear behavior of a dynamical system. (Received January 27, 2017)

1128-49-49 **Yufeng Cao*** (ycao1@hotmail.com), 1630 Ne Valley Rd Apt J202, Pullman, WA 99163.
Detection and classification of liver with tumor. Preliminary report.

Computerized liver tumor segmentation on computed tomography images is a challenging problem. In this paper, a sequence images for \$30\$ seconds were got and we use total variation for this sequence. Mumford–Shah functional \$(Chan-Vese,2006)\$ helps in finding the exact size and location of tumor. An efficient algorithm is proposed in this paper for tumor detection. (Received February 06, 2017)

1128-49-73 **Mark Schmidt*** (schmidtm@cs.ubc.ca). *Linear Convergence of Gradient and Proximal-Gradient Methods Under the Polyak-Łojasiewicz Condition.*

In 1963, Polyak proposed a simple condition that is sufficient to show a global linear convergence rate for gradient descent. This condition is a special case of the Łojasiewicz inequality proposed in the same year, and it does not require strong convexity (or even convexity). In this work, we show that this much-older Polyak-Łojasiewicz (PL) inequality is actually weaker than the main conditions that have been explored to show linear convergence rates without strong convexity over the last 25 years. We also use the PL inequality to give new analyses of randomized and greedy coordinate descent methods, sign-based gradient descent methods, and stochastic gradient methods in the classic setting (with decreasing or constant step-sizes) as well as the variance-reduced setting. We further propose a generalization that applies to proximal-gradient methods for non-smooth optimization, leading to simple proofs of linear convergence of these methods. Along the way, we give simple convergence results for a wide variety of problems in machine learning: least squares, logistic regression, boosting, resilient backpropagation, L1-regularization, support vector machines, stochastic dual coordinate ascent, and stochastic variance-reduced gradient methods. (Received February 11, 2017)

1128-49-84 **Warren Hare*** (warren.hare@ubc.ca), 3187 University Way, Kelowna, BC V1V 1V7, Canada. *Compositions of Convex Functions and Fully Linear Models.*

Derivative-free optimization (DFO) is the mathematical study of the optimization algorithms that do not use derivatives. One branch of DFO focuses on model-based DFO methods, where an approximation of the objective function is used to guide the optimization algorithm. Proving convergence of such methods often applies an assumption that the approximations form fully linear models – an assumption that requires the true objective function to be smooth. However, some recent methods have loosened this assumption and instead worked with functions that are compositions of smooth functions with simple convex functions (the max-function or the ℓ_1 norm). In this talk, we examine the error bounds resulting from the composition of a convex lower semi-continuous function with a smooth vector-valued function when it is possible to provide fully linear models for each component of the vector-valued function. We derive error bounds for the resulting function values and subgradient vectors. (Received February 14, 2017)

1128-49-125 **Frank Morgan*** (fmorgan@williams.edu). *The Isoperimetric Problem with Density.*

The classical isoperimetric theorem says that the round sphere is the least-perimeter way to enclose given volume in R^n. Since their appearance in Perelman's proof of the Poincare conjecture, there has been great interest in enhancing space with a positive density that weights both perimeter and volume. Even if the density is radial, spheres about the origin usually no longer minimize weighted perimeter for given weighted volume. We discuss some open problems and recent results using geometric measure theory, some by undergraduates. (Received February 21, 2017)

1128-49-135 **Robert M. Hardt*** (hardt@rice.edu), Rice University. *Some network flows optimizing ramified transport.* Preliminary report.

Suppose A and B are finite sums of atoms in R^n with the same total weights and T is an oriented finite mass network going from A to B. Thus, $\partial T = B - A$. Various segments of T may have different multiplicities and the mass $M(T)$ can be found by integrating the multiplicity function θ_T over the network. Q. Xia (2003) used, for $0 < \alpha < 1$, a different mass $M_\alpha(T)$ obtained by integrating $(\theta_T)^\alpha$ over the network T. Here M_α minimization favors higher multiplicity segments (See the text [Bernot-Caselles-Morel]). C.Downes recently constructed an M_a decreasing network flow T_t in analogy to the (ordinary mass) M decreasing flows of rectifiable currents of X. Cheng (1993) or Almgren-Taylor-Wang (1993) . In research with C.Downes and J.Wu, we consider time-parameterized versions of such networks, which give some models for optimal transport "routings or schedules". Some higher order functionals lead to networks with C^1 junctures, like train tracks. We will discuss briefly existence and regularity of minimizers and flows. (Received February 22, 2017)

1128-49-144 **Jean E Taylor*** (jtaylor@cims.nyu.edu). *Almgren Almost Minimal Sets.* Preliminary report.

This talk concerns what Fred Almgren called (F, ϵ, δ) minimal sets but people are now calling Almgren (almost) minimal sets. It will be for geometric measure theory enthusiasts. These sets take some effort just to define, but when $F \equiv 1$ they are the right concept for proving the structure of compound soap bubbles and of bubble-film surfaces on wire frame boundaries, as I did over 40 years ago. Instead of being constant, F can be a function of tangent plane direction (and perhaps position in space) and so gives an anisotropic surface energy function. The (F, ϵ, δ) condition can be thought of as the right codification of local stable force balance. The function ϵ and the positive parameter δ allow the minimization to be subject to various possible constraints. As the (F, ϵ, δ) condition can be expressed for all dimensions and co-dimensions, Almgren minimal sets continue to be a subject of active research. (Received February 22, 2017)

51 ► Geometry

1128-51-22 **Yunfeng Hu*** (yunfeng.hu@wsu.edu), 1630 NE Valley Rd, M106, Pullman, WA 99163, and **Bala Krishnamoorthy**, **Matthew Hudelson**, **Altansuren Tumurbaatar** and **Kevin Vixie**. *Median Shapes.*

In this paper we will introduce the variational definition of mean and median shapes where the shapes are represented as currents. And we will explore the behavior of medians in codimension 1 and codimension 2. (Received January 20, 2017)

1128-51-63 **Yunfeng Hu**, **Bala Krishnamoorthy**, **Matthew Hudelson**, **Altansuren Tumurbaatar*** (atumurbaatar@math.wsu.edu) and **Kevin R Vixie**. *Median Shapes on Simplicial Complexes.*

In this paper, we will introduce median shapes in the simplicial settings and formulate it as an Integer Linear Optimization problem which finds a median shape of input shapes represented as simplicial currents embedded in an underlying finite simplicial complex. We will show experiment results and explore related applications. (Received February 08, 2017)

1128-51-79 **Neslihan Gügümcü*** (nesli@central.ntua.gr), National Technical University of Athens, Zografou Campus, Iroon Polytechniou 9, 15780 Athens, Greece. *Parity in Knotoids.*

A classical knotoid diagram is a generic immersion of the unit interval into S^2,with two distinct endpoints.A long knot normally has its endpoints in a single region of the knot diagram.Classical knotoids generalize the notion of long knots by allowing the endpoints to be in different regions.The combinatorial distance between the endpoints(in terms of crossing the boundaries of regions) is called the height of the knotoid diagram.The height is a classical knotoid invariant that tells us how far a knotoid is from being a knot.A classical knotoid is called knot-type if it has zero height.In this talk,we first examine the basic notions of classical knotoids.We define the virtual closure map that connects the theory of knotoids with the theory of virtual knots. We show that the virtual closure map is not surjective with (an infinite set of) examples of virtual knots of genus one that are not in the image of the virtual closure map.We introduce the notion parity for classical knotoids and discuss the theorems of Nikonov and Manturov concerning projection maps from virtual knots to classical knots by using parity.We give a proof to Turaev‘s conjecture which claims minimal crossing diagrams of knot-type knotoids have zero height.This is a joint work with Louis H. Kauffman. (Received February 14, 2017)

1128-51-85 **Kellan R Toman*** (ktoman@math.wsu.edu). *The Wulff Problem.*

We describe the minimizing shape described by anisotropic surface energy, subject to constraints on the area of the surface. Along the way, the Knothe Map is presented as a useful tool as used in a proof of the minimizing shape known as the Wulff Shape. (Received February 14, 2017)

1128-51-90 **Trent A DeGiovanni*** (tdegiovanni@zagmail.gonzaga.edu), 803 E Mission Ave, Spokane, WA 99202. *Most Economical Common Dissection of a Square and Equilateral Triangle.*

The Wallace-Bolyai-Gerwien theorem states any polygon can be decomposed into a finite number of polygonal pieces that can be translated and rotated to form any polygon of equal area. The theorem was proved in the early 19th century. The minimum number of pieces necessary to form these common dissections remains an open question. In 1905, Henry Dudney demonstrated a four-piece common dissection between a square and equilateral triangle. We investigate the possible existence of a three-piece common dissection. Specifically we examine possible dissections in which all of the polygonal pieces are convex. (Received February 15, 2017)

1128-51-337 **Enrique G Alvarado*** (ealvarado9611@gmail.com), Pullman, WA 99163, and **Kevin R Vixie** (vixie@speakeasy.net), Pullman, WA 99163. *A Lower Bound on the Reach of Flat Norm Minimizers.*

One measure of the regularity of a curve in $\mathbb{R}^2$ is called the *reach* of the curve and is equal to the supremum of the radii of the disks that can be rolled around the curve, always touching the curve in exactly one spot. Curves with corners have reach $= 0$ since every ball, no matter how small touches the curve in at least two places. And it is not enough that a curve be C^1 for it to have positive reach – positive reach implies a curve is at least $C^{1,1}$.

In this talk, I will show that the minimizers of the flat norm, introduced earlier in the semester, have positive reach not too much smaller than $1/\lambda$ where λ is the bound on the curvature of the minimizer that is "hard-coded" into the flat norm metric. The proof boils down to a simple comparison argument and some calculations, but, as in most everything in geometric measure theory, there are some details! (Received February 28, 2017)

53 ► Differential geometry

1128-53-146 **Sharif Ibrahim*** (ams2017@sharifibrahim.com), **Bala Krishnamoorthy** and **Kevin Vixie**. *Some minimal shape decompositions are nice.*

The space of currents (representing generalized surfaces) under the flat norm has rich theoretical interest including, for example, the existence of area-minimizing surfaces. Computing the flat norm is equivalent to optimally decomposing a given d-dimensional current into d- and (the boundary of) $(d+1)$-dimensional pieces. We consider integral currents (a class which includes all compact oriented manifolds with boundary and integer multiplicities) and find conditions under which the optimal decomposition can be assumed integral as well. In applications, preserving integrality helps ensure the decomposition is physically meaningful. Our approach moves between the simplicial complex and continuous settings, combining a deformation theorem on simplicial complexes with the continuous polyhedral approximation and compactness theorems. For d-dimensional currents in $\mathbb{R}^n$, we prove integrality is preserved for $d < n = 2$ and present a framework (relying on a triangulation conjecture) for $d = n-1$ even for non-boundary currents. Lastly, we demonstrate counterexamples exist whenever $1 \leq d \leq n-3$. (Received February 23, 2017)

1128-53-168 **Enrique G Alvarado** (ealvarado9611@gmail.com), Pullman, WA 99163, and **Kevin R Vixie*** (vixie@speakeasy.net), Pullman, WA 99163. *A Lower Bound on the Reach of Flat Norm Minimizers.*

One measure of the regularity of a curve in R^2 is called the *reach* of the curve and is equal to the supremum of the radii of the disks that can be rolled around the curve, always touching the curve in exactly one spot. Curves with corners have reach $= 0$ since every ball, no matter how small touches the curve in at least two places. And it is not enough that a curve be C^1 for it to have positive reach – positive reach implies a curve is at least $C^{1,1}$.

In this talk, I will show that the minimizers of the flat norm, introduced earlier in the semester, have positive reach not too much smaller than $1/\lambda$ where λ is the bound on the curvature of the minimizer that is "hard-coded" into the flat norm metric. The proof boils down to a simple comparison argument and some calculations, but, as in most everything in geometric measure theory, there are some details! (Received February 24, 2017)

55 ► Algebraic topology

1128-55-23 **Louis H Kauffman*** (kauffman@uic.edu), 5530 South Shore Drive, Apt 7C, Chicago, IL 60637-1946. *Majorana Fermions and Topological Quantum Information.* Preliminary report.

This talk will discuss the relationship of Majorana Fermions and topological quantum computation for a variety of anyonic models. (Received January 21, 2017)

1128-55-24 **Louis H Kauffman*** (kauffman@uic.edu), 5530 South Shore Drive, Apt 7C, Chicago, IL 60637-1946. *Simplicial Homotopy Theory, Link Homology and Khovanov Homology.* Preliminary report.

The purpose of this talk is to point out that simplicial methods and the well-known Dold-Kan construction in simplicial homotopy theory can be fruitfully applied to convert link homology theories into homotopy theories. The construction is independent of the particular link homology theory. A simplifying point in producing a homotopy simplicial object in relation to a chain complex occurs when the chain complex is itself derived (via face maps) from a simplicial object that satisfies the Kan extension condition. Under these circumstances one can use that simplicial object rather than apply the Dold-Kan functor to the chain complex. We will give examples of this situation in regard to Khovanov homology. The purpose of this talk is to discuss the basic relationships for using simplicial methods in this domain. Thus we do more than just quote the Dold-Kan Theorem. We give a review of simplicial theory and we point to specific constructions, particularly in relation to Khovanov homology, that can be used to make simplicial homotopy types directly. (Received January 21, 2017)

1128-55-38 **Hongwei Wang*** (hongwei.wang@ttu.edu), Hongwei Wang, 1612 Ave Y, apt 116B, Lubbock, TX 79401, and **Razvan Gelca**. *Find the action of Kauffman bracket skein algebra on the skein module of the 3-twist knot complement.* Preliminary report.

Kauffman bracket skein module of a 3-manifold was introduced by Jozef H. Przytycki. My research is focused on the action of Kauffman bracket skein algebra on the skein module of the 3-twist knot complement. This is a continued work of Razvan and Nagsado's work [R.Gelca and F.Nagasato,Knot theory and its application].We consider the manifold $M = S^3\backslash K$, where K is a 3-twist knot. We know [Bullock and Lo faro, The Kauffman bracket skein module of a twist knot exterior] $K_t(S^3\backslash K)$ is free $C[t, t^{-1}]$-module with basis $x^k y^j$, k is arbitrary interger and j is 0,1,2,3, where $C[t, t^{-1}]$ is the ring of Laurent polynomials .We use the basis with chebyshev polynomials of second kind $S_n(x)$.Take the map $\pi : K_t(\pi^2 \times I) \to K_t(S^3\backslash K)$.For a pair of integers (p, q), we denote by $(p, q)_T$ the element of the Kauffman bracket skein module of the 3-twist knot complement.Take the case where $gcd(p, q) = 1$. This is the curve whose homology class in the base $(longitude, meridian)$ is (p, q).We considered curve $(1, -2)$ and $(1, -3)$ firstly. Eventually, we expect to find the action on knot complement with an arbitrary curve using the basis with chebyshev polynomials of second kind. (Received February 01, 2017)

1128-55-67 **Justin N Theriot*** (jntheriot504@gmail.com), 1230 SW Lost Trail DR, Pullman, WA 99163. *Structuring Concurrency as Knots Based on the Lamport's Theorem in Time, Clocks and the Ordering of Events in a Distributed System.* Preliminary report.

The purpose of this project is to introduce the structure of concurrency as knots. The idea behind a knot focuses on the number of crossing both under and over. Additionally, we look at the idea of adding two knots together to form a new knot. We explore these ideas to determine if this structure differs significantly and which if there are ideas open for further research. (Received February 09, 2017)

1128-55-152 **Robert M Owczarek*** (rowczare@unm.edu), Department of Mechanical Engineering, Department of Mathematics, Los Alamos, NM 87544. *Are there common features for Chebyshev polynomials, Lucas and Fibonacci polynomials, and Kauffman bracket formulation of the Jones polynomial?*

I will discuss intriguing relationships between Chebyshev polynomials of the first and the second kind, and Lucas and Fibonacci polynomials on one side, and their relationships with the Jones polynomial for knots defined using the Kauffman bracket, and its generalization inspired by the relationhips. (Received February 23, 2017)

1128-55-222 **Józef H. Przytycki** (przytyck@gwu.edu) and **Seung Yeop Yang*** (syyang@gwu.edu). *On quandle homology of the abelian extension of a quasigroup quandle.*

Rack homology is the first homology theory using right distributive structures, and it was modified to obtain state-sum invariants of knots and knotted spheres. A lot of research is being done on quandle homology of connected quandles, but not much is known about quandle homology of non-connected quandles. At the Knots in Hellas 2016 conference, Nosaka conjectured that for odd k the third quandle homology of the dihedral quandle of order $2k$ has $\mathbb{Z}_k \oplus \mathbb{Z}_k$-torsion.

We study annihilation of rack and quandle homology groups of the abelian extension of a quasigroup quandle, and based on it, we compute the torsion of its quandle homology. This is a joint work with Józef H. Przytycki. (Received February 27, 2017)

1128-55-250 **Bala Krishnamoorthy** and **Ben Rapone*** (benjamin.rapone@wsu.edu). *Minimum Homotopy Area of a Closed Curve.* Preliminary report.

We define and study the minimum homotopy area of generic closed curves in the plane as a measure of their topological complexity. We first choose two distinct points that divide the closed curve into two curves that start and end at these points. Homotopy area is then defined as the area swept by a homotopy defined between the two curves, and the minimum is considered over all possible homotopies for all choices of the pair of points. We study the computational aspects of this problem, where the closed curve has simple crossings (all are 4-way) and is embedded in $\mathbb{R}^2$. Under this settings we are able to reduce the number of choices of terminal points to a set of n^2 pairings, where n is the number of segments (edges) connecting the crossing points of the closed curve. In addition we are able to show that the minimum homotopy area will be an integer linear combination of its regions as defined by the closed curve. We present new approaches to characterize the complexity of this problem, which are based partly on results from contractibility of spaces. (Received February 27, 2017)

1128-55-252 **Bala Krishnamoorthy** and **Ben Rapone*** (benjamin.rapone@wsu.edu). *Minimum Homotopy Area of a Closed Curve.* Preliminary report.

We define and study the minimum homotopy area of generic closed curves in the plane as a measure of their topological complexity. We first choose two distinct points that divide the closed curve into two curves that start and end at these points. Homotopy area is then defined as the area swept by a homotopy defined between the two curves, and the minimum is considered over all possible homotopies for all choices of the pair of points. We study the computational aspects of this problem, where the closed curve has simple crossings (all are 4-way) and is embedded in $\mathbb{R}^2$. Under this settings we are able to reduce the number of choices of terminal points to a set of n^2 pairings, where n is the number of segments (edges) connecting the crossing points of the closed curve. In addition we are able to show that the minimum homotopy area will be an integer linear combination of its regions as defined by the closed curve. We present new approaches to characterize the complexity of this problem, which are based partly on results from contractibility of spaces. (Received February 27, 2017)

1128-55-291 **Emilie Purvine*** (emilie.purvine@pnnl.gov). *Applications and advances in topology of graphs.*

Graph and network data is ubiquitous in research domains from cyber security to transportation networks to biological interactions; network analysis typically focuses on standard properties like connectivity, clustering, and motif mining. However, these data sets can provide richer, more topological structure which may be ignored by network analysis. I will describe three areas of recent development in my work. First, the problem of evaluating system status in the domain of cyber security. Discrete topological spaces can be generated from the data and summarized using persistent homology or decomposed via combinatorial Hodge theory. These are compared to a baseline over time to discover abnormal behavior. Second, I will explore metric graphs, which arise in many application areas, and provide a complete characterization of the 1-dimensional intrinsic Čech persistence diagrams for metric graphs using persistent homology. This characterization can be used as a qualitative description to differentiate between metric graphs with significantly different topological structure. Finally, I will go beyond graphs to hypergraphs and their topological representations to motivate the use of higher order structure present in certain kinds of relational data, e.g., coauthorship networks. (Received February 28, 2017)

1128-55-294 **Cliff A Joslyn*** (cliff.joslyn@pnnl.gov), 1100 Dexter Ave # 400, Seattle, WA 98109. *Description Sheaves for Topological Information Fusion.*

Our research group has been exploring novel approaches in computational topology with application to information fusion and analysis. Our approach aims to bring methods in computational and applied toplogy to bear specifically on structured data analytics, where input sources take the form of multirelational or graphical data (as opposed to point clouds). In this context we focus on complex graph structures, specifically abstract simplicial complexes and hypergraphs (usually undirected, sometimes directed). This perspective supports a topological interpretation of hypergraphs, for example for measuring local homology; and dually network science interpretations of topological complexes. On this foundation, we then develop simplicial sheaves equipped with uncertainty quantification consistency structures to measure sensor error and sensitivity by identifying a filtration of specifically local sections. Future work aims at interpreting "data loops" through cohomology of these description sheaves, and moves towards predictive modeling with cosheaves and dual sheaves. We will demonstrate with initial applications in geolocation tracking. (Received February 28, 2017)

1128-55-295 **Jose Ceniceros*** (jcenic1@lsu.edu). *Legendrian/Transverse Knots and Knot Floer Homology.*

We will give an overview of knot theory supported in a contact 3-manifold with a focus on invariants of Legendrian and transverse knots that take values in knot Floer homology. We will also extend the definition of the BRAID invariant defined by Baldwin, Vela-Vick, Vertesi and define a new invariant that also takes values in knot Floer homology. (Received February 28, 2017)

1128-55-320 **Sepideh Nesaei*** (sepideh.nesaei@wsu.edu), vancouver, WA , and **Sahar Nesaei**. *Finding Structure In Cancer Gene Expression Data Using Topology.* Preliminary report.

We review a new method in data analysis of gene expression based on information given by tools from algebraic topology. Gene expression data sets are usually high dimensional-giving expressions of 50,000 or more genes for 100-200 subjects. Lockwood and Krishnamoorthy (2015) considered dualizing the data set, i.e., considering genes in the subject space, thus getting a much smaller dimensional problem. The found persistent topological features, i.e., holes, in several different cancer data sets thus dualized. We present the details of their work, and further explore how to analyze the stability and statistical significance of the identified features. (Received February 28, 2017)

1128-55-321 **Courtney M Thatcher*** (cthatcher@pugetsound.edu). *Comparing Directed and Weighted Graphs.*

Map construction algorithms exist for creating road maps from GPS data, but to assess the quality of these maps we need to be able to meaningfully compare different constructed road maps from the same region. Different approaches exist, but most model the road maps as undirected embedded planar graphs. In this talk we discuss an approach that compares more realistic models of road maps, ones that involve directed roads as well as weighted roads. We begin with some background, and then provide a method for comparing the same graph with two different annotations (such as weight functions and/or directions on the edges). The method broadly involves defining different filtrations that depend on the additional information on the graph, and then with persistent homology, determine the birth times of a set of cycles of interest, which can then be compared to determine the distance between the two different annotations. We then discuss how to extend these techniques to annotated graphs that are similar. (Received February 28, 2017)

1128-55-341 **Yuriy Mileyko*** (yury@math.hawaii.edu), Department of Mathematics, University of Hawaii at Manoa, 2565 McCarthy Mall, Honolulu, HI 96822. *Refinement based persistent (co)homology.*

Persistent homology has established itself as one of the main tools of topological data analysis, especially when it comes to point cloud data. In the latter case, the underlying idea is to find homology classes that are present across multiple scales, where the variation of scales is achieved by growing balls around the data points. While this approach has had a great success in many applications, it forces us to consider small scale homological features before any large scale features, which in many cases may lead to longer computation times and noisier results. In this talk we consider an approach where we track changes in homology not for a nested sequence of spaces (e.g. union of growing balls), but for a particular sequence of covers, each next cover being a refinement of the previous one. We will discuss how some theoretical results available for the filtration based persistent homology translate to the refinement based setting, and illustrate our approach on several examples. (Received February 28, 2017)

1128-55-342 **Joshua Cruz*** (joshua.cruz@duke.edu), Mathematics Department, 120 Science Drive, Rm 117 Physics Bldg, Durham, NC 27708. *Decomposing Vineyards using Sheaf Theory.* Preliminary report.

The theory of vineyards attempts to describe how persistence diagrams change over time. A vineyard is a continuous map from [0,1] into the space of persistence diagrams; it can be represented by a 3D image which looks like twisted vines. It is tempting to interpret each of these vines as a specific feature: perhaps as a connected component which is moving or a hole which is stretching. We give examples that show this cannot always be done. We also look at the theory of vineyards from a sheaf theoretic perspective, which sheds new light on the situation. For example, it does make sense to decompose a vineyard when the associated sheaf is a direct sum of smaller sheaves. This work is in collaboration with Justin Curry. (Received February 28, 2017)

1128-55-343 **Matthew S Broussard*** (mbroussard@math.wsu.edu). *Detecting Evasion Paths in Sensor Networks.*

In "Evasion paths in mobile sensor networks", Henry Adams and Gunnar Carlsson discuss necessary and sufficient conditions for the existence of an evasion path in a network of mobile ball-shaped planar sensors measuring connectivity and rotation information. I will discuss the results of Adams and Carlsson, expand on the reasoning behind their method, and perhaps discuss ways in which their method can be expanded to encompass sensors of alternate convex shapes. (Received February 28, 2017)

57 ► Manifolds and cell complexes

1128-57-11 **David Freund*** (dfreund@math.dartmouth.edu), Kemeny Hall, 27 North Main Street, Hanover, NH 03784. *Minimal Intersection Number of Flat Virtual Links.* Preliminary report.

Given two free homotopy classes of loops on a surface, it is natural to count the minimal number of intersection points up to stabilization and destabilization of the surface. We use generalizations of the Goldman Lie bracket and the Andersen–Mattes–Reshetikhin Poisson bracket to obtain lower bounds on this quantity. (Received October 14, 2016)

1128-57-19 **Heather M. Russell*** (hrussell@richmond.edu) and **Oliver T. Dasbach**. *Equivalence of edge bicolored graphs on surfaces.* Preliminary report.

Consider the collection of edge bicolored graphs cellularly embedded on some orientable surface. In this talk, we seek to count the number of equivalence classes of such graphs under two relations: reversing colors around a face and reversing colors around a vertex. In the case of the plane, this is well studied, but for other surfaces, the computation is more subtle. While this question can be stated purely graph theoretically, it has interesting connections to knot theory. (Received January 13, 2017)

1128-57-104 **Hayley Anne Olson*** (holson3@zagmail.gonzaga.edu), Gonzaga University, 502 E Boone Ave MSC#2615, Spokane, WA 99258. *Sharpening the Volume Bound on a Class of Hyperbolic Augmented Links.*

The purpose of this research is to analyze the similarities between two subclasses of hyperbolic links: fully augmented links and nested links. Results from this research show that octahedral nested links can be formed in a similar fashion to octahedral fully augmented links. Specifically, there is a class of nested links that are octahedral and their volume is determined by the number of crossing discs in the link diagram. (Received February 17, 2017)

1128-57-106 **Jim Hoste*** (jhoste@pitzer.edu), Pitzer College, Claremont, CA 91711, and **Colin Adams** and **Martin Palmer**. *Diagrammatic Moves on 3-Diagrams.* Preliminary report.

The classical theory of knots and links is often approached via link diagrams and Reidemeister moves. Recently, several papers have explored the topic of link diagrams with multi-crossings. In these diagrams, n strands are allowed to cross at a single point in the plane, creating what is known as an n-crossing. Many of the obvious results analogous to classical diagrams have been proven. However, until now, no analog of the Reidemeister moves have yet to be found for multicrossing diagrams. In this talk I will describe a set of 3-crossing diagram moves and prove that they are sufficient to pass between any two 3-crossing diagrams of the same knot. (Received February 17, 2017)

1128-57-113 **Kanako Oshiro*** (oshirok@sophia.ac.jp), Dept. of Information and Communication Scienc, Sophia University, 4-7 Yonban-cho, Chiyoda-ku, Tokyo, 1020081, Japan, and **Atsushi Ishii** (aishii@math.tsukuba.ac.jp), Institute of Mathematics, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki, 3058571, Japan. *Augmented Alexander matrices and generalizations of twisted Alexander invariants and quandle cocycle invariants.*

We introduce augmented Alexander matrices and show that several link invariants can be obtained from them. In particular, normalized twisted Alexander polynomials and quandle cocycle invariants are extracted from augmented Alexander matrices. (Received February 19, 2017)

1128-57-119 **Adam Lowrance*** (adlowrance@vassar.edu). *The Jones polynomial of an almost alternating link.* Preliminary report.

We use the Jones polynomial to study properties of almost alternating links. (Received February 20, 2017)

1128-57-131 **Steven R Beres*** (sberes@zagmail.gonzaga.edu), 502 E Boone Ave, Gonzaga University MSC#2615, Spokane, WA 99258, and **Rachael R Kuhn** (rkuhn@zagmail.gonzaga.edu), 502 E Boone Ave, Gonzaga University MSC#2615, Spokane, WA 99258. *Klein Knots and Links.*

The main goal of this project is to study and classify a collection of links known as Klein links. These links form a novel classification which has not been thoroughly studied. In particular, we specify the number and type of each knotted component in these links and which of them have an equivalent torus link. (Received February 22, 2017)

1128-57-141 **Christine Ruey Shan Lee*** (clee@math.utexas.edu). *Jones slopes and coarse volume for near-alternating links.*

We consider near-alternating links admitting a diagram where the number of crossing changes needed to obtain an alternating diagram is small compared to the number of the rest of the crossings. We show that with a mild diagrammatic condition, the Jones slopes of a near-alternating knot are realized by state surfaces, thereby verifying the Strong Slope Conjecture for these knots. In addition, we show that the colored Jones polynomial of a near-alternating knot has a tail, and we discuss geometric estimates on the knot complement from the first and second stable coefficients similar to those for an alternating knot. (Received February 22, 2017)

1128-57-160 **Natsumi Oyamaguchi***, 1-1 Daigaku-cho, Yachiyo, Chiba 276-0003. *A table of prime 2-bouquet graphs with up to seven crossings.*

We enumerate spatial 2-bouquet graphs, or spatial graphs having exactly one 4-valent vertex and no other vertices, up to rigid vertex isotopy. In order to do that, we give a method of constructing all such graphs from 2-string tangles, and distinguish the resulting graphs by computing their Yamada polynomials. We provide a table of prime spatial 2-bouquet graphs with up to seven crossings. (Received February 24, 2017)

1128-57-186 **Carmen Caprau***, 5245 N. Backer Avenue M/S PB 108, Fresno, CA 93740, and **Sarah McGahan**. *On the virtual singular braid monoid.* Preliminary report.

We describe a new categorical model for the virtual singular braid monoid in terms of a strict monoidal category. (Received February 25, 2017)

1128-57-197 **Safia Chettih***, safia@reed.edu. *Configurations with Sinks and on Graphs.* Preliminary report.

Given a graph Γ, we can construct discretized models for its n-point configuration space that are cubical complexes. The model constructed by A. Abrams in his 2000 PhD thesis is the most well-known, but in 2001 J. Świątkowski constructed a lesser-known model whose dimension stabilizes as the number of points increases. In recent work with D. Lütgehetmann, we have considered a Świątkowski-style discretized model for configurations with sinks, where multiple points are allowed to occupy certain vertices of the graph. In my talk, I will discuss these various constructions and their implications for the topology of ordered configuration spaces of graphs. (Received February 26, 2017)

1128-57-209 **Patricia Cahn*** (pcahn@smith.edu) and **Alexandra Kjuchukova**. *Signatures of 4-manifolds via linking numbers of knots in dihedral covers of S^3.*

We give an algorithm for computing the linking number of two knots in a 3-manifold, where the 3-manifold is presented as an irregular 3-fold dihedral cover of S^3 branched along a knot. We then use these linking numbers, together with a formula of Kjuchukova, to compute signatures of 4-manifolds which arise as irregular dihedral covers of S^4. (Received February 27, 2017)

1128-57-230 **Sujoy Mukherjee*** (sujoymukherjee@gwu.edu). *Properties of lbo homology.* Preliminary report.

Lbo homology is more interesting than one-term or two-term distributive homology for certain families of associative shelves. After a brief introduction to lbo homology using pre-simplicial sets, I will discuss the geometric realization corresponding to the pre-simplicial set leading to lbo homology. I will then describe my attempts to connect lbo homology to knot theory via Temperley-Lieb algebras. (Received February 27, 2017)

1128-57-238 **Alex Brandts**, **Tali Pinsky** and **Lior Silberman*** (lior@math.ubc.ca). *Volumes of hyperbolic three-manifolds associated to modular links.*

Periodic geodesics on the modular surface correspond to periodic orbits of the geodesic flow in its unit tangent bundle $\mathrm{PSL}_2(\mathbb{Z})\backslash\mathrm{PSL}_2(\mathbb{R})$. The complement in the tangent bundle of any finite number of orbits is a hyperbolic 3-manifold, which thus has a well-defined volume.

We present strong numerical evidence that, in the case of the set of geodesics corresponding to the ideal class group of a real quadratic field, the volume of the complement has linear asymptotics in terms of the total length of the geodesics. This is not the case for general sets of geodesics. (Received February 27, 2017)

1128-57-253 **Sujoy Mukherjee**, **Józef H. Przytycki**, **Marithania Silvero**, **Xiao Wang*** (wangxiao@gwu.edu) and **Seung Yeop Yang**. *Search for torsion in Khovanov homology.*

In the Khovanov homology of links, presence of $\mathbb{Z}_2$-torsion is a very common phenomenon. Finite number of examples of knots with $\mathbb{Z}_n$-torsion for $n > 2$ were also known, none for $n > 8$. In this paper, we prove that there are infinite families of links whose Khovanov homology contains $\mathbb{Z}_n$-torsion for $2 < n < 9$ and $\mathbb{Z}_{2^s}$-torsion for $s < 24$. We also introduce 4-braid links with $\mathbb{Z}_3$-torsion which are counterexamples to the PS braid conjecture. We also provide an infinite family of knots with $\mathbb{Z}_5$-torsion in reduced Khovanov homology and $\mathbb{Z}_3$-torsion in odd Khovanov homology. (Received February 27, 2017)

1128-57-265 **Radmila Sazdanovic*** (rsazdan@ncsu.edu), Department of Mathematis, NC State, PO Box 8205, Raleigh, NC 27695, and **Adam Lowrance**. *Torsion in Khovanov link homology.*

In this talk we offer further insight into torsion of Khovanov link homology via an isomorphism with the chromatic cohomology that categorifies the chromatic polynomial of a graph related to the link. In particular, we show that the categorification of the chromatic polynomial only contains torsion of order two, and hence Khovanov homology only contains torsion of order two in the gradings where the isomorphism is defined. (Received February 28, 2017)

1128-57-274 **Jozef H. Przytycki*** (przytyc@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20 052, and **Marithania Silvero**. *Does extreme Khovanov homology lead to bouquets of spheres?*

It was proven by González-Meneses, Manchón and Silvero that the extreme Khovanov homology of a link diagram is isomorphic to the reduced (co)homology of the independence simplicial complex obtained from a bipartite circle graph constructed from the diagram. In this talk we conjecture that this simplicial complex is always homotopy equivalent to a wedge of spheres. In particular, its homotopy type, if not contractible, would be a link invariant and it would imply that the extreme Khovanov homology of any link diagram does not contain torsion. We prove the conjecture in many special cases and find it convincing to generalize it to every circle graph (intersection graph of chords in a circle). In particular, we prove it for the families of cactus, outerplanar, permutation and non-nested graphs. Conversely, we also give a method for constructing a permutation graph whose independence simplicial complex is homotopy equivalent to any given finite wedge of spheres. We outline also a program how to find a finite geometric realization of the almost extreme Khovanov homology. (Received February 28, 2017)

1128-57-283 **M K Dabkowski*** (mdab@utdallas.edu) and **J H Przytycki** (przytyck@gwu.edu). *Catalan States of Lattice Crossing: Application of Plucking Polynomial.*

Let $L(m,n)$ be an $m \times n$-tangle obtained by placing n parallel vertical lines above m parallel horizontal lines. For a Catalan connection C obtained as a Kauffman state of $L(m,n)$ we consider the problem of finding its coefficient $C\,(A)$ in the Relative Kauffman Bracket Skein Module of $D^2 \times I$ with $2\,(m+n)$-points fixed on the boundary. We show that, if C has returns only on the ceiling, then $C\,(A)$ has a closed form formulae in terms of Gaussian polynomials. For C with no returns on the tangle's floor, the coefficient $C\,(A)$ can be determined by computing the plucking polynomial Q with a delay function of the associated rooted tree $T\,(C)$. (Received February 28, 2017)

1128-57-299 **Jozef H. Przytycki*** (przytyc@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20 052. *Geometric realization of partial presimplicial sets and the almost extreme Khovanov homology.*

We say that (X_n, d_i) is a partial presimplicial set if

(1) (kX_n, d_i) is a presimplicial module, that is $d_i d_j = d_{j-1} d_i$ for $i < j$, and

(2) for any $x_n \in X_n$ we have $d_i(x_n) \in X_{n-1}$ or $d_i(x_n) = 0$.

Almost presimplicial set allows a standard geometric realization: if $d_i(x_n) = 0$ then the ith face of $x_n \times \Delta^n$ is contracted. We show that almost extreme Khovanov homology of a B-adequate link can be obtained from an almost presimplicial set giving a finite CW complex geometric realization. In particular we show that for the trefoil knot its geometric realization is a projective plane, RP^2. We conjecture that the geometric realization will be homotopy equivalent either to S^m or the suspension $\Sigma^{m-2} RP^2$ depending on whether the $B-$ state graph is bipartite or contains an odd cycle. $m+1$ is the number of crossings of considered link diagram. For example for the figure eight knot we obtain ΣRP^2. We outline a proof of the conjecture which is based on the previous work of R.Sazdanovic and M.Silvero with the author. (Received February 28, 2017)

1128-57-331 **Krzysztof K. Putyra** and **Alexander N. Shumakovitch*** (shurik@gwu.edu), 801 22nd St., NW, Phillips Hall, Suite 739, Department of Mathematics, The George Washington University, Washington, DC 20052. *On unified Khovanov homology and its computations.* Preliminary report.

It was shown by Putyra that even and odd Khovanov homology can be combined into a unified Khovanov homology theory. Unified Khovanov homology groups have the structure of modules over the group ring $\mathbb{Z}\mathbb{Z}_2$ with a convenient pullback presentation. We start by showing that these modules are always separated. As such, they admit algorithmic classification as a direct product of indecomposable $\mathbb{Z}\mathbb{Z}_2$-modules which, in turn, were classified by Levy. This allows one to compare unified Khovanov homology for different knots and links. We present evidence that the unified Khovanov homology is a stronger knot invariant than the even and odd Khovanov homology combined. (Received February 28, 2017)

58 ► *Global analysis, analysis on manifolds*

1128-58-47 **Steve Zelditch***, Steve Zelditch, Department of Mathematics, Northwestern University, Evanston, IL , and **Peng Zhou**. *Interfaces in spectral and Berman kernel asymptotics.*

In Schrodinger equations $h^2\Delta + V$ with $V \geq 0$, it is well-known there for each energy level E there is an allowed region $V \leq E$ and a forbidden region $V > E$, separated by the caustic $V = E$. The asymptotics of spectral projections $\Pi_{h,E}$ kernels abruptly changes along the caustic. In the case of the isotropic Harmonic oscillator, the scaling limit of $\Pi_{h,E}$ is an Airy kernel (precisely the Tracy-Widom Airy kernel in dimension 3). This is probably universal for Schrodinger operators. There is an analogous problem in phase space. If one uses the complex holomorphic representation, there is a zone around the energy surface in which the kernel has an incomplete Gaussian shape, smoothly transitioning from 1 to 0 across the surface. A boundary also provides an interface but time will not permit a discussion of that.

This talk reviews joint work with Boris Hanin and Peng Zhou for Schrodinger operators and Peng Zhou for Bergman kernels which prove the interface asymptotics. (Received February 05, 2017)

1128-58-52 **Tanya Christiansen** and **Kiril Datchev*** (kdatchev@purdue.edu). *Resolvent estimates and wave asymptotics for mildly trapping manifolds with cylindrical ends.*

Manifolds with infinite cylindrical ends have continuous spectrum of increasing multiplicity as energy grows, and in general embedded resonances and eigenvalues can accumulate at infinity. However, we prove that if geodesic trapping is sufficiently mild, then such an accumulation is ruled out, and moreover the cutoff resolvent is uniformly bounded at high energies.

We deduce from this the existence of resonance free regions and compute asymptotic expansions for solutions of the wave equation. (Received February 06, 2017)

1128-58-80 **Eric Foley*** (efoley92@live.com). *The Inverse and Implicit Function Theorems.* Preliminary report.

We will discuss the proof and applications of the implicit and inverse functions theorems. In doing so will show their equivalence. Finally these theorems will be generalized and we will show how they are special cases of the constant rank theorem. (Received February 14, 2017)

60 ► *Probability theory and stochastic processes*

1128-60-9 **Rohini Kumar** and **Hussein Nasralah*** (hussein.nasralah@wayne.edu). *Portfolio optimization near horizon.*

Portfolio optimization is a well-known problem in mathematical finance concerned with selecting a portfolio which maximizes the expected terminal utility of an investor given today's information and subject to some constraints. We approach this problem from a partial differential equations (PDE) perspective. We find a closed-form formula for a portfolio under which the expected utility is asymptotically close to optimal under small time horizon. This is done by analyzing the problem via its associated Hamilton-Jacobi-Bellman (HJB) equation. Specifically, we work with the "marginal HJB equation." We find a classical sub- and super-solution to the marginal HJB equation. A comparison principle argument for a logarithmic transformation of the marginal HJB equation then yields the result. (Received September 22, 2016)

1128-60-74 **Rui Huang*** (huangr@me.com), 1455 NE BRANDI WAY DD104, PULLMAN, WA 99163. *Nested Archimedean Copulas and Tail Dependences.*

In probability theory, a copula is defined as a joint multivariate distribution where each of its margins is uniform and has been widely studied and applied in the risk management and actuarial world. People in this field believe that the devil is in the tail and we endeavor to watch tail dependence very closely.

In this paper, I will start with the definition, properties, tail dependence structures, advantages and limitations of copulas, and then progress to focus on Archimedean copulas and its hierarchical structure which is often referred as nested Archimedean copulas.

Data were simulated under both hierarchical and non-hierarchical structures, in contrast with the enhancement in tail dependence coefficients.

The degree of influence/stress of the inner and outer parameters that are exerting on the dependence structure of the nested Archimedean copulas will also be explored. (Received February 12, 2017)

1128-60-185 **hong qian***, University of Washington, Department of Applied Mathematics, Seattle, WA 98195. *A mathematical theory of biological population dynamics: From cells to ecology, small and large systems with and without stochasticity.*

Complex dynamics of interacting populations of intrinsically stochastic individuals can be mathematically represented by a discrete-state, continuous-time Markov jump process. T. G. Kurtz's theorem establishes a relation between this stochastic process, in the limit of a system's size tending infinity, and the traditional dynamical systems based on ODEs. We apply this theory to several problems in current cell biology in terms of the biochemical constituents, and illustrate the emergent notions of epigenetic phenotypes and their switching, and relation to the classical idea of phase transition. We show the existence of an emergent nonequilibrium landscape, as a generalization of J. W. Gibbs' energy function, for nearly any complex dynamics. We discover a rather surprising underlying mathematical structure, with geometric and thermodynamic implications. (Received February 25, 2017)

1128-60-240 **Ellie Bayat*** (elham.bayatmokhtari@umconnect.umt.edu), Department of Mathematical Sciences, University of Montana, 32 Campus Drive, Missoula, MT 59812-0864, and **Emily F. Stone**. *GABAergic Synaptic Mechanisms in Information Transmission.*

I review some of the techniques of information theory and how they relate to neuroscience in quantitative manner. Furthermore, I use a mathematical model fitted to experimental data recorded from synaptically connected pairs of neurons in mouse hippocampal. Next, I quantify the information contained in the amplitude of the postsynaptic response induced by Poisson spike trains about the preceding interspike intervals in both deterministic and stochastic models of GABAergic synapses. While the stochastic model takes into account the variability introduced by probabilistic nature of vesicle release, the deterministic synapse model imposes a linear filter. This additional variability plays an important role in reducing over all information transmission compared to the deterministic model. Also, I measure the information transmission efficiency of this synapse using extitinformation efficacy, defined as the fraction of the information within total entropy of responses. Using information efficacy measure, it is found that the probabilistic effect is not uniform over all frequencies. It has the greatest effect in reducing information transmission at very low and very high frequencies, while this effect is negligible at the optimal frequency. (Received February 28, 2017)

1128-60-289 **Gabrielle I. Warren***, Department of Mathematics, 204 S College Ave, College Place, WA 99324, and **Benjamin D. Jackson**. *Finding Order in Chaos: Modeling Hidden Markov States.* Preliminary report.

A hidden Markov model (HMM) is a stochastic process in which the relationship between the number of states and the observations is not one-to-one. HMMs are often used in speech recognition programs, bioinformatics, and scoring protein-ligand interactions in structure-based drug design. Detecting hidden states from noisy data is generally difficult. We illustrate a possible retrieval algorithm using synthetic data which was created in R by implementing a low dimensional HMM. (Received February 28, 2017)

62 ► Statistics

1128-62-34 **Jie Zhao*** (jie.zhao@wsu.edu), Neill222, Washington State University, Pullman, WA 99163, and **Robert H. Dillon**, Neill 324, Washington State University, Pullman, WA 99163. *Bayesian Network and Parameter Estimation for the nonlinear ODE System.* Preliminary report.

Differential equation models are widely used in many scientific fields that include engineering, physics , chemistry and biosciences. The solution of the differential equation system given initial values and coefficients are often unique if it is continuously differentiable. However, most systems are not solvable analytically. This makes it harder to determine the uncertainties, such as initial values or coefficients (called parameters) by using data-fitting method. Most current parameter estimation methods based on the local smoothing and some least squares-based approaches under a framework of measurement error. Their typical problems are subject to high computational cost, sensitivity to initial values or large sampling variability. This paper presents a method for estimating an nonlinear ordinary differential equation model with partially observed data and derive a parallel MCMC simulation method for a hierarchical Bayesian inference model. It can improve the convergence of the fit and avoid converging a local minima. The efficacy of the new method is illustrated by simulations and a real time-series data of $TGF\beta$ and $SDF-1$ signaling pathways in breast cancer. (Received January 31, 2017)

1128-62-107 **YAN XING*** (yanz.xing@wsu.edu), Department of Mathematics and Statistics, Washington State University, Pullman, WA 99164. *Tail Mutual Information of Multivariate Distributions.* Preliminary report.

Abstract: The mutual information (MI) of multiple random variables measures statistical dependence among the variables. Using conditional mutual information, we introduce tail mutual information that measures dependence among multivariate extremes. We show that the conditional mutual information can be expressed in terms of the underlying copula of a multivariate distribution, and that tail mutual information depends only on the tail density of the underlying copula. Our results establish a powerful invariance property of tail mutual information under monotone marginal transformation, which is useful in extreme value analysis. (Received February 17, 2017)

1128-62-134 **Quresh S Latif*** (qlatif@fs.fed.us), 1648 South 7th Ave., Bozeman, MT 59717, **Martha M Ellis** (marthamellis@fs.fed.us), 1648 South 7th Ave., Bozeman, MT 59717, **Victoria A Saab** (vsaab@fs.fed.us), Rocky Mountain Research Station, U.S. Forest, Bozeman, MT 59717, and **Kim Mellen-McLean** (kmellenmclean@fs.fed.us), Pacific Northwest Region 6, U.S. Forest Servi, Portland, OR 97204. *Simulation power analysis informs design of regional occupancy monitoring for a forest management focal species.*

White-headed woodpeckers (Picoides albolvartus) specialize on disturbance-maintained dry conifer forest habitats, making them a focal species for informing forest management. Insufficient information on population trends, however, challenges conservation and funding prioritization for this species. We employed population simulations to inform regional occupancy monitoring of this species by comparing statistical power and trend estimation error for alternative sampling and trend scenarios. Adequate power ($\geq$ 80%) to observe a long-term trend (2% yearly decline over 20 years) required monitoring $\geq$ 120 or $\geq$ 90 transects with single or repeat surveys, respectively. Employing occupancy as an index of abundance with single surveys provided the most power for a given level of sampling effort. We were also able to improve power and reduce estimation error by surveying a subset (33%) of transects each year (i.e., a panel design) and surveying fewer points per transect in exchange for a larger spatial sample. Single-survey methods with auxiliary sampling for detectability, panel designs, and aligning sampling resolution with home range size could generally benefit occupancy monitoring of sparsely distributed and territorial species. (Received February 23, 2017)

1128-62-215 **Hongbo Dong*** (hongbo.dong@wsu.edu), Washington State University, Pullman, WA 98103, **Wei Li**, WA , and **Haijun Li**. *Faster estimation and calculation of standard errors for vine copulas with automatic differentiation.* Preliminary report.

Vine copula is a flexible tool for modeling the dependence structure of multivariate continuous random variables. It is especially useful in situations where the standard Gaussian assumption is problematic. Current computational practice for maximum likelihood estimation, as well as calculating standard errors, suffers from the bottleneck of slow calculation of gradients. In this talk we will give a brief introduction on the vine copula model, its connections with Gaussian graphical models, and demonstrate that automatic differentiation tools can improve the current computation by orders of magnitude. We will also report some recent progress of integrating automatic differentiation into improve the state-of-the-art R package VineCopula. (Received February 27, 2017)

1128-62-216 **Md Bahadur Badsha**, **Evan Martin** and **Audrey Qiuyan Fu*** (audreyf@uidaho.edu). *Statistical methods for causal inference in genomics.*

How do genes regulate the expression of one another? Is it possible to learn the regulatory (or causal) relationships directly from vast amounts of observational genomic data? Mendelian Randomization (MR) makes tackling these questions possible. MR views genetic variants (SNPs, indels, and copy number variation) in a natural population as perturbations randomly performed by Nature, and provides a reasonable and potentially powerful assumption for studying causal relationships among genes. We develop machine learning and Bayesian methods in order to learn gene regulatory networks from genotype and expression data, which have directed edges that indicate causal relationships between pairs of genes. In methodology development, we also deal with several other challenges, such as controlling the false discovery rate, as well as reducing the impact of outliers. I will illustrate the performance of our methods on simulation data as well as The Cancer Genome Atlas (TCGA) data on breast cancer patients. (Received February 27, 2017)

1128-62-262 **Jillian Jinelle Morrison*** (jillian.morrison@wsu.edu), 1615 NW DEANE ST, Pullmam, WA 99163. *Student's Perceived Barriers to Higher Education in Belize.*

Belize is located in Central America and has a population of 331,900 in 2013 according to the World Bank. As of 2014/2015, there were 21,004 (4,135 in form 4) students enrolled in Secondary Schools and 8562 students enrolled in a Junior College or University according to the Ministry of Education of Belize. There is not data on how many of these students continue on to Tertiary level institutions, but, the MOE notes that many of the students are not pursuing higher education. For a preliminary/pilot study, ordinal data has been collected from form 4 students from 2 high schools in Belize based on students perceived barriers to higher education in Belize. The proportional odds model, likert scale and the Generalized Quasi Likelihood Model were all applied to the data. Results from all three models were similar in that most students claimed to be most likely or definitely sure that they would attend a tertiary level institution. This conclusion is likely to change once the entire data set has been collected. (Received February 28, 2017)

65 ► Numerical analysis

1128-65-127 **Yves Nievergelt*** (`ynievergelt@ewu.edu`), Eastern Washington University, Department of Mathematics, 216 Kingston Hall, Cheney, WA 99004. *Binary Floating-Point Subtraction of a Floating-Point Square Accurate to the Antepenultimate Digit by Deflation Without Fused Multiply-Subtract or Fused Multiply-Add.*

Differences of the form $r^2 - s$ occur, for instance, in Newton's Method to compute $\sqrt{s}$, and in the calculation of the discriminant of a monic quadratic polynomial $x^2 + 2rx + s$. To compute $r^2 - s$ accurately to the antepenultimate digit on computing systems lacking fused multiply-add and fused multiply-subtract, an algorithm is presented here that produces floating-point numbers $\hat{r}$ and $\hat{s}$ with smaller magnitudes and more trailing zeroes such that $\hat{r}^2 - \hat{s} = r^2 - s$. The algorithm may be iterated or its first result $(\hat{r}, \hat{s})$ delivered to W. Kahan's `DISC` algorithm to compute $\mathtt{DISC}(1, \hat{r}, \hat{s}) = \hat{r}^2 - \hat{s} \cdot 1$ (`www.dtic.mil/dtic/tr/fulltext/u2/a206859.pdf`). While `DISC` bases the size of each reduction on r, the algorithm presented here uses s. (Received February 21, 2017)

1128-65-279 **Marc Louis Klasky*** (`mklasky@lanl.gov`), Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545, and **Michelle Espy** and **David Moir**. *Determination of Photon Energy Spectra using Compton Spectrometer.*

The determination of the photon energy spectrum produced by radiographic systems is important in performing radiographic analyses at Los Alamos National Laboratory. Recently, a Compton Spectrometer has been fielded to perform measurements at both the Dual Axis Hydrodynamic Radiographic Test Facility as well as the Los Alamos Microtron. These experiments involve the production of electrons, via a Compton scattering interaction on a convertor target, that are then focused with a magnetic field onto an phosphor image plane. Previously to infer the incident photon spectra assumptions were made regarding the localization of the electrons attributed to a particular photon energy on the image plane. Furthermore, multiple scattering interactions and pair production interactions on the convertor target were ignored. In this presentation we will present a much more powerful method of solving this Inverse Problem utilizing point spread functions calculated with MCNP incorporating the magnetic fields. Application of the point spread functions then allows for the construction of a linear set of equations to be obtained. A simple least squares solution may then be utilized to reconstruct the incident photon energy spectra. (Received February 28, 2017)

68 ► Computer science

1128-68-14 **L. Nate Veldt*** (`lveldt@purdue.edu`), 20 Bridgewater Ct #1, Lafayette, IN 47909. *A Polynomial Time Solution for Correlation Clustering on Low-Rank Positive Semidefinite Matrices.*

Correlation clustering is the computationally challenging problem of partitioning a signed graph in a way that maximizes the weight of positive edges connecting nodes in the same cluster plus the weight of negative edges that link nodes in separate clusters. In this talk I will show that the problem admits a polynomial time solution on graphs whose adjacency matrix is low-rank and positive semidefinite. This yields several applications in clustering datasets that are inherently low-dimensional, and provides a method for clustering any unsigned graph by first projecting its vertices into a low-dimensional feature space. (Received December 23, 2016)

1128-68-93 **Prashant Gupta*** (`pragpt100@gmail.com`), 880 NE PROVIDENCE CT APT C301, PULLMAN, WA 99163-5800. *Convolution neural network for sentence classification of text data.*

When we talk about Convolution Neural Network(CNNs), we classically think of computer vision problems. CNNs are responsible for major advances in image classification and are backbone of many computer vision systems today, from self-driving cars to Facebook's automated photo tagging. More lately we started to apply CNN's to problems in natural language processing and seen some interesting results. I will summarize what CNNs are and how they are used in NLP. (Received February 15, 2017)

1128-68-112 **Mahantesh Halappanavar*** (`hala@pnnl.gov`), **Ananth Kalyanaraman**, **Hao Lu**, **Craig Bakker** and **Arun Sathanur**. *Mining for Communities in Large-Scale Graphs.*
Graph clustering (or community detection) is a fundamental graph kernel with numerous applications in science and data analysis. The goal of clustering is to partition the vertices into subsets that are tightly connected within but sparsely with the rest of the graph. The ubiquity of large-scale data drives the need for scalable clustering on graphs with diverse characteristics. Parallel clustering algorithms are challenging due to the inherently serial nature of current algorithms. In this talk I will present challenges and recent algorithmic advances for efficient parallel community detection. (Received February 19, 2017)

1128-68-116 **Austin R Benson*** (`arbenson@stanford.edu`), **David F Gleich**, **Jure Leskovec** and **Hao Yin**. *Higher-order graph clustering.*
Networks are typically described by lower-order connectivity patterns that are captured at the level of individual nodes and edges. However, higher-order connectivity patterns captured by small subgraphs, or network motifs, describe the fundamental structures that control and mediate the behavior of many complex systems. In this talk, I will discuss a higher-order graph clustering framework that finds groups of nodes that participate in many instances of a given motif. I will also show applications of this framework in ecology, biology, transportation, and social networks. (Received February 20, 2017)

1128-68-120 **Jevin D West*** (`jevinw@uw.edu`), University of Washington, Information School, Box 352840, Seattle, WA 98195, and **Jason Portenoy**. *An information theoretic approach for hierarchically clustering large acyclic graphs.* Preliminary report.
Many real-world networks are acyclic and far from ergodic. Time directed networks are a common example. A random walker released on this kind of network will walk inexorably backwards in time. These kinds of networks pose challenges to many flow-based clustering algorithms. This talk will examine nuances and modifications of the hierarchical mapequation for addressing these challenges. This will include a discussion on scaling the algorithm to citation networks with hundreds of millions of nodes and billions of links. (Received February 20, 2017)

1128-68-123 **Amir Ghasemian***, amgh5286@colorado.edu, and **Pan Zhang**, **Aaron Clauset**, **Cristopher Moore** and **Leto Peel**. *Detectability Limits in Dynamic Networks.*
Detectability limit is an interesting question in the extensively studied community detection problem. In this work we study the detectability limit in dynamic networks. Our model for dynamic networks (which is a special case of many other models) characterizes the interactions independently at each time slot through the regular stochastic block model (SBM) and the role assignments of each node are modeled as a markov chain across the time dimension. Using this model we will find the detectability threshold of dynamic networks as a function of rate of change and the strength of communities. Below this threshold we claim that no efficient algorithms can identify the communities better than chance. We also propose two algorithms that are optimal in the sense that they succeed all the way down to this threshold. The first algorithm uses belief propagation to infer the role assignments, which gives asymptotically the optimal accuracy, and the second one is a fast spectral clustering algorithm based on linearizing the BP equations around the trivial fixed point solutions. (Received February 21, 2017)

1128-68-154 **Arun V Sathanur*** (`arun.sathanur@pnnl.gov`). *Accelerating the mining of influential nodes in a complex network via community detection.*
A wide array of natural and artificial complex systems such as social, biological, cyber and power networks are characterized by interconnected entities that are best analyzed by graph-based approaches. A particular problem that has received a lot of interest is the identification of the set of influential nodes in a given complex network that have maximal impact on the network according to a given criterion. This has been tackled formally in the literature by the so-called influence maximization problem that exploits the sub-modular nature of the reachability-based objective function. However, these algorithms are associated with high computational cost. In this talk, we present some initial results on exploiting the existence of communities in complex networks to accelerate the mining of influential seeds. For a specific variant of the influence maximization problem, we show a formulation based on random walk with restart that allows us to compute the node-to-node influence in a

complex network and point out how community detection can help accelerate this process as well. (Received February 23, 2017)

1128-68-181 **Assefaw H Gebremedhin*** (assefaw@eecs.wsu.edu). *Algorithms and Software for Efficient Computation of Sparse Derivative Matrices.*

Many algorithms for nonlinear optimization, including those used in computer vision, rely on computation of derivatives. Such algorithms can benefit greatly from Algorithmic (or Automatic) Differentiation (AD), a technology for transforming a computer program for computing a function into a program for computing the function's derivatives. In this talk, we will give an overview of theory, algorithms and software we have developed over the years to enable efficient computation of derivative matrices – in particular, Jacobians and Hessians – using AD when the matrices are sparse, which is typically the case in large-scale problems. A fundamental technique that has proven effective in exploiting sparsity in large Jacobians and Hessians is computation via compression. Intuitively, the idea here is to reduce computational cost by calculating groups of columns of a derivative matrix at a time instead of calculating a single column at a time. We will discuss graph-theoretic models and algorithms we developed to address the underlying need for partitioning the columns of a matrix into groups that are amenable for such compression-based computation. (Received February 25, 2017)

1128-68-203 **Predrag T. Tosic*** (predrag.tosic7@yahoo.com), School of EECS, and Department of Mathematics & Statistics, Washington State University, Pullman, WA 99164. *On Quantitative Models of Associative Memory from Discrete Dynamical Systems and Computer Science Standpoints.*

It has been argued that complex behavior in many biological systems, including human and animal brains, is to a considerable extent a consequence of high interconnectedness among the individual elements, such as neurons. Hopfield Networks are a popular mathematical and computational model of associative memory. It has been posited that the theoretically and experimentally established complexity of possible dynamics of Hopfield Nets is largely due to their typically high level of interconnectedness. We show, however, that many aspects of provably complex, and practically unpredictable, behavior can be obtained in very sparsely connected Hopfield networks. In particular, we have shown that the most fundamental problems about the memory capacity of an associative memory are computationally intractable, even for restricted types of networks that are uniformly sparse, with only a handful of neighbors per each node. One implication is that some of the most fundamental aspects of biological networks' dynamics do not require global or even local high density, in order to exhibit provably complex, computationally intractable behavior. (Received February 26, 2017)

1128-68-236 **Ethan Moon Mahintorabi*** (emahintorabi@zagmail.gonzaga.edu) and **Justin Dickinson Marks** (marksj@gonzaga.edu). *Piracy Detection Algorithms for Obfuscated Copyrighted Videos.* Preliminary report.

Finding the nearest neighbor in a set of images and videos is of great interest to those seeking to assign a class label to a particular novel image or video. Specifically, researchers are interested in detecting piracy, namely, they would like to flag videos that are modified versions of copyrighted videos found in a database. Current methods for detecting video piracy use a combination of an image hashing algorithm like p-hash and a Hamming distance metric tree. We seek to use multiple-instance generated subspaces, i.e. Grassmann manifold points, to improve the accuracy of a piracy detection algorithm, and we compare the performance to state-of-the-art single-instance methods. Our presentation will clearly motivate and illustrate the suite of piracy detection algorithms. (Received February 27, 2017)

1128-68-248 **Alexandra Probst*** (alli.asap@gmail.com), University of Washington, Seattle, WA 98105, **Demetrios Gatziolis**, Pacific Northwest Research Station, US Forest, Portland, OR , and **Nikolay S Strigul** (nick.strigul@wsu.edu), Washington State University Vancouver, Vancouver, WA 98686. *Intercomparison of photogrammetry methods for 3D modeling of vegetation.*

Structure-from-Motion based 3D reconstruction of objects is becoming increasingly appealing in research areas unrelated to computer vision. In forestry in particular, 3D modeling facilitates the assessment of forest inventory-related parameters, and has the potential to become a standard tool for forestry surveys. We have compared several photogrammetric algorithms with respect to their utility in 3D modeling of vegetation. We selected six popular photogrammetry programs for this purpose: VisualSFM, CMPMVS, MVE, OpenMVS, SURE and Agisoft PhotoScan and assessed their performances in two different settings, namely, (a) a virtual reality scene where the precise location and dimensionality of objects is known, rendering them conducive to a quantitative comparison, and (b) using series of in-situ acquired photographs of vegetation where the photogrammetric outcomes are qualitatively compared. Performance was quantified by computing ROC curves summarizing the type-I and type-II errors between the reference and reconstructed tree models. (Received February 27, 2017)

1128-68-352 **Sudipta N Sinha*** (sudipta.sinha@gmail.com), One Microsoft Way, Redmond, WA 98052. *A brief tour of optimization methods used in 3D computer vision.*

3D scene reconstruction from multiple images is a fundamental topic in computer vision which has witnessed rapid progress in the last two decades. It involves recovering 3D shape, appearance and motion of objects in imagery and requires solving a range of parameter estimation problems that are typically formulated as optimization problems. Many vision problems are inherently ill-posed and require appropriate regularization to deal with noise and ambiguities in the input.

I will briefly review applications of nonlinear continuous optimization for geometric problems such as structure from motion and dense 3D reconstruction. I will also discuss discrete and continuous energy minimization methods used in low-level vision tasks such as stereo matching and optical flow estimation which involve assigning each image pixel a suitable label. Such pixel labeling tasks are naturally formulated as optimization problems which are equivalent to maximum a posteriori (MAP) estimation of Markov Random Field models.

I will also describe my recent work with Tatsunori Taniai and Yoichi Sato from University of Tokyo on MAP inference on hierarchical Markov Random Fields motivated by the task of joint recovery of dense semantic correspondence and cosegmentation in pairs of images. (Received March 01, 2017)

70 ► Mechanics of particles and systems

1128-70-206 **Paula R. Kimmerling*** (paula.kimmerling@wsu.edu), 1455 NE Brandi Way Apt. C204, Pullman, WA 99163, and **Jacob W. Hastings**. *Analyzing the Algebra of the Schrödinger Equation.*

This poster will explore algebraic interpretations of the Schrödinger Equation. When dealing with a system of multiple particles or of higher dimension, the energy eigenstates of the Schrödinger Equation are degenerate. Generally, degeneracy implies that an algebraic interpretation exists. We wish to demonstrate that such an interpretation also exists regarding these eigenstates and, in addition, we will explore the implications of this interpretation. (Received February 27, 2017)

76 ► Fluid mechanics

1128-76-50 **Manil Thankamani Mohan*** (manil.thankamanimohan@afit.edu), Department of Mathematics and Statistics, 2950 Hobson Way, Building 641, Room 227 A, Wright-Patterson Air Force Base, Dayton, OH 45433, and **Sivaguru S Sritharan** (sivaguru.sritharan@afit.edu), Air Force Institute of Technology, 2950 Hobson Way, Building 646 Room 301, Wright Patterson Air Force Base, Dayton, OH 45433. *Stochastic Quasilinear Evolution Equations in UMD Banach Spaces.*

Tosio Kato established the existence and uniqueness of local in time mild solutions of the Cauchy problem for various quasilinear equations of evolution in one of his seminal papers, "Quasilinear equations of evolution, with applications to partial differential equations". He showed that a wide range of important physical problems can be modeled in a unified manner by a class of quasilinear evolution equations in a Banach space. These examples include the first order symmetric hyperbolic systems, second order nonlinear wave equations, Korteweg-de Vries (KdV) equation, Navier-Stokes equations, Euler equations of fluid dynamics, equations of compressible fluid flow, compressible viscoelastic fluid flow equations, magnetohydrodynamic (MHD) equations, coupled Maxwell and Dirac equations of quantum electrodynamics, and Einstein field equations of general relativity. In this talk we establish the existence and uniqueness up to a stopping time for the stochastic counterpart of Tosio Kato's quasilinear evolutions in UMD Banach spaces. An example of stochastic Euler and Navier-Stokes equation will also be described as an application of abstract theory to concrete models. (Received February 06, 2017)

1128-76-196 **Ross E. Magi*** (ross.magi@wallawalla.edu) and **James P. Keener**. *Modelling a Biological Membrane as a Two Phase Viscous Fluid with Curvature Elasticity.*

We develop a general model of a multicomponent membrane where we treat the membrane as a two phase viscous fluid flowing on a time dependent surface. Using Flory-Huggins-de Gennes theory combined with Cahn-Hilliard theory to describe the free energy of a mixture and Helfrich theory to describe the bending energy of a membrane, we use a minimum energy dissipation argument to derive equations of motion for the two phase fluid. By examining two specific parametrizations of the surface, we explore situations under which the membrane undergoes phase separation, and demonstrate the possibility of curvature induced instability. (Received February 26, 2017)

1128-76-285 **Hantaek Bae** and **James P Kelliher*** (kelliher@math.ucr.edu). *Striated Hölder regularity of active scalar equations.* Preliminary report.
I will discuss recent results on the propagation of striated regularity as measured in Hölder spaces of active scalar equations, focusing on the 2D Euler equations and the aggregation equation. This type of regularity includes patch data as a special case. (Received February 28, 2017)

81 ► Quantum theory

1128-81-148 **Chelsea Walton*** (notlaw@temple.edu), Temple University, Department of Mathematics, 1805 N Broad St, Philadelphia, PA 19122-6104. *Deformations of semisimple Hopf algebras.*
I will discuss the bi-Galois objects and cocycle deformations of the noncommutative, noncocommutative, semisimple Hopf algebras of odd dimension p^3 and of dimension pq^2. This is joint with Adriana Mejia Castano, Susan Montgomery, Sonia Natale, and Maria Vega. (Received February 23, 2017)

1128-81-176 **Peter D. Hislop*** (peter.hislop@uky.edu), 715 Patterson Office Tower, Lexington, KY 40506-0027. *Spectral statistics for random Schrödinger operators.*
Randon Schrödinger operators in three or more dimensions are expected to exhibit a localization-delocalization transition at weak disorder at some energy. One way to detect this transition is through the local eigenvalue statistics. In the localized phase, it is known that these are described by a compound Poisson point processes. It is anticipated that the local eigenvalue statistics in the delocalized phase are similar those of the Gaussian orthogonal ensemble in random matrix theory. Presently, this transition in local eigenvalue statistics can be proved in two models: the random decaying model and the scaled disorder model. Recent results on random Schródinger operators in the localized phase, joint with M. Krishna, and on these two models, joint with F. Klopp, will be presented. (Received February 24, 2017)

1128-81-288 **Alejandro Uribe*** (uribe@umich.edu), 2074 East Hall, 530 Church St., Ann Arbor, MI 48109-1043. *Semi-classical Hermite states and applications.* Preliminary report.
Hermite states are h-dependent families of functions associated with isotropic submanifolds of phase space. They generalize lagrangian distributions. They possess symbols, which are symplectic spinors, and there is a symbol calculus. I will describe the theory of semi-classical Hermite states and outline some applications. This is in part joint work with Victor Guillemin and Zuoqin Wang. (Received February 28, 2017)

86 ► Geophysics

1128-86-260 **Demetrios Gatziolis*** (dgatziolis@fs.fed.us), 620 SW Main Street, Suite 400, Portland, OR 97205. *Voxel-based assessment of sun light in forests.*
The distribution of sunlight and solar energy within forest stands controls many environmental and ecological processes. Its precise spatial assessment, a prerequisite for sound forest management, is challenging owing to solar illumination being a dynamic phenomenon with diurnal and seasonal cycles and also to trees and other vegetation materials exhibiting notoriously complex, difficult-to-describe dimensionality. Rendering into voxel space dense point clouds generated over forested landscapes by using airborne laser scanners has enabled volumetric representations of vegetation. Subsequent ray tracing originating from voxel facets and directed towards selected sets of sun locations within a day or during a longer time period supported the assessment of solar illumination regimes and incident solar energy. Series of adaptations to the ray tracing algorithms helped improve the realism of sunlight distribution calculations while optimizations promoted computation efficiency. Comparisons with field observations of sunlight presence/absence and against in situ measurements of solar energy in a variety of biomes confirmed that this approach is capable of consistently delivering accurate and precise results wherever high-density airborne laser scanning data is available. (Received February 28, 2017)

90 ► Operations research, mathematical programming

1128-90-108 **Dmitriy Drusvyatskiy***, University of Washington, Department of Mathematics, Box 354350, Seattle, WA 98195. *Accelerated first-order methods beyond convexity.*

First-order methods with optimal convergence rates for smooth convex minimization have had a profound impact on computation. Two important downsides of such methods, often remarked in the literature, is a lack of geometric intuition and non-monotone behavior. I will begin by describing a new intuitive viewpoint on acceleration based on optimally averaging quadratic lower models of the function. Averaging only two quadratics at a time gives a new interpretation of the geometric descent method of Bubeck-Lee-Singh '15, while a longer sequence of quadratics yields limited memory extensions.

Without convexity, best-known complexity bounds worsen to those achieved by simple gradient descent. In the second part of the talk, I will present a "universal" accelerated method for non-convex optimization, which automatically accelerates in presence of convexity. The scheme extends and simplifies the universal catalyst of Lin-Mairal-Harchaoui '15 for convex minimization.

Joint work with M. Fazel (U. Washington), Z. Harchaoui (U. Washington), A.S. Lewis (Cornell), H. Lin (Inria), J. Mairal (Inria), C. Paquette (U. Washington), S.Roy (U. Washington). (Received February 17, 2017)

1128-90-259 **Bo Han*** (bo.han@wsu.edu), **Hongbo Dong** and **Ari Ariyawansa**. *Interior point methods for two-stage stochastic semidefinite programming in dual standard form.*

We consider interior point methods for two-stage stochastic semidefinite programming. In (Jin, Ariyawansa, and Zhu, 2012) the authors have proposed a polynomial time homogeneous self dual algorithm for two stage stochastic semidefinite programming(SSDP) with recourse in primal standard form by exploiting its structure in the computation of search directions. However, in much applications problems are more naturally modeled in the dual standard form. We show that SSDP in dual standard form has a different structure, and the algorithm for the primal standard form does not directly apply. Then, the homogeneous self dual algorithm for SSDP in dual standard forms will be developed. We also provide an implementation in the Mehrotra predictor-corrector framework. Our numerical results show that our algorithm is effective in exploiting the block structure and outperforms standard SDP solvers when the number of scenarios is large. (Received February 28, 2017)

1128-90-297 **Hongbo Dong**, **Miju Ahn** and **Jong-Shi Pang***, jongship@usc.edu. *Structural properties of affine sparsity constraints.*

We introduce a new constraint system for sparse variable selection in statistical learning. Such a system arises when there are logical conditions on the sparsity of certain unknown model parameters that need to be incorporated into their selection process. Formally, extending a cardinality constraint, an affine sparsity constraint (ASC) is defined by a linear inequality with two sets of variables: one set of continuous variables and the other set represented by their nonzero patterns. This paper aims to study an ASC system consisting of finitely many affine sparsity constraints. We investigate a number of fundamental structural properties of the solution set of such a non-standard system of inequalities, including its closedness and the description of its closure, continuous approximations and their set convergence, and characterizations of its tangent cones for use in optimization. Our study lays a solid mathematical foundation for solving optimization problems involving these affine sparsity constraints through their continuous approximations. (Received February 28, 2017)

1128-90-300 **Rishabh K Iyer*** (rishi@microsoft.com). *Submodular Optimization and Data Summarization with Applications to Computer Vision.*

Visual Data in the form of Images and Videos have been growing at an unprecedented rate in the last few years. Moreover, today, machine generated videos (via Drones, Dash-cams, Body-cams, Security cameras etc.) are being generated at a rate higher than what we as humans can process, and majority of this data is plagued with redundancy. In this talk, I will present a unified framework for Submodular Optimization which provides an end to end solution to these problems. We first show that submodular functions naturally model notions of diversity, coverage and representation. Moreover they also lend themselves to practical and provably near optimal algorithms for optimization, thereby providing practical data summarization strategies. We then show the utility of these for image collection summarization and video summarization, and show how we can extract key vignettes and events from large videos and image collections, considerably reducing human effort in analyzing these. Finally, we also discuss applications of the summarization framework to training data subset selection and active learning for several image and video recognition tasks, thereby reducing the training complexity and human labeling effort and cost. (Received February 28, 2017)

1128-90-314 **Bala Krishnamoorthy*** (bkrishna@math.wsu.edu), bkrishna@math.wsu.edu, and **Sudipta N Sinha**. *Image correspondence recovery via binary quadratic programming.* Preliminary report.

We investigate an approach based on global optimization for matching features in a set of images. Our technique assumes that pairwise similarities or affinities between sets of image features are given. The set of matching features found by our algorithm explicitly satisfy cycle consistency across multiple images. Unlike previous convex methods relying on semidefinite programming and low-rank matrix recovery techniques, our technique is based on binary quadratic programming. Our main insight is that using a series of carefully chosen relaxations of the binary quadratic variables into binary variables, the problem can be cast into a linear program that can be efficiently solved by existing solvers. We evaluate the utility of our method for solving difficult image correspondence problems involved in matching multiple images of different semantically related object instances. (Received February 28, 2017)

1128-90-319 **Sahar Nesaei*** (sahar.nesaei@wsu.edu), vancouver, WA , and **Sepideh Nesaei**. *Uber meets UPS–Dynamic Delivery Routing.* Preliminary report.

Recently, the Dynamic Vehicle Routing Problem (DVRP) has been a topic of much research interest. The problem is to find optimal routes for a fleet of vehicles to visit their pick-up and delivery locations. Solution methods are based on various approaches, ranging from exact algorithms to metaheuristics. In this poster, we will review the DVRP and some of its special cases. The problem we are working on is more general that DVRP, where delivery vehicles appear at random (just as in Uber), and multiple dynamic orders (also appearing at random) could be combined for overall efficiency. (Received February 28, 2017)

91 ► Game theory, economics, social and behavioral sciences

1128-91-102 **Ethan Spangler*** (ethan.spangler@wsu.edu), 1508 NW Leland Apt 301, Pullman, WA 99163, and **Ben Smith** (bosmith@unomaha.edu). *Let Them Tweet Cake: Estimating Political Stability Using Twitter Data.*

Traditional methods of estimating political stability have been shown to be unreliable, unable to adapt quickly to the realities on the ground. Thus it is the goal of this paper to create a new measure of political stability, one with a firm theoretical foundation and utilizes advances in social media technology. Twitter is a micro-blogging website that allows users to post short messages (tweets) that can be viewed and shared by other users, creating a vast network of freely and easily observable information. Tweets containing specified words or phrases voicing dissatisfaction with their government are collected, scored, and aggregated; forming the basis for the measure. Combining these estimates of aggregated dissent with macroeconomic data of the country within the previously established theoretical framework and we obtain an overall estimation of a country's political stability. A case study focusing on Canada and Kenya, has provided proof of concept. (Received February 16, 2017)

1128-91-318 **Kevin E Henrickson** and **Joseph B Kincanon*** (jkincanon@zagmail.gonzaga.edu), 502 East Boone, Spokane, WA 99258, and **Thomas McKenzie**. *Measuring Salary Inequality at Master's Colleges and Universities.* Preliminary report.

We compare salary inequality a public and private master's institutions. First we measure the Gini indices using traditional techniques. Next we fit a model suggested in a paper by Jantzen and Volpert to both data sets. We then draw some conclusions about salary inequality using this model. (Received February 28, 2017)

92 ► Biology and other natural sciences

1128-92-5 **Kazuo Yamazaki*** (kyamazak@ur.rochester.edu), Department of Mathematics, University of Rochester, Rochester, NY 14627, and **Xueying Wang** (xueying@math.wsu.edu), Department of Mathematics and Statistics, Washington State University, Pullman, WA 99164-3113. *Global stability and uniform persistence of the reaction-convection-diffusion cholera epidemic model.*

This talk concerns the speaker's collaborative work with Prof. Xueying Wang of Washington State University.

We study the global stability issue of the reaction-convection-diffusion cholera epidemic PDE model and show that the basic reproduction number serves as a threshold parameter that predicts whether cholera will persist or become globally extinct. Specifically, when the basic reproduction number is beneath one, we show that the disease-free-equilibrium is globally attractive. On the other hand, when the basic reproduction number exceeds one, if the infectious hosts or the concentration of bacteria in the contaminated water are not initially identically zero, we prove the uniform persistence result and that there exists at least one positive steady state.

We also discuss work in progress and difficult remaining problems. (Received September 19, 2016)

1128-92-28 **Jacob P Duncan***, 149 Le Mans Hall, Notre Dame, IN 46556, and **James Powell**. *Spatiotemporal Insect Epidemic Modeling: Predicting Outbreak Severity in a Changing Climate.*

Outbreaks of phytophagous forest insects are largely driven by ambient thermal energy, host demographics, and spatial effects of dispersal. We develop a structured integrodifference equation (IDE) outbreak model that tracks the demographics of sedentary hosts under insect infestation pressure. The temperature-dependent model is appropriate for a spectrum of pests attacking the later age classes of long-lived hosts, including mountain pine beetle (MPB), spruce budworm, and spruce beetle. We parameterize the model using MPB infestation data taken during a recent outbreak in central Idaho. The mechanistic model generates a train of periodic waves of infestation. We approximate the IDE with a partial differential equation and search for traveling wave solutions. The resulting ordinary differential equation predicts the shape of an outbreak wave profile and peak infestation as functions of wavefront speed, which can be calculated analytically. These results culminate in the derivation of an explicit approximation of invasion wave amplitude (a measure of outbreak severity) based on the temperature-dependent reproductive rate of the infesting insect, thus elucidating the connection between recently more severe insect epidemics and global climate change. (Received January 24, 2017)

1128-92-33 **Yu Jin*** (yjin6@unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Traveling waves for a reaction-diffusion-advection predator-prey model.*

We study a reaction-diffusion-advection predator-prey model in a river. The existence of predator-invasion traveling wave solutions and prey-spread traveling wave solutions in the upstream and downstream directions are established and the corresponding minimal wave speeds are obtained. While some crucial improvements in theoretical methods have been established, the proofs of the existence and nonexistence of such traveling waves are based on Schauder's fixed-point theorem, LaSalle's invariance principle and Laplace transform. Based on theoretical results, we investigate the effect of the hydrological and biological factors on minimal wave speeds and hence on the spread of the prey and the invasion of the predator in the river. (Received January 30, 2017)

1128-92-35 **Jie Zhao*** (jie.zhao@wsu.edu), Neill222, Washington State University, Pullman, WA 99163, and **Robert H. Dillon** (dillon@wsu.edu), Neill324, Washington State University, Pullman, WA 99163. *Mathematical Modeling of Signaling Pathways of Fibroblast in Breast Cancer.* Preliminary report.

A mathematical model has been proven as a powerfully tool in understanding, predicting, controlling a real biological system in systems biology. The most often used for dynamic biological systems is nonlinear ordinary differential equations (ODEs) or PDEs. The critical challenges is how to balance the structure of the model and parameter estimation. Usually, simplified models have simplifying assumptions and a small number of parameters; complex models allow them to provide good fits with lower residual error but have an excessively large number of parameters. How to build or choose a mathematical model for a real biological system can be very depend on what you are interested in. In this article, based on an designed experiment to investigate how cells sense the different concentrations of $TGF\beta$, we built a different mathematical models for transforming growth factor-β($TGF\beta$) signaling pathways in Fibroblast, developed a parameters estimation method based on Bayesian inference and proposed a better choice under this background. (Received January 31, 2017)

1128-92-83 **Zachary P Kilpatrick***, 526 UCB, Department of Applied Mathematics, University of Colorado Boulder, Boulder, CO 80309. *Maintaining spatial working memory across time in bump attractor models.*

We discuss various network mechanisms capable of making spatial working memory more robust to noise perturbation and error. The canonical example we begin with arises from classic oculomotor delayed response tasks whereby a subject must maintain the memory of a location around a circle over the period of a few seconds. Asymptotic methods are used to reduce the dynamics of a bump attractor to a stochastic differential equation whose dynamics are governed by a potential that reflects spatial heterogeneity in the network connectivity. Heterogeneity can serve to reduces the degradation of memory overtime, ultimately increasing the transfer of information forward in time. We also show that connectivity between multiple layers of a working memory can further serve to stabilize memory, especially if they possess propagation delays. We conclude by discussing recent

work, where we are modeling the phenomenon whereby a previous trial's response attracts the current trial's response, sometimes called repetition bias. (Received February 14, 2017)

1128-92-91 **Tilmann Glimm*** (glimmt@wwu.edu), Dept. of Mathematics, Western Washington University, 516 High Street, Bellingham, WA 98225. *Modeling the role of synchronized Hes1 oscillations in the developing chick limb skeleton.*

In avian embryonic limbs, mesenchymal cells aggregate to form chondrogenic condensations, which later turn into cartilage, then bone. It has been experimentally established that their characteristic size and spacing is mediated by a regulatory network consisting of two glycan-binding proteins: CG(chicken galectin)-1A, CG-8 and their counterreceptors.

Based on a mathematical model of this regulatory network (Glimm, Bhat and Newman, 2014), we address the role of spatially synchronized temporal oscillations of Hes1, a transcription factor that plays an important role in the Notch signaling pathway. Recent experiments show that damping these oscillations through a Notch inhibitor results in irregularly sized and fused condensations.

We incorporate Hes1 into the model and show through numerical and analytic results how the interaction of the skeletogenic galectin circuit with Hes1 is able to regularize the pattern of condensations.

Mathematically, the model consists of a system of PDEs containing a nonlocal term to represent cell-cell adhesion. Temporal oscillations lead to explicitly time-dependent parameters.

This talk is based on work with S. A. Newman (New York Medical College) and R. Bhat (Indian Institute of Science, Bangalore). (Received February 15, 2017)

1128-92-92 **Eric Cytrynbaum*** (cytryn@math.ubc.ca). *An invariant winding number for the FitzHugh-Nagumo system.*

The FitzHugh-Nagumo system of partial differential equations (FHN) is a generic model for excitable media, often used to build a qualitative understanding of electrophysiological phenomena. A well-characterized traveling-pulse solution to FHN serves as a model for action potentials in cardiac tissue and other contexts. The stability of the traveling pulse has been well-studied but the more global problem of predicting when an arbitrary initial condition will converge to the uniform rest solution and when it will converge to the traveling pulse remains unsolved. In this talk, I will present a proof of the existence of an invariant winding number in an asymptotic limit of the FHN system (the singular FHN system - SFHN) on a circular 1D domain that provides a crucial step toward a global convergence result. I will also provide evidence that this SFHN winding number result extends with limitations to FHN and outline conditions under which the SFHN approximation fails. The invariant winding number provides explanations for several observations of physiological relevance. For example, it explains the requirements on stimulus protocols that allow the formation and elimination of reentrant rhythms in cardiac tissue. (Received February 15, 2017)

1128-92-111 **Neda Nategh*** (neda.nategh@montana.edu). *Multidimensional nonlinear code of the retina.*

Inhibitory interneurons are diverse in the nervous system, though most have unknown functions. In sensory systems, two broad classes of computation have been considered – linear effects that generate the classical receptive field and nonlinear modulation that mediates non-classical contextual effects. In this study, we analyze salamander retinal amacrine cells using a general approach to directly measure and model how an interneuron pathway influences computation. Using simultaneous intracellular and multielectrode recording, we measure the linear feature contributed by an amacrine pathway and nonlinear modulatory effects on other visual features. We find great diversity in the functional effects of amacrine cells, with even apparently simple, linear amacrine cells creating both linear and diverse modulatory effects such as divisive gain control, polarity reversal and shifting threshold on distinct visual features conveyed to single target ganglion cells. (Received February 19, 2017)

1128-92-122 **Libin Rong*** (rong2@oakland.edu). *Multistage models in HIV infection and treatment.*

HIV infection and replication involves multiple intracellular processes. Different classes of antiretroviral drugs target different stages. Some studies showed that patients receiving the integrase inhibitor raltegravir based therapy were faster to achieve undetectable viral load than other therapy and that treatment intensification with raltegravir led to a lower viral load and an increase in 2-LTR, a marker for ongoing viral replication. In this talk, using multistage models we will provide a quantitative and systematic comparison of the effect of different drug classes on HIV decay dynamics and particularly explain the viral load decline in HIV patients treated with raltegravir-based regimens. We will also evaluate the influence of raltegravir intensification on viral load and 2-LTR dynamics in HIV patients on suppressive antiretroviral therapy. (Received February 21, 2017)

1128-92-161 **Todd Ray Young*** (youngt@ohio.edu), 321 Morton, Athens, OH 45701. *Yeast Cell Cycle and Metabolism can be Coupled in Nontrivial Ways.*

Synchrony, the phenomenon where components of a system experience events in unison, seems to be common in biological systems. Relatedly, Temporal Clustering or Phase Synchrony, is where sub-groups (or cohorts) of components synchronize among themselves, but are out of phase with other cohorts.

In bioreactor experiments on yeast metabolic oscillations we discovered a case where a culture of yeast exhibits temporal clustering in which two groups progress through their cell cycles in anti-phase. In these experiments the cell cycle clusters and oscillations in the metabolism are seen to be tightly linked.

The discovery raises a number of mathematical questions such as: 'What accounts for the difference between a system that synchronizes and one that forms clusters?', 'What determines the number of clusters that appear?', and 'How do individual cells distribute among clusters?'. In this talk we will discuss how questions such as these can be studied mathematically using biologically motivated non-linear models and in many cases answers can be found. Biologically, we propose a possible coupling mechanism between the cell cycle and metabolism that relies on the fact that in the experiments the bioreactor is operating near carrying capacity. (Received February 24, 2017)

1128-92-178 **Emily Stone*** (stone@mso.umt.edu), Dept. of Math. Sciences, University of Montana, 32 Campus Drive, Missoula, MT 59807, **Elham Bayat-Mokhtari** (elham.bayatmokhtari@umontana.edu), Dept. of Math. Sciences, University of Montana, 32 Campus Drive, Missoula, MT 59807, and **J. Josh Lawrence** (john.lawrence@ttuhsc.edu), Pharmacology and Neuroscience, Texas Tech University, 2500 Broadway, Lubbock, TX 79409. *Effect of Neuromodulation of Short-term Plasticity on Information Processing in Hippocampal Interneuron Synapses.* Preliminary report.

Neurons in a microcircuit connected by chemical synapses can have their connectivity affected by the prior activity of the cells. The number of synapses available for releasing neurotransmitter (NT) can be decreased by repetitive activation through depletion of readily releasable NT, or increased through facilitation, where the probability of release of NT is increased by prior activation. These competing effects can create a complicated and subtle range of time dependent connectivity. Here we investigate the probabilistic properties of facilitation and depression (FD) for a presynaptic neuron that is receiving a Poisson spike train of input. We use a model of FD that was parameterized with experimental data from a basket cell and pyramidal cell connection in rodent hippocampus (roughly 8-10 synapses were counted), for fixed frequency input spikes. Hence our results will apply to micro-circuits in the hippocampus which are responsible for the gamma rhythms associated with learning and memory. (Received February 24, 2017)

1128-92-205 **Nikolay S Strigul*** (nick.strigul@wsu.edu), 14204 NE Salmon Creek Ave, Vancouver, WA 98686. *Linking mathematical models of forest dynamics operating at different scales.*

Hierarchical patch dynamics concept provides theoretical foundation for scaling vegetation dynamics across temporal and spatial scales. One fundamental challenge to obtaining trustworthy predictions of forest dynamics has been our limited proficiency to scale crops functional traits and mortality characteristics to the landscape level. This difficulty is owed in part to complexity of forested ecosystems, variable land use practices and ecological and climatic factors such as non-stationary disturbance regimes numerous non-linear functional relationships and feedback loops between different organisms. In this work I link two models predicting dynamics of individual trees, the individual-based forest simulator called LES and the analytically tractable model called the Perfect Plasticity Approximation, PPA, with the discrete landscape-level patch dynamics models of forest stand dynamics formulated as inhomogeneous Markov Chains. This upscaling technique allows to formulate Markov Chain model of forest patch dynamics based on the individual tree traits employed in LES and PPA. This hierarchical scaling approach naturally includes non-stationary disturbance regimes and it can be directly employed to simulate vegetation changes under different climate change scenarios. (Received February 27, 2017)

1128-92-219 **Olga Alekseevna Rumyantseva*** (olga.rumyantseva@wsu.edu), 14204 NE Salmon Creek Ave, Vancouver, WA 98686, and **Nikolay S Strigul**. *Data-intensive modeling of Pitch Pine range in North America.*

Climate envelop models are traditionally employed in predicting species ranges. In this work we develop a generalized multidimensional climate envelop model of Pitch Pine (*Pinus Rigida*) distribution in the contiguous United States. The proposed data-intensive methodology bridges information extracted by data-mining of US Forest Inventories (FIA dataset) and climatic datasets (19 climatic characteristics on the 1 km^2 grid). This novel approach allowed us to study how every single climatic variable affect Pitch Pine distribution, and to evaluate whether interactions between climatic factors are important for this species. In particular, we ranked 19 climatic factors in order of their relative effects on the species range and isolated 5 most important factors. Finally we demonstrated that the interaction between factors is essential for understanding of Pitch Pine distribution and should not be ignored in the development of climate envelop species range models. (Received February 28, 2017)

1128-92-225 **Anatoly AB Buchin*** (bigneuron@alleninstitute.org), 615 Westlake Ave N, Seattle, WA 98109, **Anton AC Chizhov** (anton.chizhov@mail.ioffe.ru), 26 Politekhnicheskaya, Saint Petersburg, St Petersb 194021, **Gilles GH Huberfeld** (gilles.huberfeld@mac.com), 47-83 Boulevard de l'Hôpital, 75013 Paris, Ile de Fra, France, **Richard RM Miles** (richard.miles@upmc.fr), 47 Boulevard Hôpital, 75005 Paris, Ile de Fra, France, and **Boris BG Gutkin** (anat.buchin@gmail.com), 29 rue d'Ulm, 75005 Paris, Ile de Fra, France. *Reduced efficacy of the KCC2 cotransporter promotes epileptic oscillations in a subiculum network model.*

Ion regulation in the brain is a major determinant of neural excitability. Intracellular chloride in neurons, partial determinant of the resting potential and the inhibitory reversal potentials, is regulated together with extracellular potassium via kation chloride cotransporters. During temporal lobe epilepsy the homeostatic regulation of intracellular chloride is impaired in pyramidal cells, yet how this dysregulation may lead to seizures has been unexplored. Using realistic neural network model describing ion mechanisms we show that chloride homeostasis pathology provokes seizure activity analogous to recordings from epileptogenic brain tissue. We show that there is a critical percentage of pathological cells required for seizure initiation. Our model predicts that restoration of the chloride homeostasis in pyramidal cells could be a viable anti-epileptic strategy. (Received February 27, 2017)

1128-92-228 **Alexander G Dimitrov*** (alex.dimitrov@wsu.edu), 14204 NE Salmon Creek Ave, Vancouver, WA 98686. *Modeling perceptual invariances in biological auditory processing.* Preliminary report.

Sounds reaching our ears vary in multiple features: pitch, intensity, rate. Yet when we parse speech, our comprehension is little affected by the vast variety of ways in which a single phrase can be uttered. This ability to extract relevant information from wildly varying sensory signals is also ubiquitous in other sensory modalities. Even though the effect itself is well characterized, we do not understand the approaches used by different neural systems to achieve such performance.

In an ongoing project, we are testing the hypothesis that broadly invariant signal processing is achieved through various combinations of locally invariant elements. The main questions we would like to address are: 1. What are the characteristics of locally-invariant units in auditory pathways? 2. How are biological locally-invariant units combined to form globally invariant processors? 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 27, 2017)

1128-92-231 **Eric S. Walsh*** (wals0292@vandals.uidaho.edu) and **Tara Hudiburg** (thudiburg@uidaho.edu). *Future Carbon Dynamics of the Northern Rockies Ecoregion due to Climate Impacts and Fire Effects.* Preliminary report.

The balance between disturbance and production affects the sink potential of forested ecosystems. However, regional forest C dynamics, structure, and composition are expected to shift with climate-induced changes, affecting the sink potential that can mitigate climate change. Forest management is one of the primary mitigation tools available to increase C uptake and can benefit from fire-vegetation-climate interaction models of this century. Using a forest landscape model (LANDIS-II), we modeled the response of the Northern Rockies Ecoregion in ID to two climate change scenarios (RCP 4.5 and 8.5 emissions trajectories) and fire regime shifts within this century. The climate change scenario with the greatest mean temperature increase (RCP 8.5) resulted in a 63% increase in Douglas fir (Pseudotsuga menziesii) and 64% decrease in sub-alpine fir (Abies lasiocarpa) biomass per unit area. Among all climate scenarios, the relative sink potential weakened by the end of the century. However, compared to current conditions, the higher emissions trajectory model (RCP 8.5) resulted in a similar sink potential in 2100. Aging Idaho forests in this century underlies the trend towards a weaker sink, thus highlighting the potential importance of forest harvest management in this century. (Received February 27, 2017)

1128-92-235 **David J Wollkind*** (dwollkind@wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-2930, and **Mitchell G Davis**, **Richard A Cangelosi** and **Bonni J Dichone**. *The Behavior of a Population Interaction-Diffusion Equation in its Subcritical Regime.*

A model interaction-diffusion equation for population density originally analyzed through terms of third-order in its supercritical parameter range is extended through terms of fifth-order to examine its behavior in its subcritical regime.It is shown that under the proper conditions the two subcritical cases behave in exactly the same manner as the two supercritical ones unlike the outcome for the truncated system. Further there also exists a region of metastability allowing for the possibility of population outbreaks. These results are then used to offer an explanation for the occurrence of isolated patches and sparse homogeneous distributions in the relevant ecological parameter range where there is subcriticality for a plant-ground water model system as opposed to periodic patterns and dense homogeneous distributions occurring in its supercritical regime. (Received February 27, 2017)

1128-92-247 **Niall M Mangan*** (niallmm@uw.edu), **J N Kutz**, **S L Brunton** and **J L Proctor**. *Model selection for dynamical systems via sparse regression and information criteria.*

Inferring the structure and dynamical interactions of complex systems is critical to understanding and controlling their behavior. As higher fidelity data becomes available, rapid generation and evaluation of mechanistically meaningful models from data is increasingly possible. We present a data-driven framework for sparse identification of nonlinear dynamical systems (SINDy). SINDy subselects a set of models from the combinatorial possibilities represented in the feature library. By integrating the Akaike Information Criteria (AIC) into the framework, we can rank the models in a principled way. The combined framework also allows us to mitigate measurement error, missing variables, incomplete feature libraries, and insufficient data. To enable discovery of a broader class of functions, we have also developed implicit-SINDy, which combines a compact feature library, implicit formulation, and sparsity promoting non-convex optimization. The method successfully identifies models for metabolic, regulatory and epidemiological networks. Rapid construction of such models could be leveraged for therapeutic gene modulation, metabolic engineering, or disease intervention. (Received February 27, 2017)

1128-92-258 **Benjamin D. Jackson*** (benjamin.jackson@wallawalla.edu), Department of Mathematics, Walla Walla University, 204 S. College Ave., College Place, WA 99324. *Transport of Particles in a Biofilm-lined Hot Spring Effluent Channel.* Preliminary report.

Communities of bacteria adhering to surfaces–biofilms–are commonly found in natural and industrial systems, including hot spring effluent channels under flow conditions. Thus, modeling biofilms in the context of channel flow is important in understanding many natural systems. We develop a model which addresses the rate at which cells move in or out of the flow in a natural hot spring drainage channel. This is done by building a two-dimensional partial differential equation model of the stream. The model is parameterized using data gathered at Mushroom Spring in Yellowstone National Park. Using this data, we calculate erosion and adhesion rates at steady state in both upper and lower regions of the stream. (Received February 28, 2017)

1128-92-266 **Brandon McNellis***, brandon.mcnellis@gmail.com, and **Tara Hudiburg**. *Predicting forest mortality and landscape change under novel climates using an analytical approach to drought response physiology and probabilistic scaling.* Preliminary report.

Climate forecasts for the next century predict substantial shifts in drought severity and intensity across the Western U.S., and tree water stress physiology has attracted significant attention due to rapid and recent observed mortality. Models can attempt to predict which forests are most at risk from drought, but novel environments may preclude analysis that relies on past observations. Mechanistic models may reduce uncertainty in predictions but currently suffer from issues of mechanism identification. Furthermore, scaling mortality from the individual tree to model landscapes introduces stochastic elements that are difficult to assess with process-based models. To improve model performance, we integrate current theory on within-tree carbon dynamics and drought stress physiology with hydraulic models using an explicit analytical approach. Plant performance at the scale of individual trees is used to probabilistically assess the impact of drought on landscape-level gas fluxes and biomass using CLM 5.0. An on-going field experiment in managed stands of Pinus ponderosa and mixed conifers is assessed for model parameterization and performance across PNW forests, with important implications for future forest management strategy. (Received February 28, 2017)

1128-92-275 **Keefe Koenig*** (keefe_k@msn.com), Washington State University Vancouver, Vancouver, WA 98686, and **Nikolay S. Strigul**, Washington State University Vancouver, Vancouver, WA 98686. *Modeling Tree Species Distribution as a Function of Climate.*

Plant species distribution is a complicated and multidimensional problem. Knowing how the potential area of a given species changes when various climate variables are introduced could allow us to assess which variables have the largest effect on the potential area the species occupies. Plant distributions are at least somewhat based on climate and knowing more about which aspects of climate a particular species is may help further understand the biology and physiology of that plant species. While there are many different factors that impact plant distribution (i.e. human influence, competition with other organisms, geographic barriers) our original analysis looks at just how climate alone can explain the realized distribution of a species. We utilized datamining and multivariable statistics to combine data from WorldClim and FIA (Forest Inventory and Analysis) databases for information on the current distribution of tree species in the conterminous United States and the climate in those locations. We have employed several methods (Brute Force, Greedy Algorithm, Refined Greedy Algorithm, and Shapley Values) to analyses distribution of White Oak and Sitka Spruce in the conterminous United States. (Received February 28, 2017)

1128-92-281 **Daniel Grunbaum*** (random@uw.edu), School of Oceanography, Box 357940, University of Washington, Seattle, WA 98195. *Unconventional mechanisms of population renewal: Analysis of spontaneous cloning in marine invertebrate larvae.*

Many marine invertebrate populations are undergoing rapid changes due to excessive harvesting, changes in ocean temperature and pH, invasions by exotic organisms and emerging diseases. In many species, larvae can feed and grow while dispersing in the plankton. Typically, larvae from larger eggs develop faster than larvae from smaller eggs, subjecting them to less predation during development. The trade-off between allocating limited maternal resources to fewer, larger, more quickly developing offspring vs. more numerous, smaller, more slowly developing larvae has been analyzed in several evolutionary models of larval life history. In some marine invertebrates, partly developed larvae can spontaneously divide into two smaller, genetically identical clones. Environmental factors such as food availability, pH, predator odors, and temperature can stimulate larval cloning. Clones can themselves clone, significantly altering both individual fitness of cloning larvae and population dynamics of cloning species. I will present the first theoretical analysis of larval life history to consider demographic and evolutionary consequences of cloning, conditions under which cloning is evolutionarily favored, and cloning effects on demographic processes like recovery from catastrophic epidemics. (Received February 28, 2017)

1128-92-303 **Leonardo Calle*** (leonardo.calle@montana.edu), P.O. Box 173460, Bozeman, MT 59715, and **Benjamin Poulter**. *Epistemic uncertainties in global-scale modeling of secondary forest dynamics.*

Secondary forests are known to represent an important global carbon sink. In large-scale vegetation models, however, it remains a challenge to represent every forest stand that differs in age, mainly due to limits in computation. A common solution has been to represent forests in different stages of succession, but to set limits on the maximum number of stands represented, and then to combine, by a weighted-average, state variables for similar forest stands when the number of stands tracked exceeds such limit. We present an alternate approach for representing ecosystem heterogeneity at large scales by using a fixed-width age-structured model of forest age. We compare the state variables (e.g. aboveground biomass, stem density, tree height) simulated using alternate models of secondary forests to observations from forest inventory data. We demonstrate how alternate representations of forest age can result in artifacts of biomass 'dilution' and 'inflation', resulting in down-stream effects on ecosystem function and altering the perceived sensitivity of forest stands to climatic stress. We also highlight the importance of alternate approaches for representing tree establishment within the context of large-scale age-structured forest models. (Received February 28, 2017)

1128-92-306 **Frank H Lynch*** (lynch@ewu.edu), 216 Kingston Hall, Eastern Washington University, Cheney, WA 99004. *Decomposing leaf hydraulic conductance with a hybrid numerical method.*

We analyze a hybrid numerical method used to solve an initial value problem where an unknown parameter is chosen to satisfy one additional boundary condition. Physically, the determination of the unknown parameter is equivalent to decomposition of total leaf hydraulic conductance into components in the axial and radial directions.
(Received February 28, 2017)

1128-92-312 **Adnan Morshed*** (adnan.morshed@wsu.edu), Mechanical and Materials Engineering, Pullman, WA 99164, **Prashanta Dutta**, Mechanical and Materials Engineering, Pullman, WA 99164, and **Robert Dillon**, Mathematics and Statistics, Pullman, WA 99164.
Modeling the TGFβ–SMAD signaling pathway interactions in a tumor microenvironment.

The TGFβ–SMAD interaction is prevalent in a wide range of tumor microenvironments with autocrine and paracrine mechanisms driving the temporal evolution. However, the dual nature of TGFβ as tumor suppressor and promoter still remains poorly understood. We investigated the dynamic landscapes of TGFβ–SMAD signaling pathway for different levels of extracellular TGFβ. This required a hybrid spatio-temporal description of the extracellular environment with cell membranes being the immersed interfaces. Intracellular reaction network was connected to the extracellular domain through surface reactions. Model tuning with PE25 cells indicate the production of intracellular TGFβ is activated in a switch-like manner depending on the extracellular levels. Additionally, spatial effect of cellular proximity in a microfluidic cell culture setting is explored where the variation in intercellular distance between different cells show transformation in intracellular behavior similar to tumor mediated transformation of fibroblasts to myofibroblasts. Our model also predicts that TGFβ distribution in the domain to be largely affected by receptor concentrations in different types of cells and diffusivity of the media.
(Received February 28, 2017)

1128-92-313 **Gabriel Barello** and **Yashar Ahmadian*** (yashar@uoregon.edu), Eugene, OR 97403.
Noise-limited Inference Predicts Facilitatory Normalization in the Visual Cortex.
Preliminary report.

Visual cortical neurons integrate information across the visual field to support global perception, manifesting in the modulation of neurons' responses by the surrounding context of their receptive fields, as in surround suppression. Contextual modulations are canonical brain computations iterated across cortical areas; they are typically suppressive and sub-additive, with suppression weakening with diminishing stimulus strength. We have formerly shown that a parsimonious model of cortical circuitry mechanistically explains this weakening, and predicts a transition to facilitative or super-additive summation for weak stimuli. Here we show that a normative analysis based on principles of efficient coding of natural scenes, robustly leads to a similar prediction in the primary visual cortex (V1). When we take into account the trial-to-trial noise in the thalamic inputs to V1 neurons, we find that optimal responses exhibit weakening of suppressive normalization and a transition to facilitative stimulus summation as contrast is lowered. Our results provide an explanation based on optimal Bayesian inference for why the cortex should switch from suppressive to facilitative summation as stimulus strength is lowered, and corroborate the previous mechanistic prediction of this transition.
(Received February 28, 2017)

1128-92-315 **Andrew M. Oster*** (aoster@ewu.edu) and **Paul C. Bressloff**.
Laminar Development of the Primary Visual Cortex.

In this talk, we will introduce the architecture of the visual system in higher order primates and cats. Through activity-dependent plasticity mechanisms, the left and right eye streams segregate in the cortex in a stripe-like manner, resulting in a pattern called an ocular dominance map. We introduce a mathematical model to study how such a neural wiring pattern emerges and extend it to consider the joint development of the ocular dominance map with another feature of the visual system, the cytochrome oxidase (CO) blobs, which appear in the center of the ocular dominance stripes. Since cortex is in fact comprised of layers, we introduce a simple laminar model and perform a stability analysis of the wiring pattern. This intricate biological structure (ocular dominance stripes with 'blobs' periodically distributed in their centers) can be understood as occurring due to two Turing instabilities combined with the first-order dynamics of the system. We show recent numerical simulations showing how monocular deprivation during development can dramatically alter the ocular dominance pattern, while leaving the CO blob distribution nearly unaltered.
(Received February 28, 2017)

1128-92-317 **Michael J. Rempe*** (mrempe@whitworth.edu), Whitworth University, Dept. of Mathematics and Computer Science, Spokane, WA 99251, **Jonathan P. Wisor** (j_wisor@wsu.edu), Sleep and Performance Research Center, Washington State University, Spokane, WA 99210, and **Janne Gronli** (janne.gronli@uib.no), Dept. of Biological and Medical Psychology, University of Bergen, 5009 Bergen, Norway.
Mathematical Modeling of sleep-wake state dynamics in a rodent model of night shift work.

Millions of people worldwide are required to work during the times when their bodies are primed for sleep. This disruption of the body's normal sleep and circadian rhythmicity related to the work schedule may mediate the relationship between shift work and numerous adverse health consequences (i.e. insomnia, metabolic disturbances, digestion problems). Here, we simulate shift work in rodents and model the data with a simple system

of differential equations containing 1) a circadian process, 2) a homeostatic process and 3) a stochastic process to mimic the rodent's polyphasic sleep pattern. The model correctly reproduces sleep state bout durations and sleep state percentages of rat sleep under baseline and working conditions. By changing only the time at which the rodents are forced to be awake, the model reproduces some key changes in the sleep-wake pattern measured by brain activity. Also, the Markov Chain model suggests that the shorter sleep episodes recorded in 'night workers' as compared to 'day workers' is due to circadian effects. Mathematical modeling of sleep – wake state dynamics allows for deeper insight into the circadian and homeostatic processes of sleep regulation in behavioral induced sleep disruption. (Received February 28, 2017)

1128-92-322 **Aminul Islam Khan***, Mechanical and Materials Engineering, Pullman, WA 99164, and **Prashanta Dutta**, Mechanical and Materials Engineering, Pullman, WA 99164. *A Computational Model for Iron Transport across Blood-Brain Barrier.*

Iron is a crucial element for our fundamental metabolic processes. Transferrin (Tf), an iron-binding protein, facilitates iron uptake in brain endothelial cells (ECs) and subsequent transport across the blood-brain barrier (BBB). Apo-Tf first binds with ferric iron to form holo-Tf, which is then internalized through receptor-mediated endocytosis. The iron-containing vesicles are sorted within the early endosomes, where some of them are recycled in cerebral capillaries and the rest are directed to the basolateral membrane for exocytosis to brain parenchyma. In this study, we have developed a detailed pathway based mathematical model of these processes. The developed model includes both Tf-bound and non Tf-bound iron transcytosis from cerebral capillaries to brain parenchyma. Our simulation results indicate that the developed model can successfully reconstruct in vitro experimental results of bovine brain ECs. Moreover, we studied the effects of cerebral iron and transferrin concentration as well as receptor density on the cell surface to predict iron accumulation inside the cell and exocytosis from the EC. We found that the transcytosis of iron through EC is mainly regulated by extracellular Tf-bound iron and expression of Tf-receptors on the luminal surface of ECs. (Received February 28, 2017)

1128-92-325 **Prashanta Dutta***, Mechanical and Materials Engineering, Washington State University, Pullman, WA 99164, **Deng Hua**, Mechanical and Materials Engineering, Pullman, WA 99164, and **Jin Liu**, Mechanical and Materials Engineering, Pullman, WA 99164. *Mesoscale stochastic modeling of receptor-mediated bioparticle transport.*

Internalization of bioparticles, such as viruses and drug carriers, through receptor-mediated endocytosis (RME) plays essential roles in fundamental understanding of viral infections and targeted drug deliveries through blood brain barrier. RME of bioparticles is a highly complex process that may involve hundreds of proteins. The overall process is dictated by collective and cooperative interplay of many dynamic events, such as particle motion, membrane deformation, receptor diffusion, as well as molecular scale protein-protein and protein-lipid interactions. In this talk, we present a mesoscale stochastic computational model for the receptor-mediated endocytosis based on Metropolis Monte Carlo method. The model is a combination of a stochastic binding model with a mesoscopic membrane model based on the discretization of Helfrich Hamiltonian on a curvilinear space. Using our model, we will discuss two important biological processes involving RME: the entry of herpes simplex virus with the absence of clathrin and the internalization of trasferin-coated nanoparticles into endothelial cells with the existence of clathrin. Through these two examples, we investigate the key roles of particle size, ligand/receptor density and type, and the clathrin on RME. (Received February 28, 2017)

1128-92-328 **Xin Gao*** (tommy.gao@wsu.edu), Department of Crop and Soil Sciences, 229 Johnson Hall, Washington State University, Pullman, WA 99164-6420, **Hongbo Dong** (hongbo.dong@wsu.edu), Department of Mathematics and Statistics, Neill Hall 409, PO Box 643113, Pullman, WA 99164-3113, **Haiying Tao** (haiying.tao@wsu.edu), Department of Crop and Soil Sciences, 253 Johnson Hall, PO Box 646420, Pullman, WA 99164-6420, **David R Huggins** (dhuggins@wsu.edu), Department of Crop and Soil Sciences, Johnson Hall 247, PO Box 646420, Pullman, WA 99164-6420, and **Tabitha T Brown** (tabitha_brown@wsu.edu), Department of Crop and Soil Sciences, Johnson Hall 253, PO Box 646420, Pullman, WA 99164-6420. *Optimizing nitrogen management for simultaneous control of yield and protein content for wheat.* Preliminary report.

Current nitrogen recommendation for wheat is based on yield goal, adjusted by soil residual nitrogen and organic matter, crop rotation and residue management. It doesn't include grain protein content into consideration, which is the market premium based on. In addition, nitrogen recommendation is based on field average yield goal. The diverse climate and dramatic within/across-field variability in landscapes and soil types result in great variability of yield potential and yield responses to nitrogen rate. Previous models mainly considered nitrogen content, with many other important factors ignored, such as weather, landscapes, plant density and so on, which make these models overly simplistic. In this study, statistical models are established with 3-year data, using grain yield and protein content as output variables simultaneously. Important factors include nitrogen content, soil types and weather conditions. We will demonstrate via simulations that with such statistical models, simultaneous optimal control of crop yield and protein content via nitrogen management is possible. This preliminary study motivates us to extend/apply the framework to larger scale data sets, and develop decision-making tools with a combination of stochastic optimization methods and statistical models. (Received February 28, 2017)

1128-92-336 **Matthew J. Pruett*** (matthew.pruett@wsu.edu), Matthew Pruett, 14204 NE Salmon Creek Ave, Vancouver, WA 98686, **Nikolay Strigul** (nick.strigul@wsu.edu), Dr. Nick Strigul, 14204 NE Salmon Creek Ave, Vancouver, WA 98686, and **Kevan B. Moffett**. *Direct Canopy Interception Measurements using the Euler Bernoulli Equation.*

Interception is a key hydrological process whereby the plant canopy captures and holds precipitation. Traditional methods of measuring or estimating interception are laborious and inaccurate. Utilizing a parametrized and simplified form of the Euler-Bernoilli beam equation, $\frac{d^2}{dx^2}(EI\frac{d^2w}{dx^2}) = q$ an in situ technique was reinvestigated for directly measuring intercepted water mass. A mature Acer macrophyllum (Bigleaf maple) branch was instrumented with 2 strain gauges logging at 1 minute intervals for 3 months while collecting weather and Leaf Wetness Sensor (LWS) data. The periodic daily signal of night tree water uptake and daytime branch mass (water) loss from transpiration was evident in the strain gauge data and had to be removed to show the effects of rain alone; novel empirical and modeling approaches to do so were compared. Eight rain events of various sizes were recorded during the experiment, ranging from 0.8 to 17.6 mm of rainfall over a 24-hour period. Further modeling will examine the influence of meteorological conditions on branch rainwater interception dynamics, provide effective calibration for qualitative LWSs, and extract important metrics like the maximum water mass such a branch can hold for a given storm size and intensity. (Received February 28, 2017)

1128-92-339 **Predrag T Tosic*** (pedja.tosic@gmail.com), predrag.tosic@wsu.edu. *A Computational and Discrete Dynamical Systems View of The Brain As An Associative Memory: Some Insights into Why Determining Memory Capacity Is An Intrinsically Hard Problem.*

We study Boolean Networks (BNs) and Discrete Hopfield Networks (DHNs) as a crude approximation of the brain's circuitry, focusing on the problem of storage capacity of brain as an associative memory. We identify the patterns that can be stored to and recovered from an associative memory with the stable configurations of a DHN viewed as a discrete-time, discrete-state dynamical system. We formally establish, that even a uniformly sparse such discrete dynamical system i) may have exponentially many stable configurations and ii) the number of those configurations, in the worst-case, is provably hard to determine either exactly or even approximately. One implication is, that determining the storage capacity of an associative memory is computationally intractable for most non-trivial models of network structures and local interaction models/update rules. (Received February 28, 2017)

1128-92-345 **Guillaume Lajoie*** (glajoie@uw.edu). *Artificially-induced synaptic plasticity in motor cortex: a theoretical model of a bidirectional brain-computer interface.*

The field of online, closed-loop Brain-Computer-Interfaces (BBCI) is rapidly evolving, with applications ranging from a science-oriented tool to clinical treatments of motor injuries. However, with the enhanced capability of novel devices that can record and stimulate an ever-growing number of neural sites comes growing complexity. It is therefore crucial to develop a theoretical understanding of the effects of closed-loop artificial stimulation in the highly recurrent neural circuits found in cortex, and how such protocols affect functional cotex-to-muscle mappings across a range of timescales. In parallel with ongoing experiments, we developed a mathematical model of recurrent networks in cortex with probabilistic spiking mechanisms and spike-time-dependent plastic synapses (STDP) capable of capturing both neural and synaptic activity statistics relevant to BBCI protocols. This model successfully reproduces key experimental results and we use analytical derivations to predict optimal operational regimes for BBCIs. We make experimental predictions concerning the efficacy of spike-triggered stimulation in different regimes of cortical activity such as awake behaving states or sleep. (Received February 28, 2017)

1128-92-347 **Gabriel Koch Ocker***, Allen Institute for Brain Science, 615 Westlake Ave N, Seattle, WA 98109, and **Ramakrishnan Iyer** (rami@alleninstitute.org), Allen Institute for Brain Science, 615 Westlake Ave N, Seattle, WA 98109. *An overview of Allen Institute for Brain Science data.*

The Allen Institute for Brain Science provides an open-source platform for large scale, standardized experimental datasets concerning the structure, composition and activity of the mouse and human nervous systems. Current freely available resources focus on gene expression, mesoscopic connectivity, neuronal morphology and activity both in slice and in vivo (www.brain-map.org). We present an overview of these datasets, focusing on two recently released datasets of high-throughput recordings of neural activity - the Allen Brain Observatory and the Allen Cell Types Database.

The Allen Brain Observatory is comprised of high-throughout recordings of populations of neurons, with cellular resolution, in visual areas of the awake mouse. The Allen Cell Types Database, on the other hand, contains (among other data) the responses of individual neurons from brain slices to different types of current injection in the soma. We discuss our efforts to understand the dimensionality of in vivo activity and relate population activity to external sensory stimuli and internal states, as well as our efforts to characterize and constrain dynamical single-cell models. (Received February 28, 2017)

1128-92-348 **Allison Beth Fisher*** (allison.fisher@wsu.edu), Pullman, WA 99163. *Ion Channels in Neurons.*

Understanding how varying geometries of neurons and the different types of ions affect signaling in neurons. (Received February 28, 2017)

1128-92-349 **Ramakrishnan Iyer***, Allen Institute for Brain Science, 615 Westlake Ave N, Seattle, WA 98109, and **Gabriel Koch Ocker**, Allen Institute for Brain Science, 615 Westlake Ave N, Seattle, WA 98109. *Modeling approaches to the understanding of cortical computations at the Allen Institute for Brain Science.*

A primary goal of the Allen Institute for Brain Science is to understand the computations performed in the corticothalamic system, and their mechanisms. Models deriving the activity and structure of neuronal networks from postulated coding tasks provide predictions for the structure and dynamics of cortical networks. Conversely, a theoretical understanding of the dynamics and statistics of network activity can link specified structure and dynamics with potential functions.

We present a characterization of cortical neurons using data-driven point and spatially extended models of single neurons from brain slices, to construct networks using such components and connectivity hypotheses. We also discuss two approaches to the prediction of the statistics of population activity in neuronal networks from the single-neuron dynamics. Populations of integrate-and-fire type models admit a representation of the distribution of voltages through a partial differential equation with displacement. On the other hand, stochastically spiking network models admit techniques from statistical field theory to calculate arbitrary joint cumulant densities of the spike trains. Each of these approaches reveals different potential computations carried out by cortical circuits. (Received February 28, 2017)

1128-92-351 **Shuiwang Ji*** (sji@eecs.wsu.edu). *Deep Learning for Connectomics.*

Abstract: The importance of research that aims to unlock the mystery of the human brain has recently been recognized worldwide. In January 2013, the European Union selected the Human Brain Project to be one of its two flagship projects. In April 2013, the White House announced the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative to generate a dynamic map of the brain. As these projects move forward, big data analytics will be playing increasingly important roles in converting big brain data into useful knowledge. A key challenge in analyzing brain data is to construct feature representations from brain images. In this talk, I will discuss our efforts in developing deep computational models for learning representations from brain data. In particular, I will provide details on how to use deep learning methods to elucidate the micro-scale brain connectomics among neurons. I will also show that our methods can be used in a number of diverse computational brain discovery tasks. Additionally, they may be used in other areas beyond brain analytics. (Received February 28, 2017)

1128-92-354 **Ilia Karatsoreos***, Dept. Integrative Physiology & Neuroscience, Pullman, WA 99164. *Circadian Clocks and Disease: Some Opportunities for Dialogue between Mathematics and Biology.*

Abstract: Circadian (daily) rhythms are phylogenetically ancient, and present in nearly all organisms that have a life span greater than 24h. It has been hypothesized that circadian clocks impart adaptive fitness, making them a key component of life. In mammals, the master circadian clock is located in the small hypothalamic suprachiasmatic nucleus (SCN), comprised of nearly 10,000 independent oscillators that couple together to form a cohesive network clock. Disruption of this clock, especially by mistimed light exposure, leads to significant mental and physical health problems. However, the process by which oscillators become disrupted at a cellular level remain elusive. My lab explores how intact and robust circadian timing promotes resilience at various levels of biological organization, and how disrupting these rhythms leads to negative health outcomes. I will present

data highlighting what is known about the structure and function of the SCN oscillator, and how disruption of this clock by light can affect health. It is hoped that this presentation can help form a basis for future in-depth discussion and potential collaboration at the interface between math and biology in the context of circadian rhythms and health. (Received March 01, 2017)

93 ► Systems theory; control

1128-93-213 **Krishnamurthy Dvijotham*** (dvij@cs.washington.edu), 1850 Stevens Drive Apt 225, Richland, WA 99354. *Robust optimization of infrastructure networks.*

Infrastructure networks like the electric power grid, the gas pipeline network and the water distribution network deliver critical services for a modern economy. However, the steady-state behavior of these networks is described by nonlinear "flow equations" and poses a challenge for optimization and optimal control of these networks. Furthermore, these networks are being subject to ever-increasing sources of uncertainty (intermittent renewable generation in the power grid, increased coupling between the gas and power grid, the water-energy nexus etc.) and the traditional operating paradigms are insufficient to deal with the uncertainty while still ensuring optimal utilization of network resources. We present a new framework to construct convex inner approximations of the nonconvex feasible sets defined by the nonlinear flow equations and use these to compute robust-feasible solutions to the nonlinear systems. We further identify special cases when the robust nonconvex optimization problems can be solved to global optimality using convex relaxations. Finally, we present numerical results validating our approach. (Received February 27, 2017)

97 ► Mathematics education

1128-97-40 **J OShaughnessy*** (joshaugh@su.edu). *Town Hall Research Project in Introductory Statistics.*

As part of a general education initiative, guided research projects have been introduced in selected general education courses, including introductory statistics. The project involves students delving into independent research using a topic related to social concerns and coming up with a solution to a particular problem. The students then gather with students from other general education courses to discuss their research and debate solutions along with community consultants. This talk explains how the research project works in introductory statistics and some of the advantages and challenges of this type of project in a lower level math course. This project is funded by a Teagle Consortium Grant. (Received February 03, 2017)

1128-97-56 **Abigail L. Higgins*** (ahiggins@math.wsu.edu), Department of Mathematics and Statistics, Washington State University, PO Box 643113, Pullman, WA 99164. *Student Agency and Engagement in an Active-Learning Business Calculus Class.*

Business calculus at my institution covers the derivative, the integral, and their applications. This course is a requirement for every major within the school of business. This results in a high volume of students taking this course each semester. Through my own experience teaching this course and interviews with students, I found that many of these students perceive the content to be irrelevant. Student participation in this course tends to be quite low.

The design of my course was intended to provide students with opportunities to be active in class and emphasized applications of the derivative and the integral. I video- and audio-recorded each class session and identified three students during the semester who seemed to represent three different ways of engaging and achieving agency. These students were interviewed.

This project seeks to address concerns with this course (see first paragraph). In the context of my classroom, I consider student agency to be supportive or resistive moves to instructional design, classroom norms, and prescribed curriculum. What are the student moves in response to these dimensions of structure? What do these moves indicate about a student's agency or engagement? What instructional practices support student agency? (Received February 08, 2017)

1128-97-57 **Candace Mae Chappelle*** (candace.chappelle@wsu.edu), Pullman, WA 99163. *Critical Components of a Developmental Online Mathematics Course.*

A number of students who have been accepted to Washington State University (WSU) are unprepared or underprepared to enter into a required math course mandated by their selected area of study. In response to this issue, WSU created a basic math course, Math 100 to strengthen students' basic math skills. In addition to the

face-to-face Math 100 course, a parallel virtual course was proposed in hopes of reaching students who selected the WSU Global Campus. I found certain modifications to the Math 100 online course that are important to include in order to produce successful results. In particular online students need a great deal of encouragement, a review of effective study habits, a syllabus that clearly details class expectations in terms of performance and deadlines, and a skillful, patient, caring, encouraging but firm instructor. (Received February 08, 2017)

1128-97-58 **Shiv Karunakaran*** (shivk@math.wsu.edu), Department of Mathematics and Statistics, Washington State University, PO Box 643113, Pullman, WA 99164, and **James Whitbread** and **Abigail L. Higgins**. *Uses of Neurocognitive Measures to Evaluate Cognitive Load During the Mathematical Proving Process.* Preliminary report.

Using fNIRS (functional near-infrared spectroscopy), we were able to measure subjects' cognitive load while working on mathematical tasks. fNIRS measures the difference between oxygenated hemoglobin and deoxygenated hemoglobin. Cognitive load is associated with an increase in oxygenated hemoglobin. Subjects were graduate students from our institution. Each subject was administered four mathematical tasks in increasing order of difficulty while wearing the fNIRS device. Our study seeks to better understand the connection between cognitive workload and mathematical proving activities. Additionally, we are interested in bridging the gap between mathematics education and neuroscience in order to better understand the learning and doing of mathematics. (Received February 08, 2017)

1128-97-143 **Spencer Payton*** (spayton@math.wsu.edu). *Student mathematical connections in an introductory linear algebra course employing inquiry-oriented teaching.*

Mathematical connections are considered an important yet difficult aspect of an introductory linear algebra course. In an attempt to improve my teaching of mathematical connections, I explored how inquiry-oriented teaching could be used to provide opportunities for linear algebra students to develop connections. Specifically, I attempted to answer the following research questions: 1. What does it look like when a teacher attempts to incorporate inquiry-oriented teaching in an undergraduate introductory linear algebra class? 2. How do students take advantage of inquiry-oriented teaching to make mathematical connections in an introductory linear algebra class? Inquiry-oriented teaching was implemented in a limited capacity due to constraints such as a large class size and limited class time; inquiry was specifically reserved for the teaching of mathematical connections. Through a variety of inquiry-oriented activities, students were provided with several opportunities to develop mathematical connections. Results of the study suggest that these activities were successful in allowing students to develop their own interpretations of various concepts and that students' interpretations of those concepts may play an important role in the connections that students evoke. (Received February 22, 2017)

1128-97-173 **Carolyn A Otto*** (ottoa@uwec.edu), 1428 Bell Street, Eau Claire, WI 54703, and **Michael Penkava** (penkavmr@uwec.edu), Department of Mathematics, University of Wisconsin-Eau Claire, 105 Garfield Ave, Eau Claire, WI 54702. *Development and Implementation of a Research Methods Course.*

In this talk, we will discuss the development and implementation of our new math research methods course. The main premise of this course is to instruct future mathematicians on the art and procedures of mathematics research. We will discuss the structure and content of the course, which includes an original student research project that utilizes all the skills they had learned over the course of the semester. A description on how this course and research project help prepare students for future undergraduate and graduate research will be addressed. In addition, we will show how this course and its course work fits into our new comprehensive math research major. (Received February 24, 2017)

1128-97-189 **Heather A. Moon*** (hamoon@lcsc.edu), 500 8th Ave, Lewiston, ID 83501. *Using Image and Data Problems to Introduce Research-Like Experiences for Undergraduate Students.*

In this talk, I will discuss how I introduce open ended data problems in a Math Applications course to give students a research-like experience. Students are given an opportunity to participate in research without being admitted into an REU. I will share example problems, the path that students are encouraged to take, and the pros and cons that I've observed in such a classroom setting. (Received February 26, 2017)

1128-97-195 **Tom Asaki*** (tasaki@wsu.edu), Department of Mathematics and Statistics, 103 Neill Hall, Washington State University, Pullman, WA 99164-3115, and **Marie Snipes**, **Chris Camfield** and **Heather A Moon**. *Application-Inspired Linear Algebra.*

A student's ability to engage in scientific research is becoming the norm for undergraduates. The classroom can be a significant stepping stone toward achieving necessary skills and relevance through research practices. In this talk, we show how we have introduced research-like practices and applications as the key motivator for discovering Linear Algebra concepts. Activities and questions are designed as open-ended explorations, training students to grapple with undefined concepts and the unknown. Current research topics for classroom use include limited view tomography, noise removal from images, and visually-pleasing image blending. While students gain new appreciation for the utility of linear algebra, they also gain confidence in their own skills and ability to address research questions. By the end of one semester, students are more confident in addressing research-like tasks and can view questions through a mathematically enlightened and critical lens. Modules for classroom use are being developed and tested as part of the NSF-funded IMAGE Math project which is developing materials for use in undergraduate Analysis, Linear Algebra, Differential Equations, and Mathematical Modeling. (Received February 26, 2017)

1128-97-293 **Tyler Kloefkorn*** (tkloefkorn@math.arizona.edu). *Support for a Variety of Pathways to Undergraduate Research.*

An undergraduate research project in mathematics is traditionally offered as a capstone or via independent study. Unfortunately, this model may not serve the entire population of undergraduate mathematics majors. Fortunately, mathematics departments now integrate research in the classroom, and this offers students more pathways to undergraduate research. In modeling and statistics courses, we will discuss opportunities for undergraduate research and identify the student population. In addition, we will address how these courses integrate with capstones and independent study projects. (Received February 28, 2017)

1128-97-305 **Brian Dietel*** (bcdietel@lcsc.edu), Lewis-Clark State College, Lewiston, ID 83501. *Mathematical modeling with math, biology, and computer science majors.*

In Spring 2016, Lewis-Clark State College offered a cross-disciplinary course in mathematical modeling, with the goal of helping connect math, computer science, and biology majors. As a final project, the students were required to review primary literature for research to convert into a model using STELLA Professional software. Working on the projects with students from a wide variety of mathematical backgrounds presented unique challenges. I will discuss how we designed the course to meet the needs of the students, and how we plan on changing the course in the future. (Received February 28, 2017)

1128-97-338 **Cameron Sweet*** (csweet@math.wsu.edu), Department of Mathematics and Statistics, Washington State University, Pullman, WA 99164-3113. *Symbol System Flexibility and Justifications in Multiplying Polynomials.* Preliminary report.

While there is an extensive amount of research demonstrating that the ability to relate one representation of a function to another is necessary for understanding the concept of function, there are few studies on using multiple representations to help high school algebra students relate multiplication of polynomials to multiplication of integers. A representational dilemma emerges when students are taught the unfamiliar concept of multiplying polynomials using the unfamiliar symbolic representation for the distributive property. The goal of this study is to gain an understanding of whether presenting multiplication of polynomials using the same methods in which integers are multiplied may be beneficial to students' ability to make appropriate representational choices when multiplying polynomials. Student choices and accuracy will be compared to assessments in which students are instructed to solve similar problems using specific symbolic representations, namely the standard distributive property, lattice multiplication and the place value method. (Received February 28, 2017)

1128-97-350 **Jonas D'Andrea*** (jdandrea@westminstercollege.edu). *Choose your own adventure.* Preliminary report.

Extended student projects from a topics in applied mathematics course on signal processing will be discussed. After learning some basic ideas from Fourier analysis and wavelet theory, students were given four to five weeks (out of a 15 week semester) to explore topics of their choice using primary sources. More time than originally planned, it actually allowed for greater student ownership and exploration of *their* topic than expected. And was closer to a summer research experience for most students than the experience that a typical semester project usually affords. (Received February 28, 2017)

NEW YORK, NY, May 6–7, 2017

Abstracts of the 1129th Meeting.

00 ► General

1129-00-11 **Kevin K. Ferland*** (kferland@bloomu.edu), Mathematics Department, Bloomsburg University, 400 East Second Street, Bloomsburg, PA 17815. *Proving the Law of Cosines Like the Pythagorean Theorem.*

We consider two classic geometric dissection proofs of the Pythagorean Theorem and explain how to modify these original proofs for general triangles to obtain the Law of Cosines. (Received December 08, 2016)

1129-00-175 **Ramón Flores** and **Delaram Kahrobaei*** (dkharobaei@gc.cuny.edu), PhD Program in Computer Science, CUNY Graduate Center, The City University of New York, 365 Fifth Av, New York, NY 10016. *Cryptography with right-angled Artin groups.* Preliminary report.

In this paper we propose right-angled Artin groups as a platform for secret sharing schemes based on the efficiency (linear time) of the word problem. Inspired by previous work of Grigoriev-Shpilrain in the context of graphs, we define two new problems: Subgroup Isomorphism Problem and Group Homomorphism Problem. Based on them, we also propose two new authentication schemes. For right-angled Artin groups, the Group Homomorphism and Graph Homomorphism problems are equivalent, and the later is known to be NP-complete. In the case of the Subgroup Isomorphism problem, we bring some results due to Bridson who shows there are right-angled Artin groups in which this problem is unsolvable. (Received March 14, 2017)

1129-00-238 **Chris D. Lynd*** (clynd@bloomu.edu), Bloomsbug, PA 17815, and **James Wright Sharpe** (clynd@bloomu.edu), Bloomsburg, PA 17815. *Powers of the Fibonacci Recurrence Relation and the M&m Theorem to the Rescue.*

The sequence generated by the Fibonacci recurrence relation diverges to infinity. However, the sequence generated by the square root of the Fibonacci recurrence relation converges to two. We examine different powers of the Fibonacci recurrence relation and we examine higher-order Fibonacci recurrence relations. We then use the M&m theorem to prove a theorem that gives the limit of sequences that are generated by the pth-power of the kth-order Fibonacci recurrence relation. (Received March 16, 2017)

1129-00-239 **James Maynard*** (james.maynard@magd.ox.ac.uk), Mathematical Institute, Oxford, OX1 6GG, United Kingdom. *Large gaps between prime numbers.*

What is the largest gap between prime numbers less than some large number X?

This simple question has a long and rich history in number theory, and is also important in real world computer algorithms. Despite this, our knowledge about large gaps between primes remains frustratingly limited!

Paul Erdős particularly popularised this question. He used to offer cash prizes for problems as a challenge to the mathematical community. The largest prize he ever offered ($10,000) was for improving our state of knowledge about large prime gaps. Erdős' challenge was solved in 2014 independently by two groups of researchers, but the general picture is still very mysterious.

I will describe the history of the problem, some of its outside relevance, and the new ideas behind the solution to Erdős' problem. (Received March 16, 2017)

1129-00-408 **Ella Pavlechko*** (epavlechko@gm.slc.edu), 1 Mead Way, Bronxville, NY 10708. *On Determining if Tree-based Networks Contain Fixed Trees.*

In a paper by Francis and Steel, they give a polynomial time algorithm to decide if a phylogenetic network, N, is tree-based. They then ask if given any fixed tree T and network N, can it be decided in polynomial time whether N is based on T? We are able to show that such an algorithm would be NP-hard, and that the problem itself is fixed-parameter tractable. This is joint work with M. Anaya, O. Anipchenko-Ulaj, A. Ashfaq, J. Chiu, M. Kaiser, M. Shoji Ohsawa, M. Owen, E. Pavlechko, K. St. John, S. Suleria, K. Thompson, and C. Yap as part of the Fall 2016 Treespace REU at Lehman College, CUNY. (Received March 20, 2017)

1129-00-440 **Aamena Al-Qabani*** (rn030601@reading.ac.uk), 4 Odell Close, Reading, RG6 4DU, United Kingdom, and **Titus Hilberdink** and **Jani Virtanen**. .

Abstract In this paper we investigate the Fredholm property of Toeplitz operators T_μ on doubling Fock space F^p_φ for $1 < p < \infty$, where the symbol μ is Carleson measure and φ is subharmonic with $\Delta\varphi dA$ a doubling

measure. We give necessary and sufficient conditions on these symbols for T_f to be Frdholm. We also succeeded to compute the index and to describe the essential spectrum for these Toeplitz operators. Furthermore, we study the Fredholm Property of Toeplitz operator on the space $F^p_{|z|^m}$ with $m \in \mathcal{N}$. (Received March 21, 2017)

1129-00-479 **Bogdan G Nita*** (nitab@mail.montclair.edu), 1 Normal Avenue, Montclair, NJ 07043. *The Mathematics of Pan Flutes.*

Pan Flutes, also known as Pan Pipes, have been used in various cultures all over the world, ranging from ancient Greece to the Incas of Peru. The idea behind a pan flute is very simple: blowing into a closed tube creates a sound, the frequency of which depends on the length of that tube. However, the mathematics behind this process can become very complicated. In this study, we look at the relationship between the length of such a tube and the musical note that it produces and how this relationship influences the geometry of a Pan Flute. Based on this relation we create several models of the musical instrument in Python. (Received March 21, 2017)

03 ► Mathematical logic and foundations

1129-03-102 **David Marker*** (marker@uic.edu), Dept Mathematics (MC 249), University of Illinois at Chicago, 851 S. Morgan St., Chicago, IL 60607. *The Logical Complexity of Schanuel's Conjecture and Exponential Derivations.*

Schanuel's Conjecture is naturally a Π^1_1-statement. We show that it is equivalent to a Π^0_3-statement in arithmetic by showing that if there are counterexamples, then there are computable counterexamples. The main ideas in the proof come from the work of Johnathan Kirby on exponential algebraic closure and exponential derivations. I will survey Kirby's work and explain the application. (Received March 07, 2017)

1129-03-104 **Pierre Simon*** (pierre.simon@berkeley.edu), **Samaria Montenegro** and **Alf Onshuus**. *Groups in NTP$_2$, stabilizers and PRC fields.*

PRC fields are to real closed fields what PAC fields are to algebraically closed fields. Groups definable in bounded PAC fields were understood by Hrushovski and Pillay making use of the fact that those structures are simple with finite U-rank. In this talk I will explain how those results can be adapted to study definably amenable groups in bounded PRC fields, which are only NTP$_2$. This requires a couple of different tools, in particular: a generalization of the theory of definably amenable groups from NIP to NTP$_2$ and a strengthening of Hrushovski's stabilizer theorem from his work on approximate subgroups. (Received March 07, 2017)

1129-03-120 **Rachel D Stahl*** (rachel.stahl@uconn.edu), University of Connecticut, 341 Mansfield Road U1009, Storrs, CT 06269. *Computability Theory and the Game of Cops and Robbers on Infinite Graphs.* Preliminary report.

Cops and Robbers is a vertex-pursuit game played on a connected graph wherein two players, a cop and a robber, begin on a pair of vertices and alternate turns moving to adjacent vertices. A graph is cop-win if, from any pair of starting vertices, the cop can occupy the same vertex as the robber after finitely many rounds. In this talk, we discuss computability theoretic results for the game when played on infinite computable graphs. We will consider known characterizations of cop-win graphs, and explore the complexity of winning strategies for both players, as well as of various index sets. (Received March 09, 2017)

1129-03-123 **Timothy H McNicholl*** (mcnichol@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50010. *Analytic computable structure theory and L^p spaces.*

Until recently computable structure theory has focused on classes of countable algebraic structures. However, a program has now emerged to use computable analysis to broaden the purview of computable structure theory so as to include analytic structures such as metric spaces and Banach spaces. We will present a classification of the computably categorical L^p spaces in terms of p and the structure of the underlying measure space. (Joint work with T. Brown, J. Clanin, and D. Stull) (Received March 09, 2017)

1129-03-213 **Philipp Hieronymi*** (phierony@illinois.edu), Department of Mathematics, University of Illinois, 1409 W Green St, Urbana, IL 61801. *On continuous functions definable in expansions of the ordered real additive group.*

For every expansion of the ordered real additive group one of the following holds: every continuous definable function $[0,1] \to \mathbb{R}$ is C^2 on an open dense subset of $[0,1]$, or every definable C^2 function $[0,1] \to \mathbb{R}$ is affine, or every continuous function $[0,1] \to \mathbb{R}$ is definable. The first case holds for any NTP$_2$ expansion of $(\mathbb{R}, <, +)$, more generally for any expansion that does not interpret the monadic second order theory of one successor. This is joint work with Erik Walsberg. (Received March 16, 2017)

1129-03-220 **Albert Garreta**, **Alexei Miasnikov** and **Denis Ovchinnikov*** (dovchinn@stevens.edu). *Interpretations by Positive Existential Formulas and the Diophantine-Class Problems.*

The *Diophantine problem* (D(M)) over a structure M is formulated as follows: given a (finite) system of equations over M decide if it has a solution in M or not. Studying decidability of $D(M)$ is a classical topic: Tenth Hilbert problem shows that $D(\mathbb{Z})$ is undecidable; Makanin-Razborov algorithm shows that $D(F)$ is decidable for any free group F of finite rank. Despite continuing interest in this kind of problems (e.g., $D(\mathbb{Q})$), transferring undecidability from one structure to another (even closely related) remains a difficult task. We develop machinery that allows one to approach this kind of problems in a more structured way.

The classical notion of interpretations is widely used to show undecidability of first-order theory of a given structure (among other applications). We define more strict *positive existential* (or PE) interpretations, and show that they can be used in a similar fashion to prove that $D(M)$ is undecidable for certain M.

I will explain the definition of PE-interpretations, provide some of their basic properties, and show examples of non-trivial new results about decidability of $D(M)$ that can be obtained using these definitions (finitely generated nilpotent or metabelian groups, free associative algebras). (Received March 16, 2017)

1129-03-254 **Vince N Guingona*** (vguingona@towson.edu), Department of Mathematics, 8000 York Road, Towson, MD 21252. *Generalized indiscernibles and dividing lines.*

I discuss a general framework for the characterization of dividing lines in model theory via the collapse of generalized indiscernibles. With this in mind, I will also explore a framework for the concept of positive local combinatorial dividing lines. I apply these concepts to a selection of specific cases, including theories of random hypergraphs. This work is joint with C. D. Hill (Received March 17, 2017)

1129-03-258 **Victoria Gitman*** (vgitman@gmail.com). *Computable processes which produce any desired output in the right nonstandard model.*

A total computable function will produce the same output on the standard natural numbers regardless of which model of PA it is evaluated in. But a (partial) computable function can be the empty function in the standard model $\mathbb{N}$ and a total function in some nonstandard model. I will discuss some extreme instances of this phenomena, investigated recently by Woodin and Hamkins, showing that there are computable processes which produce any desired output by going to the right nonstandard model. Hamkins showed that there is a single TM program p with the property that given any function $f : \mathbb{N} \to \mathbb{N}$, there is a model $M_f \models \mathrm{PA}$ so that in M_f p computes f on the standard part. Even more drastically, Woodin has shown that there is a single index e, for which PA proves that W_e is finite, with the property that for any finite set s of natural numbers, there is a model $M_s \models \mathrm{PA}$ in which $W_e = s$. It follows for instance, by the MRDP theorem, that there is a single Diophantine equation $p(n, \bar{x}) = 0$, which PA proves has solutions for finitely many n, and given any finite set s, we can pass to a model in which $p(n, \bar{x}) = 0$ has a solution if and only if $n \in s$. (Received March 17, 2017)

1129-03-265 **Athar Abdul-Quader*** (aabdulquader@gradcenter.cuny.edu), 247-12 88th Road, Bellerose, NY 11426. *Lattices and coded sets.*

Give an elementary extension $\mathcal{M} \prec \mathcal{N}$ of models of Peano Arithmetic (PA), the set of all $\mathcal{K}$ such that $\mathcal{M} \preceq \mathcal{K} \preceq \mathcal{N}$ forms a lattice under inclusion. If $\mathcal{N}$ is an elementary end extension of $\mathcal{M}$ and $X \subseteq M$, we say X is *coded* in $\mathcal{N}$ if there is $Y \in \mathrm{Def}(\mathcal{N})$ such that $X = Y \cap M$. In this talk, I will discuss the relationship between interstructure lattices and coded sets. Recent work by Schmerl determined those collections of subsets of a model which could be coded in a minimal extension; in this talk, we explore the same question for elementary extensions whose interstructure lattices form a finite distributive lattice. (Received March 17, 2017)

1129-03-289 **Henry P Towsner*** (htowsner@math.upenn.edu). *If a sequence converges, how computable should the rate be?*

Standard examples show that when a sequence converges, the rate of convergence need not be computable. Nonetheless, a "rate of metastable" convergence" usually is computable, and can be used as a substitute in certain arguments.

We ask about an intermediate notion: computability of a bound on the number of fluctuations. While a bound on the number of fluctuations need not be computable, it often is, and whether or not it is turns out to be crucially connected to how the sequence behaves when extended to the nonstandard natural numbers. (Received March 18, 2017)

1129-03-294 **Cheng Chang*** (cchang4@mercy.edu), Dobbs Ferry, NY 10522. *On Totally Disconnected Locally Compact Second Countable Groups with Two-sided Invariant Metrics.*

We consider the class of totally disconnected locally compact second countable groups with two-sided invariant metrics, and give several characterizations of such groups. Using these characterizations, we show that there exist subjectively universal groups for this class, but there does not exists a universal group. (Received March 18, 2017)

1129-03-306 **Jonathan Stephenson*** (j9stephe@uwaterloo.ca), Pure Mathematics, University of Waterloo, 200 University Ave W, Waterloo, Ontario N2L 3G1, Canada, and **Barbara Csima** (csima@uwaterloo.ca), Pure Mathematics, University of Waterloo, 200 University Ave W, Waterloo, Ontario N2L 3G1, Canada. *Computable categoricity on a cone and degrees of categoricity.*

A structure $\mathcal{A}$ is said to be computably categorical on the cone above a Turing degree $\mathbf{d}$ if, for any degree $\mathbf{c} \geq \mathbf{d}$, and any two $\mathbf{c}$-computable copies of $\mathcal{A}$, there is a $\mathbf{c}$-computable isomorphism between them. This condition implies that automorphism orbits of the structure $\mathcal{A}$ are defined by formulas of low syntactic complexity. This in turn creates a natural upper bound on how hard it is to compute an isomorphism between two computable copies of $\mathcal{A}$. We give a structure $\mathcal{A}$ which attains this bound, as part of a more general family of structures. This is joint work with Barbara Csima. (Received March 19, 2017)

1129-03-310 **Lev M Shneerson*** (lshneers@hunter.cuny.edu), Department of Mathematics and Statistics, Hunter College, 695 Park Avenue, New York, NY 10065. *On finite presentations of inverse semigroups having polynomial growth.* Preliminary report.

We study connections between rank, deficiency and types of growth in various classes of finitely presented inverse semigroups. Let m and n be positive integers and let S be a Rees quotient of a free inverse semigroup, given by an irredundant presentation with n generators and m relators. We show that if S has polynomial growth, then $m \geq n^2 - 1$ and for any fixed value of n, this lower bound for the number of relators is sharp. Some applications of this result will be considered.

Joint work with David Easdown (University of Sydney, Australia). (Received March 19, 2017)

1129-03-328 **Adam Day**, **Rod Downey** and **Linda Brown Westrick*** (westrick@uconn.edu). *Turing-, tt-, and m-reductions for functions in the Baire hierarchy.* Preliminary report.

For arbitrary functions $f : [0, 1] \to \mathbb{R}$, (including in particular highly discontinuous functions), what would be the right notion of Turing reducibility and its variants? We present a computationally motivated definition of $\leq_T$, $\leq_{tt}$, and $\leq_m$ for such functions, and show that within the Baire hierarchy, the linearly ordered $\leq_T$-equivalence classes correspond precisely to the proper Baire classes. Further, within the Baire 1 functions, the $\leq_{tt}$ and $\leq_m$ equivalence classes enjoy a natural correspondence with levels of the α rank on Baire 1 functions considered in Kechris and Louveau (1990). (Received March 19, 2017)

1129-03-363 **Michael Deveau*** (m2deveau@uwaterloo.ca). *High / Low Hierarchies and Jump Inversion for the Bounded Jump in the Bounded Turing Degrees.*

Given a set A, the *bounded jump* of A is defined as $A^b = \{x \mid (\exists i < x)[\varphi_i(x) \downarrow \wedge \Phi_x^{A \restriction \varphi_i(x)}(x) \downarrow]\}$. Introduced by Anderson and Csima in 2014, this operator acts in many ways as an analogue to the standard jump operator when working with bounded Turing reductions (also known as weak truth table reductions). In this talk, we present some results about the high and low hierarchies of this operator and how they relate to the standard high and low hierarchies. We also discuss jump inversion in the bounded Turing degrees. (Received March 20, 2017)

1129-03-381 **Joseph S. Miller***, University of Wisconsin–Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706. *A cornucopia of characterizations of cototality.*

An enumeration degree is cototal if it contains a set that is enumeration reducible to its complement. The cototal degrees form a natural substructure of the enumeration degrees. We give evidence for this by describing several very different characterizations of the class, coming from different areas of mathematics: symbolic dynamics, computable structure theory, effective topology, graph theory, and degree theory. (Received March 20, 2017)

1129-03-382 **Damir D Dzhafarov*** (damir@math.uconn.edu), 341 Mansfield Road, Storrs, CT 06269-1009. *Joins in the strong Weihrauch degrees.*

Weihrauch reducibility is a tool for comparing the difficulty of various mathematical problems that has been widely applied in computable analysis and complexity theory, and more recently, also in computable combinatorics. In many ways, it is a refinement both of effective mathematics and reverse mathematics, and over the past few years it has seen a surge of interest. Many open problems remain about the basic algebraic structure of the Weihrauch degrees. We answer a question of Brattka and Pauly by showing that the so-called strong Weihrauch degrees, which are a natural and well-studied subclass of the Weihrauch degrees, form a lattice. Previously, these were known only to form a lower semi-lattice. I will present a general introduction to this problem and give a sketch of the proof. (Received March 20, 2017)

1129-03-386 **James S Barnes*** (jsb437@cornell.edu). *The theory of the hyperarithmetic degrees as an uppersemilattice is decidable.*

Hyperarithmetic reducibility, $\leq_h$, is a notion of reducibility between subsets of $\mathbb{N}$. We say a set X is hyperarithmetic in Y, $X \leq_h Y$, if X is Turing reducible $Y^{(\delta)}$, the δth jump of Y, for some ordinal δ which has a Y-computable representative. The hyperarithmetic degrees are formed by taking the quotient of the powerset of $\mathbb{N}$ under mutual hyperarithmetic reducibility: $X \equiv_h Y$ iff $X \leq_h Y$ and $Y \leq_h X$.

It is interesting to find similarities and differences between the Turing degrees and the hyperarithmetic degrees. For instance, the hyperarithmetic degrees are known to be rigid, but this is still an open problem for the Turing degrees. The theories of these structures are both undecidable: as complicated as full second-order arithmetic. Indeed, the Σ_3 theories of these structures in the language with $\leq$ are undecidable.

Jockush and Slaman showed the Σ_2 theory of the Turing degrees in the language of uppersemilattices (i.e., with $\leq, \vee$ and 0) is decidable. I will present a proof of this result in the hyperarithmetic setting, and discuss the delicacies of forcing constructions in the hyperarithmetic degrees. (Received March 20, 2017)

1129-03-399 **Reese Johnston***, rwjohnston@math.wisc.edu. *Computability in* 2^{ω_1}.

Cantor space has been an object of significant study in computability theory; of particular interest are the properties of Π^0_1 classes, or "computably closed" sets. It seems natural to ask whether this wealth of results can be transferred to other topological spaces that are in some sense similar. One possible direction for this study is the theory of Polish spaces; we take another direction, using admissible recursion theory to study 2^{ω_1}, a space that is much larger but conceptually similar. (Received March 20, 2017)

1129-03-406 **Mariya I. Soskova*** (msoskova@fmi.uni-sofia.bg). *Generic Muchnik reducibility and expansions of the reals.*

We want to understand the relative complexity of algebraic structures. For countable structures, computability theory gives a good method, Muchnik reducibility: $A \leq_w B$ if every ω-copy of B computes an ω-copy of A. Schweber extended this to arbitrary structures: if A and B are (possibly uncountable) structures, then A is generically Muchnik reducible to B ($A \leq^*_w B$) if in some (equivalently, any) forcing extension that makes A and B countable, $A \leq_w B$.

Computability theorists often use the word *real* interchangeably to describe an element of Cantor space, 2^ω, Baire space, ω^ω, or the ordered field of the reals, $\mathbb{R}$. Using generic Muchnik reducibility, we see computability theoretic differences between these structures and their expansions. For example, $2^\omega <^*_w \omega^\omega$, while any expansion of $\mathbb{R}$ by countably many continuous functions is equivalent to ω^ω. On the other hand, we can expand ω^ω by a continuous function to get a strictly more complicated structure, one that is generic Muchnik above every Borel structure.

This work is joint with Andrews, Knight, Kuyper, Lempp, and Miller. (Received March 20, 2017)

1129-03-437 **Noah Schweber***, 425 W. Washington Ave., Apt. 512, Madison, WI 53703. *What should higher reverse math be?*

There are many possible ways to extend reverse mathematics to a higher-order setting. I'll present some approaches to developing a natural third-order version of reverse mathematics from a computability-theoretic viewpoint. I'll also discuss how these relate to the more proof-theoretic approach, which so far has received more attention. (Received March 21, 2017)

1129-03-441 **Christopher P Porter*** (cp@cpporter.com), Drake University, Des Moines, IA 50310, and **Rupert Hölzl** (r@hoelzl.fr), Bundeswehr University Munich, 85579 Neubiberg, Germany. *Rank and randomness.*

A straightforward result in algorithmic randomness is that no Martin-Löf random sequence is a member of a countable Π^0_1 class (and not even a Π^0_1 class of Lebesgue measure zero). However, it has been shown by Bienvenu and Porter that there is a computable measure μ with the property that there is a non-computable sequence that is Martin-Löf random with respect to μ and is contained in a countable Π^0_1 class; in fact, this particular sequence has Cantor-Bendixson rank 1. This raises a question: For each computable ordinal α, is there a sequence that is Martin-Löf random with respect to some computable measure and has Cantor-Bendixson rank α? In this talk, I will show that not only is there an affirmative answer to this question, but also that such a sequence can be found in every Δ^0_2 degree that contains a Martin-Löf random sequence (with respect to the Lebesgue measure). This is joint work with Rupert Hölzl. (Received March 21, 2017)

1129-03-450 **Reid Dale*** (reiddale@math.berkeley.edu). *Generalized Differential Galois Extensions.*
In a recent paper, Kamensky and Pillay give sufficient conditions for the existence of a differential Galois extension for a logarithmic differential equation defined over an algebraic group G over the constants. In this talk we extend this result to arbitrary algebraic D-groups and find sufficient conditions for the existence and uniqueness of such extensions. This work is joint with J. Nagloo. (Received March 21, 2017)

1129-03-463 **Timothy H. McNicholl** and **Jason M. Rute*** (jmr71@math.psu.edu). *A uniform reducibility in computably presented Polish spaces.* Preliminary report.
Given computably presented Polish spaces $\mathbb{X}$ and $\mathbb{Y}$, we say $x \in \mathbb{X}$ is *reducible to* $y \in \mathbb{Y}$ if there is a Π^0_1 set $P \subseteq \mathbb{Y}$ and a computable map $f\colon P \to \mathbb{X}$ such that $f(y) = x$. For each space $\mathbb{X}$ one may consider the corresponding degree structure $\mathbf{deg}(\mathbb{X})$. For example, $\mathbf{deg}(2^{\mathbb{N}})$ is (isomorphic to) the truth-table degrees, whereas both $\mathbf{deg}(\mathbb{N}^{\mathbb{N}})$ and $\mathbf{deg}(\mathbb{R})$ are proper extensions of $\mathbf{deg}(2^{\mathbb{N}})$.

This new reducibility has many motivations. First, truth-table reducibility on $2^{\mathbb{N}}$ is too restrictive of a setting for computable analysis. For example, there are functions $f \in \mathbb{N}^{\mathbb{N}}$ not truth-table reducible to any $X \in 2^{\mathbb{N}}$ and sequences $X \in 2^{\mathbb{N}}$ such that $X/3 \not\leq_{tt} X$. Second, this project mirrors Miller's non-trivial work extending Turing reducibility to computably presented Polish spaces. Last, our reducibility grew naturally out of work of the first author on computable arcs and the second author on Schnorr randomness. For example, we show that, for $\mathbb{R}^d$, every Schnorr random is found in some computable arc. (Received March 21, 2017)

1129-03-465 **U Andrews**, **G Igusa*** (gigusa@nd.edu), **J Miller**, **N Schweber** and **M Soskova**.
Continuous degrees and almost totality in the enumeration degrees. Preliminary report.
Enumeration reducibility is a reducibility from classical recursion theory. The Turing degrees embed in the enumeration degrees, and it has recently been shown that these embedded degrees, known as total degrees, are definable in the degree structure. This has brought increased attention to the enumeration degrees, and especially to the way the total degrees sit inside them.

The continuous degrees are a substructure of the enumeration degrees, strictly containing the total degrees, introduced by Joe Miller in 2004. It was recently observed that even non-total continuous degrees are almost total: They become total if any additional total information is added.

We investigate the question of whether every almost total degree is continuous. A yes answer would provide a definition of the continuous degrees within the enumeration degrees, which would allow many results about continuous degrees to translate into definability results. We provide a partial result, using certain uniformity assumptions. We also discuss several other combinatorial properties that are relevant to the question, producing a chain of implications with at least one strict nonimplication somewhere in the chain. (Received March 21, 2017)

1129-03-483 **Wesley Calvert*** (wcalvert@siu.edu), Department of Mathematics, Mail Code 4408, 1245 LINCOLN DRIVE, CARBONDALE, IL 62918. *Computability and Continuous Logic.*
Continuous first-order (CFO) logic arose in efforts to use model-theoretic ideas about independence in certain analytic contexts (collectively called "metric structures"). It also has a natural relationship with randomized computation, in that an effective completeness theorem guarantees a probabilistically computable model of every decidable CFO theory.

In the present talk, we will discuss computability-theoretic aspects of metric structures and CFO logic, and their relations to several other aspects of logic and computation, including random structures, probability, and complexity. (Received March 21, 2017)

1129-03-489 **Rehana Patel*** (patel_rehana@wheatoncollege.edu), 26 E. Main Street, Norton, MA 02766. *A computable construction for exchangeable measures.*
In recent work with Ackerman and Freer, we characterize those sentences of $L_{\omega_1,\omega}$ that admit exchangeable measures. In the positive direction, our construction begins with a model of such a sentence and constructs an exchangeable measure concentrated on (countable models of) the sentence using a Morleyization of the model. In this talk we show that this construction is computable; in particular, if we start with a model whose Morleyization is computable then the resulting exchangeable measure is computable as well. (Received March 21, 2017)

05 ► Combinatorics

1129-05-15 **Papa A. Sissokho***, Illinois State University, 4520 Mathematics Department, Normal, IL 61790-4520, and **Esmeralda L. Nastase**. *The maximum size of a partial t-spread of V(n,q).*

Let $V = V(n,q)$ denote the vector space of dimension n over the field with q elements. A partial t-spread of V is a collection of t-dimensional subspaces of V whose pairwise intersection is trivial. In a recent paper, we determined the maximum cardinality of a partial t-spread for almost all values of the parameters n, t, and q. We will talk about this result and its relevance to coding theory. This is joint work with Esmeralda Nastase (Xavier University). (Received January 04, 2017)

1129-05-25 **Nathan B. Shank*** (shankn@moravian.edu), Moravian College, 1200 Main Street, Bethlehem, PA 18018. *Component Order Connectivity and Variants.*

The *Component Order Connectivity* (COC) of a graph is a network reliability measure introduced by Suffel et al. in 1996. The COC parameter measures the minimum number of vertices that must be removed (and incident edges) from a graph so that each remaining component has order less than some predetermined value k. The COC parameter has lead to many other interesting variations and examples of conditional connectivity parameters. During this talk we will consider different conditional connectivity parameters related to COC. We will look at examples, recent results, and talk about some ongoing research in hopes of stimulating collaboration.
(Received January 19, 2017)

1129-05-49 **Justin Allman*** (allman@usna.edu) and **Richard Rimanyi**. *Quantum dilogarithm identities for the square product of A-type Dynkin quivers.* Preliminary report.

The famous pentagon identity for quantum dilogarithms has a generalization for every Dynkin quiver, due to Reineke. A more advanced generalization is associated with a pair of alternating Dynkin quivers, due to Keller. The description and proof of Keller's identities involves cluster algebras and cluster categories, and the statement of the identity is implicit. In this talk we describe Keller's identities explicitly by a dimension counting argument. Namely, we consider the quiver representation space together with a superpotential function, and calculate the Betti numbers of the equivariant rapid decay cohomology algebra in two different ways corresponding to two natural stratifications. This approach is suggested by Kontsevich and Soibelman in relation with the Cohomological Hall Algebra of quivers, and the associated Donaldson–Thomas invariants. (Received February 17, 2017)

1129-05-73 **Sami Assaf** and **Dominic Searles*** (dsearles@usc.edu), Department of Mathematics, 3620 S Vermont Ave KAP 104, Los Angeles, CA 90089. *Kohnert tableaux and quasi-key polynomials.*

We introduce the combinatorial model of Kohnert tableaux, based on the diagram model of A. Kohnert. We use Kohnert tableaux to introduce the quasi-key basis of the polynomial ring, which lifts the quasi-Schur polynomials of Haglund, Luoto, Mason and van Willigenburg. Key polynomials expand positively in quasi-key polynomials which in turn expand positively in fundamental slide polynomials. We give simple, positive combinatorial formulas for these expansions in terms of Kohnert tableaux, lifting the parallel expansions of a Schur polynomial into quasi-Schur polynomials into fundamental quasisymmetric polynomials. (Received March 02, 2017)

1129-05-74 **John T Saccoman*** (saccomjt@shu.edu), 400 South Orange Ave., South Orange, NJ 07079. *The Contributions of the Seton Hall/Stevens Graph Theory Group to the Spanning Tree Problem.*

The Stevens Tech Graph Theory group, originated by Charlie Suffel and the late Frank Boesch, was a hub of research throughout the 1980s and early 90s. The group produced scores of papers and mentored dozens of Ph.D. theses. Of particular interest in the early years was the spanning tree problem, as the number of spanning trees of a graph is a measure of vulnerability of the related network to disconnection by edge failure. We present some of the results from the group as well as more recent results from its current incarnation as the Seton Hall/Stevens Graph Theory Group.

Keywords: spanning trees, eigenvalues, multigraphs, spectral graph theory (Received March 02, 2017)

1129-05-85 **Robert Davis*** (davisr@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824, and **Bruce Sagan** (sagan@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Pattern Avoidance and the Birkhoff Polytope.*

The Birkhoff polytope B_n is the convex hull of all $n \times n$ permutation matrices, and is a long-studied polytope related to many areas of mathematics. This talk will discuss a generalization which considers subpolytopes $B_n(\Pi)$ of B_n whose vertices correspond to permutations avoiding a given set of patterns Π. We will pay special attention to $B_n(132, 312)$ due to its relationships with certain EL-shellable posets, shifted standard Young tableaux, and (P, ω)-partitions. These relationships allow us to determine the Ehrhart series of the polytope as well as an exact formula for its normalized volume. (Received March 05, 2017)

1129-05-106 **Ilke Canakci** and **Ralf Schiffler*** (schiffler@math.uconn.edu), University of Connecticut, Department of Mathematics U1009, 341 Mansfield Road, Storrs, CT 06269-1009. *Cluster algebras, snake graphs and continued fractions.*

This talk is on a combinatorial realization of continued fractions in terms of perfect matchings of the so-called snake graphs, which are planar graphs that have first appeared in expansion formulas for the cluster variables in cluster algebras from triangulated marked surfaces. I will also explain applications to cluster algebras, as well as to elementary number theory.

This is a joint work with Ilke Canakci. (Received March 07, 2017)

1129-05-111 **Cara Monical**, **Neriman Tokcan** and **Alexander Yong***, Math Dept UIUC, 1409 W. Green St, Urbana, IL 61801. *Newton polytopes in algebraic combinatorics.*

A polynomial has *saturated Newton polytope* (SNP) if every lattice point of the convex hull of its exponent vectors corresponds to a monomial. We compile instances of SNP in algebraic combinatorics (some with proofs, others conjecturally): skew Schur polynomials; symmetric polynomials associated to reduced words, Redfield–Pólya theory, Witt vectors, and totally nonnegative matrices; resultants; discriminants (up to quartics); Macdonald polynomials; key polynomials; Demazure atoms; Schubert polynomials; and Grothendieck polynomials, among others.

Our principal construction is the *Schubitope.* For any subset of $[n]^2$, we describe it by linear inequalities. This generalized permutahedron conjecturally has positive Ehrhart polynomial. We conjecture it describes the Newton polytope of Schubert and key polynomials. We also define *dominance order* on permutations and study its poset-theoretic properties. (Received March 08, 2017)

1129-05-161 **Sandra R Kingan*** (skingan@brooklyn.cuny.edu). *Pressure Networks in Climate.* Preliminary report.

Abstract: In the early 20th century statistician Gilbert Walker became interested in meteorology and published a series of papers in which he analyzed time series of sea level pressure at various locations. He published large tables of correlations and auto-correlations and highlighted those that were statistically significant. Using this data, Walker and E. W. Bliss identified large-scale oscillations in climate, such as the Southern Oscillation, which is the atmospheric companion to El Ninö. Although Walker does mention or use any concepts from graph theory, a careful analysis of his work reveals he was thinking in terms of graphs. Following Walker's example we construct and analyze pressure networks using modern data sources. This is joint work with M. Tomkiewicz and R. J. Kingan. (Received March 13, 2017)

1129-05-169 **Sebastian Franco** (sfranco@ccny.cuny.edu), Department of Physics, New York, NY 10031, and **Gregg Musiker*** (musiker@math.umn.edu), School of Mathematics, Minneapolis, MN 55455. *Higher Cluster Categories and Physics.* Preliminary report.

We describe recent developments and work in progress connecting the theory of higher cluster categories to string theory. (Received March 13, 2017)

1129-05-174 **Richárd Rimányi**, **Anna Weigandt*** (weigndt2@illinois.edu) and **Alexander Yong**. *Partition Identities and Quiver Representations.*

We present a particular connection between classical partition combinatorics and the theory of quiver representations. Specifically, we give a bijective proof of an analogue of A. L. Cauchy's Durfee square identity to multipartitions. We then use this result to give a new proof of M. Reineke's identity in the case of quivers Q of Dynkin type A. Our identity is stated in terms of the lacing diagrams of S. Abeasis - A. Del Fra, which parameterize orbits of the representation space of Q. (Received March 14, 2017)

1129-05-176 **Monika M. Heinig*** (monikamheinig@gmail.com), 24 W 76th Street, Apt BR, New York, NY 10023, and **Daniel Gross**, **Charles Suffel**, **John T. Saccoman** and **Khaldoun Khashanah**. *Cutting a Tree into a Forest: An Edge Weighted Algorithm.*

In many industries, data is collected to see how things change over time or how things may or may not relate to each other. Networks can be formed from this data where the nodes represent industry specific areas of interest (such as S&P 500 sector indices in financial engineering, people in a social network, or areas of the brain in neurology) and the edges are assigned weights that correspond to a relation, distance, or change over time between its endnodes. The network can be reduced to either a minimum (or maximum) spanning tree based on the weights of the edges, and such a spanning tree will retain characteristic properties of the original network. If a predetermined threshold value k is chosen, the tree can be decomposed into components such that the sum of all the edge weights of each component is less than the threshold value. To minimize the loss of network information, we want to remove the minimum number of edges necessary to yield such a forest. In this talk, we present a polynomial time algorithm for cutting a weighted spanning tree into a forest such that each tree of the forest has total weight less than a predetermined threshold value k. (Received March 14, 2017)

1129-05-177 **Kerry Ojakian*** (kerryojakian@gmail.com). *Three graph duals and a bijection.*

In 1959 Denes showed that the number of vertex labeled trees on n vertices is the same as the number of factorizations of the permutation $(1, \ldots, n)$ into $n-1$ transpositions. Various research uncovered interesting bijections between these two sets; a bijection of particular interest is the bijection of Goulden and Yong, from 2002. The definition of their bijection is based on their topological notion of dual that applies to trees. I will speak about three alternative definitions of dual that we have devloped: a graph-theoretic one, an algebraic one, and a combinatorial "mind-body" dual. It is of interest to note that though our three definitions are different in spirit, they will turn out to be the same. Furthermore, on trees, our dual is the same as that of Goulden and Yong, but our dual in fact makes sense on any graph and allows us to give alternative proofs for Goulden and Yong's work. I will mention the bijection and motivate our definitions of dual, in particular, in honor of Charlie Suffel, we will consider what happens if Charlie's mind is swapped with the mind of one of his students! This is joint work with Nikolaos Apostolakis. (Received March 14, 2017)

1129-05-181 **J. M. S. Simoes-Pereira*** (siper@mat.uc.pt), Departamento de Matemática, Universidade de Coimbra, PT3001-454 Coimbra, Portugal. *Determinants and permanents: Extreme values they reach.* Preliminary report.

We discuss several aspects related with the problem of finding the maximum and minimum values attained by determinants and permanents of n x n matrices given their real positive entries. Relevant seems to be the existence of configurations where these extreme values are attained or the non-existence of such configurations which means the need for algorithms to solve these problems. (Received March 14, 2017)

1129-05-192 **Lakshmi Iswara Chandra Vidyasagar*** (laks_vs@yahoo.com) and **Praveenkumar Khethavath**. *Resource Allocation in Hierarchical Distributed Cloud Using Weighted Component Edge Connectivity.* Preliminary report.

The main goal of the project is to develop novel resource discovery algorithms in a hierarchical distributed cloud. In order to perform the resource discovery, we intend to use the weighted order edge connectivity mechanism. In this mechanism, we assign weight to the edges connecting two nodes. This weight will be able to determine the traffic between two or more nodes, based on which we will be able to discover nodes, with in a certain weight such that performance of the resource offered is not compromised. (Received March 15, 2017)

1129-05-200 **Sara C. Billey*** (billey@math.washington.edu), Box 354350, Math dept, Seattle, WA 98105, **Benjamin Young**, OR , and **Alexander Holroyd**. *Reduced words and a formula of Macdonald.*

Macdonald gave a remarkable formula connecting a weighted sum of reduced words for a permutation with the number of terms in a Schubert polynomial. We will review some of the fascinating results on the set of reduced words in order to put our main results in context. Then we will discuss a new bijective proof of Macdonald's formula based on Little's bumping algorithm. We will also discuss some generalizations of this formula based on work of Fomin, Kirillov, Stanely and Wachs. This project extends earlier work by Benjamin Young on a Markov process for reduced words of the longest permutation.

This is joint work with Ben Young and Alexander Holroyd. (Received March 15, 2017)

1129-05-221 **Matthias Beck*** (mattbeck@sfsu.edu), **Katharina Jochemko** and **Emily McCullough**. *Ehrhart polynomials of zonotopes.*

The *Ehrhart polynomial* of a lattice polytope P encodes fundamental arithmetic data of P, namely, the number of integer lattice points in positive integral dilates of P. Mirroring Herb Wilf's much-cherished and still-wide-open question *which polynomials are chromatic polynomials?*, we present some new classification results for Ehrhart polynomials of *zonotopes*, i.e., projections of (higher dimensional) cubes. This includes a combinatorial description in terms of refined descent statistics of permutations and a formula in matroidal terms which complements a well-known zonotopal identity of Stanley (1991). Finally, we give a complete description of the convex hull of the Ehrhart coefficients of zonotopes in a given dimension: it is a simplicial cone spanned by refined Eulerian polynomials. (Received March 16, 2017)

1129-05-244 **Pavel Galashin*** (galashin@mit.edu) and **Pavlo Pylyavskyy**. *Zamolodchikov periodicity and integrability.*

The T-system is a certain discrete dynamical system associated with a quiver. Keller showed in 2013 that the T-system is periodic when the quiver is a product of two finite Dynkin diagrams. We prove that the T-system is periodic if and only if the quiver is a finite $\boxtimes$ finite quiver. Such quivers have been classified by Stembridge in the context of Kazhdan-Lusztig theory. We show that if the T-system is linearizable then the quiver is necessarily an affine $\boxtimes$ finite quiver. We classify such quivers and conjecture that the T-system is linearizable for each of them. Next, we show that if the T-system has algebraic entropy zero then the quiver is an affine $\boxtimes$ affine quiver, and classify them as well. For the octahedron and the cube recurrence, we prove the converse direction of each of the three statements using explicit formulas due to Speyer and Carroll combined with our general linearizability result for cylindrical networks. (Received March 17, 2017)

1129-05-252 **Nathan Kahl***, Nathan.Kahl@shu.edu. *On Constructing Rational Spanning Tree Edge Densities.*

Let $\tau(G)$ and $\tau_G(e)$ denote the number of spanning trees of a graph G and the number of spanning trees of G containing edge e of G, respectively. Ferrara, Gould, and Suffel asked if, for every rational $0 < p/q < 1$ there existed a graph G with edge $e \in E(G)$ such that $\tau_G(e)/\tau(G) = p/q$. In this note we provide constructions that show this is indeed the case. Moreover, we show this is true even if we restrict G to claw-free graphs, bipartite graphs, or planar graphs. Let $\text{dep}(G) = \max_{e\in G} \tau_G(e)/\tau(G)$. Ferrara et al. also asked if, for every rational $0 < p/q < 1$ there existed a graph G with $\text{dep}(G) = p/q$. For the claw-free construction, we are also able to answer this question in the affirmative. (Received March 17, 2017)

1129-05-292 **Emily Gunawan*** (egunawan@umn.edu), **Gregg Musiker** (musiker@umn.edu) and **Hannah Vogel** (hajvogel@gmail.com). *Cluster algebraic interpretation of infinite friezes.*

Originally studied by Conway and Coxeter, friezes appeared in various recreational mathematics publications in the 1970s. More recently, in 2015, Baur, Parsons, and Tschabold constructed periodic infinite friezes and related them to matching numbers in the once-punctured disk and annulus. In this paper, we study such infinite friezes with an eye towards cluster algebras of type D and affine A, respectively. By examining infinite friezes with Laurent polynomials entries, we discover new symmetries and formulas relating the entries of this frieze to one another. (Received March 18, 2017)

1129-05-314 **Anna Weigandt*** (weigndt2@illinois.edu). *Prism tableaux for alternating sign matrix varieties.* Preliminary report.

A. Lascoux and M. P. Schützenberger showed that the lattice of alternating sign matrices (ASMs) forms the MacNeille completion of the strong Bruhat order on the symmetric group. To each ASM, we associate X_A, a subvariety of the space of square matrices. When A is a permutation matrix, X_A is a matrix Schubert variety. In this case, A. Knutson and E. Miller showed the multidegree of X_A is a Schubert polynomial. We give a formula for the multidegree of X_A as a generating series over prism tableaux, extending joint work with A. Yong. (Received March 19, 2017)

1129-05-325 **Benjamin P. Fischer*** (ben.fischer@loomis.org). *Perturbed Polyhedra and a Local Euler-Maclaurin Formula.*

A polyhedron P is a subset of a rational vector space V bounded by hyperplanes. If we fix a lattice in V, then we may consider the exponential integral and sum, two meromorphic functions on the dual vector space, which serve to generalize the notion of volume of and number of lattice points in P, respectively. In 2007, Berline and Vergne constructed an Euler-Maclaurin formula that relates the exponential sum of a given polyhedron to the exponential integral of each face. This formula was 'local', meaning that the coefficients in this formula had certain properties independent of the given polyhedron. In this talk, we will describe a new, direct construction for this formula which is very different from the inductive construction given by Berline and Vergne. We will consider a ring of differential operators $R(P)$ on the exponential volume of a 'perturbed' polyhedron, an object which is closely related to the equivariant cohomology ring of the toric variety corresponding to P. Due to the remarkable combinatorial properties of the exponential integral and sum, no algebraic geometry is necessary to understand the construction. (Received March 19, 2017)

1129-05-346 **Tiffany Callanan** and **Daniel Gross*** (daniel.gross@shu.edu), Seton Hall Univerity, Department of Mathematics and Computer Scienc, South Orange, NJ 07079, and **Charles Suffel**. *k-Component Size Edge Connectivity of a Complete Graph.*

A graph is considered operational if it contains one or more components with size at least k, where 1 <= k <= —E(G)— is a predetermined threshold value, and is in a failure state if all components have size less than k. The k-component size edge connectivity of a graph G is defined to be the minimum number of edges that must be deleted so that the resulting graph is in a failure state. In the case that G is a tree this parameter is the same as the (k+1)-component order edge connectivity of G. In the case that the graph is the complete graph there is no similar relation between the two parameters. In this talk we describe maximum size failure states for a complete graph. If N is the size of such a failure state, then the k-component size edge connectivity is C(n,2)-N. (Received March 20, 2017)

1129-05-362 **Cara P Monical*** (cmonica2@illinois.edu). *Set-Valued Skyline Fillings.*

Set-valued tableaux play an important role in combinatorial K-theory. Separately, semistandard skyline fillings are a combinatorial model for Demazure atoms and key polynomials. We unify these two concepts by defining a set-valued extension of semistandard skyline fillings and then give analogues of results of J. Haglund, K. Luoto, S. Mason, and S. van Willigenburg. Additionally, we give a bijection between set-valued semistandard Young tableaux and C. Lenart's Schur expansion of the Grothendieck polynomial G_λ, using the uncrowding operator of V. Reiner, B. Tenner, and A. Yong. (Received March 20, 2017)

1129-05-369 **Maria M Gillespie*** (mgillespie@math.ucdavis.edu), 1528 Walnut St, Apt 4, Berkeley, CA 94709. *Crystal structures on shifted tableaux.* Preliminary report.

I will describe raising and lowering operators E, F and E', F' on shifted semistandard tableaux – more generally, on words from an alphabet with primed and unprimed letters – which commute with shifted jeu de taquin. These operators give rise to a crystal-like structure on such tableaux, recovering the combinatorics of Schur P-functions and the Littlewood-Richardson rule for the odd orthogonal Grassmannian. This is joint work with Jake Levinson and Kevin Purbhoo. (Received March 20, 2017)

1129-05-388 **Maria Gillespie**, **Jake Levinson*** (jakelev@umich.edu) and **Kevin Purbhoo**. *Schubert curves in the odd orthogonal Grassmannian.* Preliminary report.

The rational normal curve in $\mathbb{P}^{2n}$ has a natural orthogonal structure: its tangent flags are isotropic for a canonical symmetric form on the associated $\mathbb{C}^{2n+1}$. I will discuss the geometry of intersections of Schubert varieties with respect to (a finite number of) such flags, in the odd orthogonal Grassmannian $OG(n, 2n + 1)$. When the intersection has dimension 1, it is called a (Type B) Schubert curve, and its real algebraic structure is explicitly determined by the combinatorics of shifted semistandard tableaux, jeu de taquin and certain "Type B crystal operators". This is joint work with Maria Gillespie and Kevin Purbhoo. (Received March 21, 2017)

1129-05-390 **Martha E Precup*** (martha.precup@northwestern.edu). *Regular Hessenberg varieties and the dot action.*

Regular semisimple Hessenberg varieties are smooth subvarieties of the flag variety that carry an action of the Weyl group on their cohomology called the dot action. Brosnan and Chow have proven that this representation is partially determined by the Betti numbers of other regular Hessenberg varieties. In this talk, we will define the dot action and give a combinatorial formula for these Betti numbers. Time permitting, we'll discuss ongoing work and open questions regarding this representation in the type A case. (Received March 20, 2017)

1129-05-391 **Jessica Striker*** (jessica.striker@ndsu.edu). *Revisiting promotion and rowmotion, revisited.* Preliminary report.

We extend results in dynamical algebraic combinatorics connecting the actions of promotion on (standard Young and increasing) tableaux and rowmotion on order ideals to a more general setting. This is joint work with Kevin Dilks and Corey Vorland. (Received March 20, 2017)

1129-05-397 **Zachary Hamaker*** (zachary.hamaker@gmail.com). *Some thoughts on K-theory of the Lagrangian Grassmannian.* Preliminary report.

The cohomology of the Lagrangian Grassmannian has been understood for some time. It's structure coefficients are given by the Littlewood-Richardson coefficients for Schur-Q functions, as shown by Pragazc. However, unlike the ordinary Grassmannian and orthogonal Grassmannian, the product structure of the K-theory ring is not known. We will summarize some recent progress towards this topic, such as the Buch-Ravikumar Pieri rule and explicit polynomial representatives due independently to Ikeda-Naruse and Graham-Kreiman. With these results in mind, we will outline some purely combinatorial approaches for the structure coefficients of this ring. (Received March 20, 2017)

1129-05-400 **Ryan Kaliszewski*** (ryk216@lehigh.edu). *Surprising Relations Among Catalan Polynomials and Hikita Polynomials.*

In 2012 Hikita showed that the Borel-Moore homology of certain affine Springer fibers of type A produced bigraded S_n modules whose bigraded Frobenius series is a generalization of polynomials introduced by Haglund, Haiman, Loehr, Remmel, and Ulyanov to describe characters of diagonal coinvariants. Since then, great effort has gone into understanding basic phenomena about Hikita's polynomials, with a complete description only given in the most basic cases.

Recently, a complete formula for the 3-column bigraded rational Catalan polynomial was found. While it is known that the lowest order term of Hikita's polynomials is equal to the rational Catalan polynomial, other Catalan-like expressions arise in the description of the 3-row Hikita polynomial. (Received March 20, 2017)

1129-05-402 **Allen Knutson*** (allenknutson@gmail.com), allenk@math.cornell.edu, and **Paul Zinn-Justin**. *Schubert puzzles and minuscule representations.* Preliminary report.

The label content on one side of a Schubert calculus puzzle indicates what flag manifold it is for, so for the puzzle to be sensible, that content should match the label content on the other two sides. Asking that this matching should stem from a local conservation law (plus some experimental data from small Schubert calculus problems) leads us to collections of vectors we recognize as the weights of some minuscule representations. The R-matrices of those representations (which, for 2-step flag manifolds, involve triality of D_4) degenerate to give us puzzle formulæ for two previously unsolved Schubert calculus problems: K_T(2-step flag manifolds) and K(3-step flag manifolds). The K(3-step flag manifolds) formula, which involves 151 new puzzle pieces, implies Buch's correction to the first author's 1999 conjecture for H^*(3-step flag manifolds). (Received March 21, 2017)

1129-05-415 **Sultan Al-Suleiman**, **Mahir Can**, **Susanna Fishel*** (sfishel1@asu.edu), **Luke Nelson** and **Kevin Treat**. *Maximal chains in the Tamari lattice and its generalizations.*

I will discuss recent results on the enumeration of maximal chains in the Tamari lattice and its generalizations. This is joint work with Sultan Al-Suleiman, Mahir Can, Luke Nelson, and Kevin Treat. (Received March 20, 2017)

1129-05-418 **Matthew R Mills*** (matthew.mills@huskers.unl.edu) and **John W Lawson**. *Properties of mutation-finite and minimal mutation-infinite quivers.*

We discuss recent results on the existence of maximal green sequences for mutation-finite and minimal mutation-infinite quivers. We will also discuss if the cluster algebras associated with these quivers are equal to their upper cluster algebras. (Received March 20, 2017)

1129-05-429 **Maitreyee C Kulkarni*** (mkulka2@lsu.edu), 3942 Gourrier Avenue Apt 209, Baton Rouge, LA 70808. *Cylinders over Dynkin digrams and cluster algebras.*

Let G be a Lie group of type ADE and P be a parabolic subgroup. It is known that there exists a cluster structure on the coordinate ring of the partial flag variety G/P (see the work of Geiss, Leclerc, and Schroer). Since then there has been a great deal of activity towards categorifying these cluster algebras. Jensen, King, and Su gave a direct categorification of the cluster structure on the homogeneous coordinate ring for Grassmannians (that is, when G is of type A and P is a maximal parabolic subgroup). In this setting, Baur, King, and Marsh gave an interpretation of this categorification in terms of dimer models. In this talk, I will give an analog of dimer models for groups in other types by introducing a technique called "constructing cylinders over Dynkin diagrams", which can (conjecturally) be used to generalize the result of Baur, King, and Marsh. (Received March 20, 2017)

1129-05-430 **Elizabeth Drellich***, edrelli1@swarthmore.edu. *The spline model of equivariant cohomology.*

The GKM model of equivariant cohomology allows for explicit computation of cohomology rings for GKM spaces. But how useful can this model be for non-GKM spaces? This talk will address several recent expansions of the GKM model as a computational method for non-GKM spaces. (Received March 20, 2017)

1129-05-444 **Thomas McConville*** (thomasmcconvillea@gmail.com) and **Alexander Garver** (alexander.garver@gmail.com). *Trees with automorphisms and skew group algebras.* Preliminary report.

To a tree embedded in a disk we associate a gentle algebra called a tiling algebra. When this embedded tree has some rotational symmetry, this symmetry acts as an automorphism of the tiling algebra, from which one may consider the skew group algebra. In this talk, I will relate various combinatorial and lattice structures determined by a symmetric tree with the representation theory of these skew group algebras. This is a preliminary report on joint work with Alexander Garver and Christophe Hohlweg. (Received March 21, 2017)

1129-05-456 **Federico Castillo** and **Fu Liu*** (fuliu@math.ucdavis.edu), One Shields Avenue, Davis, CA 95616. *Uniqueness of Berline-Vergne's valuation.*

Berline-Vergne constructs a valuation that assigns values to faces of polytope, and it satisfies what we call "the McMullen's formula". There are different solutions to the McMullen's formula. Any solution provides a way to write the coefficients of the Ehrhart polynomial of a polytope as positive sums of these values.

We study the Berline-Vergne's valuation on generalized permutohedra, and show that their construction is the unique solution to the McMullen's formula that is symmetric about the coordinates. This is joint work with Federico Castillo. (Received March 21, 2017)

1129-05-521 **Miaomiao Zhang*** (miaomiaozhang@gmail.com). *Efficient Cryptographic Construction from Redactable Precedence Graphs.*

We introduce a new family of (probability distributions over) labeled graphs: Redactable precedence graphs and propose a construction of a redactable precedence graph family based on multinomial distributions, and prove that, for properly chosen parameters, the expected size of a graph is linear.

Our interest in redactable precedence graphs is motivated by the problem of designing digital signature schemes that support redaction. Given a document containing n subdocuments, a precedence relationship is a connection between two or more subdocuments where a subdocument must appear before another in order for the document integrity to be kept intact. We describe how to use our new graph family to obtain efficient transparent redactable signature algorithms that hide the number and locations of redacted subdocuments.

Based on joint work with Stuart Haber and Bill Horne. (Received March 22, 2017)

06 ► Order, lattices, ordered algebraic structures

1129-06-54 **Adam Clay**, **Kathryn Mann** and **Cristóbal Rivas*** (cristobal.rivas@usach.cl). *Classifications of groups with finitely many circular orderings.* Preliminary report.

I will report on an ongoing work about the classification of groups allowing only finitely many left-invariant circular orders.

Our approach follows Tararin's approach for classifying groups allowing only finitely many total orders, but in the circular case one subtle difference makes things much more involved. In this talk i will try to explain this difference and the method we use to deal with it. (Received February 23, 2017)

1129-06-436 **Kevin Dilks*** (kevin.dilks@ndsu.edu). *Rowvacuation.* Preliminary report.

While the cyclic action of promotion on standard Young tableaux is more commonly studied, its origins are related to the associated involutive action called evacuation, which naturally arises in the RSK correspondence. The relationship between these two actions can be group-theoretically formalized and extended to any operators satisfying certain relations. In this talk, we present some preliminary results on what does (and does not) work when using this framework to extend the study of rowmotion on order ideals of a poset. (Received March 21, 2017)

11 ► Number theory

1129-11-63 **Jeffery Breeding-Allison*** (breeding@bc.edu), Mathematics Department, Maloney Hall, Fifth Floor, Boston College, Chestnut Hill, MA 02062. *Depths of representations expressed in terms of conductors.*

Let G be a reductive algebraic group defined over a local non-archimedean field k of characteristic 0. Let π be an irreducible smooth admissible complex representation of $G(k)$. To such a representation π, Moy and Prasad attached a rational number called its depth. Also, the Local Langlands Conjecture predicts a surjective finite-to-one map from the set of equivalence classes of irreducible smooth representations of $G(k)$ to the set of conjugacy classes of L-parameters for G. In this talk we explore relationships between depths of representations, their conductors (if defined), and conductors of associated L-parameters. (Received February 28, 2017)

1129-11-64 **Jayce Robert Getz*** (jgetz@math.duke.edu). *A summation formula for the Rankin-Selberg monoid via the circle method.*

Influential conjectures of Braverman and Kazhdan that have also been investigated by L.Lafforgue and Ngo assert the existence of nonabelian Fourier transforms and associated summation formulae for a class of reductive monoids. The motivation stems from the fact that these conjectural summation formulae imply the analytic continuation and functional equation of many Langlands L functions. Motivated by this, we prove a summation formula for the monoid given by the set of pairs of two by two matrices with equal determinant. The proof boils down to a form of the circle method. (Received February 28, 2017)

1129-11-76 **Przemyslaw Gorka*** (pgorka@mini.pw.edu.pl), Department of Mathematics and Information, Sciences, Warsaw University of Technology, Ul. Koszykowa 75, 00-662 Warsaw, Poland. *Sobolev embeddings vs lower bound for the measure.*

We shall discuss Sobolev inequalities on metric measure spaces. The relation between Sobolev embeddings and lower bound for the measure will be described. The talk will be based on the papers

Adimurthi, P. Górka, *Global Trudinger-Moser inequality on metric spaces*, Math. Inequal. Appl. **19** (2016), 1131-1139.

P. Górka, *In Metric-measure Spaces Sobolev Embedding is Equivalent to a Lower Bound for the Measure*, Potential Anal. (2016). doi:10.1007/s11118-016-9605-7 (Received March 03, 2017)

1129-11-103 **Alia Hamieh*** (alia.hamieh@uleth.ca), University of Lethbridge, Department of Mathematics & Computer Science, 4401 University Drive West, Lethbridge, Alberta T1K3M4, Canada, and **Naomi Tanabe** (naomi.tanabe@dartmouth.edu), Dartmouth College, Department of Mathematics, 6188 Kemeny Hall, Hanover, NH 03755. *Non-vanishing of central values of Rankin-Selberg L-functions.*

In this talk, we discuss some results on the non-vanishing of the central values of Rankin-Selberg L-functions of families of Hilbert modular forms. Such results are obtained by establishing some asymptotics of certain twisted first and second moments. (Received March 07, 2017)

1129-11-105 **Ellen Eischen*** (eeischen@uoregon.edu), Eugene, OR 97403, **Michael Harris**, New York, NY, and **Jian-Shu Li** and **Christopher Skinner**. *Automorphic forms, congruences, and p-adic L-functions.*

One approach to studying the p-adic behavior of L-functions relies on understanding p-adic properties of certain automorphic forms, for example congruences satisfied by their Fourier coefficients. In this talk, I will provide an introduction to key techniques used in several constructions of p-adic L-functions. I will start with the earliest examples of p-adic L-functions (due to Serre, Leopoldt, and Kubota) and conclude by mentioning a recently completed construction of myself, Harris, Li, and Skinner. (Received March 07, 2017)

1129-11-119 **Nelson Carella***, Department of Mathematics, 365 Fifth Avenue, New York City, NY 10016. *Note On Elliptic Primitive Points.*

Let E be an elliptic curve of rank $\mathrm{rk}(E) \geq 1$, and let $P \in E(\mathbb{Q})$ be a point of infinite order. The number of elliptic primes $p \leq x$ for which $\langle P \rangle = E(\mathbb{F}_p)$ is expected to be $\pi(x, E, P) = \delta(E, P)x/\log x + o(x/\log x)$, where $\delta(E, P) \geq 0$ is a constant. This note proves the lower bound $\pi(x, E, P) \gg x/\log x$. (Received March 09, 2017)

1129-11-157 **Neranga Fernando*** (w.fernando@northeastern.edu), Department of Mathematics, 567 Lake Hall, Northeastern University, Boston, MA 02115. *Reversed Dickson polynomials of the $(k+1)$-th kind over finite fields.*

Let p be a prime and q a power of p. Let $\mathbb{F}_q$ be the finite field with q elements. For $a \in \mathbb{F}_q$, the n-th reversed Dickson polynomial of the $(k+1)$-th kind $D_{n,k}(a,x)$ is defined by

$$D_{n,k}(a,x) = \sum_{i=0}^{\lfloor \frac{n}{2} \rfloor} \frac{n-ki}{n-i} \binom{n-i}{i} (-x)^i a^{n-2i},$$

and $D_{0,k}(a,x) = 2-k$.

I am primarily interested in the question: When is $D_{n,k}(a,x)$ a permutation polynomial (PP) of $\mathbb{F}_q$? In this talk, I will completely explain the permutation behaviour of the reversed Dickson polynomials of the $(k+1)$-th kind $D_{n,k}(a,x)$ when $a=0$, $n=p^l$, $n=p^l+1$, and $n=p^l+2$, where $l \geq 0$ is an integer. I will also talk about some general properties of the reversed Dickson polynomials of the $(k+1)$-th kind.

In particular, I will explain the explicit evaluation of the sum $\sum_{a\in\mathbb{F}_q} D_{n,k}(1,a)$ which provides a necessary condition for $D_{n,k}(1,x)$ to be a PP of $\mathbb{F}_q$. These results unify and generalize many recently discovered results on reversed Dickson polynomials over finite fields. (Received March 12, 2017)

1129-11-172 **Yuanqing Cai** and **Solomon Friedberg*** (solomon.friedberg@bc.edu), Department of Mathematics, Boston College, Chestnut Hill, MA 02467-3806, and **David Ginzburg** and **Eyal Kaplan**. *New integrals for tensor product L-functions.* Preliminary report.

I will discuss new integrals representing tensor product L-functions of classical groups with general linear groups. These make use of new ingredients from the representation theory of p-adic groups (new kinds of unique models). The integrals also work for covering groups under certain hypotheses. Critically, these integrals are applicable to all automorphic representations—they do not require genericity. (Received March 13, 2017)

1129-11-183 **Catherine M Hsu*** (cathyh@uoregon.edu), 1874 Emerald St, Apt 3, Eugene, OR 97403. *Higher congruences between newforms and Eisenstein series of squarefree level.*

Let $p \geq 3$ be prime. For squarefree level $N > 6$, we use a commutative algebra result of Berger, Klosin, and Kramer to bound the depth of Eisenstein congruences modulo p (from below) by the p-adic valuation of the numerator of $\frac{\varphi(N)}{24}$. We then show that if N has at least three prime factors and some prime $p \geq 5$ divides $\varphi(N)$, the Eisenstein ideal is not locally principal. Time-permitting, we will illustrate these results with explicit computations as well as discuss generalizations to other families of modular forms. (Received March 14, 2017)

1129-11-232 **Aaron Pollack** and **Shrenik Shah*** (snshah@math.columbia.edu), Rm 626, MC 4403, 2990 Broadway, New York, NY 10027. *A class number formula for Picard modular surfaces.*

We investigate arithmetic aspects of the cohomology of the smooth compactified Picard modular surfaces X attached to the unitary group $\mathrm{GU}(2,1)$ for an imaginary quadratic extension $E/\mathbf{Q}$. We find elements in the motivic cohomology $H^3_{\mathcal{M}}(X, \mathbf{Q}(2))$. We then compute their regulator as an element of Deligne cohomology by interpreting this map via the pairing of these classes against automorphic differential forms. We show that the regulator is non-vanishing when predicted. We obtain a special value formula, akin to a class number formula, involving a non-critical L-value, a Whittaker period, and the regulator. Our investigation provides support for Beilinson's regulator conjecture in this setting. One interesting aspect of this work is that we must account for endoscopic forms via a period, which is predicted by the conjecture. This is joint work with Aaron Pollack. (Received March 16, 2017)

1129-11-251 **Beth Malmskog*** (beth.malmskog@gmail.com), **Gretchen Matthews** and **Katie Haymaker**. *Locally Recoverable Codes with Many Recovery Sets from Fiber Products of Curves.*

Locally recoverable codes (LRCs) have benefits for distributed storage applications. Barg, Tamo, and Vladut recently constructed LRCs with one and two recovery sets from algebraic curves. This talk presents a generalization of this construction to $t \geq 3$ recovery sets, using iterated fiber products of curves. Codes with arbitrarily many recovery sets are constructed, employing maximal curves from fiber products devised by Van der Geer and Van der Vlugt. (Received March 17, 2017)

1129-11-262 **Stephen D. Miller*** (miller@math.rutgers.edu) and **Joseph Hundley**. *Arthur's Conjectures and Residual Eisenstein series.*

Arthur's conjectures on the discrete automorphic spectrum have striking implications to representation theory, in that they predict the unitarity of representations that are difficult to understand directly. The conjectures concern packets of representations, which are hard to describe aside from a "basepoint" element with straightforward Langlands parameters. We show that this basepoint representation is always unitary for real groups, using special values and residues of Eisenstein series on exceptional groups. (Received March 17, 2017)

1129-11-266 **Joseph Hundley*** (joseph.hundley@gmail.com). *On holomorphy of adjoint L-functions.*
The adjoint L-function of an irreducible cuspidal automorphic representation π of $GL_n(\mathbb{A})$ ($\mathbb{A}$ the adeles of a number field), may be defined as $L(s,\pi,Ad) = L(s,\pi\times\tilde{\pi})/\zeta(s)$, where $\tilde{\pi}$ is the contragredient. It is expected that this L function is always entire. We discuss an approach to proving this in the special case $n=3$, which is based on the integral representation for the partial adjoint L function due to Ginzburg. Our approach also applies to quasisplit unitary groups and to twisted adjoint L functions. (Received March 17, 2017)

1129-11-278 **Wei Zhang*** (wzhang@math.columbia.edu). *Shtukas and Taylor expansion of L-functions: Iwahori level and ramified double covering.*
We study automorphic L-functions for GL(2) over a global field (e.g., those attached to elliptic curves). In the case of function fields, we found a family of algebraic cycles on the moduli of Drinfeld Shtukas, and we prove that their intersection numbers give higher order derivatives of L-function. In this talk I will report the extension of this to the case when the automorphic representation has Iwahori level and the relevant double covering of the curve is ramified. This is a joint work with Zhiwei Yun. (Received March 17, 2017)

1129-11-291 **Armand Brumer** and **Kenneth Kramer*** (kkramer@qc.cuny.edu). *Uniqueness of isogeny class for "favorable" abelian surfaces.* Preliminary report.
This work was prompted by our conjecture on the modularity of abelian surfaces. Let $A_{/\mathbb{Q}}$ be an abelian surface of conductor N. We had shown that A is isogenous to a Jacobian when N is prime. Earlier, we had introduced conditions for non-existence, based on the Galois module structure of ℓ-division points. In the present work, we develop criteria under which there is at most one isogeny class of abelian surfaces with a given 2-division field and prime conductor. Numerical experiments suggest that our criteria may imply uniqueness in infinitely many "favorable" cases.

In particular, there is exactly one isogeny class of abelian surfaces for $N = 277$. According to our Paramodular Conjecture, there should be a unique (up to scalar multiple) paramodular eigenform of suitable type, as Chris Poor and David Yuen have demonstrated. Joint work of several people shows that the Galois representation associated to this paramodular form agrees with that of the isogeny class of abelian surfaces for $N = 277$. With our uniqueness result, this is the first full verification of the Paramodular Conjecture in a non-endoscopic case. (Received March 18, 2017)

1129-11-293 **Jeremy Rouse*** (rouseja@wfu.edu), P.O. Box 7388, Winston-Salem, NC 27109. *Integers represented by quaternary quadratic forms and Petersson inner products.* Preliminary report.
Let $Q(\vec{x}) = \frac{1}{2}\vec{x}^T A\vec{x}$ be a positive-definite quaternary quadratic form with $D(Q) = \det(A)$ and level $N(Q)$. We give general bounds on the largest positive integer n that is not represented by Q, but is locally represented. For example, we show that if $\gcd(n, D(Q)) = 1$, $n \geq C_\epsilon(N(Q)^2 D(Q))^{1+\epsilon}$, and n is locally represented by Q, then it is represented.

The method is to bound the Petersson norm of the cuspidal part of the theta series by using an explicit formula for the Weil representation due to Scheithauer. (Received March 18, 2017)

1129-11-318 **Eric Rowland*** (eric.rowland@hofstra.edu) and **Reem Yassawi**. *p-adic asymptotic properties of integer sequences.*
Much attention has been paid to asymptotic growth rates of integer sequences, particularly for sequences arising in combinatorics that count objects of interest. On the other hand, the study of p-adic asymptotic properties of such sequences began only recently. By interpolating subsequences to the p-adic integers, we show we can compute certain p-adic limits, as well as the asymptotic density of the residues modulo powers of p attained by a sequence. We illustrate these results by computing some particular limits for the Fibonacci sequence. (Received March 19, 2017)

1129-11-320 **Dani Szpruch*** (daniel.szpruchalper@howard.edu). *A short proof for the relation between Weil indices and ϵ-factors.*
Let F be a p-adic field and let ψ be a non-trivial character of F. For $a \in F^*$ let $\gamma_\psi(a)$ be the normalized Weil index. It is known that $a \mapsto \gamma_\psi(a)$ splits the quadratic Hilbert symbol. $\gamma_\psi(a)$ appears in the theory of Weil representation and is used in the construction of genuine representations of parabolic subgroups of the metaplectic double cover of $Sp_{2n}(F)$. Recently it also appeared in the parametrization of genuine principle series

representations of even-fold Brylinski-Deligne covering groups. Let $\epsilon(s, \chi, \psi)$ be the epsilon factor appearing in Tate's thesis. In this talk we shall give a short proof for the identity

$$\gamma_\psi(a) = \epsilon(1/2, \eta_a, \overline{\psi})$$

where η_a is the quadratic character associated with a by the quadratic Hilbert symbol. This equality of these two fundamental local factors was proven by Kahn around 1984. Our proof is shorter than the proof given by Kahn and is perhaps simpler as it mostly uses harmonic analysis on the finite abelian group of square classes in F^*. (Received March 19, 2017)

1129-11-334 **Jorge Florez***, jflorez@bmcc.cuny.edu. *Explicit reciprocity laws for higher local fields.*
In this talk we present a generalization of Kolyvagin's explicit reciprocity laws to higher local fields. This involves explicit formulas for the generalized Kummer pairing associated to an arbitrary formal group, in terms of multidimensional p-adic derivations, the logarithm of the formal group, the generalized trace and the norm on Milnor K-groups. In the specific case of a Lubin-Tate formal group, these formulas give a higher-dimensional version of the explicit reciprocity laws of Artin-Hasse, Iwasawa and Wiles. (Received March 19, 2017)

1129-11-352 **Ameya Pitale*** (apitale@ou.edu). *Integral representation and critical L-values for holomorphic forms on $GSp(2n) \times GL(1)$.*
In this talk, we will report on recent joint work with Abhishek Saha and Ralf Schmidt on integral representation of the standard L-function for holomorphic vector-valued Siegel modular forms of arbitrary genus and with respect to arbitrary congruence subgroup. A lot of work has been done on this topic by Andrianov, Harris, Sturm, Garrett, Shimura, Piatetski-Shapiro, Rallis and many others. To obtain the most general result, we adopt the adelic approach and obtain the pullback of an Eisenstein series on $GSp(4n)$ to $GSp(2n) \times GSp(2n)$. The innovation is the choice of vectors in the ramified and the archimedean cases allowing us to get explicit formulas. The potential applications are arithmeticity of special values of L-functions as algebraic numbers (normalized by suitable periods), and one can further ask the prime factorization of those algebraic numbers. We will report on the arithmeticity results for the genus 2 case, which involves a deeper understanding of the structure of nearly holomorphic modular forms. (Received March 20, 2017)

1129-11-365 **Taylor Dupuy*** (taylor.dupuy@uvm.edu), 16 Colchester Ave., Burlington, VT 05401. *Deforming Derivatives.* Preliminary report.
We will talk about algebraic parameter spaces of rings with extra operations. In particular we will talk about deforming derivative operations into difference operations and what this means algebraically. (Received March 20, 2017)

1129-11-395 **Amanda Folsom*** (afolsom@amherst.edu), Department of Mathematics, Amherst College, Amherst, MA 01002. *Quantum and mock modular forms.*
Mock modular forms were first formally defined in the literature by Zagier in 2007, though their roots trace back to Ramanujan's mock theta functions from 1920. Zagier also defined quantum modular forms in 2010; they are like mock modular forms in that they feign modularity in some way, but they are not, a priori, defined on the upper-half of the complex plane. In this talk, we will discuss recent connections made between these two developing subjects over the past few years by Bringmann, Ono, Rhoades, Rolen, Zagier and others. As an application of these theories, we will also discuss connections to combinatorics and partitions, and a claim made by Ramanujan. (Received March 20, 2017)

1129-11-403 **Yiannis Sakellaridis*** (sakellar@rutgers.edu), 101 Warren Street, Smith Hall 216, Newark, NJ 07102. *Regularization of orbital integrals.*
Let G be a reductive group acting on a smooth affine variety X over a global field k. Consider the space of Schwartz functions on the adelic points $X(\mathbb{A})$ of X, and let x be an element of $X(k)$. Under what conditions does it make sense to define, purely by geometric means, a regularized orbital integral over the $G(\mathbb{A})$-orbit of x? This is a question that shows up on the geometric side of the trace formula, and its generalizations (such as the relative trace formula). I will present a new approach to this problem, that does not use truncation. In this approach, toric geometry is used to understand asymptotics on the automorphic space $H(k)\backslash H(\mathbb{A})$, where H is the stabilizer of a point on a closed orbit, and then it is shown that the integral that one wants to regularize is, essentially, an integral of an asymptotically multiplicative function on a toric variety. I will also discuss how these ideas may shed light on the spectral decomposition of a relative trace formula. (Received March 20, 2017)

1129-11-404 **Daniel J. Garbin*** (dgarbin@qcc.cuny.edu), Queensborough Community College, Dept. of Mathematics and Computer Science, 222-05 56th Avenue, Bayside, NY 11364. *Spectral asymptotics on sequences of elliptically degenerating Riemann surfaces.* Preliminary report.

This is the second in a series of two articles where we study various aspects of the spectral theory associated to families of hyperbolic Riemann surfaces obtained through elliptic degeneration. In the first article, we investigate the asymptotics of the trace of the heat kernel both near zero and infinity and we show the convergence of small eigenvalues and corresponding eigenfunctions. Having obtained necessary bounds for the trace, this second article presents the behavior of several spectral invariants. Some of these invariants, such as the Selberg zeta function and the spectral counting functions associated to small eigenvalues below 1/4, converge to their respective counterparts on the limiting surface. Other spectral invariants, such as the spectral zeta function and the logarithm of the determinant of the Laplacian diverge. In these latter cases, we identify diverging terms and remove their contributions, thus regularizing convergence of these spectral invariants. Our study is motivated by a result which D. Hejhal attributes to A. Selberg, proving spectral accumulation for the family of Hecke triangle groups. In this article, we obtain a quantitative result to Selberg's remark. (Received March 20, 2017)

1129-11-409 **Maria Sabitova*** (maria.sabitova@qc.cuny.edu), 108 Quaker Path, Stony Brook, NY 11790. *Root numbers of hyperelliptic curves.*

Root numbers occur as signs in conjectural functional equations for L-functions attached to abelian varieties. We analyze the root number of an abelian variety over a local non-archimedean field. As an application of the obtained results we calculate several cases of (global) root numbers of Jacobians of hyperelliptic curves of genus 2 over the field of rational numbers. This is joint work with A. Brumer and K. Kramer. (Received March 20, 2017)

1129-11-413 **S Ali Altug*** (altug@mit.edu). *On the structure of the geometric side of the Arthur-Selberg trace formula for $GL(N)$.*

The Arthur-Selberg trace formula (we will only be considering the trace formula for $GL(N)$ for this talk) is one of the most powerful tools in number theory and automorphic forms. Roughly, for a suitable test function f it gives a distributional identity $I_{spec}(f) = I_{geom}(f)$ between a spectral and a geometric expansion. Both $I_{spec}(f)$ and $I_{geom}(f)$ are sums of (integrals of) distributions in f. The part that contribute discretely to the spectral side, I_{disc}, is central to the trace formula. At the heart of I_{disc} is the so-called cuspidal part $I_{cusp}(f)$. In many applications one is naturally lead to study I_{cusp} (or quantities related to I_{cusp}) and hence it is fundamental to get an "explicit" (and, in a certain sense, geometric) expression for the difference $I_{geom}(f)-(I_{disc}(f)-I_{cusp}(f))$.

I will talk about the problem of isolating the contribution of $I_{disc}(f) - I_{cusp}(f)$ in $I_{geom}(f)$. I will present a solution of this in the case $GL(2)$ and describe recent conjectures of Arthur for $G = GL(N)$. If time permits I will also say a few words about what kind of obstacles one encounters when one tries to execute the $GL(2)$ strategy in higher rank, and possible directions one can pursue to overcome these. (Received March 20, 2017)

1129-11-414 **Victor Manuel Rodriguez Aricheta**, 400 Dowman Dr NE, Atlanta, GA 30322, and **Lea Beneish*** (lea.beneish@emory.edu), 400 Dowman Drive, Atlanta, GA 30322. *Moonshine modules and a question of Griess.*

Recent work on monstrous moonshine has shown that there are exact formulas for the multiplicities of the irreducible components of the moonshine modules, showing in particular that these multiplicities are asymptotically proportional to the dimensions. With the recent proof of the umbral moonshine conjecture it is natural to ask whether this distribution result extends to other instances of moonshine, including umbral moonshine. In joint work with Victor Manuel Aricheta, we consider the general situation in which a finite group acts on an infinite-dimensional graded module in such a way that the graded-trace functions are weakly holomorphic modular forms. under some mild hypotheses we completely describe the asymptotic module structure of the homogeneous subspaces. As a consequence we find that moonshine for a group gives rise to partial orderings on its irreducible representations. This serves as a first answer to a question posed by Griess. (Received March 20, 2017)

1129-11-419 **Bernd C. Kellner** and **Jonathan Sondow***, jsondow@alumni.princeton.edu. *Power-sum denominators.*

The *power sum* $1^n + 2^n + \cdots + x^n$ has been of interest to mathematicians since classical times. Johann Faulhaber, Jacob Bernoulli, and others who followed expressed power sums as polynomials in x of degree $n+1$ with rational coefficients. Here we consider the denominators of these polynomials, and prove some of their properties. A remarkable one is that such a denominator equals $n+1$ times the squarefree product of certain primes p obeying

the condition that the sum of the base-p digits of $n+1$ is at least p. As an application, we derive a squarefree product formula for the denominators of the Bernoulli polynomials.

Our paper is to appear in the *Amer. Math. Monthly* in 2017/18. (Received March 20, 2017)

1129-11-428 **Cihan Karabulut*** (karabulutc@wpunj.edu), William Paterson University, 300 Pompton Rd, Wayne, NJ 07470. *Eisenstein cocycles for $GL(n)$ and values of L-functions in imaginary quadratic extensions.*

Abstract: We generalize Sczech's Eisenstein cocycle for $GL(n)$ over totally real extensions of $\mathbb{Q}$ to finite extensions of imaginary quadratic fields. By evaluating the cocyle on certain cycles, we parametrize complex values of Hecke L-functions previously considered by Colmez, giving a cohomological interpretation of his algebraicity result on special values of the L-functions. (Received March 20, 2017)

1129-11-432 **Gautam Chinta*** (gchinta@ccny.cuny.edu), **Nathan Kaplan** and **Shaked Koplewitz**. *Counting lattices by cotype.*

We discuss the problem of computing the density of sublattices L of $\mathbb{Z}^d$ which have the property that the quotient of $\mathbb{Z}^d$ by L has m invariant factors, for fixed m. We find that these densities follow a Cohen-Lenstra distribution. Our main tool is a generalization of the subgroup growth zeta function of $\mathbb{Z}^d$ originally introduced by V. Petrogradsky. This is a joint work with N. Kaplan and S. Koplewitz. (Received March 21, 2017)

1129-11-472 **Thomas A Hulse** (tahulse@colby.edu) and **Naomi Tanabe*** (naomi.tanabe@dartmouth.edu). *The Sign of Fourier Coefficients of Hilbert Modular Forms.*

In this talk, we report on some properties of Fourier coefficients of Hilbert modular forms, with a special focus on their sign-change intervals. This is an ongoing joint project with Thomas Hulse. (Received March 21, 2017)

1129-11-473 **Nathan Kaplan*** (nckaplan@math.uci.edu), 340 Rowland Hall, Irvine, CA 92697. *Arcs in the Projective Plane and del Pezzo Surfaces over Finite Fields.*

An n-arc in $\mathbb{P}^2(\mathbb{F}_q)$ is a collection of n distinct points, no three of which lie on a line. A theorem of Segre says that when q is odd the largest arc is of size $q+1$ and when q is even the largest arc is of size $q+2$. In addition to asking for the largest size of an arc, we can ask for the number of arcs of a given size.

A del Pezzo surface of degree d over $\mathbb{F}_q$ has at most $q^2+(10-d)q+1$ $\mathbb{F}_q$-rational points. A surface attaining this maximum is called *split*, and if all of these rational points lie on the exceptional curves of the surface then it is called *full*. We explain the connection between counting problems for arcs and the classification of these extremal del Pezzo surfaces, focusing on the case of del Pezzo surfaces of degree 3, cubic surfaces, and of degree 2, double covers of $\mathbb{P}^2$ branched over a quartic curve. (Received March 21, 2017)

1129-11-476 **C. Ballantine** and **B. Feigon***, Department of Mathematics, The City College of New York, New York, NY 10031, and **K. Maurischat**. *Ramanujan bigraphs.* Preliminary report.

We will discuss explicit constructions and realizations of families of bipartite, biregular Ramanujan graphs that come from the Bruhat-Tits building of an inner form of SU(3) over a p-adic field. (Received March 21, 2017)

1129-11-484 **Jonathan Cohen*** (jonscohen99@gmail.com), 6202 Satinwood Drive, Columbia, MD 21044. *Title: Transfer of representations and the Bernstein center for inner forms of $GL(n)$.*

I will discuss a construction and characterization of the Local Langlands Correspondence for Inner Forms of GL(n), and its relation to a method for constructing explicit matching functions via a transference of Bernstein centers. (Received March 21, 2017)

1129-11-488 **Carlos Julio Moreno*** (cmoreno@baruch.cuny.edu), P O Box 545, N. Salem, NY 10560. *Stieckelberger's theorem and applications.* Preliminary report.

Applications of Stieckelberger's Theorem

Stieckelberger's Theorem provides a powerful tool in the study of exponential sums and their applications to finite fields. We shall discuss within this framework the refinements that have been made to the Chevalley-Warning Theorem and possibly an alternative road to the proof of the existence of primitive normal basis for finite fields. (Received March 21, 2017)

1129-11-494 **Dianbin Bao*** (tud53299@temple.edu), 521 Wachman Hall 1805 North Broad Street, Philadelphia, PA 19122. *Polynomial Identities between Hecke Eigenforms.*

Polynomial identities between Hecke Eigenforms can give relations between their Fourier coefficients, which often contain important arithmetic information. Polynomial identities of specific type have been studied by various authors. In this talk, we will show that, assuming Maeda's conjecture, solutions to the equation of the type $X^2 = \sum_i a_i Y_i$ in terms of Hecke eigenforms for the full modular group $SL_2(\mathbb{Z})$ are all forced by dimension considerations. Our proof uses Galois theory for the eigenvalues of the Hecke operators acting the space of cusp forms for $SL_2(\mathbb{Z})$. We will also talk about the congruence subgroup case. (Received March 21, 2017)

1129-11-504 **Wladimir de Azevedo Pribitkin*** (wladimir.pribitkin@csi.cuny.edu). *Modularity Is the Thing.* Preliminary report.

We revisit and interconnect certain seminal works of Petersson and Rademacher, Eichler and Knopp, Selberg and Niebur. We focus especially on the Fourier expansions of modular invariants, modular forms, modular integrals, and beyond. (Received March 21, 2017)

1129-11-512 **Karen Taylor***, karen.taylor@bcc.cuny.edu. *Title: Special Values of the Dedekind Zeta Function.* Preliminary report.

We give a brief survey of work on special values of the Dedekind zeta function of a real quadratic field. In particular, we will discuss formulas due to Siegel and Zagier (Received March 21, 2017)

1129-11-517 **Austin Daughton*** (adaughto@fandm.edu). *Coefficients of Logarithmic Vector-Valued Poincaré Series.*

In 2004, Knopp and Mason computed the coefficients of vector-valued Poincaré series associated to a normal representation. Their expression for these coefficients strongly parallels the classical case and involves Bessel functions and 'generalized' Kloosterman sums. For logarithmic representations, Knopp and Mason wrote down a matrix-valued Poincaré series whose columns are logarithmic vector-valued modular forms, but they do not give exact expressions for these coefficients. However, for representations where $\rho(T)$ is a single Jordan block, we can instead construct a Poincaré series that is the natural analogue of the classical series and the series associated to a normal representation. In this talk, I'll discuss this construction and give an exact expression for the Fourier coefficients of this Poincare'e series. (Received March 21, 2017)

1129-11-522 **Michael Wijaya*** (mwijaya@bhsec.bard.edu). *A function-field analogue of Conway's topograph.*

In *The Sensual (Quadratic) Form*, Conway introduces a visual method to display values of an integral binary quadratic form $Q(x, y) = ax^2 + bxy + cy^2 \in \mathbb{Z}[x, y]$. This topograph method, as he calls it, leads to a simple and elegant method of classifying integral binary quadratic forms and answering some basic questions about them. In particular, Conway uses his climbing lemma to show that the topograph of any definite (respectively, indefinite) integral binary quadratic form has a unique "well" (respectively, "river").

We will present an analogue of Conway's topograph method in the function-field setting, that is, for binary quadratic forms with coefficients in $\mathbb{F}_q[T]$, where q is an odd prime power. Our starting point was the connection between Conway's topograph method and hyperbolic geometry; this led us to consider the Bruhat–Tits tree of $\mathrm{SL}_2\big(\mathbb{F}_q((T^{-1}))\big)$ as the natural setting for our work. After we formulate and prove an analogue of Conway's climbing lemma, we establish that just as in the classical setting, there is a unique "well" (respectively, "river") on the topograph of any definite (respectively, indefinite) binary quadratic form with coefficients in $\mathbb{F}_q[T]$. (Received March 22, 2017)

12 ► Field theory and polynomials

1129-12-167 **Alexander Levin*** (levin@cua.edu), 620 Michigan Avenue, NE, Washington, DC 20064. *Dimension Quasi-polynomials of Inversive Difference Field Extensions with Weighted Translations.*

Let K be an inversive difference field with basic translations $\sigma_1, \dots, \sigma_m$ that are assigned positive integer weights $w_1, \dots, w_m$, respectively. Let Γ denote the set of all power products $\tau = \sigma_1^{k_1} \dots \sigma_m^{k_m}$ $(k_i \in \mathbb{Z})$, let the order of such a power product be defined as $ord_w \tau = \sum_{i=1}^{m} w_i |k_i|$, and for every $r \in \mathbb{N}$, let $\Gamma(r) = \{\tau \in \Gamma \mid ord_w \tau \leq r\}$. We prove that if L is a finitely generated inversive difference field extension of K with a set of difference generators $\eta = \{\eta_1, \dots, \eta_n\}$, then the function $\phi_\eta(r) = tr.deg_K K(\cup_{i=1}^{n} \Gamma(r)\eta_i)$ is a quasi-polynomial in r that can be expressed as an alternating sum of certain Ehrhart quasi-polynomials. We also determine some difference birational invariants of this quasi-polynomial and give a generalization of the obtained results to the case of multivariate dimension quasi-polynomials associated with partitions of the set of basic translations. (Received March 13, 2017)

1129-12-187 **William D. Simmons*** (wsimmo@sas.upenn.edu) and **Henry Towsner** (htowsner@math.upenn.edu). *Mining effective information from nonconstructive proofs in differential algebra.*

Ultraproducts and other nonconstructive tools often yield existence results without explicit values. We examine the interplay of such arguments with "proof mining" techniques that systematically extract effective information even when it is not apparent. Our main result is a uniform bound related to the detection of prime differential ideals. (Received March 14, 2017)

1129-12-264 **Daniel Panario*** (daniel@math.carleton.ca). *Covering arrays from m-sequences and character sums over finite fields.*

A covering array of strength t on v symbols is an array with the property that, for every t-combination of column vectors, every one of the possible v^t t-tuples of symbols appears as a row at least once in the subarray defined by these column vectors. Arrays whose rows are cyclic shifts of an m-sequence over a finite fields possess many combinatorial properties and have been used to construct various combinatorial objects; see [2].

In this talk we consider covering arrays consisting of discrete logarithms of carefully selected m-sequence elements. Inspired by [1], we connect the covering array definition for this type of arrays to the value of certain character sums over finite fields. Taking advantage of the balanced way in which the m-sequence elements are distributed, we are able to evaluate these sums. This provides new infinite families of covering arrays of arbitrary strength.

Joint work with L. Moura, B. Stevens and G. Tzanakis to appear in Designs, Codes and Cryptography.

References:

[1] C. J. Colbourn, Covering arrays from cyclotomy, Designs, Codes and Cryptography 55 (2010), 201-219.

[2] L. Moura, G. L. Mullen, D. Panario. Finite field constructions of combinatorial arrays, Designs, Codes and Cryptography 78 (2016), 197-219. (Received March 17, 2017)

1129-12-358 **Julia Hartmann*** (hartmann@math.upenn.edu), 209 S 33rd Street, DRL/Department of Mathematics, Philadelphia, PA 19146. *Differential Torsors and Differential Embedding Problems.*

We introduce the notion of a differential torsor, which allows us to state and prove a converse to Kolchin's structure theorem for Picard-Vessiot rings. This is used to obtain a patching result for Picard-Vessiot rings. As an application, we deduce the solvability of differential embedding problems over one variable complex function fields. (Joint work with A. Bachmayr, D. Harbater, and M. Wibmer.) (Received March 20, 2017)

1129-12-507 **Alice Medvedev*** (medvedev.math.ccny@gmail.com). *Sparse difference equations with high transcendence degree but difference Krull dimension 1.*

For fixed integers r and $m_0, \ldots m_r$, the difference equation

$$\prod_{i=0}^{r} (\sigma^{ni}(x))^{m_i} = 1$$

defines a subgroup G_n of the multiplicative group of transcendence degree nr.

We show that whenever no zero of the polynomial $\chi(z) := \sum_{i=0}^{r} m_i z^i$ is a root of unity, the difference Krull dimension of G_n is bounded, independently of n. Indeed, the difference Krull dimension of G_n is 1 whenever $\chi(z)$ is *hereditarily irreducible*, and it usually is. (Received March 21, 2017)

13 ► Commutative rings and algebras

1129-13-17 **Thomas Dreyfus*** (thomas.dreyfus@ens-cachan.org), **Charlotte Hardouin**, **Julien Roques** and **Michael Singer**. *On the nature of the generating series of random walks in the quarter plane.*

In the recent years, the nature of the generating series of the walks in the quarter plane has attracted the attention of many authors. The main questions are: are they algebraic, holonomic (solutions of linear differential equations) or at least hyperalgebraic (solutions of algebraic differential equations)?

This problem was first considered in a seminal paper, where Bousquet-Mélou and Mishna attach a group to any walk in the quarter plane and make the conjecture that a walk has an holonomic generating series if and only if the associated group is finite. They proved that, if the group of the walk is finite, then the generating series is holonomic, except, maybe, in one case, which was solved positively by Bostan, van Hoeij and Kauers. In the infinite group case, Kurkova and Raschel proved that if the walk is in addition non singular, then the corresponding generating series is not holonomic. This work is very delicate, and relies on the explicit uniformization of a certain elliptic curve. Recently, it has been proved that 9 over the 51 such walks have a generating series which is hyperalgebraic. In this talk, we will prove, using the difference Galois theory, that the remaining 42 walks, have a generating series which is not hyperalgebraic. (Received January 06, 2017)

1129-13-22 **Anupam Saikia** (a.saikia@iitg.ernet.in), Department of Mathematics, Indian Institute of Technology, Guwahati, Assam 781039, India, and **Kumari Saloni Singh*** (saloni.kumari@iitg.ernet.in), Department of Mathematics, Indian Institute of Technology Guwahati, Guwahati, Assam 781039, India. *Bounding Hilbert coefficients of parameter ideals.*

Let (R, m) be a Noetherian local ring of dimension $d > 0$ and $depth R \geq d-1$. Let Q be a parameter ideal of R. We will derive uniform lower and upper bounds for the Hilbert coefficient $e_i(Q)$ under certain assumptions on the depth of associated graded ring $G(Q)$. For $2 \leq i \leq d$, we will show that (1) $e_i(Q) \leq 0$ provided $depth G(Q) \geq d-2$ and (2) $e_i(Q) \geq -\lambda_R(H_m^{d-1}(R))$ provided $depth G(Q) \geq d-1$. We will prove that $e_3(Q) \leq 0$. Further, we will obtain a necessary condition for the vanishing of the last coefficient $e_d(Q)$. As a consequence, we characterize the vanishing of $e_2(Q)$. Our results generalize preceeding results of Goto and Ozeki. (Received January 16, 2017)

1129-13-39 **Eloísa Grifo***, eloisa.grifo@virginia.edu, and **Craig Huneke**. *Symbolic powers of ideals defining F-pure rings.*

Given a radical ideal I in a regular ring R, the containment problem of symbolic and ordinary powers of I consists of determining which symbolic powers of I are contained in each power of I. By work of Ein-Lazersfeld-Smith and Hochster-Huneke, there is a uniform answer to this question, but the containments it provides are not necessarily best possible.

In this talk, we will discuss the containment problem and present new results for the case when R/I is F-pure or when R/I is strongly F-regular; in particular, that a conjecture of Harbourne holds in the F-pure case. (Received February 01, 2017)

1129-13-40 **Chris Fraser***, chfraser@iupui.edu. *Braid group symmetries of Grassmannian cluster algebras.*

We define an action of the k-strand braid group on the set of cluster variables for the Grassmannian $\mathrm{Gr}(k, n)$, whenever k divides n. The action sends clusters to clusters, preserving the underlying quivers, defining a homomorphism from the braid group to the cluster modular group for $\mathrm{Gr}(k, n)$. Then we apply our results to the Grassmannian $\mathrm{Gr}(3, 9)$. We prove the $n = 9$ case of a conjecture of Fomin-Pylyavskyy describing the cluster combinatorics for $\mathrm{Gr}(3, n)$, in terms of Kuperberg's basis of non-elliptic webs. (Received February 01, 2017)

1129-13-50 **Shiro Goto*** (shirogoto@gmail.com), 1-1-1 Higashi-mita, Tama-ku, Kawasaki, 214-8571, Japan. *Almost Gorenstein rings.*

A survey on almost Gorenstein local/graded rings is given. The notion of almost Gorenstein local ring (*AGL ring* for short) in my sense dates back to the paper of V. Barucci and R. Fröberg in 1997, where they introduced the notion to one-dimensional analytically unramified local rings. In 2013 the author, N. Matsuoka, and T. T. Phuong gave a new definition of AGL rings for arbitrary but still one-dimensional Cohen-Macaulay local rings. This research has been succeeded by recent two works of T. D. M. Chau, the author, S. Kumashiro, N. Matsuoka, R. Takahashi, and N. Taniguchi in 2015 and 2017. In the latter work, one can find the notion of 2-almost Gorenstein local ring (2-*AGL ring* for short) of dimension one, which is a generalization of AGL rings. Using Sally modules of canonical ideals, the authors show that 2-AGL rings behave well as if they were twins of AGL rings. The aim of the former research started in a different direction. They have extended the notion of AGL ring to higher dimensional Cohen-Macaulay local/graded rings, using the concept of Ulrich module. Researches on AGL/AGG rings are in progress, exploring, for example, the problem of when the Rees algebras of ideals/modules are almost Gorenstein graded rings. (Received February 19, 2017)

1129-13-61 **Rafael H Villarreal*** (vila@math.cinvestav.mx), **Jose Martinez-Bernal** and **Yuriko Pitones**. *Minimum distance functions of complete intersections.*

We study the minimum distance function of a complete intersection graded ideal in a polynomial ring with coefficients in a field. For graded ideals of dimension one, whose initial ideal is a complete intersection, we use the footprint function to give a sharp lower bound for the minimum distance function. (Received February 28, 2017)

1129-13-72 **Tai Ha***, Tulane University, Mathematics department, 6823 St. Charles Avenue, New Orleans, LA 70118. *Depth function of ideals in polynomial rings.*

We shall discuss what can be the depth function of ideals in polynomial rings. That is, for which function $f : \mathbb{N} \to \mathbb{N}$ there exists an ideal Q in a polynomial ring S such that $f(n) = \mathrm{depth} S/Q^n$ for all $n \geq 1$. (Received March 02, 2017)

1129-13-87 **Sara Faridi*** (faridi@mathstat.dal.ca). *Lattice complements and the subadditivity of syzygies of simplicial forests.*

This talk is about the subadditivity property for the maximal degrees of the syzygies of monomial ideals. It is known that the this property fails for general ideals in a graded ring, but for some classes of monomial ideals it is known to hold.

In this talk we will relate the the subadditivity property for any monomial ideal to a property of homologies of its lcm lattice and present a technique to study the question from a new perspective. Using this tool we prove the subadditivity property for facet ideals of simplicial forests. (Received March 05, 2017)

1129-13-122 **Michelle Rabideau*** (michelle.rabideau@uconn.edu), Department of Mathematics, University of Connecticut, 341 Mansfield Road U1009, Storrs, CT 06269-1009. *F-polynomial formula from continued fractions.*

We work in the setting of cluster algebras from surfaces with principal coefficients. There is a correspondence between arcs on the surface, cluster variables in the cluster algebra and snake graphs. In fact, there is a formula for cluster variables and thus F-polynomials in terms of the perfect matchings of snake graphs. It is also known that the number of perfect matchings of a snake graph is equal to the numerator of the positive continued fraction describing that snake graph. Moreover, there is a continued fraction equation for cluster variables with trivial coefficients. A natural question is to investigate the relationship between the positive continued fraction and the F-polynomial of a cluster variable. In this talk we describe how the F-polynomial is determined by a continued fraction of Laurent polynomials. (Received March 09, 2017)

1129-13-151 **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 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, provided $\mathbf{B}$ is Gorenstein-linear. This is a joint work with Andrew Kustin. (Received March 12, 2017)

1129-13-173 **Jennifer Biermann**, **Augustine O'Keefe*** (aokeefe@conncoll.edu) and **Adam Van Tuyl**. *Bounds on the regularity of toric ideals of graphs.*

Let G be a finite simple graph. We give a lower bound for the Castelnuovo-Mumford regularity of the toric ideal I_G associated to G in terms of the sizes and number of induced complete bipartite graphs in G. When G is a chordal bipartite graph, we find an upper bound for the regularity of I_G in terms of the size of the bipartition of G. (Received March 13, 2017)

1129-13-197 **Selvi Beyarslan*** (sbeyarsl@tulane.edu), 6823 St. Charles Ave., New Orleans, LA 70118, and **Tai Huy Ha** and **Augustine O'Keefe**. *Cohen-Macaulay toric rings associated to graphs.*

Let $G = (V, E)$ be a simple graph. We give a necessary condition for the toric ring $k[G]$ associated to G to be Cohen-Macaulay. Particularly, we investigate a "forbidden" structure in G that prevents $k[G]$ from being Cohen-Macaulay. We also give a bound for the regularity and projective dimension of $k[G]$ in terms of those of its induced subgraphs. (Received March 15, 2017)

1129-13-214 **Mark Johnson*** (markj@uark.edu), Fayetteville, AR 72701. *Reduced symmetric algebras and linear syzygies.*

Given a finitely generated module over a commutative noetherian domain, it is shown that it's symmetric algebra is integral once it is reduced and the module has (locally) few "linear syzygies". This result has been independently proven by Aron Simis. (Received March 16, 2017)

1129-13-235 **Ian M Aberbach*** (aberbachi@missouri.edu), Department of Mathematics, University of Missouri, Columbai, MO 65211, and **Thomas Polstra**. *The dual free syzygy property and the homological theorems.* Preliminary report.

Let $A = R/I$, where R is a Cohen-Macaulay local ring and I is a height n ideal. We will say that A satisfies the *dual free syzygy property* over A if the nth syzygy module in a minimal R-free resolution of $\mathrm{Ext}^n_R(A, R)$ has an R-free summand.

S. Dutta has shown that the validity of the homological conjectures (now theorems) for all local rings is equivalent to the condition that every homomorphic image of every regular local ring R satisfies the dual free summand property over R.

We explore this condition more carefully, especially as it pertains to the relationships among the various homological conjectures/theorems. (Received March 16, 2017)

1129-13-297 **Louiza Fouli**, **Paolo Mantero*** (pmantero@uark.edu) and **Yu Xie**. *Symbolic powers of points and Chudnovsky's conjecture.*

What is the smallest possible degree of an equation passing at least m times through a given set X of points in the complex projective space $\mathbb{P}^N$? The answer is not known (except in few special cases), however the complex analyst G. V. Chudnovsky in 1979 conjectured a lower bound, which - until last year - was only known to hold for points in $\mathbb{P}^2$, general points in $\mathbb{P}^3$ and certain extremal configurations in $\mathbb{P}^N$.

In this talk we will survey the evolving framework of conjectures and results around the above question, and prove Chudnovsky's conjecture for any set of very general points in $\mathbb{P}^N$. (Received March 18, 2017)

1129-13-304 **Jason McCullough***, Rider University, Department of Mathematics, 2083 Lawrenceville Road, Lawrenceville, NJ 08648. *On the maximal graded shifts of modules over a polynomial ring.*

Let $S = K[x_1, \ldots, x_n]$ be a polynomial ring over a field K and let M be a finitely generated graded S-module. Let $T_i = dim_K Tor_i(M, K)_j$. Then T_i denotes the maximal degree of an ith syzygy of M and is of interest primarily because of its connection with regularity, i.e. $reg(M) = max\{T_i - i \,|\, 0 \leq i \leq pd(M)\}$. In my talk I will present some new bounds on T_n for modules with certain assumptions about the annihilator. Special cases give interesting results on the maximal graded shifts of ideals. (Received March 19, 2017)

1129-13-329 **Andy Magid***, Department of Mathematics, University of Oklahoma, 601 Elm, Room 423, Norman, OK 73019, and **Lourdes Juan**. *Differential Projective Modules and Azumaya Algebras over Differential Rings.* Preliminary report.

Differential modules over a commutative differential ring which are finitely generated and projective as ring modules, with differential homomorphisms, form an additive category. All such are shown to be direct summands of objects which are free as ring modules; those which are differential direct summands of differential direct sums of the ring are shown to be induced from the subring of constants. And any object has this form after a suitable extension of the base. Thus the K theory of the differential category reduces to that of ordinary K theory and kernels. Differential Azumaya algebras over the ring whose underlying modules are finitely generated and projective form a multiplicative category, and similar results to the above are obtained. The K theory of this multiplicative category can accordingly be analyzed in a similar way. (Received March 19, 2017)

1129-13-351 **Lars Winther Christensen*** (lars.w.christensen@ttu.edu), **Srikanth B Iyengar** and **Thomas Marley**. *Homological dimensions of modules over a commutative noetherian ring; what's new?*

For a finitely generated module M over a commutative noetherian local ring $(R, \mathfrak{m}, k)$, vanishing of $\mathrm{Tor}^R_{n+1}(k, M)$ for some $n \geq 0$ implies that M has finite flat dimension at most n. Similarly, vanishing of $\mathrm{Ext}^{n+1}_R(k, M)$ implies that M has finite injective dimension, as long as n is large enough, say, $n \geq \dim R$.

For modules that are not finitely generated, we prove similar statements that take all residue fields $k(\mathfrak{p}) = R_\mathfrak{p}/\mathfrak{p}R_\mathfrak{p}$ into account. (Received March 20, 2017)

1129-13-373 **Carlos E. Arreche*** (cearrech@math.ncsu.edu). *Differential square-zero extensions and Picard-Vessiot theory.* Preliminary report.

In algebraic geometry, understanding square-zero extensions of commutative rings is the first step in the cohomological classification of infinitesimal deformations of schemes. Following recent work of Magid in the case of one derivation, we have developed analogous results for differential square-zero extensions of simple differential rings with several commuting derivations. We prove that such extensions become differentially split in a Picard-Vessiot extension. This is joint work with Raymond Hoobler. (Received March 20, 2017)

1129-13-375 **Eric Bucher*** (ebuche2@math.msu.edu) and **Milen Yakimov**. *Recovering the topology of surfaces from cluster algebras.*

We present an effective method for recovering the topology of a bordered oriented surface with marked points from its cluster algebra. The information is extracted from the maximal triangulations of the surface; giving rise to a connection between cluster automorphisms and the mapping class group of the surface. The method gives new proofs of the automorphism and isomorphism problems for the surface cluster algebras as well as the uniqueness of the Fomin–Shapiro–Thurston block decompositions of the exchange quivers of the surface cluster algebras. (Received March 20, 2017)

1129-13-396 **Branden Stone*** (bstone@adelphi.edu), **Courtney Gibbons** and **Robert Huben**. *Progress on Boij-Soederberg Decomposition of Complete Intersections.* Preliminary report.

In this talk we will discuss resent work in the study of betti table decompositions of complete intersections. New algorithms will be introduced as well as recursive techniques to compute decompositions of complete intersections with high codimension using rings of lower codimension. (Received March 20, 2017)

1129-13-446 **Hamid Kulosman*** (hamid.kulosman@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Ryan Gipson** (ryan.gipson@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292. *Atomic and AP semigroup rings.*

We will talk about the atomicity and the AP property of the semigroup rings $F[X;M]$, where F is a field, X is a variable and M is a submonoid of the additive monoid of nonnegative rational numbers. (Received March 21, 2017)

1129-13-490 **Greg Muller***, 2119 Glencoe Hills Dr, Apt 1, Ann Arbor, MI 48018. *Opposite g-vectors.* Preliminary report.

Negating the exchange matrix has no effect on a cluster algebra or the cluster variables, but it has a significant effect on the g-vectors of those cluster variables. The map which sends a g-vector to the corresponding 'opposite g-vector' can be given by tropicalizing a maximal green sequence of Y-mutations. Time permitting, I will show how this is a consequence of a conjectural duality in theta functions. (Received March 21, 2017)

14 ► Algebraic geometry

1129-14-30 **Sean Lawton*** (slawton3@gmu.edu), George Mason University, Department of Mathematical Sciences, 4400 University Dr, Fairfax, VA 22030. *Compactification of Character Varieties.* Preliminary report.

In this talk we will first discuss a general procedure for compactifying G-character varieties of discrete groups, where G is a semisimple algebraic group of adjoint type over an algebraically closed field. We will then discuss various properties of this compactification in special cases of the discrete group. This work is in collaboration with Dan Ramras and Indranil Biswas. (Received January 24, 2017)

1129-14-77 **Fabrizio ME Catanese*** (fabrizio.catanese@uni-bayreuth.de), mathe 8, 95448 bayreuth, Germany. *Canonical surfaces of high degree and uniformization.* Preliminary report.

Given a projective algebraic surface S of general type, one defines its canonical degree d as the degree of its image under the canonical map (a rational map). The canonical degree is bounded by the canonical volume K_S^2. There is the Noether inequality $d \geq K_S^2$, and the BMY inequality says that $K_S^2 \leq 9(1-q+p_g) \leq 9(1+p_g)$. Together with Ingrid Bauer, we constructed a ball quotient surface with $p_g = 4, q = 0$ and maximal canonical volume K_S^2, against a prediction of Enriques. However the canonical degree was only 19. I shall present several new results concerning the canonical degrees and the canonical map of some surfaces isogenous to a product (these are uniformized by the bidisk), and raise several open questions. For example we obtain d=56 for $p_g = 6$, but the question of finding surfaces with $p_g = 6$ which are canonically embedded and with high K_S^2 is related with some difficult question in homological algebra. (Received March 03, 2017)

1129-14-91 **A Knecht***, 800 Lancaster Ave, St Augustine Ctr Rm 305, Villanova, PA 19085, and **K Reyes**. *Full Degree 2 del Pezzo Surfaces.*

A smooth two dimensional variety X defined over a field k is called a *del Pezzo surface* if its anticanonical divisor $-\omega_X$ is ample. The degree d of a del Pezzo surface is the self intersection number of its canonical class and $1 \leq d \leq 9$. The most popular examples of del Pezzo surfaces are cubic surfaces because they are the zero sets of degree three homogeneous polynomials in four variables. Over algebraically closed fields, the geometry of del Pezzo surfaces is well understood. For example, we know exactly how many lines each surface contains based on the degree. Over finite fields, these lines may not be defined. In the rare case that they are all defined over the finite field, we call the surface *split*. Hirschfeld classified split del Pezzo surfaces of degree at least three whose points are all contained on the lines in the surface. We continue his work and begin the classification of split degree two del Pezzo surfaces over finite fields whose points are all on the fifty-six lines of the surfaces. (Received March 06, 2017)

1129-14-255 **Jihyeon Jessie Yang*** (jyang@marian.edu). *Bott Canonical Bases of Representations.*

Raoul Bott showed that if a compact torus $(S^1)^n$ acts holomorphically on a complex n-dimensional manifold M with an isolated fixed point and equivariant line bundle L, the induced representation on the space of sections $\Gamma(M, L)$ splits into complex lines. Motivated by this fact it was hoped that there was such an action on a manifold closely related to the flag manifold G/B of a complex semi-simple Lie group G so that this would lead to a geometrically constructed canonical basis for G-representations via Borel-Weil-Bott theory. Bott succeeded to find a maximal dimensional torus action on a Bott-Samelson manifold (a birational model for G/B). This action, however, turned out to be non-holomorphic and this idea was not successful in the original context. Instead of the original Bott-Samelson manifold, we constructed its deformation that admits a nice action. This action extends the natural maximal torus action on G/B and provides a decomposition of the irreducible representation V_λ with highest weight λ into complex lines, as Bott hoped to achieve. This work is motivated by a suggestion from J. Berenstein and also filtrations induced by test configurations introduced by D. W. Nystöm. This is a joint work with Yael Karshon. (Received March 17, 2017)

1129-14-315 **Raymond T. Hoobler*** (rhoobler@ccny.cuny.edu), Department of Mathematics, The Graduate Center, CUNY, 365 Fifth Avenue, New York, NY 10016. *Differential Brauer Group.* Preliminary report.

Let X be a quasi-projective, compact scheme over a field of characteristic 0. Recent work shows that given a torsion element $x \in H^2\left(X_{et}, Gm\right)$, there is an Azumayua algebra Λ on X admitting an integrable biconnection, i.e. a connection such that $\nabla(ab) = a\nabla(b) + \nabla(a)\, b$, whose cohomology class is x. We use this to define the *differential Brauer group* $Br_\nabla(X)$ on such a scheme. We use the $\delta - flat$ topology to give a cohomological interpretation of $Br_\nabla(X)$ and show its relation to the usual Brauer group. If X is smooth and projective, we illustrate this relationship with respect to Hodge theory. (Received March 19, 2017)

1129-14-323 **Anders S. Buch*** (asbuch@math.rutgers.edu). *Quantum cohomology.*

The (small) quantum cohomology ring of a flag variety is a deformation of the ordinary cohomology ring that encodes the (3-point, genus 0) Gromov-Witten invariants as its Schubert structure constants. Focusing mostly on Grassmannians, I will review some of the things we know about this ring as well as its K-theoretic and equivariant generalizations. I will also discuss some of my favorite open questions about quantum cohomology, some of which go back to the beginnings in the 1990s. (Received March 19, 2017)

1129-14-377 **Gabriele Di Cerbo***, dicerbo@math.columbia.edu, and **Luca Fabrizio Di Cerbo**. *On Seshadri constants of varieties with large fundamental group.*

Let X be a smooth variety and let L be an ample line bundle over X. If the algebraic fundamental group is large, I will show that the Seshadri constant can be made arbitrarily large by passing to a finite etale cover. This result answers affirmatively a conjecture of J.-M. Hwang. Moreover, we prove an analogous result when the fundamental group is large and residually finite. If time permits, I will talk about a generalization of the same result for big and nef line bundles. (Received March 20, 2017)

1129-14-442 **James E Pommersheim*** (jamie@reed.edu), Department of Mathematics, Reed College, 3203 SE Woodstock Blvd, Portland, OR 97202. *An Algebraic Approach to Euler-Maclaurin Via Toric Varieties.*

As has been well known for some time, the problem of counting lattice points in a polytope can be recast using the theory of toric varieties. Given a polytope, we give a concrete algebraic cycle-level action of Cartier divisors on the associated toric variety. This leads in turn to an Euler-Maclaurin formula for summing a polynomial function over the lattice points of a polytope. This is work of Ben Fischer and the speaker. (Received March 21, 2017)

1129-14-447 **James Freitag*** (freitagj@gmail.com), 913 S. Chester, Park Ridge, IL 60068. *Model theory and transformations of Painleve equations.*

We will discuss how to use model theory to prove some classification results on transformations of Painleve equations. (Received March 21, 2017)

1129-14-455 **Sanghoon Baek** and **Rostislav Devyatov*** (deviatov@mccme.ru), 585 King Edward, Ottawa, Ontario K1N0G8, Canada, and **Kirill Zainoulline**. *On invariant ideals of representation rings of semisimple groups.*

The talk is based on my joint work with Sanghoon Baek and Kirill Zainoulline, see arXiv:1612.07278.

To any semisimple group G over an algebraically closed field of characteristic 0, one can associate its weight lattice Λ, the set of fundamental weights, and the Weyl group W acting on Λ. One can consider the Laurent polynomial ring $\mathbb{Z}[\Lambda]$ and the *augmented orbit polynomials.* These polynomials generate an ideal $I \subset \mathbb{Z}[\Lambda]$.

One can also consider the character lattice of the maximal torus of G: $T^* \subseteq \Lambda$ and the corresponding Laurent polynomial subring $\mathbb{Z}[T^*] \subseteq \mathbb{Z}[\Lambda]$.

The ideals $I \subset \mathbb{Z}[\Lambda]$ and $I \cap \mathbb{Z}[T^*] \subset \mathbb{Z}[T^*]$ can be used to compute the ring $K_0(X)$, where X is a variety over a (possibly non algebraically closed field) whose algebraically closed form is the variety of complete flags of G.

If certain conditions on T^* and Λ are satisfied, I will try to explain the approach used in our paper to find an explicit description the intersection $I \cap \mathbb{Z}[T^*]$. (Received March 21, 2017)

1129-14-460 **Sjuvon Chung*** (sjuvon.chung@rutgers.edu) and **Anders S. Buch**. *Euler characteristics and quantum K-theory of cominuscule flag varieties.*

The quantum K-theory ring of a flag variety G/P is a K-theoretic version of its quantum cohomology ring. In this talk we will discuss a quantum K-theoretic identity satisfied by opposite Schubert varieties of G/P, when G/P is cominuscule. This identity uses the Euler characteristic map—i.e., pushforward to a point—to relate the quantum K-theoretic product of opposite Schubert varieties to the minimal degree of a rational curve connecting them. In conclusion we will discuss consequences of this identity to the quantum (and non-quantum) K-theory of G/P. (Received March 21, 2017)

1129-14-513 **Benjamin Bakker***, Dept. Of Mathematics, University of Georgia, Athens, GA. *The birational geometry of complex ball quotients.*

Ball quotients arise frequently in algebraic geometry as moduli spaces—for instance, those of low genus curves, del Pezzo surfaces, certain K3 surfaces, and cubic threefolds—and in this case the birational geometry has important implications to the geometry of the moduli problem. In joint work with J. Tsimerman, we show that in dimension $n \geq 4$ every smooth complex ball quotient is of general type, and further that the canonical bundle $K_{\overline{X}}$ of the toroidal compactification $\overline{X}$ is ample for $n \geq 6$. The proof uses a hybrid technique employing both the hyperbolic geometry of the uniformizing group and the algebraic geometry of the toroidal compactification. We will also discuss applications to bounding the number of cusps and the Green–Griffiths conjecture. (Received March 21, 2017)

16 ► Associative rings and algebras

1129-16-27 **L Li**, **B Ransingh** and **Ashish K Srivastava*** (asrivas3@slu.edu), 221 N. Grand Blvd., Saint Louis, MO 63013. *Some steps toward cluster superalgebras.* Preliminary report.

A superalgebra is a $\mathbb{Z}_2$-graded associative algebra. We introduce the notion of a cluster superalgebra which is a natural super analogue of classical cluster algebra. We will give some examples and discuss its importance in the mathematics of supersymmetry. (Received January 21, 2017)

1129-16-92 **Kyu-Hwan Lee** and **Kyungyong Lee*** (klee24@unl.edu), 203 Avery Hall, Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *A conjectural Description for real Schur roots of acyclic quivers.*

Let $\mathcal{Q}$ be an acyclic quiver. The dimension vectors of indecomposable rigid representations are called real Schur roots. We give a conjectural description for real Schur roots of $\mathcal{Q}$ using non-self-intersecting paths on Riemann surfaces, and prove it for certain quivers of finite type and for the quivers with three or less vertices and multiple arrows between every pair of vertices. Each of such paths gives rise to a reflection of the Weyl group of the corresponding Kac–Moody algebra and determines a real Schur root uniquely. (Received March 06, 2017)

1129-16-240 **Thomas Brüstle*** (tbruestl@ubishops.ca), 2600 College Street, Sherbrooke, Quebec J1M1Z7, Canada, and **David Smith** and **Hipolito Treffinger**. *Stability for abelian categories and green sequences.*

The general notion of stability was formalised in the context of abelian categories by Rudakov. We study in this talk Rudakov's stability functions on abelian categories, and relate them to the language of torsion classes, partially inspired by Bridgeland's work on scattering diagrams. Finally, we generalize in this context the notion of maximal green sequences to green paths. (Received March 16, 2017)

1129-16-260 **Thomas Brüstle**, **David Smith** and **Hipolito Treffinger***, h.treffinger@usherbrooke.ca. *Stability for module categories and tau-tilting theory.*

The notion of stability conditions in module categories was introduced by King. The aim of the talk is to give a new interpretation of this conditions under the light of the τ-tilting theory, recently introduced by Adachi, Iyama and Reiten. Finally, we will show some geometrical consequences of our results, relating them with the wall and chamber structure of an algebra. (Received March 17, 2017)

1129-16-438 **Pramod N. Achar** (pramod@math.lsu.edu), **Maitreyee Kulkarni** (mkulka2@lsu.edu) and **Jacob P. Matherne*** (matherne@math.umass.edu). *Combinatorial Fourier transform for type A quiver representation varieties.* Preliminary report.

For a given dimension vector $\mathbf{d}$, we consider the space of representations of the linearly-oriented type A quiver $\bullet \longrightarrow \bullet \longrightarrow \cdots \longrightarrow \bullet$. This affine space has a stratification by orbits for a product of general linear groups, where the orbits are isomorphism classes of representations with dimension vector $\mathbf{d}$. The Fourier–Sato transform, a geometric version of the Fourier transform that we meet in analysis, is a functor which matches up orbits for this quiver with orbits for the reversed quiver in an interesting way. We introduce certain triangular arrays of nonnegative integers and, with them, give a combinatorial algorithm for computing the Fourier–Sato transform in this setting. This is joint (in progress) work with Pramod N. Achar and Maitreyee Kulkarni. (Received March 21, 2017)

18 ► Category theory; homological algebra

1129-18-128 **Stephen Hermes*** (shermes@math.harvard.edu). *Maximal Green Sequences and Semi-invariant Geometry.*

Maximal green sequences are important sequences of cluster mutations which naturally arise in combinatorics, representation theory, geometry and mathematical physics. They have applications to torsion theories, tilting, Donaldson–Thomas invariants, and supersymmetric field theory, to name but a few. In this talk I will explain how quiver semi-invariants are an indispensable tool in the study of green mutation, allowing for the proof of several outstanding conjectures about maximal green sequences. (Received March 10, 2017)

1129-18-199 **Bhanumati Nayak Dasgupta*** (bhanumati@msn.com) and **Soura Dasgupta**. *A hermitian analog of a Morita theorem.*

Bass came up with an important tool, the Morita theorems which Frohlich et al generalized for rings with involution. Bass' Morita I states that the tensor product by a suitable bimodule with connecting maps called a Morita context naturally gives rise to an equivalence between categories of modules over rings(CMR). Morita II states that every equivalence between CMR can be given by such a tensor product. The former has a hermitian analog by Hahn for rings with antistructure, in particular rings with involutions. Hermitian analogs of Morita II exist but have conditions hard to verify. This paper has a relatively simple analog and shows that every equivalence \$F_1\$ between categories of modules with hermitian forms over rings with antistructure arises by tensoring the module and form with a suitable bimodule and a form resp. from a hermitian Morita context if \$F_1\$ agrees with an equivalence \$F\$ between the underlying CMR on the underlying modules and morphisms and if \$F_1\$ preserves non-singularity. This theorem is important because all equivalences under these conditions then give rise to isomorphic Witt groups of the underlying rings, and induce generalized Brauer groups and Azumaya algebras with antistructure. (Received March 15, 2017)

1129-18-361 **Mikhail Khovanov*** (khovanov@math.columbia.edu), Department of Mathematics, Columbia Universit, 2990 Broadway, New York, NY 10463. *How to categorify the ring of integers with two inverted.*

We'll describe a triangulated monoidal category with the Grothendieck ring isomorphic to the ring of integers localized at two. This is a joint work with Yin Tian. (Received March 20, 2017)

20 ► Group theory and generalizations

1129-20-16 **John G Ratcliffe*** (j.g.ratcliffe@vanderbilt.edu), Department of Mathematics, Vanderbilt University, 1326 Stevenson Center, Nashville, TN 37240, **Steven T Tschantz** (steven.tschantz@vanderbilt.edu), Department of Mathematics, Vanderbilt University, 1326 Stevenson Center, Nashville, TN 37240, and **Vincent Emery** (vincent.emery@gmail.com), Department of Mathematics and Statistics, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland. *Salem numbers and arithmetic hyperbolic groups.*

In this paper we prove that there is a direct relationship between Salem numbers and translation lengths of hyperbolic elements of arithmetic hyperbolic groups that are determined by a quadratic form over a totally real number field. As an application we determine a sharp lower bound for the length of a closed geodesic in a noncompact arithmetic hyperbolic n-orbifold for each dimension $n > 1$. (Received January 04, 2017)

1129-20-42 **Gabe Cunningham** and **Mark Mixer***, 550 Huntington Ave, Boston, MA 02115. *Internal and external duality in abstract polytopes.*

An abstract regular polytope is internally self-dual if its self-duality can be realized as one of its symmetries. This property has many interesting implications on the structure of the polytope.

We will discuss the implications of a structure being internally self-dual, and prove the existence of many different types of internally self-dual polyhedra, as well as polytopes in higher ranks. (Received February 04, 2017)

1129-20-46 **Colin Reid** and **Phillip Wesolek*** (pwesolek@binghamton.edu). *The essentially chief series of compactly generated locally compact groups.*

In locally compact groups, studying the tension between topological structure and geometric structure often yields surprising, general results. In this talk, we show the normal subgroup structure of a locally compact group is restricted by this tension. A closed normal factor K/L of a locally compact group G is called a chief factor if there is no closed normal subgroup of G strictly between L and K. We show that every compactly generated locally compact group G admits a finite series $\{1\} = G_0 \leq G_1 \leq \cdots \leq G_n = G$ of closed normal subgroups such that each normal factor G_i/G_{i-1} is either discrete, compact, or chief; such a series is called an essentially chief series. We then demonstrate a uniqueness result for essentially chief series. (Received February 16, 2017)

1129-20-56 **Arman Darbinyan*** (arman.darbinyan@vanderbilt.edu), 1023 17th Ave South, apt #103, Nashville, TN 37212. *Word and Conjugacy Problems in Lacunary Hyperbolic Groups.*

We study word and conjugacy problems in lacunary hyperbolic groups (briefly, LHG) from different perspectives: from the perspective of the relationship between WP and CP in LHGs; from the perspective of computability and from the perspective of computational complexity. In particular, we describe "if and only if" conditions for decidability of the word problem in LHGs. Then we formulate special small cancellation conditions which allow us to build a rich class of LHGs with highly controllable word and conjugacy problems. Careful examination of this class allows us to formulate several interesting applications as well as to answer several open questions. (Received February 24, 2017)

1129-20-65 **Vladimir Shpilrain*** (shpil@groups.sci.ccny.cuny.edu), Department of Mathematics, The City College of New York, New York, NY 10031. *Randomness and complexity in matrix groups.*

We reflect on how to define complexity of a matrix and how to sample a random invertible matrix. We also discuss a related issue of complexity of algorithms in matrix groups. (Received March 01, 2017)

1129-20-86 **Jane Gilman***, gilman@rutgers.edu. *Discreteness and adjoining roots of primitive generators to a rank two Fuchsian groups.*

We give necessary and sufficient discreteness conditions when a root or a rational power of an algorithmic *stopping generator* is adjoined to a discrete free rank two subgroup of $PSL(2, \mathbb{R})$. We also present results for non-free groups. (Received March 05, 2017)

1129-20-125 **Gerhard Rosenberger*** (gerhard.rosenberger@uni-hamburg.de), Heinrich-Barth-Str. 1, 20146 Hamburg, Germany. *On the classification of arithmetic Fuchsian groups.*

We discuss possibilities to classify arithmetic Fuchsian groups with a given signature. (Received March 10, 2017)

1129-20-145 **James B Wilson*** (james.wilson@colostate.edu), Department of Mathematics, Colorado State University, 101 Weber Building, Fort Collins, CO 80523. *Coordinatizing groups with Lie tensor products.* Preliminary report.

We show how to recognize that an abstractly presented group is a group of matrices and recover its commutative ring of coordinates. Thus, automorphisms of parabolic algebraic and arithmetic groups can be described using ideal class groups and Picard groups of the coordinate ring. Critical to our method is the construction of tensor products over Lie algebras (rather than associative rings). That sets off a cascade of new tools and results. (Received March 11, 2017)

1129-20-153 **Alexei Miasnikov*** (amiasnikov@gmail.com), Castle Point on Hudson, Hoboken, NJ 07030. *Algorithmic problems in metabelian groups.*

Decidability of algorithmic problems in finitely generated metabelian groups is a well-studied area, even though some famous algorithmic problems here still stand widely open. Furthermore, the complexity of the known decision algorithms is mostly unknown. It seems there is a big gap in our knowledge between decidability and complexity in metabelian groups. Is it by chance or there are real reasons? In this talk I will address the question above and discuss some new results. (Received March 12, 2017)

1129-20-154 **Laura Ciobanu**, Department of Mahematics, Herriott-Watt University, Edinburgh, EH14AS, United Kingdom, **Benjamin Fine*** (fine@fairfield.edu), Department of Mathematics, Fairfield University, Fairfield, CT 06824, and **Gerhard Rosenberger**. *The Surface Group Conjecture : Cyclically Pinched and Conjugacy Pinched One-Relator Groups.*

The general**surface group conjecture** asks whether a one-relator group where every subgroup of finite index is again a one-relator group and every noncyclic subgroup of infinite index is a free group (Property IF). We resolve several related conjectures given in by Fine, Kharlampovich, Myasnikov, Remeslennikov abd Rosenberger [FKMRR]. First we obtain the Surface Group Conjecture B for cyclically pinched and conjugacy pinched one-relator groups. That is: if G is a cyclically pinched one-relator group or conjugacy pinched one-relator group satisfying property IF then G is free, a surface group or a solvable Baumslag-Solitar Group. Further combining results in [FKMRR] on Property IF with a theorem of H. Wilton [W] and results of Stallings, and Gildenhuys, Kharlampovich and Myasnikov we show that Surface Group Conjecture C proposed in [FKMRR] is true, namely: If G is a finitely generated nonfree freely indecomposable fully residually free group with property IF, then G is a surface group.
(Received March 12, 2017)

1129-20-156 **Matias Carrasco*** (mcarrasco@fing.edu.uy), Instituto de Matematica y Estadistica, Facultad de Ingenieria, Julio Herrera y Reissig 565, 11300 Montevideo, Montevideo, Uruguay, and **Emiliano Sequeira** (esequeira@cmat.edu.uy), Instituto de Matematica y Estadistica, Facultad de Ingenieria, Julio Herrera y Reissig 565, 11300 Montevideo, Montevideo, Uruguay. *Quasi-isometry invariants associated to Heintze groups.*

Negatively curved homogeneous manifolds were characterized by Heintze in 1974. Each such manifold is isometric to a solvable Lie group equipped with a left invariant metric, and the group is a semi-direct product of N times the reals R, where N is a nilpotent simply connected Lie group, and the action of R on N is given by a derivation whose eigenvalues all have positive real parts. Such a group is called a Heintze group.

An important conjecture regarding the large scale geometry of (purely) real Heintze groups states that two such groups are quasi-isometric if, and only if, they are isomorphic.

In this talk I will describe some quasi-isometry invariants associated to the derivation of a Heintze group, and I will give some applications to the case where N is a Heisenberg group.

This is a joint work with Emiliano Sequeira. (Received March 12, 2017)

1129-20-191 **Svetla Vassileva*** (svetla.vassileva@gmail.com). *Low complexity algorithmic problems in groups.*

The focus of the study of the complexity of algorithmic problems in groups has shifted over time – from decidability, to polynomial time, and most recently to logspace and TC^0 complexity. We will consider the classical decision problems, as well as some computational problems (such as finding normal forms) in the light of their logspace and TC^0 complexity. (Received March 15, 2017)

1129-20-224 **Sam van Gool** and **Benjamin Steinberg*** (bsteinberg@ccny.cuny.edu). *Model theory and free pro-aperiodic monoids.*

Buchi showed that regular languages are exactly the languages definable in monadic second order logic. Schutzenberger characterized in the sixties the languages definable in first order logic as those whose syntactic monoid is a aperiodic. This gives a decidable criterion to determine if an MSO formula is equivalent to a first order formula.

Many natural questions in formal language theory, such as separation by first order formulas, are naturally attacked via profinite monoids. Building on Schutzenberger's theorem and duality theory, we observe that the free pro-aperiodic monoid can be identified with the space of elementary equivalence classes of pseudofinite words. The algebraic structure can easily be interpreted as natural operations on pseudofinite words. Using techniques from model theory, such as saturated models, we are able to obtain simpler proofs of known structural results as well as new results about free pro-aperiodic monoids.

In this talk we will introduce some of the main ideas and concepts. Sam van Gool's talk will then go into some applications of these techniques. (Received March 16, 2017)

1129-20-225 **Sam van Gool*** (samvangool@me.com) and **Benjamin Steinberg** (bsteinbg@gmail.com). *Applications of saturated models to pro-aperiodic monoids.*

We show how saturated models can be used to answer questions about pro-aperiodic monoids. The main idea is that saturated models allow us to transfer combinatorial arguments on finite words to the pro-aperiodic setting. In particular, we give an easy proof that factors of elements given by omega-terms are again given by omega-terms. Moreover, we give a new correctness proof for a decision procedure for equality of aperiodic omega-terms.

This talk builds on the theoretical results presented in Ben Steinberg's talk. (Received March 16, 2017)

1129-20-226 **Robert Gray** and **Benjamin Steinberg*** (bsteinberg@ccny.cuny.edu). *Homological finiteness conditions for one-relator monoids and related monoids.* Preliminary report.

A special monoid presentation (in the sense of Adian and Makanin) is a finite monoid presentation of the form $\langle A \mid w_1 = 1, \ldots, w_k \rangle$. The group of units of a special monoid is known to also be finitely presented with the same number of relations and there is a reduction from the word problem of the monoid to the word problem of its group of units.

Motivated by the question of whether every one-relator monoid admits a finite complete rewriting system, we investigate homological finiteness properties of special monoids. Our main result is that if the group of units is of type FP_n, then so is the monoid. We also obtain a tight relation between the cohomological dimension of a special monoid and its group of units. As a consequence, we obtain that every special one-relator monoid is of type FP_∞, providing a partial answer to an old question of Kobayashi from the nineties.

Our techniques are topological in nature. (Received March 16, 2017)

1129-20-230 **Jorge Almeida**, **M. H. Shahzamanian** and **Benjamin Steinberg*** (bsteinberg@ccny.cuny.edu). *Computing closures in the pro-nilpotent topology on a free group.*

In the nineties, Margolis, Sapir and Weil gave an algorithm to compute the closure of a finitely generated subgroup of a free group in the pro-nilpotent topology.

Motivated by questions in automata theory, we provide an algorithm to compute the closure of a language accepted by a finite state automaton in the the pro-nilpotent topology. This boils down to computing the closure of a product $H_1 H_2 \cdots H_n$ of finitely generated subgroups in the pro-nilpotent topology. Here, a crucial role is played by the Ribes-Zalesskii product theorem, which implies that if p is a prime then a finite product of pro-p closed finitely generated subgroups of a free group is closed in the pro-p topology. (Received March 16, 2017)

1129-20-236 **Keivan Mallahi-Karai***, Campus Ring I, 28759 Bremen, Germany, and **Hadi Salmasian**, **Mohammad Bardestani** and **Camelia Karimianpour**. *Minimal Faithful Representation of Chevalley Groups over finite rings.*

For a finite group G, denote by $m_f(G)$ the least possible dimension of a faithful linear representation of G over the field of complex numbers. Let $G_n = \mathbf{G}\,(\mathbb{Z}/p^n\mathbb{Z})$ stand for the group of $\mathbb{Z}/p^n\mathbb{Z}$-points of the adjoint Chevalley group $\mathbf{G}$. In this talk, we will discuss recent developments on obtaining lower bounds for $m_f(G)$. These bounds, which are asymptotically the same as the results of Landazuri, Seitz and Zalesskii in the case of split Chevalley groups over finite fields, can potentially have applications in arithmetic combinatorics of non-abelian groups. This is a joint work with Mohammad Bardestani, Camelia Karimianpour, and Hadi Salmasian. (Received March 16, 2017)

1129-20-237 **Daniela B Nikolova-Popova*** (dpopova@fau.du), 777 Glades road, Boca Raton, FL 33435, and **Luise-Charlotte Kappe**, **Spyros Magliveras**, **Eric Swartz** and **Michael Epstein**. *On the Covering Number of Small Symmetric, Alternating Groups, and Some Sporadic Simple Groups.*

We say that a group G has a finite covering if G is a set theoretical union of finitely many proper subgroups. The minimal number of subgroups needed for such a covering is called the covering number of G denoted by σ(G): Let Sn be the symmetric group on n letters. For odd n Maroti determined σ(Sn) with the exception of n = 9, and gave estimates for n even showing that σ(Sn) $\leq$ 2n - 2. We show that σ(S8) = 64, σ(S10) = 221, σ(S12) = 761. We also show that Maroti's result for odd n holds without exception proving that σ(S9) = 256. We establish in addition that the Mathieu group M12 has covering number 208, and improve the estimate for the Janko group J1 given by P.E.Holmes. In another paper, we establish the covering number of A9, and A11. As of now, the smallest values of n for which the covering numbers of Sn, and An are not known are n=14, and n=12 respectively. The methods we use involve GAP calculations, incidence matrices and linear programming. The coverings turn out to be dependent on the arithmetic nature of n. However, some results for larger classes of Sn have been established. (Received March 16, 2017)

1129-20-241 **Vladimir Shpilrain** (shpil@groups.sci.ccny.cuny.edu), City College of New York, NY , and **Bianca Sosnovski*** (bsosnovski@qcc.cuny.edu), Queensborough Community College, NY. *Semigroups of linear functions applied to Cayley hash functions.*

Cayley hash functions are based on the idea of using a pair of elements in a (semi)group, A and B, to hash the 0 and 1 bit, respectively. A bit string is associated to a string of A's and B's and the hash value is computed by multiplying the sequence of A's and B's in the (semi)group.

We present a new semigroup platform for a Cayley hash function. Our proposed hash function uses a pair of two linear functions in one variable over $\mathbb{F}_p$ under composition operation. The semigroup is generated by the functions $f(x) = 2x + 1$ and $g(x) = 3x + 1$ modulo a prime $p > 3$. The result is an efficient hash function whose outputs are of size $2 \log p$. We give explicit lower bound on the length of collisions for the proposed hash function. (Received March 20, 2017)

1129-20-253 **Juan Alonso*** (juan@cmat.edu.uy), **Joaquin Brum** and **Cristobal Rivas**. *Flexibility of surface group actions on the line.*

Let Σ be a closed orientable hyperbolic surface, and $R(\Sigma)$ be the space of representations of $\pi_1(\Sigma)$ on $Homeo_+(\mathbb{R})$ with no global fixed points. In a joint work with J. Brum and C. Rivas, we obtain perturbations of any $\rho \in R(\Sigma)$ within this space that are not semi-conjugated to ρ. We also generalize this for a slightly larger class of groups. I will present these results statements, as well as discussing their relevance and some ideas of the proof. (Received March 17, 2017)

1129-20-261 **Primož Potočnik*** (primoz.potocnik@fmf.uni-lj.si), UL FMF, Jadranska 19, Ljubljana, Slovenia. *Controling the automorphism group of a covering graph.*

Given a connected finite graph Γ and a group of automorphisms $G \leq \mathrm{Aut}(\Gamma)$, it is often desired to find a covering projection of graphs $\wp\colon \tilde{\Gamma} \to \Gamma$ (with $\tilde{\Gamma}$ finite, if possible) satisfying one or both of the conditions: (1) G is the largest group that lifts along $\wp$; (2) $\mathrm{Aut}(\tilde{\Gamma})$ projects along $\wp$.

Even though the existence of such a covering projection seems to ba a question about finite graphs, the problem can be translated into the language of totally disconnected locally compact groups acting on an infinite tree.

In my talk, I will present a recent result stating that under some mild assumptions on Γ and G, a covering projection $\wp$ satisfying (1) always exists and that under some further restrictions (for example, if Γ is cubic and G is arc-transitive), the covering projection can be chosen in such a way that it satisfies (2) as well. (Received March 17, 2017)

1129-20-272 **Joaquín Brum*** (joaquinbrum@gmail.com). *Minimal laminations by hyperbolic surfaces.*

Let Σ_0 be a closed hyperbolic surface and $(\Sigma_0, x_0) \leftarrow (\Sigma_1, x_1) \leftarrow ...$ an infinite tower of finite covers. The inverse limit of this array is naturally a minimal lamination by hyperbolic surfaces and the leaf containing the sequence $(x_0, x_1, ...)$ is the Gromov-Hausdorff limit of the sequence (Σ_n, x_n).

We play with the previous observation to construct new examples of minimal laminations by hyperbolic surfaces. In particular, we construct examples where leafs of finite and infinite type coexist.

This is a joint work with Sebastien Alvarez, Matilde Martínez and Rafael Potrie. (Received March 17, 2017)

1129-20-283 **Jonathan Gryak*** (gryakj@gmail.com), **Delaram Kahrobaei** and **Conchita Martinez-Perez**. *On The Conjugacy Problem In Certain Metabelian Groups.*

Non-commutative cryptography seeks to develop cryptosystems that utilize algorithmic problems from group theory for their hardness assumptions. The security of such systems is contingent upon the computational complexity of the chosen algorithmic problem in the underlying platform group.

In this talk, we analyze the computational complexity of the conjugacy search problem in a certain family of metabelian groups. We prove that in general the time complexity of the conjugacy search problem for these groups is at most exponential. For a subfamily of groups we prove that the conjugacy search problem is polynomial. We also show that for some of these groups the conjugacy search problem reduces to the discrete logarithm problem. (Received March 18, 2017)

1129-20-295 **Olga Kharlampovich*** (okharlampovich@gmail.com), New York, NY 10029. *Geometry of limit groups is definable in their group algebras.*

We will show that the set of all free bases of a free group F is 0-definable in the group algebra $K(F)$ when K is an infinite field, the set of geodesics is definable, and many geometric properties of F are definable in $K(F)$. Therefore $K(F)$ "knows" some very important information about F. We will show that similar results hold for group algebras of limit groups. The talk is based on joint results with A. Myasnikov. (Received March 18, 2017)

1129-20-296 **Pascal Weil***, pascal.weil@labri.fr. *A graph-based method to randomly generate subgroups of free groups.*

The study of random algebraic objects sheds a different light on these objects, which complements the algebraic and the algorithmic points of view. When it comes to finitely generated subgroups of free groups, we have a remarkable graphical representation called the Stallings graph: the Stallings graph of a subgroup H is a finite labeled graph uniquely associated with H, efficiently computed from a set of generators of H (say, given as reduced words), and from which one can efficiently compute many invariants of H.

I will discuss enumerating and randomly generating finitely generated subgroups of free groups, for the distribution given by Stallings graphs: for each positive integer n, one considers the finite number of subgroups whose Stallings graph has n vertices, and one considers the uniform distribution on that set. This requires understanding the combinatorial structure of Stallings graphs, which are interesting objects per se. I will also exhibit natural properties of subgroups which are 'generic' for this distribution.

This is joint work with F. Bassino (U. Paris-Nord) and C. Nicaud (U. Paris-Est) (Received March 18, 2017)

1129-20-298 **Catherine Eva Pfaff*** (cpfaff@math.ucsb.edu), UCSB Math Dept., South Hall, Room 6607, Santa Barbara, CA 93106. *Geodesics of Outer Space in an Algorithmic Setting.*

The outer automorphism group of the free group is understood via its action on Culler-Vogtmann Outer Space. Because of its rich, intriguing complexity, many aspects of Outer Space, and hence many aspects of the outer automorphism group of the free group, are difficult to tackle in an algorithmic manner. As one approach to taming this situation, we have isolated particular outer automorphisms and associated geodesics that can in fact be understood algorithmically. We explain theorems sprouting from our investigation into these outer automorphisms and geodesics. This is joint work with Yael Algom-Kfir, Ilya Kapovich, and Lee Mosher. (Received March 18, 2017)

1129-20-299 **Ievgen Bondarenko**, vul.Volodymyrska 64, Kyiv, 01033, Ukraine, and **Dmytro M Savchuk*** (savchuk@usf.edu), 4202 E Fowler ave, CMC 342, Tampa, FL 33620. *Duality in reversible automata generating lamplighter type groups.* Preliminary report.

We study a class of groups generated by reversible automata modeling multiplication in the ring of formal power series. The realization of the lamplighter type groups by similar types of automata has been studied by several authors since the beginning of 2000's.

We show that in many cases the group generated by the dual automaton is again of lamplighter type and that it also acts on series in certain rational function. (Received March 18, 2017)

1129-20-300 **Inna Bumagin*** (bumagin@math.carleton.ca) and **Nicholas Touikan**. *On limit groups of relatively hyperbolic groups.* Preliminary report.

I will discuss basic properties and some examples of limit groups of relatively hyperbolic groups. This is joint work with Nicholas Touikan. (Received March 18, 2017)

1129-20-305 **Robert H Gilman*** (rgilman@stevens.edu), Stevens Institute of technology, Department of Mathematical Sciences, Hoboken, NJ 07030. *The generic complexity of coset enumeration.*

It is well known that most decision problems about finitely presented groups are undecidable. Every algorithm for such a problem must fail on some inputs. Generic complexity was proposed some years ago by Ilya Kapovich, Alexei Myasnikov, Paul Schupp, Vladimir Shpilrain as a method of estimating the efficacy of such algorithms. In this talk we see what generic complexity can tell us about the efficacy of coset enumeration, a well known algorithm for verifying that a finite presentation presents a finite group. (Received March 19, 2017)

1129-20-337 **Maggie E. Habeeb*** (habeeb@calu.edu), 250 University Ave, #54, California, PA 15419. *Oblivious Transfer using Groups.* Preliminary report.

In an oblivious transfer protocol one considers the situation where Alice sends messages to Bob, but Alice must not learn what information, if any, Bob has received. Additionally, Bob should learn nothing more than his chosen message. In this talk, we will explore oblivious transfer protocols using non-abelian groups. (Received March 20, 2017)

1129-20-340 **Colin Reid*** (colin.d.reid@newcastle.edu.au). *Compactly generated subgroups of totally disconnected, locally compact groups.*

Much of the theory of totally disconnected, locally compact (t.d.l.c.) groups is based on an interplay between large-scale structure (which is of a 'geometric' nature in the sense of geometric group theory) and the small-scale 'local' structure (that is, the structure formed by the compact open subgroups). There is also a third 'regional' scale, that of the compactly generated subgroups of a t.d.l.c. group; these turn out to have some surprising restrictions on their structure, which in turn affects how they can fit together to form an arbitrary t.d.l.c. group. I will talk about some recent progress on developing this 'regional' approach to the theory of t.d.l.c. groups. (Received March 20, 2017)

1129-20-341 **Luke Morgan*** (luke.morgan@uwa.edu.au). *Discrete groups of automorphism of trees.*

A G-locally-transitive graph D is called locally semiprimitive if for each vertex x of D, the stabiliser of x in G induces a semiprimitive permutation group on the neighbourhood of x. A recent conjecture of Potocnik, Spiga and Verret states that the order of vertex stabilisers in vertex-transitive locally semiprimitive graphs are bounded by a function of the valency of the graph. This generalises the long-standing Weiss and Praeger Conjectures. I'll discuss some equivalent formulations, in terms of amalgams and automorphism groups of trees. In the latter case, the problem is concerned with the discrete subgroups of the automorphism group of a tree (which satisfy the additional symmetry condition). Seen this way the question concerns the number of conjugacy classes of such subgroups. I'll give an overview on the progress on these conjectures and present some new results on the former. Plenty of examples will be discussed that demonstrate the current edge of our knowledge. I'll also discuss what is known in the locally-transitive case. (Received March 20, 2017)

1129-20-348 **Anja I. S. Moldenhauer*** (a.moldenhauer@gmx.net) and **Gerhard Rosenberger**. *Private Key Cryptosystem using Nielsen Transformations.*

We explain a private key cryptosystem which uses finitely generated free groups, Nielsen Transformations (which are a linear technique to study free groups and general infinite groups) and the negative answer to Hilbert's Tenth Problem. (Received March 20, 2017)

1129-20-359 **Lisa Carbone***, 110 Frelinghuysen Rd, Hill Center/Busch Campus, Piscataway, NJ 08854. *Commutation relations and structure constants for Kac-Moody groups.* Preliminary report.

We outline a construction of Kac–Moody groups as Chevalley groups. The question of determining the commutation relations between real root group generators χ_α and χ_β may be reduced to the rank 2 root subsystem generated by the real roots α and β. These commutation relations are known up to integral structure constants and their signs. We determine the structure constants for these commutation relations as well as consistent systems of signs. This requires a knowledge of the root strings containing real roots and the cases where sums of real roots are not real roots. (Received March 20, 2017)

1129-20-371 **Alice Mark** and **Julien Paupert***, paupert@asu.edu. *Presentations for cusped hyperbolic lattices.*

We present a general method to compute a presentation for any cusped hyperbolic lattice Γ, applying a classical result of Macbeath to a suitable Γ-invariant horoball cover of the corresponding symmetric space. As applications we compute presentations for the Picard modular groups $\mathrm{SU}(2,1,\mathcal{O}_d)$ for small d $(d = 1, 2, 3, 7)$ and the quaternionic lattice $\mathrm{SU}(2,1,\mathcal{H})$ with entries in the Hurwitz integers $\mathcal{H}$. (Received March 20, 2017)

1129-20-378 **Jeremy Macdonald*** (jeremodm@gmail.com). *Logspace computations in groups.*
Many algorithmic problems in groups have polynomial-time solutions, but can we solve the same problems using the more stringent condition of logarithmic space? Despite the restrictions of logspace computation, the list of group-theoretic problems solvable in logspace has been growing in the last few years. We will describe some of these recent advances, and add a few new results including logspace normal forms for C'(1/6) small cancellation groups. (Received March 20, 2017)

1129-20-424 **Dmitry Panteleev*** (dpantel1@stevens.edu) and **Alexander Ushakov**. *Conjugacy search problem and the Andrews–Curtis conjecture.*
We develop new computational methods for studying potential counterexamples to the Andrews–Curtis conjecture, in particular, Akbulut–Kurby examples AK(n). We devise a number of algorithms in an attempt to disprove the most interesting counterexample AK(3). To improve metric properties of the search space (the set of balanced presentations of the trivial group) we introduce a new transformation that generalizes the original Andrews-Curtis transformations and discuss the practical implementation based on pseudo-conjugacy graphs folding. To reduce growth of the search space we introduce a strong equivalence relation on balanced presentations and study the space modulo automorphisms of the underlying free group. We prove that automorphism moves can be applied to Akbulut–Kurby presentations. The improved technique allows us to enumerate balanced presentations AC-equivalent to AK(3) with relations of lengths up to 20 and split all balanced presentations of length 14 into 6 AC-classes. (Received March 20, 2017)

1129-20-443 **Yago Antolin*** (yago.antolin@uam.es). *Coset growth and formal languages.*
In this talk I will present some conditions that guarantee that the formal language of minimal length coset representatives is regular and the generating functin of the coset growth is rational. (Received March 21, 2017)

1129-20-449 **Catherine E Pfaff***, UCSB Math Department, South Hall, Room 6607, Santa Barbara, CA 93106. *Outer Space Dictating Normalizers and Centralizers.*
A significant lure in studying outer automorphism groups of free groups is the natural action on a space, Culler-Vogtmann Outer Space, which both strongly resembles and intricately differs from some of the most well-known and studied spaces, such as Teichmuller space and hyperbolic spaces. We give an example of harnessing this resemblance to identify particular subgroups of the outer automorphism group, namely the normalizers and centralizers of "lone axis fully irreducible outer automorphisms." This is joint work with Lee Mosher and Yael Algom-Kfir. (Received March 21, 2017)

1129-20-451 **Jerrod M Smith*** (jerrod.smith@utoronto.ca), Department of Mathematics, University of Toronto, 40 St. George Street, Toronto, Ontario M5S 2E4, Canada. *Relative discrete series for quotients of p-adic $\mathbf{GL}_n$.*
Let F be a p-adic field and $G = \mathbf{G}(F)$ the F-points of a connected reductive group defined over F. Given an involution θ of $\mathbf{G}$, we define $H = \mathbf{G}^\theta(F)$ to be the subgroup of θ-fixed points in G. The quotient $H\backslash G$ is a p-adic symmetric space. It is of particular interest to understand the irreducible subrepresentations of $L^2(H\backslash G)$, the relative discrete series (RDS). The representations of G that can be realized in a space of functions on $H\backslash G$ are said to be H-distinguished. By work of Kato and Takano, it is known that an H-distinguished discrete series representation of G is a RDS. We construct families of non-discrete RDS representations for three quotients of the general linear group. We consider:

(1) $\mathbf{GL}_n(F) \times \mathbf{GL}_n(F)\backslash\mathbf{GL}_{2n}(F)$,

(2) $\mathbf{GL}_n(F)\backslash\mathbf{GL}_n(E)$, where E is a quadratic Galois extension of F, and

(3) $\mathbf{U}_{E/F}(F)\backslash\mathbf{GL}_{2n}(E)$, where $\mathbf{U}_{E/F}$ is a quasi-split unitary group over F.

(Received March 21, 2017)

1129-20-491 **Susan Hermiller** and **Zoran Sunic*** (sunic@math.tamu.edu). *No positive cone in a free product is regular.* Preliminary report.
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 geometric approach to a result by Cristobal Rivas stating that the positive cone in a free product of nontrivial, finitely generated, left-orderable groups cannot be finitely generated as a semigroup. (Received March 21, 2017)

1129-20-515 **Maxim Zyskin*** (maxim.zyskin@nottingham.ac.uk), School of Mathematical Sciences, University of Nottingham, Nottingham, NG7 2QL, United Kingdom. *Transformation groups and discrete structures in continuum description of defective crystals.*

Davini description of elasticity and plasticity of defective crystal involves a frame of continuum 'lattice vector' fields, and dislocation density matrix, capturing the structure constants of the Lie bracket of those vector fields. Those fields together describe kinematics of a defective crystal, allowing for elastic and certain plastic deformations. A truncation assumption for the energy functional leads to consider finite dimensional Lie algebras of 'lattice vector' fields and corresponding transformation groups. In low spatial dimensions, such groups may be classified. Discrete crystal structures emerge in such context as discrete subgroups of the corresponding Lie groups. This approach includes the usual crystal lattices as a particular case. I will present computational approach to determine, up to an equivalence, 'lattice vector fields' of 2 dimensional defective crystals corresponding to 3 dimensional Lie algebras, and discrete subgroups for those. In the nilpotent case, lattice vector fields and discrete structures were presented in our recent paper http://rdcu.be/nD07 (Received March 21, 2017)

22 ▸ Topological groups, Lie groups

1129-22-2 **Jeremy Kahn*** (jeremy_kahn@brown.edu), Brown University, Providence, RI. *Applications and frontiers in surface subgroups.*

In 2009 V. Markovic and the speaker proved that there are ubiquitous nearly geodesic subgroups in the fundamental groups of closed hyperbolic 3-manifolds. Since then there have been many attempts—some successful—to extend these results to other settings, including lattices in other Lie groups, nonuniform lattices, δ-hyperbolic groups, and the mapping class group. After a review of the fundamental principles and methods, I will try to describe some of the successes, some of the difficulties, and some of the applications of these kinds of results.
(Received March 16, 2016)

1129-22-36 **Bernardo Villarreal***, bernvh@math.ubc.ca. *On the homotopy stable decomposition of spaces of homomorphisms.*

Let G be a real linear algebraic group and L a finitely generated cosimplicial group. We prove that the space of homomorphisms $Hom(L_n, G)$ has a homotopy stable decomposition for each $n \geq 1$. When G is a compact Lie group, we show that the decomposition is G-equivariant with respect to the induced action of conjugation by elements of G. In particular, under these hypothesis on G, we obtain stable decompositions for $Hom(F_n/\Gamma_n^q, G)$ and $Rep(F_n/\Gamma_n^q, G)$ respectively, where F_n/Γ_n^q are the finitely generated free nilpotent groups of nipotency class $q-1$. We give the explicit stable decomposition for $Hom(F_n/\Gamma_n^q, SU(2))$ using a description of its connected components. This last description is joint work with O. Antolín. (Received January 30, 2017)

1129-22-38 **Maxime Bergeron*** (mbergeron@math.uchicago.edu), Department of Mathematics, University of Chicago, 5734 S. University Avenue, Chicago, IL 60637. *The Topology of Representation Varieties.*

I will discuss aspects of the topology and arithmetic of the space Hom(H,G) of homomorphisms from a finitely generated group H into a reductive linear algebraic group G (e.g. a special linear group). (Received February 01, 2017)

1129-22-108 **Jeffrey Adler*** (jadler@american.edu), **Jessica Fintzen** and **Sandeep Varma**. *The Kostant section and topologically nilpotent elements.*

Let G denote a connected reductive group over a field F that is complete with respect to a discrete valuation and that has perfect residue field. We re-prove, under weaker hypotheses, a joint result of DeBacker and one of the authors. That is, we produce a subset of the Lie algebra $\mathfrak{g}(F)$ that picks out a $G(F)$-conjugacy class in every stable, regular, topologically nilpotent conjugacy class in $\mathfrak{g}(F)$. We then show that when F is p-adic, the characteristic function of this set behaves well with respect to endoscopic transfer. (Received March 08, 2017)

1129-22-134 **Xuhua He*** (xuhuahe@math.umd.edu). *Cocenter of p-adic groups.*

I have been developing a new method to study the ordinary and mod-l representations of p-adic groups via the cocenter of their Hecke algebras. In this talk, I will give a brief summary on the structure of the cocenter and applications to representation theory. (Received March 10, 2017)

1129-22-166 **Rögnvaldur G. Möller*** (roggi@hi.is), Science Institute, University of Iceland, Dunhaga 5, Reykjavik, Iceland. *Minimal valency of an Abels-Cayley graph and group properties.* Preliminary report.

Let G be a totally disconnected locally compact compactly generated group. An Abels–Cayley graph for G is a locally finite connected graph that G acts transitively on such that the stabilisers of vertices are compact open subgroups. Many results for finitely generated groups connecting Cayley graphs and group structure have analogues involving Abels–Cayley graphs.

Some years ago George A. Willis asked me about the connections between the minimal valency of an Abels–Cayley graph for G and properties of the topological group G. In this talk I will describe some thought on this question, e.g. characterize those groups where the minimal valency is 2, describe special properties of groups where the minimal valency is 3 and show lower bounds for the minimal valency based on the modular function and the scale function on G.

Some of these results are contained in the master thesis of Arnbjörg Soffía Árnadóttir at the University of Iceland. (Received March 13, 2017)

1129-22-179 **Ran Cui*** (cranmail@gmail.com). *The Real-Quaternionic Indicator and it's relation with the Frobenius-Schur Indicator.*

The well-known Frobenius-Schur indicator (we call the ε indicator) tells if a self-dual representation is orthogonal or symplectic. The real-quaternionic indicator (the δ indicator) indicates if a self-conjugate representation is of real or quaternionic type. The computation of the ε indicator is relatively straightforward. In fact, it has been proven in large generality that $\varepsilon(\pi)$ is given by a particular value of the central character. We would like a similar result for the δ indicator.

When G is compact, $\delta(\pi)$ and $\varepsilon(\pi)$ coincide. In general, they are not necessarily the same. In this talk, we will discuss a relation between the two indicators when G is semi-simple. We will also give a formula for $\delta(\pi)$ in terms of the central character when π is finite dimensional. The main tool we are using is the c-invariant Hermitian form and the theory of extended groups. (Received March 14, 2017)

1129-22-263 **Jeffrey Hakim*** (jhakim@american.edu). *Constructing supercuspidal representations without using Howe factorizations.*

We describe a simple reformulation of Jiu-Kang Yu's construction of tame supercuspidal representations. We apply it to simplify the study of distinguished supercuspidal representations and to unify aspects of this theory with the corresponding theory over finite fields. (Received March 17, 2017)

1129-22-459 **Xuhua He** and **Julee Kim*** (juleekim@mit.edu). *Rigid cocenters of p-adic groups: Jordan decomposition.* Preliminary report.

We introduce a Jordan decomposition of rigid cocenters of Hecke algebras of connected semisimple p-adic groups. This is a preliminary report on a joint work with Xuhua He. (Received March 21, 2017)

1129-22-519 **Joshua M. Lansky*** (lansky@american.edu), Department of Mathematics and Statistics, American University, 4400 Massachusetts Avenue, NW, Washington, DC 20016-8050, and **Jeffrey D. Adler** (jadler@american.edu), Department of Mathematics and Statistics, American University, 4400 Massachusetts Avenue, NW, Washington, DC 20016-8050. *Root Data with Group Actions.*

Suppose k is a field, G is a connected reductive k-group, and T is a maximal k-torus of G. Let Γ be a finite group that acts via quasi-semisimple k-automorphisms on G, fixing T. Then the pair (G, T) gives rise to a root datum Ψ on which $\mathrm{Gal}(k) \times \Gamma$ acts. We construct a right inverse to this process. That is, given a root datum on which $\mathrm{Gal}(k) \times \Gamma$ acts, we show how to construct a pair (G, T) as above, canonical up to an equivalence relation, where G is k-quasisplit. We discuss applications of this result to the representation theory of finite reductive groups. (Received March 21, 2017)

28 ► Measure and integration

1129-28-69 **Oscar Guzmán*** (omguzmanf@unal.edu.co), 615 Black Bears way apt 8, Tuscaloosa, AL 35401. *Variable exponent bounded variation spaces in the Riesz sense.*

This talk introduces Variable Exponent Bounded Variation Spaces in the Riesz Sense. We prove some embedding results and present a Riesz representation lemma in our setting. Also it shows an application of the latter result by characterizing the global Lipschitz Nemytskii operator on the newly introduced spaces. (Received March 02, 2017)

1129-28-201 **Guy C. David***, Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York, NY 10012, and **Kyle Kinneberg**. *Lipschitz differentiability, embeddings in Carnot groups, and rigidity for group actions.*

We discuss metric measure spaces that support a first-order calculus for Lipschitz functions, in the sense of Cheeger. After introducing these spaces, we will survey some of their embedding properties and explain a theorem of the speaker and Kyle Kinneberg concerning embeddings in Carnot groups. Time-permitting, we will also explain an application of this last result to a problem on group actions in hyperbolic geometry. (Received March 15, 2017)

30 ► Functions of a complex variable

1129-30-62 **Alastair Fletcher*** (fletcher@math.niu.edu). *Infinitesimal space of quasiregular mappings.*

Quasiregular mappings are only differentiable almost everywhere. To replace the notion of the derivative at points where the mapping is not differentiable, Gutlyanskii et al introduced the notion of the infinitesimal space in 2000. There does not appear to have been much study into the properties of this space subsequently. In this talk, I will report on a couple of projects undertaken with graduate students at NIU into the infinitesimal space. As a sample result, we obtain that the infinitesimal space contains either one or uncountably many elements. (Received February 28, 2017)

1129-30-95 **Gerardo R. Chacon*** (gerardo.chacon@gallaudet.edu), 800 Florida Ave. NE, Washington, DC 20002. *Variable Exponent Fock Spaces.*

Fock spaces $\mathcal{F}^p(\mathbb{C})$, $1 < p < \infty$, are defined as spaces of entire functions $f : \mathbb{C} \to \mathbb{C}$ such that

$$\|f\|_p^p = \frac{p}{\pi}\int_{\mathbb{C}} \left| f(z)e^{-\frac{\alpha}{2}|z|^2} \right|^p dA(z) < \infty.$$

where A denotes the Lebesgue area measure defined on the complex plane $\mathbb{C}$. In this talk we will introduce a variable exponent version $\mathcal{F}^{p(\cdot)}(\mathbb{C})$ of the Fock spaces and we will show that there exists a constant $C > 0$ such that if $f \in \mathcal{F}^{p(\cdot)}(\mathbb{C})$ then

$$|f(z)| \leq Ce^{|z|^2}\|f\|_{p(\cdot)}.$$

This proves that the evaluation functionals are bounded and as a consequence it is possible to show properties of the spaces such as the density of polynomials and a duality result. (Received March 06, 2017)

1129-30-112 **Doug M MacClure*** (doug.macclure@gmail.com), 335 Heatherfield Lane, DeKalb, IL 60115, and **A N Fletcher**. *Strongly automorphic linearizers and uniformly quasiregular mappings.*

A theorem of Ritt states the a linearizer of a holomorphic function at a repelling fixed point is periodic if and only if the holomorphic map is conjugate to a power of z, a Chebyshev polynomial or a Lattès map. In this talk, a proof of the analogous statement in the setting of strongly automorphic quasiregular mappings and uniformly quasiregular mappings in $\mathbb{R}^n$ will be given. (Received March 08, 2017)

1129-30-140 **Hideki Miyachi*** (miyachi@math.sci.osaka-u.ac.jp), Department of Mathematics, Osaka University, Machikaneyama 1-1, Toyonaka, Osaka 560-0043, Japan. *Deformation of singular flat structures from quadratic differentials and Riemann surfaces.*

Singular flat structures are defined by composing polygonal tiles under gluing operations by Euclidean isometries, and piecewise affine deformations of singular flat structures induces quasiconformal deformations of the underlying conformal structures. In this talk, I would like to a description of the infinitesimal deformations of conformal stuctures on the underlying Riemann surfaces in deforming singular flat structures from generic quadratic differentials under infinitesimal piecewise affine deformations. (Received March 11, 2017)

1129-30-149 **Jinsong Liu*** (liujsong@math.ac.cn), Institute of Mathematics, AMSS, Chinese Academic of Sciences, Beijing, Beijing 100190, Peoples Rep of China, and **xiaojun huang** (hxj@cqu.edu.cn), University of Chongqing, ChongQing, Chongqing 401331, Peoples Rep of China. *Quasihyperbolic metric and Quasisymmetric mappings between metric spaces.*

In this talk we prove that the quasihyperbolic metric is quasi-invariant under a quasisymmetric mapping in the suitable metric space. Meanwhile, we also show that the quasi-invariant of the quasihyperbolic metric implies the quasiconformality. At the end, as an application of above theorems, we prove that the compose of two quasisymmetric mappings in metric spaces is a quasiconformal mapping.

This is a joint work with Prof Xiaojun Huang. (Received March 11, 2017)

1129-30-152 **Hiroshige Shiga*** (shiga@math.titech.ac.jp). *On the extension problem of holomorphic motions.*

Let E be a closed set in the Riemann sphere $\widehat{\mathbb{C}}$. We consider a holomorphic motion ϕ of E over a complex manifold M, that is, a holomorphic family of injections on E parametrized by M. A striking theorem by Slodkowski says that if M is the unit disk Δ in the complex plane, then any holomorphic motion of E over Δ can be extended to a holomorphic motion of the Riemann sphere over Δ. In this talk, we consider a generalization of Slodkowski's theorem. (Received March 12, 2017)

1129-30-159 **Ara S. Basmajian*** (abasmajian@gc.cuny.edu), 695 Park Ave., New York, NY 10065, and **Dragomir Saric**. *The type problem and Fenchel-Nielsen coordinates for hyperbolic surfaces - Part 1.* Preliminary report.

This is part one of a two part talk in which we describe new results involving the relationship between Fenchel-Nielsen coordinates and a version of the classical type problem (whether or not the surface carries a Green's function). In particular, we study so called tight flute surfaces- possibly incomplete hyperbolic surfaces constructed by linearly gluing infinitely many tight pairs of pants along their cuffs- and the relationship between their type and geometric structure. This is joint work with Dragomir Saric who will give part two. (Received March 12, 2017)

1129-30-160 **Dragomir Saric*** (dragomir.saric@queens.cuny.edu) and **Ara Basmajian**. *The type problem and Fenchel-Nielsen coordinates for hyperbolic surfaces-Part 2.* Preliminary report.

This is part two of a two part talk in which we describe new results involving the relationship between Fenchel-Nielsen coordinates and a version of the classical type problem (whether or not the surface carries a Green's function). In particular, we study so called tight flute surfaces- possibly incomplete hyperbolic surfaces constructed by linearly gluing infinitely many tight pairs of pants along their cuffs- and the relationship between their type and geometric structure. This is joint work with Ara Basmajian who will give part one. (Received March 12, 2017)

1129-30-209 **Yunchun Hu*** (yunchun.hu@bcc.cuny.edu), 2155 University Avenue, Bronx, NY 10453. *Markov partitions and symmetric conjugacy of circle endomorphisms.*

An interesting problem in the study of rigidity for one-dimensional dynamical systems is to show that one-point property implies the global property for conjugacies. In this talk, I will introduce an example of a conjugacy between two expanding Blaschke products on the unit circle which preserve the Lebesgue measure. This conjugacy is symmetric at one point but not symmetric on the whole circle. (Received March 15, 2017)

1129-30-301 **Ricardo A. Sáenz*** (rasaenz@ucol.mx), Facultad de Ciencias, Universidad de Colima, 28045 Colima, Colima, Mexico. *Hardy spaces on PCF fractals.*

On appropriate self-similar fractals, of the "post-critically finite" (PCF) type, one can define a harmonic structure that induces a Laplacian, which in turns defines a Poisson semigroup. The Poisson integrals correspond to harmonic functions in a tube on the fractal, and one can define the Hardy spaces in terms of their maximal functions. We discuss the properties of the Hardy space H^1 and its atomic decomposition. (Received March 19, 2017)

1129-30-322 **William Harvey*** (bill.harvey@kcl.ac.uk), Math Dept., King's College London, Strand, London, WC2R 2LS, United Kingdom. *Symmetry and Veech curves in moduli spaces.* Preliminary report.

The study of Teichmüller moduli spaces has developed into a penetrating study of the interaction between the local properties of a Riemann surface, perhaps decorated with extra structure (points, spin structure, holomorphic 1-form,...), and the global geometry of the deformation space of such structures. We discuss an example of how finite symmetry is reflected in a particular pattern of an embedded complex curve in the quotient modular varieties. (Received March 19, 2017)

32 ► Several complex variables and analytic spaces

1129-32-67 **F. P. Gardiner*** (frederick.gardiner@gmail.com), Mathematics Program, The Graduate Center, CUNY, 365 Fifth Avenue, New York, NY 10016. *Kobayashi's and Carathéodory's metrics on Teichmüller spaces.*

Carathéodory's infinitesimal metric is strictly less than Kobayashi's on Teichmüller spaces in the direction of tangent vectors that correspond to stretching in the direction of maximal separating cylinders. (Received March 01, 2017)

1129-32-210 **Pierre Py*** (py@im.unam.mx) and **Thomas Delzant**. *Cubulable Kähler groups.*

We will explain why a Kähler group which acts geometrically on a CAT(0) cubical complex must be virtually isomorphic to a direct product of surface groups, possibly with a free Abelian factor. Along the way, we introducte a new criterion to obtain fibrations of closed Kähler manifolds over Riemann surfaces. This is a joint work with Thomas Delzant. (Received March 15, 2017)

1129-32-229 **Domingo Toledo*** (toledo@math.utah.edu). *Complex hyperbolic manifolds and their totally geodesic sub-manifolds.*

This will be a survey of various constructions of compact (or complete and finite volume) complex hyperbolic manifolds. There are very general arithmetic constructions that work in all dimensions, and geometric constructions that work in low dimensions. The latter are based on monodromy of families of algebraic varieties. The earliest example is Picard's use of part of the period matrix of a family of curves of genus 3 to give an example of a complete, finite volume quotient of the complex hyperbolic plane.

Picard's example has been extended in many ways to construct other complex hyperbolic manifolds, for example, the ones of Deligne and Mostow, using different families of curves. One example using higher-dimensional varieties is the uniformization of the moduli space of cubic surfaces by complex hyperbolic 4-space (Allcock-Carlson-Toledo).

A special feature of these geometric constructions is that they contain totally geodesic complex sub-manifolds. Their geometry can be used to get some understanding of the geometry of the ambient manifold. (Received March 16, 2017)

33 ► Special functions

1129-33-370 **Joel C R Nagloo*** (joel.nagloo@bcc.cuny.edu). *On the Algebraic Independence Conjecture for the Generic Painlevé Equations.* Preliminary report.

In this talk, we explain how the Riccati equations can be used to show that the solutions (and derivatives) of the generic sixth Painlevé equation are algebraically independent over $\mathbb{C}(t)$. This extends recent progress made on the third Painlevé equations and hence fully proves the algebraic independence conjecture for the generic Painlevé equations. (Received March 20, 2017)

1129-33-477 **Diego E Dominici*** (dominicd@newpaltz.edu), 1 Hawk Dr., New Paltz, NY 12561. *Orthogonality of generalized Dickson polynomials.* Preliminary report.

The Dickson polynomials of the $(k+1)$-th kind introduced by Q. Wang and J. L. Yucas in [1] are defined by

$$D_{n,k}(x;a) = \sum_{j=0}^{\lfloor \frac{n}{2} \rfloor} \frac{n-kj}{n-j} \binom{n-j}{j} (-a)^j \, x^{n-2j}.$$

In this talk, we will present some properties of these polynomials and show that they are orthogonal with respect to a complex measure.

[1] Finite Fields Appl. 18 (2012), no. 4, 814–831. (Received March 21, 2017)

34 ► Ordinary differential equations

1129-34-45 **Lianwen Wang***, School of Computer Science and Mathematics, University of Central Missouri, Warrensburg, MO 64093. *Solution Classifications of Nonlinear Systems of Differential Equations.*

In this talk we consider solution classifications as well as boundedness and monotonicity of solutions of nonlinear systems of differential equations. All monotonic solutions can be classified into four categories, and necessary and sufficient conditions for the existence of each category are established. Moreover, necessary and sufficient conditions for the boundedness of all solutions are provided. (Received February 12, 2017)

1129-34-184 **D D Hai** and **Ratnasingham Shivaji*** (r_shivaj@uncg.edu), Dept of Mathematics & Statistics, 116 Petty, 317 College, UNC- Greensboro, Greensboro, NC 27412. *On radial solutions for singular combined superlinear elliptic systems on annular domains.*

We prove the existence of a large positive solution to the system

$$\begin{cases} -(r^{N-1}\phi_1(u'))' = \lambda r^{N-1} f_1(v), \quad a < r < b, \\ -(r^{N-1}\phi_2(v'))' = \lambda r^{N-1} f_2(u), \quad a < r < b, \\ \qquad u(a) = 0 = u(b), v(a) = 0 = v(b), \end{cases}$$

where $a > 0$, λ is a small positive parameter, $f_i : (0, \infty) \to \mathbb{R}$ are continuous and $\lim_{z\to\infty} \frac{\phi_1^{-1}(f_1(c(\phi_2^{-1}(f_2(z)))}{z} = \infty$ for all $c > 0$. (Received March 14, 2017)

1129-34-276 **Eli Amzallag***, eamzallag@gradcenter.cuny.edu, and **Gleb Pogudin** and **Andrei Minchenko**. *On the complexity of Hrushovski's algorithm.*

We analyze the complexity of Hrushovski's algorithm to compute the Galois group of a linear differential equation of order \$n\$ over \$C(t)\$, where \$C\$ is an algebraically closed field of characteristic zero. Hrushovski presented his algorithm in a 2002 paper, using model-theoretic language in his explanation of the algorithm's various steps. In a 2015 paper, Feng described the steps using differential-algebraic notions in place of model-theoretic ones. He also turned to complexity considerations in that paper, his analysis beginning with the algorithm's computation of a group that contains the Galois group of the given differential equation. His estimate of a bound for the degrees of defining polynomials of this group was sextuply exponential in \$n\$. In this talk, we will present an improved bound and discuss our approaches to analyzing the complexity of the rest of the algorithm. This is joint work with Andrei Minchenko and Gleb Pogudin. (Received March 17, 2017)

35 ► Partial differential equations

1129-35-9 **Alexander Pankov*** (alexander.pankov@morgan.edu), Mathematics Department, Morgan State University, Baltimore, MD 21251. *Monotone elliptic operators with nonstandard growth condition.*

In this talk we consider nonlinear, monotone, generally, multivalued elliptic operators that satisfy sufficiently general nonstandard growth condition. In particular, the so-called Lavrentiev phenomenon may occur. This means that, in general, smooth functions are not dense in the naturally defined Sobolev type space and, hence, such an operator possesses Dirichlet problems of many different types. In this talk we consider two extreme Dirichlet problems. The first main result is on the existence of solutions of such problems under natural assumptions. Then we consider various approximating problems and obtain some results on the convergence of approximate solutions. (Received February 20, 2017)

1129-35-12 **Eric C Stachura*** (estachura@haverford.edu). *Existence of Propagators for Coulomb-like Potentials in Time Dependent Density Functional Theory.* Preliminary report.

Density Functional Theory (DFT) is one of the most widely used methods for electronic structure calculations in materials science. Motivated by the classical Runge-Gross Theorem of Time Dependent DFT, we prove existence and uniqueness of propagators for a time dependent N particle, M nuclei Schrödinger equation in $\mathbb{R}^{3N}$ with a new class of smoothed out Coulomb potentials. We consider time dependent potentials by treating the nuclei as classical particles moving along sufficiently smooth trajectories. Spectral properties of the corresponding static Hamiltonian are analyzed, and it is shown that these new potentials are dilatation analytic. (Received December 16, 2016)

1129-35-19 **Li Congming*** (congmingli@gmail.com), **Cheng Tingzhi** and **Huang Genggeng**. *The maximum principles for fractional Laplacian equations and their applications.*

In this talk, we present some recent work on the study of positive solutions to nonlinear equations of fractional type on domains with convexity as well as symmetry in some directions. We are focused on the symmetry and monotonicity of solutions in these directions.The main tool is some forms of maximum principles which are 'much better' than in the Laplace case. (Received January 11, 2017)

1129-35-47 **Katarina Jegdic*** (jegdick@uhd.edu), One Main Street, Houston, TX 77002. *Analysis in semi-hyperbolic patches for the unsteady transonic small disturbance equation.*

We consider a Riemann problem for the unsteady transonic small disturbance equation resulting in diverging rarefaction waves. We write the problem in self-similar coordinates and we obtain a mixed-type hyperbolic-elliptic system. We use the theory of generalized characteristics and we formulate the problem in a semi-hyperbolic patch that is between the hyperbolic and the elliptic regions. Using the characteristic decomposition in the semi-hyperbolic patch, we prove existence of a smooth local solution and obtain various properties of global smooth solutions. (Received February 16, 2017)

1129-35-48 **Ping Wang*** (pxw10@psu.edu), Mathematics Department, 200 University Drive, Schuylkill Haven, PA 17901, and **Kewang Zheng**. *Numerical and Theoretical Determination of Unknown Source in Heat Conduction.*

We consider the problem of determining an unknown source/sink term in heat conduction with ill-posed nature. Applying Tikhonov's regularization approach, we develop a numerical procedure to find an proximate solution of the problem from over-specified data. (Received February 17, 2017)

1129-35-60 **Yan Li*** (yali3@mail.yu.edu), 480 W 187th St apt 6A, New York, NY 10033, and **Pei Ma**. *Symmetry of Solutions for a Fractional System.*

We consider a pseudo-differential system involving different fractional orders. Through an iteration method, we obtain the key ingredients –the maximum principles–of the *method of moving planes.* Then we derive symmetry on non-negative solutions without any decay assumption at infinity. (Received February 27, 2017)

1129-35-78 **Wenxiong Chen*** (wchen@yu.edu), Department of Mathematics, Yeshiva University, 2495 Amsterdam Av., New York, NY 10033, and **Congming Li**. *Symmetry of solutions for nonlinear equations involving the fractional p-Laplian.*

we consider nonlinear equations involving the fractional p-Laplacian

$$(-\Delta)^s_p u(x)) \equiv C_{n,s,p} PV \int_{\mathbb{R}^n} \frac{|u(x)-u(y)|^{p-2}[u(x)-u(y)]}{|x-z|^{n+ps}} dz = f(x,u).$$

We prove a *maximum principle* and obtain key ingredients for carrying on the method of moving planes, such as *a Hopf type lemma.* Then we establish radial symmetry and monotonicity for positive solutions to semilinear equations involving the fractional p-Laplacian in a unit ball and in the whole space. We believe that the methods developed here can be applied to a variety of problems involving nonlinear nonlocal operators. (Received March 03, 2017)

1129-35-79 **Pengfei Liu*** (plliu@caltech.edu) and **Thomas Y Hou**. *Stable self-similar singularity for a 1D model of the Axisymmetric Euler.*

We study the self-similar singularity of a 1D model of the 3D axisymmetric Euler equations. The model approximates the dynamics of the Euler equations on the solid boundary of a cylindrical domain. We prove the existence of a discrete family of self-similar profiles for this model corresponding to different lead orders of the initial data. We demonstrate the stability of the self-similar singularity scenario by linearizing the discretized dynamic rescaling equations which govern the evolution of spatial profiles in the singular solutions. (Received March 03, 2017)

1129-35-80 **Gerard Misiolek*** (gmisiole@nd.edu). *Continuity of the solution map of the Euler equations in Holder and Besov spaces.*

I will describe a simple example showing that the solution map of the Euler equations is not continuous in $C^{1,\alpha}$. Time permitting, I will also describe a result for Besov spaces near $B^2_{2,1}$. This is based on a joint work with Tsuyoshi Yoneda. (Received March 03, 2017)

1129-35-81 **Shaohua Chen*** (george_chen@cbu.ca), 37 Franklyn Drive, Sydney, Nova Scoti B1M1A6, Canada. *Global Existence for a Singular Gierer-Meinhardt System.*

In this talk we discuss the existence results for a singular system subject to zero Dirichlet boundary conditions, which originally arose in studies of pattern-formation in biology. The mathematical difficulties are that the system becomes singular near the boundary and it lacks a variational structure. We use a functional method to obtain both upper and lower bounds for the perturbed system and then use Sobolev embedding theorem to prove the existence of a pair of positive solutions under suitable conditions. This method is first used in a singular parabolic system and is completely different than the traditional methods of sub and super solutions. (Received March 03, 2017)

1129-35-89 **jiuyi zhu*** (zhu@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803, and **Blair Davey**, Department of Mathematics, The City College of New York, New York, NY. *Quantitative uniqueness of elliptic equations.*

Motivated by the study of eigenfunctions, we consider the quantitative uniqueness of elliptic equations. The quantitative uniqueness is characterized by the order of vanishing of solutions, which describes quantitative behavior of strong unique continuation property. Strong unique continuation property states that if a solution that vanishes of infinite order at a point vanishes identically. It is interesting to know how the norm of the potential functions and gradient potentials control the order of vanishing. We will report some recent progresses about quantitative uniqueness in different Lebesgue L^p spaces for elliptic equations. Carleman estimates play an important role in the strong unique continuation property. By using some delicate quantitative Carleman estimates, we obtain some Hadamard three-sphere theorems which lead to the order of vanishing of solutions. (Received March 05, 2017)

1129-35-93 **Hongjie Dong*** (hongjie_dong@brown.edu), 182 George Street, Providence, RI 02912, and **Seick Kim**. *Weak type-$(1,1)$ estimates for linear elliptic operators.*

I will present some recent work on C^1, C^2, and weak type-$(1,1)$ estimates for linear elliptic operators with coefficients under a condition which is weaker than the classical Dini continuity condition. Both interior and boundary estimates will be discussed. Joint work with Seick Kim. (Received March 06, 2017)

1129-35-96 **Changfeng Gui*** (changfeng.gui@utsa.edu) and **Amir Moradifam**. *The Sphere Covering Inequality and its applications to a Moser-Trudinger type inequality and mean field equations.*

In this talk, I will introduce a new geometric inequality: the Sphere Covering Inequality. The inequality states that the total area of two *distinct* surfaces with Gaussian curvature less than 1, which are also conformal to the Euclidean unit disk with the same conformal factor on the boundary, must be at least 4π. In other words, the areas of these surfaces must cover the whole unit sphere after a proper rearrangement. We apply the Sphere Covering Inequality to show the best constant of a Moser-Trudinger type inequality conjectured by A. Chang and P. Yang. Other applications of this inequality include the classification of certain Onsager vortices on the sphere, the radially symmetry of solutions to Gaussian curvature equation on the plane, classification of solutions for mean field equations on flat tori and the standard sphere, etc. The resolution of several open problems in these areas will be presented. (Received March 06, 2017)

1129-35-97 **Changfeng Gui*** (changfeng.gui@utsa.edu), **Zhuoran Du** and **Jie Zhang**. *Periodic solutions of nonlinear equations with a fractional Laplacian.*

We consider periodic solutions of some nonlinear equations with a fractional Laplacian, and show the existence of periodic solutions with large periods. Estimates of the energy of the periodic solutions are also established. (Received March 06, 2017)

1129-35-98 **Meijun Zhu***, mzhu@ou.edu. *Integral equations on bounded domains.*

In this talk, I will introduce some new integral equations on a bounded domain that are closely related to the study of sharp Hardy-Littlewood-Sobolev inequality. Existence results as well as non-existence results will be discussed. This is a joint work with Jingbo Dou. (Received March 06, 2017)

1129-35-99 **Marcelo Mendes Disconzi*** (marcelo.disconzi@vanderbilt.edu), 1326 Stevenson Center, Nashville, TN 37240, and **Igor Kukavica** (kukavica@usc.edu), 3620 S. Vermont Avenue, Los Angeles, CA 90089-2532. *The three-dimensional free-boundary Euler equations with surface tension.*

We derive a priori estiamtes for the incompressible free-boundary Euler equations in three spatial dimensions with surface tension. We work in Lagrangian coordinates. Our methods are reather direct and involve three key elements: good estimates for the pressure, the boundary regularity provided by the mean curvature, and the Cauchy invariance. We shall also briefly discuss a generalization of these results for the compressible case. (Received March 06, 2017)

1129-35-101 **Marius Ghergu** and **Steven D Taliaferro*** (stalia@math.tamu.edu), Mathematics Department, Texas A&M University, College Station, TX 77843-3368, and **Igor Verbitsky**. *Pointwise Bounds and Blow-up for Systems of Semilinear Elliptic and Parabolic Inequalities.*

We discuss the behavior near the origin of positive solutions $u(x)$ and $v(x)$ of the elliptic system

$$\begin{aligned} 0 \le -\Delta u \le v^\lambda \\ 0 \le -\Delta v \le u^\sigma \end{aligned} \quad \text{in } B_1(0) \setminus \{0\} \subset \mathbb{R}^n,\ n \ge 3, \tag{1}$$

where λ and σ are nonnegative constants.

We also present similar results on the behavior for t small and positive of nonnegative solutions $u(x,t)$ and $v(x,t)$ of the parabolic system

$$\begin{aligned} 0 \le u_t - \Delta u \le v^\lambda \\ 0 \le v_t - \Delta v \le u^\sigma \end{aligned} \quad \text{in } \Omega \times (0,1), \tag{2}$$

where λ and σ are nonnegative constants and Ω is an open subset of $\mathbb{R}^n$, $n \ge 1$.

The extension of our results for the elliptic system (1) to the parabolic system (2) requires new parabolic versions of Hedbergs inequality, the Hardy-Littlewood-Sobolev inequality, and nonlinear Riesz potential estimates. These new parabolic tools are proved using a modified version of the Hardy-Littlewood maximal function inequality in which Euclidean balls in $\mathbb{R}^n$ are replaced with heat balls in $\mathbb{R}^n \times \mathbb{R}$. (Received March 06, 2017)

1129-35-107 **Dennis Kriventsov*** (dennisk@cims.nyu.edu). *Regularity in spectral optimization problems.*

A classical problem in analysis is to relate information about the spectrum of the Laplacian of a domain to that domain's shape. One approach to this program is by studying sets which minimize some function of their Laplacian's eigenvalues, with, say, a volume constraint. I will explain how to study the local structure of the boundaries of these minimizers by interpreting the configuration as a vector-valued free boundary problem. This is based on joint work with Fanghua Lin. (Received March 07, 2017)

1129-35-126 **Cyril Tintarev*** (tammouz@gmail.com). *Concentration-compactness analysis in the functional-analytic setting.*

Concentration compactness is a convergence method for functional spaces that identifies defect of convergence for functional sequences as sums of well-structured "blowups". Traditionally concentration has been connected only with one "concentration mechanism" - the scaling group, that is, with blowups and shifts ("concentration at infinity").

This talk will present the functional-analytic theory of concentration in general Banach spaces. The functional-analytic setting allows not only to study new functional spaces, but also to engage different concentration mechanisms. As an example we present the concentration mechanism for Sobolev spaces of the hyperbolic space, and related concentration structure for elliptic problems of Moser-Trudinger type. Applications to PDE include problems with critical nonlinearities and singular potentials on the hyperbolic space. Part of results is a joint work with K. Sandeep. (Received March 10, 2017)

1129-35-129 **Agnieszka Kalamajska*** (a.kalamajska@mimuw.edu.pl), Institute of Mathematics, University of Warsaw, ul. Krakowskie Przedmiescie 26/28, PL 00-927 Warsaw, Poland. *Trace and extension theorems dealing with weighted Orlicz-Sobolev and weighted Orlicz-Slobodetskii spaces and applications to nonlinear PDEs.*

We plan to discuss trace embedding and trace extension theorems between weighted Orlicz-Sobolev spaces of functions defined on domain $\Omega \subseteq \mathbf{R}^n$ and weighted Orlicz-Slobodetski spaces of functions defined on the boundary of Ω. We will consider weights which have the form $\rho(x) = \tau(dist(x, \partial\Omega))$ for weighted Orlicz-Sobolev spaces and weights having the form $\omega(x,y) = |x-y|^{2-n}\tau(|x-y|)$, for weighted Orlicz- Slobodetski spaces, within certain class of admissible functions $\tau(\cdot)$. This gives the new tool to deal with elliptic problems like:

$$\begin{cases} -\mathrm{div}\,(\rho(x)B(\nabla u(x))) = f & \text{in} \quad \Omega \\ \qquad u = g & \text{in} \quad \partial\Omega. \end{cases} \tag{1}$$

with inhomogeneous boundary data $g(\cdot)$, where $B(\cdot) : \mathbf{R}^n \to \mathbf{R}$, provided in the weighted Orlicz-Sobolev setting.

Results will be based on series of works obtained together with Raj Narayan Dhara and Miroslav Krbec. (Received March 10, 2017)

1129-35-135 **Tarek M Elgindi***, Fine Hall, Washington Road, Princeton, NJ 08544, and **In-Jee Jeong**. *On the degeneration of solutions to the incompressible Euler equation.*

We discuss some recent constructions of solutions to the incompressible Euler equation which exhibit different types of norm growth. This includes some situations of ill-posedness (at low regularity) where infinite norm growth happens on arbitrarily short time intervals as well as situations where the solutions are more regular but exhibit infinite norm growth as $t \to \infty$. (Received March 10, 2017)

1129-35-136 **Tarek M Elgindi***, Fine Hall, Washington Road, Princeton, NJ 08544, and **In-Jee Jeong**. *Finite-time singularity formation for De Gregorio's model of the three-dimensional vorticity equation.*

We discuss a proof of singularity formation for De Gregorio's model of the three dimensional vorticity equation. We explain the three main parts of the proof:

(1) Understanding the interaction between vortex stretching and advection and how one could (heuristically) win over the other.

(2) Considering self-similar solutions to the equation without advection and formally perturbing them to get solutions to the (full) equation with advection.

(3) A good understanding of how the Hilbert transform behaves in certain settings. (Received March 10, 2017)

1129-35-137 **Patricia Bauman**, IN, **Daniel Phillips**, IN , and **Changyou Wang*** (wang2482@purdue.edu), 150 N. University Street, West Lafayette, IN 40907. *High dimensional Ginzburg-Landau equations under weak anchoring boundary conditions.* Preliminary report.

In this talk, I will consider the asymptotic limits of critical points u_ϵ of a sequence of Ginzburg-Laudau energy functional E_ϵ that contains a surface energy at the boundary $\epsilon^{-\alpha}\int_{\partial\Omega}|u_\epsilon - g_\epsilon|^2$, whose energy is of the order $|\log\epsilon|$. By establishing the boundary eta-compactness and global $W^{1,p}$-estimate, we can give a description of the structure global vortex set and the limit map. Joint with P. Bauman, and D. Phillips. (Received March 10, 2017)

1129-35-138 **Qianyun Miao**, , Peoples Rep of China, **Yuan Zhou**, , Peoples Rep of China, and **Changyou Wang*** (wang2482@purdue.edu), 150 N. University Street, West Lafayette, IN 40907. *Uniqueness of absolute minimizers of L-infinity functionals involving Hamiltonians $H(x,p)$.*

In this talk, I will discuss a uniqueness theorem on absolute minimizers of L-infinity functional generating by a x-dependent Hamiltonian functions $H(x,p)$, which satisfy (i) lower semicontinuous in x and convex in p; (ii) the union of minimal level sets $\cup_x\{p : H(x,p) = 0\}$ is contained in a hyperplane of R^n; and (iii) a uniform in x interior and exterior ball condition of $\{p : H(x,p) < \lambda\}$. This is a joint work with Yuan Zhou and Qianyun Miao. (Received March 10, 2017)

1129-35-141 **XUWEN CHEN*** (xuwenchen@rochester.edu), Department of Mathematics, University of Rochester, Rochester, NY 14627, and **Justin Holmer**, Department of Mathematics, Brown University, Providence, RI 02912. *The rigorous derivation of focusing NLS from quantum many-body evolutions.*

The rigorous justification of mean-field type equations (Boltzmann, Vlasov-Poisson, NLS...) from the many-body systems they are supposed to describe is a vast and fundamental subject. In this talk, we talk about recent advances in this area on the derivation of focusing nonlinear Schrodinger equations (NLS) from quantum many-body evolutions in the context of Bose-Einstein condensation, which has been one of the most active areas of contemporary research since the Nobel prize winning experiments. We survey the background and the evolution of the results and techniques in the field during the talk. (Received March 11, 2017)

1129-35-168 **Ratnasingham Shivaji**, **Inbo Sim** and **Byungjae Son*** (b_son@uncg.edu), 830 West Market Street, Apt 623, Greensboro, NC 27401. *Uniqueness results for classes of semipositone p-Laplacian problems.*

We consider steady state reaction diffusion equations on the exterior of a ball, namely, boundary value problems of the form:

$$\begin{cases} -\Delta_p u = \lambda K(|x|)f(u) & \text{in } \Omega_E, \\ Bu = 0 & \text{on } |x| = r_0, \\ u \to 0 & \text{when } |x| \to \infty, \end{cases}$$

where $\Delta_p z := \operatorname{div}(|\nabla z|^{p-2}\nabla z)$, $1 < p < n$, $\lambda > 0$, $\Omega_E := \{x \in \mathbb{R}^n \mid |x| > r_0 > 0\}$ and the boundary operator B is either $Bu \equiv u$ or $Bu \equiv \frac{\partial u}{\partial y} + c(u)u$ where $c \in C((0,\infty),(0,\infty))$ and $\frac{\partial u}{\partial \eta}$ is the outward normal derivative of u on $|x| = r_0$. Here the weight function $K \in C^1([r_0,\infty),(0,\infty))$ satisfies $\lim_{r\to\infty} K(r) = 0$, and the reaction term $f \in C^1[0,\infty)$ is strictly increasing and satisfies $f(0) < 0$, $\lim_{s\to\infty} f(s) = \infty$, $\lim_{s\to\infty} \frac{f(s)}{s^{p-1}} = 0$ and $\frac{f(s)}{s^q}$

is nonincreasing on $[a, \infty)$ for some $a > 0$ and $q \in (0, p-1)$. We establish uniqueness results for positive radial solutions for $\lambda \gg 1$. (Received March 13, 2017)

1129-35-170 **Philip L. Korman*** (kormanp@ucmail.uc.edu), Dept. of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221, and **Yi Li** and **Tiancheng Ouyang**. *On the perturbed Gelfand equation from combustion theory.*

For the perturbed Gelfand's equation on the unit ball in two dimensions, Y. Du and Y. Lou (JDE-2001) proved that the curve of positive solutions is exactly S-shaped, for sufficiently small values of the secondary parameter. We present a simplified proof and some extensions. This problem is prominent in combustion theory, see e.g., the book of J. Bebernes and D. Eberly (Springer-1989). (Received March 13, 2017)

1129-35-185 **Martin Barlow**, **Lyudmila Korobenko** and **Cristian Rios*** (crios@ucalgary.ca), Department of Mathematics and Statistics, 2500 University Dr. NW, Calgary, AB T2N 1N4, Canada, and **Eric Sawyer** and **Ruipeng Shen**. *Hölder continuity of bounded weak solutions to certain degenerate elliptic equations in the plane.* Preliminary report.

We consider a model infinitely degenerate elliptic equation in the plane of the form $\frac{\partial}{\partial x^2} + f(x)\frac{\partial}{\partial y^2}$. Here $f \geq 0$ is allowed to vanish to arbitrary infinite order. Under certain geometric conditions on the domain of existence, we establish Hölder continuity for bounded weak solutions. We rely on probabilistic techniques and an approximation scheme in associated degenerate Sobolev spaces. (Received March 14, 2017)

1129-35-195 **Daniela De Silva*** (desilva@math.columbia.edu), 2990 Broadway, New York, NY 10027. *Lipschitz regularity of solutions to two-phase free boundary problems.*

We discuss the Lipschitz continuity of viscosity solutions to a class of two-phase free boundary problems governed by fully nonlinear operators. We also provide a classification of Lipschitz global solutions. (Received March 15, 2017)

1129-35-206 **Theodore D Drivas*** (tdrivas2@jhu.edu) and **Gregory L Eyink**. *An Onsager Singularity Theorem for Solutions of the Compressible Euler Equations.*

We prove that any bounded weak solutions of the compressible Euler system satisfy kinetic energy, internal energy and entropy balance equations with possible 'inertial range' defect terms. These defects are non-vanishing only if the weak solutions have sufficiently low Besov regularity of the type observed empirically in compressible turbulence. Under some assumptions, we prove that these defects match on to the dissipative anomaly terms appearing in the inviscid limit for compressible Navier-Stokes solutions, thereby deriving Kolmogorov 4/5th–type laws. Stationary, planar shocks with an ideal-gas equation of state provide simple examples of dissipation solutions appearing in the inviscid limit and demonstrate the sharpness of our L^3-based regularity conditions. (Received March 15, 2017)

1129-35-212 **Chunqin Zhou*** (cqzhou@sjtu.edu.cn), School of Mathematics Sciences, Shanghai Jiaotong University, Shanghai, 200240. *Extremal functions for Moser-Trudinger inequality involving Finsler-Laplacian.*

In this talk, we will present a Moser-Trudinger inequality which involves Finsler-Laplacian. By using the blow up analysis for a nonlinear Finsler-Laplacian equation and by using the level set method, we will show the existence of the extremal functions for Moser-Trudinger functional. (Received March 16, 2017)

1129-35-215 **Michele Coti Zelati*** (micotize@umd.edu). *Stochastic perturbations of passive scalars and small noise inviscid limits.*

We consider a class of invariant measures for a passive scalar driven by an incompressible velocity field on a periodic domain. The measures are obtained as limits of stochastic viscous perturbations. We prove that the span of the H1 eigenfunctions of the transport operator contains the support of these measures, and apply the result to a number of examples in which explicit computations are possible (relaxation enhancing, shear, cellular flows). In the case of shear flows, anomalous scalings can be handled in view of a precise quantification of the enhanced dissipation effects due to the flow. (Received March 16, 2017)

1129-35-222 **Igor Verbitsky*** (verbitskyi@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Global pointwise estimates of solutions to nonlinear elliptic equations.*

Global pointwise estimates of positive solutions will be discussed for equations of the type $-Lu + V\,u^q = f$, where L is an elliptic operator in divergence form, $q \in \mathbf{R} \setminus \{0\}$, $f \geq 0$ and V is a function which may change sign, in a domain $\Omega \subseteq \mathbf{R}^n$, or in a weighted Riemannian manifold, with a positive Green's function. This is joint work with Alexander Grigor'yan. (Received March 16, 2017)

1129-35-227 **Mathew Gluck*** (mathew.r.gluck-1@ou.edu), Department of Mathematics, 601 Elm Ave., Norman, OK 73019-3103, and **Meijun Zhu**. *An Extension Operator on Bounded Domains and Applications.*

For bounded smooth domains $\Omega \subset \mathbb{R}^n$ and suitable exponents p and q we study a Hardy-Littlewood-Sobolev (HLS) type inequality related to a harmonic-extension operator $L^p(\partial\Omega) \to L^q(\Omega)$. In the case that $\Omega = B_1$, the sharp form of the HLS type inequality was obtained by Dou and Zhu. Here we obtain the inequality for a general bounded domain Ω and show that if the extension constant for Ω is strictly larger than the extension constant for B_1 then extremal functions exist. Using suitable test functions we show that this criterion is satisfied by an annular domain whose hole is sufficiently small. The construction of the test functions is remarkably simple and is not based on any positive mass type theorems. By using a similar choice of test functions with the Poisson-kernel-based extension operator we prove the existence of abstract domain having zero scalar curvature and strictly smaller isoperimetric constant than that of a Euclidean ball. (Received March 16, 2017)

1129-35-242 **Tristan Buckmaster** and **Pierre Germain***, pgermain@cims.nyu.edu, and **Zaher Hani** and **Jalal Shatah**. *The big box limit for the nonlinear Schrodinger equation.*

I will present results, obtained in collaboration with T. Buckmaster, Z. Hani, and J. Shatah, on the big box limit for NLS on the torus. I will consider either deterministic, or random data, and compare these two cases.
(Received March 16, 2017)

1129-35-243 **Fengbo Hang*** (fengbo@cims.nyu.edu), 251 Mercer Street, New York, NY 10012, and **Paul Yang** (yang@math.princeton.edu). *Positivity issue for Q curvature equations in dimension 3.*

Fourth order Q curvature equation in dimension 3 is a semilinear equation with negative power on the right hand side. We will discuss several type of positivity conditions associated with this equation and the Paneitz operator and the relations among these conditions. (Received March 17, 2017)

1129-35-246 **Guanfeng Li*** (liguanfeng@hit.edu.cn). *The symmetry of solutions for nonlinear fractional order system of m equations.* Preliminary report.

In this paper, we consider the system of m equations involving fully nonlinear nonlocal operators

$$\begin{cases} F_{\alpha_1}(u_1(x)) \equiv C_{n,\alpha_1} PV \displaystyle\int_{\mathbb{R}^n} \frac{G_1(u_1(x)-u_1(z))}{|x-z|^{n+\alpha_1}} dz = f_1(x, u_1, u_2, \cdots, u_m), \\ \vdots \\ F_{\alpha_m}(u_m(x)) \equiv C_{n,\alpha_m} PV \displaystyle\int_{\mathbb{R}^n} \frac{G_m(u_m(x)-u_m(z))}{|x-z|^{n+\alpha_m}} dz = f_m(x, u_1, u_2, \cdots, u_m). \end{cases}$$

where $0 < \alpha_i < 2$, $f_i(x, t_1, \cdots, t_m) : \mathbb{R}^n \times \mathbb{R}^m \to \mathbb{R}$ are functions satisfying some monotonicity assumption, $i = 1, 2, \cdots, m$ and m is any positive integer.

We will establish the radial symmetry and monotonicity for positive solutions to the nonlinear fractional order system of m equations in the unit ball and in the whole space $\mathbb{R}^n$, as well as non-existence of solutions on a half space. We will use the method of moving planes to prove our results. As key ingredients for carrying on the method of moving planes, maximum principle, narrow region principle and decay at infinity will be established.
(Received March 17, 2017)

1129-35-257 **Tam Do*** (tam.do@rice.edu), **Alexander Kiselev**, **Lenya Ryzhik** and **Changhui Tan**. *Global regularity for the fractional Euler alignment system.*

We study a pressureless Euler alignment system with nonlinear density-dependent alignment term. The system originates from Cucker-Smale flocking models. The alignment term is dissipative and has the same order as the fractional Laplacian $(-\Delta)^\alpha$, $\alpha \in (0, 1)$. The corresponding system with the fractional Laplacian is the fractional Burgers equation, which forms shocks in finite time. We show solutions are globally regular for all $\alpha \in (0, 1)$.
(Received March 17, 2017)

1129-35-267 **Alexander Kiselev**, **Lenya Ryzhik**, **Yao Yao** and **Andrej Zlatos***, 9500 Gilman Dr #0112, La Jolla, CA 92093. *Growth and singularity in 2D fluids.*

The question of global regularity remains open for many fundamental models of fluid dynamics. In two dimensions, solutions to the incompressible Euler equations have been known to be globally regular since the 1930s, although their derivatives can grow double-exponentially with time. On the other hand, this question has not yet been resolved for the more singular surface quasi-geostrophic (SQG) equation, which is used in atmospheric models. The latter state of affairs is also true for the modified SQG equations, a family of PDE which interpolate between these two models.

I will discuss two results about the patch dynamics version of these equations on the half-plane. The first is global-in-time regularity for the Euler patch model, even if the patches initially touch the boundary of the half-plane. The second is local-in-time regularity for those modified SQG patch equations that are only slightly more singular than Euler, but also existence of their solutions that blow up in finite time. (Received March 17, 2017)

1129-35-270 **Jeffrey Case** and **Yi Wang*** (ywang@math.jhu.edu), 3400 N. Charles St, 404 Krieger Hall Math Dept, Johns Hopkins Univ., Baltimore, MD 21218. *Title: A fully nonlinear Sobolev trace inequality.*

Abstract: The k-Hessian operator σ_k is the k-th elementary symmetric function of the eigenvalues of the Hessian. It is known that the k-Hessian equation $\sigma_k(D^2u) = f$ with Dirichlet boundary condition $u = 0$ is variational; indeed, this problem can be studied by means of the k-Hessian energy $\int -u\sigma_k(D^2u)$. We construct a natural boundary functional which, when added to the k-Hessian energy, yields as its critical points solutions of k-Hessian equations with general non-vanishing boundary data. As a consequence, we prove a sharp Sobolev trace inequality for k-admissible functions u which estimates the k-Hessian energy in terms of the boundary values of u. This is joint work with Jeffrey Case. (Received March 17, 2017)

1129-35-273 **Mihaela Ignatova*** (ignatova@math.princeton.edu) and **Peter Constantin**. *Critical SQG in bounded domains.*

We establish nonlinear lower bounds (nonlinear maximum principle) and commutator estimates for the Dirichlet fractional Laplacian in bounded domains. As an application global existence of weak solutions of critical SQG were obtained. We prove global a priori interior Hölder bounds for large data. This is a joint work with Peter Constantin. (Received March 17, 2017)

1129-35-274 **Richard Gustavson*** (rgustavson@gradcenter.cuny.edu), CUNY Graduate Center, Ph.D. Program in Mathematics, 365 Fifth Avenue, New York, NY 10016, **Alexey Ovchinnikov** (alexey.ovchinnikov@qc.cuny.edu), CUNY Queens College, Department of Mathematics, 65-30 Kissena Boulevard, Queens, NY 11367, and **Gleb Pogudin** (pogudin@algebra.uni-linz.ac.at), Johannes Kepler University, Institute for Algebra, Science Park II, 4040 Linz, Austria. *New upper bounds for differential elimination algorithms.*

Differential elimination is the process of eliminating a fixed set of differential unknowns from a system of differential equations in order to obtain consequences of the system that do not depend on that fixed set of unknowns. Decomposition algorithms approach this problem by decomposing a system of differential equations into a collection of simpler systems that can be more easily studied. In this talk, we will discuss the Rosenfeld-Gröbner algorithm for systems of partial differential equations, one of the most common decomposition algorithms, which has been implemented in computer algebra systems such as Maple. Specifically, we will address the complexity of the Rosenfeld-Gröbner algorithm by computing an upper bound for the orders of the derivatives that appear in all intermediate steps and in the output of the algorithm. (Received March 17, 2017)

1129-35-280 **Nestor Guillen***, nguillen@math.umass.edu, and **Russell Schwab**. *Homogenization for Neumann problems for operators with singular gradient dependence.*

Consider a linear elliptic operator with highly oscillatory periodic coefficients and with a drift whose amplitude is of the same order as the frequency. We study the Neumann problem for such operators where the Neumann condition is also highly oscillatory, and analyze the behavior of solutions as the frequency goes to infinity. Such homogenization problems appear naturally in the study of stochastic processes in periodic media with reflective boundary conditions, or in the study of boundary layers for Dirichlet problems with oscillatory data. Previous works by Arisawa, by Tanaka, and by Barles-Da Lio-LionsSouganidis determined the limiting behavior in the case of an infinite strip aligned with a subspace of the Cartesian lattice. The novel idea in our analysis is translating the problem into a integro-differential problem on the boundary, by a proper study of the Dirichlet-to-Neumann map, at which the point the problem is amenable to integro-differential tools, and to ideas of Ishii used first in the homogenization of almost periodic Hamilton-Jacobi equations. (Received March 18, 2017)

1129-35-281 **Nestor Guillen***, nguillen@math.umass.edu, and **Russell Schwab**. *Min-max formulas for nonlocal elliptic operators and applications.*

A mapping F between spaces of real valued functions is said to have the "global comparison property" (GCP) if $u \leq v$ everywhere with $u = v$ at some point x means that $F(u) \leq F(v)$ at this point x. A classical result of Courrege says that a continuous linear map from $C^2(\mathbb{R}^d)$ to $C^0(\mathbb{R}^d)$ has the GCP if and only if it is a sum of jump and drift-diffusion operators. In work with Russell Schwab, we characterize nonlinear maps having the GCP as those given by a min-max of linear operators having the GCP. This result provides representation formulas for the Dirichlet-to-Neumann map of nonlinear elliptic equations, and for the interface velocity for various free boundary problems, respective applications will be discussed along with a list of related questions which are open. (Received March 18, 2017)

1129-35-282 **Liming Sun*** (ls680@math.rutgers.edu), 110 Frelinghuysen Rd., Piscataway, NJ 08854, and **Xuezhang Chen**. *Existence of conformal metrics with constant scalar curvature and constant boundary mean curvature on compact manifolds.*

We study the problem of deforming a Riemannian metric to a conformal one with nonzero constant scalar curvature and nonzero constant boundary mean curvature on a compact manifold of dimension $n \geq 3$. We prove the existence of such conformal metrics in the cases of $n = 6, 7$ or the manifold is spin and some other remaining ones left by Escobar. Furthermore, in the positive Yamabe constant case, by normalizing scalar curvature to be 1, there exists a sequence of conformal metrics such that their constant boundary mean curvatures go to $+\infty$. This fact can partially answer the Han-Li conjecture. (Received March 18, 2017)

1129-35-303 **Hector A Chang-Lara*** (changlara@math.columbia.edu), Department of Mathematics Columbia University, Room 509, MC 4406 2990 Broadway, New York, NY 10027, and **Nestor Guillen**. *From the free boundary condition for Hele-Shaw to the fractional parabolic equation.*

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 March 19, 2017)

1129-35-311 **Stan Alama** and **Lia Bronsard*** (bronsard@mcmaster.ca), Dept of Math and Stats, Hamilton, ON L8S 4K1, Canada, and **Xavier Lamy**. *Minimizers of the Landau-de Gennes energy around a spherical colloid particle.*

We consider energy minimizing configurations of a nematic liquid crystal around a spherical colloid particle, in the context of the Landau-de Gennes model. The nematic is assumed to occupy the exterior of a ball, and satisfy homeotropic weak anchoring at the surface of the colloid and approach a uniform uniaxial state far from the colloid. We study the minimizers in two different limiting regimes: for balls which are small compared to the characteristic length scale, and for large balls. The relationship between the radius and the anchoring strength is also relevant. For small balls we obtain a limiting quadrupolar configuration, with a "Saturn ring" defect for relatively strong anchoring, corresponding to an exchange of eigenvalues of the Q-tensor. In the limit of very large balls we obtain an axisymmetric minimizer of the Oseen—Frank energy, and a dipole configuration with exactly one point defect is obtained. This is joint work with Stan Alama and Xavier Lamy. (Received March 19, 2017)

1129-35-313 **Damir Kinzebulatov*** (damir.kinzebulatov@mat.ulaval.ca), Pavillon Alexandre-Vachon, Bureau 2217, 1045 av. de la Medécine, Québec, Québec G1V 0A6, Canada. *$W^{1,p}$-regularity for $-\nabla \cdot a \cdot \nabla$ and $-a \cdot \nabla^2$ perturbed by form-bounded drift, and Krylov-Safonov theory.*

We obtain $W^{1,p}$-regularity estimates for operators $-\nabla \cdot a \cdot \nabla + b \cdot \nabla$ and $-a \cdot \nabla^2 + b \cdot \nabla$ with matrix a, vector field b having critical singularities, strengthening some aspects of the theory of Krylov-Safonov, as well as obtaining new results not reachable by their technique. Joint with Yu.A.Semenov. (Received March 19, 2017)

1129-35-330 **Zheng-Chao Han*** (zchan@math.rutgers.edu), Department of Mathematics, Hill Center, Busch Campus, Rutgers University, Piscataway, NJ 08854, **Sun-Yung Alice Chang** (chang@math.princeton.edu), Department of Mathematics, Princeton University, Princeton, NJ 08540, and **Paul C Yang** (yang@math.princeton.edu), Department of Mathematics, Princeton University, Princeton, NJ 08540. *Some remarks on the symmetry of complete, locally conformally flat metrics on canonical domains of the round sphere with constant Q-curvature.*

We will report on some results, jointly with Alice Chang and Paul Yang of Princeton University, on the symmetry of complete, locally conformally flat metrics on canonical domains of the round sphere with constant Q-curvature. More specifically

Theorem. *Any complete, conformal metric g on $\mathbb{S}^n \setminus \mathbb{S}^l$ for $l \leq \frac{n-2}{2}$ satisfying*

$$Q_g \equiv 1 \text{ or } 0, \tag{1}$$

and

$$R_g \geq 0, \tag{2}$$

in $\mathbb{S}^n \setminus \mathbb{S}^l$ *has to be symmetric with respect to rotations of* $\mathbb{S}^n$ *which leave* $\mathbb{S}^l$ *invariant.* This theorem is a corollary of the following

Theorem. *Let* g *be a conformal, complete metric on* $\Omega \subsetneq \mathbb{S}^n$ *such that* (1) *and* (2) *hold in* Ω. *Then for any ball* $B \subset\subset \Omega$ *in the canonical metric* $g_{\mathbb{S}^n}$, *the mean curvature of its boundary* ∂B *in metric* g *with respect to its inner normal is nonnegative.* (Received March 21, 2017)

1129-35-332 **Diego Cordoba**, **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 March 19, 2017)

1129-35-338 **Jerome Goddard II**, **Quinn A. Morris*** (`qamorris@uncg.edu`), **Catherine Payne** and **R. Shivaji**. *Steady states for classes of reaction-diffusion equations with U-shaped density dependent dispersal on the boundary.*

We consider positive solutions to equations of the form

$$\begin{cases} -\Delta u = \lambda u(1-u), & x \in \Omega, \\ \frac{\partial u}{\partial \eta} + \gamma\sqrt{\lambda}(u-A)^2 u = 0, & x \in \partial\Omega, \end{cases}$$

where $\lambda > 0, \gamma > 0, A \in (0,1)$ are parameters, Ω is a bounded domain in $\mathbb{R}^n$; $n \geq 1$ with smooth boundary $\partial\Omega$ and $\frac{\partial u}{\partial \eta}$ is the outward normal derivative. Such models arise in the study of population dynamics in a habitat Ω when the population exhibits U-shaped density dependent dispersal on the boundary. We analyze the persistence of the population (existence, non-existence, uniqueness and multiplicity of positive solutions) as the patch size (λ) and the hostility of the outside matrix (γ) vary. We obtain results when $\Omega = (0,1)$ via a quadrature method, and when Ω is any bounded domain in $\mathbb{R}^n$; $n > 1$ by the method of sub-super solutions. (Received March 20, 2017)

1129-35-342 **Irina Mitrea*** (`imitrea@temple.edu`), Temple University, Department of Mathematics, 1805 N. Broad Street, Philadelphia, PA 19122. *THE BMO-DIRICHLET PROBLEM FOR ELLIPTIC SYSTEMS IN THE UPPER-HALF SPACE.*

In this talk I will discuss the BMO-Dirichlet boundary value problem for homogeneous, second order, constant complex coefficient elliptic systems and show well-posedness in the class of functions for which the Littlewood-Paley measure associated with it is a Carleson measure in the upper-half space. This is joint work with J. Maria Martell, D. Mitrea, and M. Mitrea. (Received March 20, 2017)

1129-35-343 **Arghir Dani Zarnescu***, Alameda de Mazarredo 14, 48010 Bilbao, Spain. *On the inertia in several Qian-Sheng models of liquid crystals.*

One of the most intriguing aspects of liquid crystals, from both a physical and mathematical point of view concerns the presence of inertia, manifested as a second-order material derivative. Usually, based on physical considerations, the inertia is considered to be negligible and dropped from the equations, which conveniently simplifies the equations significantly.

We consider one of the simplest cases in which the inertia is kept, within the Qian-Sheng formalism, and provide a basic global well-posedness result for regular enough solutions.

Furthermore we consider the issue of weak solutions for a simpler looking but mathematically more complicated version of this model, in which the viscous newtonian inertia is dropped. A new concept of dissipative solution is proposed, for which a global-in-time existence theorem is shown.

The first part is joint work with Francesco de Anna (Penn State) and the second part with Eduard Fereisl (Prague), Elisabetta Rocca (Pavia) and Giulio Schimperna (Pavia). (Received March 20, 2017)

1129-35-347 **Francis J Chung***, fj.chung@uky.edu. *Elliptic inverse boundary problems and control.*

In a typical inverse boundary problem, we are given information about the boundary values of the solution to an equation, and asked to recover the coefficients of the equation on the interior. Solving the problem usually requires a control theory type result – we need to understand how to control solutions inside the domain using the boundary values. In this talk I will give a brief introduction to this connection, and give some examples of recent results in this area. (Received March 20, 2017)

1129-35-379 **Jessica Lin*** (jessica@math.wisc.edu) and **Andrej Zlatos** (zlatos@ucsd.edu).
Stochastic Homogenization for Reaction-Diffusion Equations.

We consider heterogeneous reaction-diffusion equations with a random ignition or KPP-type nonlinearity. Under certain hypotheses on the environment, we show that the typical large-time large-scale behavior of solutions is governed by a deterministic Hamilton-Jacobi equation modeling front propagation. In particular, we prove the existence of asymptotic, deterministic speeds of propagation for solutions with both spark-like and front-like initial data. Such models are relevant for predicting the evolution of a population or the spread of a fire in a heterogeneous environment. (Received March 20, 2017)

1129-35-380 **William Chen** and **Alejandro Sarria*** (as29@williams.edu), 150 meacham street, Williamstown, MA 01267. *Infinite energy solutions of the 3D incompressible Euler equations with damping.*

We study periodic solutions of the damped 3D incompressible Euler equations of the form $u = (u_1(x,y,t), u_2(x,y,t), z\gamma(x,y,t))$ on an infinite 3D channel of rectangular cross-section. In 2000, Constantin showed that, starting from a smooth initial condition u_0, such class of solutions ceases to be smooth at some finite time $T = T(u_0)$. We incorporate a damping term αu into the system and derive conditions on the damping coefficient $\alpha > 0$ that suppress the aforementioned (undamped) blowup. (Received March 20, 2017)

1129-35-387 **Andrew Lorent** and **Guanying Peng***, Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221-0025. *Regularity of the Eikonal equation with two vanishing entropies.*

We study regularity of solutions to the Eikonal equation $|\nabla u| = 1$ a.e. in a bounded simply-connected two dimensional domain. With the help of two vanishing entropies, we prove that solutions of the Eikonal equation are locally Lipschitz continuous, except at a locally finite set of points in the domain. The motivation of our problem comes from the zero energy state of the Aviles-Giga functional in connection with the theory of smectic liquid crystals and thin film blisters. Our results for the first time use only two entropies to characterize regularity properties in this direction. This is joint work with Andrew Lorent. (Received March 20, 2017)

1129-35-393 **Thomas Backing** (dgarofal@purdue.edu), IN, **Donatella Danielli*** (dgarofal@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 the optimal regularity of solutions and the structure of the free boundary in a two-penalty boundary obstacle problem modeling fluid flow through a permeable membrane. (Received March 20, 2017)

1129-35-412 **Peter Constantin*** (const@math.princeton.edu), Department of Mathematics, Princeton University, Princeton, NJ 08544. *The Lagrangian-Eulerian method.*

We present results based on the Lagrangian-Eulerian method of constructing solutions to hydrodynamic PDE. The method uses Lagrangian deformations and analysis in Eulerian variables. The outcome is Lipschitz dependence in path space for a number of models, including inviscid Boussinesq, Oldroyd B, incompressible porous medium, SQG and Euler equations. (Received March 20, 2017)

1129-35-435 **Cecilia F. Mondaini*** (cfmondaini@gmail.com). *On the convergence of statistical solutions of evolution equations.*

The concept of statistical solutions of evolution equations in fluid dynamics has emerged with the aim of proving rigorous results concerning the conventional theory of turbulence. For well-posed systems, a statistical solution corresponding to a given initial probability measure is trivially given by the transport of the initial measure by the semigroup. In this talk, I will present an abstract framework that allows one to prove the existence of such statistical solutions for evolution equations which are not known to be well-posed, by considering regularized approximate models. The aim is to show that the statistical solutions of the approximate models converge to a statistical solution of the original system. An application of this framework to the inviscid limit of the 2D incompressible Navier-Stokes equations will be discussed. This is a joint work with A. Bronzi and R. Rosa. (Received March 21, 2017)

1129-35-453 **Qui-Qiang Chen**, **Apala Majumdar**, **Dehua Wang** and **Rongfang Zhang*** (roz14@pitt.edu). *Global Existence and Regularity for the Active Liquid Crystal System.*

We study the hydrodynamics of active liquid crystals in the Beris-Edwards hydrodynamic framework with the Landau-de Gennes Q-tensor order parameter to describe liquid crystalline ordering. For the incompressible case, the existence of global weak solutions in two and three spatial dimensions is established and the higher regularity of the weak solutions and the weak-strong uniqueness are also obtained by the Littlewood-Paley decomposition in dimension two. The existence of global weak solutions for the inhomogeneous case and compressible case is also obtained. (Received March 21, 2017)

1129-35-458 **Feride Tiglay*** (tiglay.1@osu.edu), 1179 University Dr, Newark, OH 43055, and **Barbara L. Keyfitz**, Columbus, OH. *Nonuniform dependence on initial data for compressible gas dynamics.*

We start with the classic result that the Cauchy problem for ideal compressible gas dynamics is locally well posed in time in the sense of Hadamard; there is a unique solution that depends continuously on initial data in Sobolev spaces with high enough index. We prove that the data to solution map for periodic data in two dimensions although continuous is not uniformly continuous. (Received March 21, 2017)

1129-35-464 **Zineb Hassainia**, **Nader Masmoudi** and **Miles H Wheeler*** (mwheeler@cims.nyu.edu). *Global bifurcation of rotating vortex patches.*

Vortex patch solutions of the two-dimensional Euler equations that rotate with constant angular velocity have been rigorously constructed as perturbations of the disk. For each $m \geq 3$, there is a small curve of solutions which have the symmetry of a regular m-gon. In this talk we prove that these local bifurcation curves can be extended to global ones. Near the end of each global curve, the minimum value on the patch boundary of the angular fluid velocity becomes arbitrarily small, consistent with the formation of sharp corners that has been observed numerically. (Received March 21, 2017)

1129-35-466 **Changfeng Gui** and **Amir Moradifam*** (amirm@ucr.edu). *Uniqueness of solutions of mean field equations.*

I will talk about the uniqueness of solutions of mean field equations in two dimensions in the critical and subcritical total mass regime, and present some symmetry results for mean field equations on R^2, flat tori, and annuli. The proofs are based on the Sphere Covering Inequality. This is a joint work with Changdenf Gui. (Received March 21, 2017)

1129-35-467 **Lidia Mrad*** (lmrad@math.arizona.edu) and **Daniel Phillips**. *Dynamic Analysis of Chevron Structures in Smectics.*

Smectic liquid crystals trapped between two flat substrates exhibit V-shaped defect structures called chevrons under the effect of an applied electric or magnetic field. We consider two models, smectic-A under the effect of a magnetic field using de Gennes energy model and smectic-C under the effect of an electric field using Chen-Lubensky energy model. To understand chevron formation, we analyze the dynamics of these systems. We construct a discretized-in-time gradient flow through energy minimization and prove existence and uniqueness of the continuous gradient flow. (Received March 21, 2017)

1129-35-468 **David G. Ebin*** (ebin@math.sunysb.edu), Mathematics Department, Stony Brook University, Stony Brook, NY 11794-3651. *Blowup of Solutions to Euler-like Equations (after T. Tao).*

The equations of motion of perfect fluids are commonly expressed as a system of evolution equations in the velocity field of the fluid. It is a long standing question whether the initial value problem for this system has strong long-time solutions. We cannot answer this question, but following T. Tao, we describe related equations for which some solutions blow up in finite time. Our approach uses the equations for the vorticity of the fluid ω rather than the velocity v. This gives a pair of equations

$$\partial_t\omega + \mathcal{L}_v\omega = 0 \qquad v = \delta\Delta^{-1}\omega$$

where $\mathcal{L}_v$ denotes the Lie derivative with respect to v, δ denotes divergence and Δ denotes the Laplacian. By changing Δ^{-1} to other operators of degree -2, one can find solutions that blow up in finite time. Thus any proof which showed there was no blow up would have to be sufficiently specific so that it would not work for the other operators. (Received March 21, 2017)

1129-35-474 **Magdalena Czubak*** (czubak@colorado.edu), Department of Mathematics, University of Colorado at Boulder, Campus Box 395, Boulder, CO 80309. *Wellposedness for 2D wave equations with null forms.*

The null condition was introduced by Klainerman. The nonlinearities exhibiting null structure appear in many systems including Wave Maps, Yang Mills, Maxwell-Klein-Gordon and the space-time Monopole equation. Two dimensions create obstacles towards low regularity wellposedness that are not present in higher dimensions. In this talk we describe recent progress on improving the wellposedness results by suitably randomizing the initial data. We discuss both a periodic and nonperiodic setting. (Received March 21, 2017)

1129-35-478 **Andres Contreras*** (acontre@nmsu.edu) and **Robert Jerrard**. *Vortex filament clustering in 3D Ginzburg-Landau.*

In Ginzburg-Landau theory, vortex filament concentration can occur due to magnetic, geometric and other effects. When this happens, a vorticity region with high multiplicity circulation can be found near an optimal curve inside the domain. In joint work with Robert Jerrard we are able to zoom in this region to identify several individual vortex filaments and derive an energy of these that takes into account the geometry of the filaments and their interaction. This energy is a higher order expansion of the Ginzburg-Landau energy in the $\varepsilon \to 0$ limit. (Received March 21, 2017)

1129-35-480 **Francesco De Anna*** (fzd16@psu.edu), Department of Mathematics, McAllister Building, University Park, PA 16802, State College, PA 16802. *Global well-posedness for dynamical models of nematic liquid crystals.*

We present recent developments on the dynamics of nematic liquid crystals, through the models proposed by Ericksen-Leslie and Beris-Edwards. We perform some well-posedness results such as existence and uniqueness of global-in-time weak or classical solutions. The general framework for the initial data is that of Besov spaces. We consider the Ericksen-Leslie system assuming the density to be no constant and allowing it to present discontinuities along an interface. Moreover, we emphasize the specific structure of the nonlinear terms arising from the Beris-Edwards theory. This structure plays a main role, especially in uniqueness results achieved by a double-logarithmic estimate and a deeply decomposition given by the paradifferential calculus. (Received March 21, 2017)

1129-35-481 **Lizheng Tao*** (leedstao@ucr.edu), Riverside, CA. *Inviscid Limit Problem for Navier Stokes Equations with Fractional Laplacian.*

We will discuss some recent results in the inviscid limit problem for Navier-Stokes equations with fractional Laplacian in a domain. Some sufficient conditions will be given. (Received March 21, 2017)

1129-35-492 **Lihe Wang*** (lihe-wang@uiowa.edu), Department of Mathematics, University of Iowa, Iowa City, IA 52242. *Rigidity theorem with capacity of sets in Euclidean space.*

We will introduce a notion of capacity on open sets in the Euclidean space and study its consequences in the regularity of the sets and particularly the boundaries. (Received March 21, 2017)

1129-35-493 **Guozhen Lu*** (guozhen.lu@uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269. *Concentration-compactness principle and existence of ground state solutions to certain quasilinear equations.*

In this talk, we present a number of results on concentration-compactness principle for Trudinger-Moser inequalities on Euclidean spaces, Riemannian manifolds, Heisenberg groups, etc. and apply them to establish the existence of ground state solutions to certain quasilinear partial differential equations. These are joint works with Jungang Li (University of Connecticut, USA), Maochun Zhu (Jiangsu University, China) and Lu Chen and Caifeng Zhang (Beijing Normal University, China). (Received March 21, 2017)

1129-35-495 **Boris Hanin*** (bhanin@mit.edu) and **Yaiza Canzani**. *Scaling Limit of Spectral Projector for the Laplacian on a.*

Let (M,g) be a compact smooth Riemannian manifold. I will give some new off-diagonal estimates for the remainder in the pointwise Weyl Law. A corollary is that, when rescaled around a non self-focal point, the kernel of the spectral projector of the Laplacian onto the frequency interval (lambda,lambda+1] has a universal scaling limit as lambda goes to infinity (depending only on the dimension of M). This is joint work with Y. Canzani. (Received March 21, 2017)

1129-35-497 **Zineb Hassainia*** (zh14@nyu.edu), 251 Mercer St, New York, NY 10012. *Relative equilibria for active scalar equations.*

Vortex relative equilibria are configurations of vortices that maintain their basic shapes for all time, while rotating or translating rigidly in space. We shall discuss in this talk the immersion of these patterns where the underlying dynamics are governed by the two-dimensional Euler equations and the inviscid generalized surface quasi-geostrophic equations. The main concern is to establish the existence of rotating vortex patches for different topological structures including the pairs of patches and multi-polar vortex patches. The proofs are based on the bifurcation theory combined with the conformal parametrizations. (Received March 21, 2017)

1129-35-501 **Jacob Bedrossian*** (jacob@cscamm.umd.edu), 4176 Campus Drive - William E. Kirwan Hall, College Park, MD 20742. *Landau damping and nonlinear oscillations in nearly collisionless plasmas.*

In this talk we will discuss some of the intricacies of Landau damping in the collisionless Vlasov equations or the collisionless limits of Vlasov-Fokker-Planck equations. We will discuss the construction of solutions to the Vlasov-Poisson equations on S x R which are arbitrarily close to homogeneous equilibrium in Sobolev regularity but which display arbitrarily long sequences of nonlinear oscillations known as plasma echoes. In particular, these oscillations show that the collisionless linearization is not valid for long times in Sobolev regularity. Further, we show that the inclusion of weak collisional effects suppress these plasma echoes and make it possible to obtain Sobolev regularity results. We also prove that Debye shielding and dispersive effects can suppress such nonlinear oscillations (joint with Nader Masmoudi and Clement Mouhot). Combined with the existing results of Mouhot and Villani, these confirm or refute a variety of conjectures made by mathematicians and physicists over the last 50 years. (Received March 21, 2017)

1129-35-502 **Adam Larios*** (alarios@unl.edu), **Mark Petersen**, **Edriss S Titi** and **Beth Wingate**. *Computational study of the blow-up of the 3D Euler equations of fluids via the 3D Euler-Voigt equations.*

We report the results of a computational investigation of two recently proved blow-up criteria for the 3D incompressible Euler equations. These criteria are based on an inviscid regularization of the Euler equations known as the 3D Euler-Voigt equations. The latter are known to be globally well-posed. Moreover, simulations of the 3D Euler-Voigt equations also require less resolution than simulations of the 3D Euler equations for fixed values of the regularization parameter. Therefore, the new blow-up criteria allow one to gain information about possible singularity formation in the 3D Euler equations indirectly; namely, by simulating the better-behaved 3D Euler-Voigt equations. To test the robustness of the inviscid-regularization approach, we also investigate analogous criteria for blow-up of the 1D Burgers equation, where blow-up is well-known to occur. (Received March 21, 2017)

1129-35-505 **Vincent R Martinez*** (vmartin6@tulane.edu), Mathematics Department, Tulane University, 6823 St. Charles Ave, New Orleans, LA 70118, and **Animikh Biswas**, **Prabath Silva** and **Kun Zhao**. *Studies in analyticity for hydrodynamic and chemotaxis models.*

In their 1987 seminal paper, Foias and Temam established analyticity in both space and time for solutions of the two- (2D) and three-dimensional (3D) Navier-Stokes equations (NSE) by developing an energy method known as the Gevrey-norm technique, i.e., a norm which characterizes real analyticity of a function. This technique has since become standard for establishing spatial analyticity of solutions to various parabolic equations. In this talk, we shed light on the relation between the structure of the equation and its well-posedness theory in various analytic Gevrey-norm regularity classes. We do so in the context of the supercritical SQG equation, the Keller-Segel equation, and coupled chemotaxis-hydrodynamic models. (Received March 21, 2017)

1129-35-508 **Jae Min Lee*** (jlee10@gradcenter.cuny.edu), 365 Fifth Avenue Room 4208, Department of Mathematics, New York, NY 11104, and **Stephen Carl Preston** (stephen.preston@brooklyn.cuny.edu), 1156 Ingersoll Hall, Department of Mathematics, Brooklyn, NY 11210-2889. *Local Well-posedness of the Camassa-Holm equation on the real line.*

In this paper we prove the local well-posedness of the Camassa-Holm equation on the real line in the space of continuously differentiable diffeomorphisms with an appropriate decaying condition. This work was motivated by G. Misiolek who proved the same result for the Camassa-Holm equation on the periodic domain. We use the Lagrangian approach and rewrite the equation as an ODE on the Banach space. Then by using the standard ODE technique, we prove existence and uniqueness. Finally, we show the continuous depdendence of the solution on the initial data by using the topological group property of the diffeomorphism group. (Received March 21, 2017)

1129-35-509 **Juraj Foldes*** (foldes@virginia.edu), 141 Cabell Drive, Kerchof Hall, Charlottesville, VA 22901, and **Nathan Glatt-Holtz**, **Geordie Richards** and **Jared Whitehead**. *Invariant measures for stochastically forced Boussinesq equations and onset of convection.*

We will discuss statistically stable steady states for stochastically forced Boussinesq system and investigate possible scenarios for the onset of convection. In particular, we will show that in comparison to the deteministic forcing, stochastic forcing with small strength can have stabilizing effect whereas large strength can have destabilizing effect. Most of the analysis will be performed in the highly degenerate case that has not been considered in the literature. The core of the proofs is a subtle analysis of non-trivial stochastic variational problems.

This is a joint work with Nathan Glatt-Holtz, Geordie Richards, and Jared Whitehead. (Received March 21, 2017)

1129-35-510 **Bo Guan*** (guan.19@osu.edu). *Some fully nonlinear degenerate elliptic equations on Hermitian manifolds.*

We consider fully nonlinear elliptic equations on complex manifolds, some of which arise from complex geometry. We are concerned with deriving a priori estimates for such equations and present recent results on a special class of equations which may be degenerate and involve gradient terms. The talk is based on joint work with Xiaolan Nie, Chunhui Qiu and Rirong Ruan. (Received March 21, 2017)

1129-35-511 **Nathan Glatt-Holtz**, **Juraj Földes**, **Susan Friedlander**, **Geordie Richards*** (geordie.richards@usu.edu) and **Jared Whitehead**. *Singular parameter limits for stochastic PDEs from geophysics.*

We will discuss a technique for proving the weak convergence of invariant measures with respect to singular parameter limits for systems of stochastic PDEs with degenerate forcing. The crucial ingredients are a contraction property of the limiting dynamics relative to a Wasserstein metric, and the convergence of solutions in the singular parameter limit on finite time scales. Two applications from geophysics, with distinct challenges, will be highlighted: the infinite Prandtl number limit for stochastic Boussinesq equations, and the vanishing Rossby and magnetic Reynolds number limit for stochastic magnetohydrodynamics (MHD) equations. This talk is based on joint works with Juraj Földes, Susan Friedlander, Nathan Glatt-Holtz and Jared Whitehead. (Received March 21, 2017)

1129-35-514 **Cheng Yu*** (yucheng@math.utexas.edu), Austin, TX 78712. *The energy conservation for the compressible Navier-Stokes equations.* Preliminary report.

In this talk, I will talk on the energy conservation for the weak solutions of the compressible Navier-Stokes equations globally in time, under certain conditions. (Received March 21, 2017)

1129-35-518 **Ovidiu Savin*** (savin@math.columbia.edu), 2990 Broadway, New York, NY 10027. *Viscosity solutions and the minimal surface system.*

We give a definition of viscosity solution for the minimal surface system and prove a version of Allard regularity theorem in this setting. (Received March 21, 2017)

37 ► Dynamical systems and ergodic theory

1129-37-58 **Howard Masur*** (masur@math.uchicago.edu), 5734 S. University, Chicago, IL 60637. *Ergodic Theory of Interval Exchange Transformations.*

Interval exchange transformations are an interesting class of dynamical systems. An IET is determined by a collection of d positive numbers and a permutation on d letters. Many years ago Veech and Keane constructed examples which are minimal but not uniquely ergodic. For a given permutation the set of (normalized) interval exchanges on d intervals forms a standard d-1 dimensional simplex. One can ask how big is the subset of minimal non uniquely ergodic interval exchanges It is known that it has measure zero. In this talk, after giving background, I will discuss the theorem, joint with Jonathan Chaika that for certain permutations and d at least 4, the Hausdorff dimension is exactly d-3/2. (Received February 27, 2017)

1129-37-75 **Tao Chen*** (tchen@lagcc.cuny.edu), 3110 Thomson Avenue, Long Island City, NY 11101, and **Linda Keen** (linda.keenbrezin@gmail.com), 365 fifth Avenue, New York, NY 10016. *Dynamics of $\lambda tan^m z$, for $m \geq 2$.*

In this talk, we will discuss the dynamics of the family of meromorphic functions $\lambda \tan^m z$, $m \geq 2$. Comparing with the well studied family $f_c(z) = z^2 + c$, we will describe the basic properties of the dynamical plane and the combinatorics of the parametric plane. (Received March 02, 2017)

1129-37-124 **Yunping Jiang*** (yunping.jiang@qc.cuny.edu), Department of Mathematics, Queens College of CUNY, 65-30 Kissena Blvd, Flushing, NY 11367. *Teichmüller Metric on the Space of Geometric Gibbs Measures.*

In dynamical systems, an important equilibrium state is a Gibbs measure. The deformation of a Gibbs measure associated with the change of underline dynamical system becomes an important subject in these areas. An appropriate metric on the space of underlying dynamical systems is going to be very helpful in the study of deformation. The Teichmüller metric becomes a natural choice. The Teichmüller metric, just like the hyperbolic metric on the open unit disk, makes the space of underlying dynamical systems a complete space. The Teichmüller metric precisely measures the change of the eigenvalues at all periodic points which are essential data needed to obtain the Gibbs measure for a given dynamical system. In this article, I will introduce the Teichmüller metric and, subsequently, a generalization of Gibbs theory which we call geometric Gibbs theory. (Received March 09, 2017)

1129-37-139 **Alex M Blumenthal*** (alexb123@math.umd.edu), 4305 Kirwan Hall, 4176 Campus Drive, University of Maryland, College Park, MD 20742. *SRB measures for Banach space mappings.*

I will talk about the extension to the setting of Banach space mappings a concept which has proven highly useful in the study of finite dimensional dissipative dynamical systems, that of SRB measures. Our results apply to a large class of dissipative PDE which includes many dissipative parabolic and dispersive wave equations.

We generalize two results known in the finite-dimensional setting: the first is the characterization of the SRB property in terms of the relationship between Lyapunov exponents and metric entropy. The second is a technical result, absolute continuity of the stable foliation, which in particular implies that an SRB measure with no zero exponents is 'visible' to a 'positive volume' subset of phase space (where 'positive volume' must be suitably interpreted in the infinite-dimensional setting).

A major complication we address is that Banach spaces do not possess an a priori notion of k-dimensional volume element, whereas the finite dimensional theory heavily involves the notion of volume growth along unstable leaves. Another is that mappings in our setting are not differentiably invertible: maps may exhibit arbitrarily strong rates of contraction, and are not locally onto.

This work is joint with Lai-Sang Young. (Received March 11, 2017)

1129-37-144 **John Hamal Hubbard*** (jhh8@cornell.edu), Department of Mathematics, Malott Hall, Ithaca, NY 14853. *A new entry in the Sullivan dictionary: Parabolic blowups, limits of dynamical systems and group actions.*

Limits of a dynamical system $f : X \to X$ should be thought of as the limit of all the iterates $f^{\circ n}$, in an appropriate Hausdorff topology. Similarly, the limit of a family of group actions should be thought of as the limit of the entire group, in the Chabauty topology. In the world of dynamics, this goes under the name of *parabolic implosion*; in the world of Kleinian groups, under the name *geometric limits*.

These may be quite different from the dynamical systems or group actions generated by the limits of the generators: they may be *enriched*. I will attempt to describe the space of enriched dynamical systems, as an appropriate projective limit of *parabolic blowups*. It is a complicated space, even if the original dynamical systems are just $p_c : z \mapsto z^2 + c$. But it is possible to compute its cohomology, and to describe parts as generalized continued fractions. (Received March 11, 2017)

1129-37-155 **Genady Ya Grabarnik** (grabarng@stjohns.edu), 8000 Utopia Pkwy, Jamaica, PA 11439, and **Serge Yaskolko*** (syaskolko@southuniversity.edu), 2838 Beechwood Blvd, Pittsburgh, PA 15217. *Note On Continuity Of The Lyapunov Exponents For The Random Matrices In SL(2,R).*

Classic results of Furstenberg and Kifer state the continuity of the Lyapunov exponents when either the limit measure support acts irreducibly or the supports of the converging measures are localized near one matrix. Recently in the works of Bocker, Viana, and Avila the second alternative was generalized requiring the supports of the converging measures being localized near the support of the limit measure. In this paper we prove the continuity for a case, where neither irreducibility of the limit measure support nor localization of the supports of the converging measures is required.

Key words and phrases: Lyapunov Exponents, continuity, SL(2,R). (Received March 12, 2017)

1129-37-171 **Yun Yang*** (summeryangyun@gmail.com), The Mathematics Department, Graduate Center, City University of New York, New York, NY 10016. *Measurable rigidity of C^1 generic conservative Anosov diffeomorphisms.*

It is a classical result that for C^2 conservative Anosov diffeomorphisms, measurable rigidity holds. In this talk, I will prove that measurable rigidity is also true for C^1 generic conservative Anosov diffeomorphisms. The main ingredient in the proof is Central Limit Theorem. (Received March 13, 2017)

1129-37-190 **Linda Keen*** (lkeen@gc.cuny.edu), Graduate Center CUNY Mathematics Program, 365 Fifth Ave, New York, NY 10016. *Dynamically Natural Slices of Parameter Space for Transcendental Functions.*

Dynamically Natural Slices of Parameter Space for Transcendental Functions

Abstract: In this talk, based on joint work with Nuria Fagella and Tao Chen, I will discuss how to choose one dimensional slices of the parameter space of certain families of transcendental meromorphic functions of finite type. We will show how the hyperbolic components of these slices can be described combinatorially in terms of "centers" or "virtual centers". (Received March 15, 2017)

1129-37-196 **John Franks** and **Michael Handel*** (michael.handel@lehman.cuny.edu), Department of Mathematics, Lehman College, Bronx, NY 10468. *Entropy zero area preserving diffeomorphisms of surfaces.* Preliminary report.

We continue our study of entropy zero, area preserving diffeomorphisms $F : S \to S$ of a compact surface S with negative Euler characteristic. Our previous work presented a 'structure theorem' in the genus zero case. We have now extended this to arbitrary genus. As an important special case, suppose that the set of periodic points equals the set of fixed points. In this case we prove that there is a finite set of open, disjoint, F-invariant, finite type subsurfaces S_i, whose union is dense, and a finite set of oriented minimal geodesic laminations Λ_i, such that the F-orbit of each birecurrent point in S_i 'tracks' a leaf of Λ_i. (Received March 15, 2017)

1129-37-207 **Alex Blumenthal**, **Jinxin Xue** and **Lai-Sang Young*** (lsy@cims.nyu.edu). *Lyapunov exponents and correlation decay for random perturbations of some prototypical 2D maps.*

To illustrate the more tractable properties of random dynamical systems, we consider a class of 2D maps with strong expansion on large – but non-invariant – subsets of their phase spaces. In the deterministic case, such maps are not precluded from having sinks, as derivative growth on disjoint time intervals can be cancelled when stable and unstable directions are reversed. Our main result is that when randomly perturbed, these maps possess positive Lyapunov exponents commensurate with the amount of expansion in the system. We show also that initial conditions converge exponentially fast to the stationary state, equivalently time correlations decay exponentially fast. These properties depend only on finite-time dynamics, and do not involve parameter selections, which are necessary for deterministic maps with nonuniform derivative growth. (Received March 15, 2017)

1129-37-245 **Jian Li** and **Piotr Oprocha*** (oprocha@agh.edu.pl), Faculty of Applied Mathematics, AGH University, 30-059 Kraków, Poland. *Shadowing property and supports of invariant measures.*

By classical results of Sigmund, ergodic measures are dense in the space of invariant measures, when the system has specification property (and these measures are supported on periodic orbits).

We show that when a transitive system has shadowing property then ergodic measures supported on odometers are dense, and ergodic measures on almost 1-1 extensions of odometers can approximate invariant measures together with their entropy. In particular, measures with entropy between c and $c + \varepsilon$ are dense in the space of invariant measures with entropy at least c, for every c smaller than entropy of the system. If in addition the entropy function is upper semi-continuous, then ergodic measures with entropy exactly c are generic in the above set. On the other hand, there are dynamical systems with shadowing property but without measure of maximal entropy. (Received March 17, 2017)

1129-37-248 **Matthew Foreman*** (mforeman@math.uci.edu), Mathematics Dept., UC Irvine, Irvine, CA 92697. *A symbolic presentation for odometer based transformations.*

In joint work with B. Weiss we prove that every finite entropy ergodic transformation T with a non-trivial odometer factor can be realized as a cut-and-stack construction where all of the stacks have the same height and no fillers are used. From this we give a presentation of T as a certain type of symbolic subshift. (Received March 17, 2017)

1129-37-284 **Andrey Gogolev***, agogolev@math.binghamton.edu. *Surgery constructions of higher dimensional Anosov flows.*

I will discuss joint work with T. Barthelme, C. Bonatti and F. Rodriguez Hertz. We begin with the geodesic flow on a closed hyperbolic manifold. Then we explain how to excise a neighborhood of a totally geodesic codimension one submanifold and take a "twisted double" which can be equipped with an Anosov flow (derived from the geodesic flow). This yields new examples of higher dimensional Anosov flows (any odd dimension).

The construciton follows the idea of classical Franks-Williams construction of a non-transitive Anosov flow. (Received March 18, 2017)

1129-37-285 **Thomas Bellsky*** (thomas.bellsky@maine.edu), Department of Mathematics & Statistics, University of Maine, Orono, ME 04469. *Stalking methods for ensemble Kalman filter covariance inflation.*

The artificial inflation of ensembles is a common technique in ensemble data assimilation whereby the ensemble variance is increased in order to prevent deviation of the ensemble from the truth. Various techniques for inflating ensembles exist in the literature. This talk will discuss shadowing and stalking methods and our implementation of stalking techniques as a method of ensemble inflation. We will also offer results from a low order chaotic system supporting the use of stalking methods. (Received March 18, 2017)

1129-37-326 **Moisey Guysinsky*** (mxg30@psu.edu), 109 McAllister Bld, University Park, PA 16802. *Splitting of of the Mather-Sacker-Sell spectrum over hyperbolic systems with Lyapunov exponents almost constant at periodic points.* Preliminary report.

Let X be a compact metric space and TX a vector bundle over X, $\Gamma(TX)$ a Banach space of continuos vector fields. If $f : X \to X$ is a homeomorphism and $A(x) : T_x \to T_{f(x)}$ is a continuos family of linear maps we can define an operator $B : \Gamma(TX) \to \Gamma(TX)$ as $B(v)(x) = A_{f^{-1}(x)}(v(f^{-1}(x))$. The spectrum of the complexification of this operator was first studied by J.Mather in the case when X is a manifold, f is differentiable and $A(x) = Df(x)$. In the general case this spectrum was studied by R.Sacker and G.Sell. Under a mild condition the spectrum consists from several disjoint rings and the splitting of the spectrum of this operator implies splitting of $\Gamma(TX)$ in invariant subbundels. We show that if $f, A(x)$ are Hölder continuous, f is hyperbolic, then closeness of Lyapunov exponents to constants at periodic points implies splitting of the spectrum. This result has several applications (Received March 19, 2017)

1129-37-345 **Jim Wiseman*** (jwiseman@agnesscott.edu), Department of Mathematics, Agnes Scott College, 141 E. College Ave., Decatur, GA 30030. *Generalized recurrence for powers and products.*

For a continuous map f of a compact metric space, Fathi and Pageault have recently shown a connection between Auslander's generalized recurrent set $GR(f)$ and Easton's strong chain recurrent set. We exploit that result to examine the relationships among $GR(f)$, $GR(f^k)$, and $GR(f \times g)$, as well as the connections between generalized recurrence and other types of topological recurrence. (Received March 20, 2017)

1129-37-353 **Mahesh G Nerurkar*** (nmahesh@camden.rutgers.edu), 311 N 5th Street, Department of Mathematics, Rutgers University, Camden, NJ 08102. *Tau topology on Aut(M) and a question regarding the difference of syndetic sets.* Preliminary report.

We shall discuss an approach to proving a conjecture, (independently due to R. Ellis and Y. Katznelson) and for abelian acting groups give a proof. The abelian case is a joint work with David Ellis. (Received March 20, 2017)

1129-37-374 **David B Ellis*** (ellis@beloit.edu), Beloit College, Box 82, Beloit, WI 53511. *Automorphism Groups in Topological Dynamics.*

The τ-closed subgroups of the group G of automorphisms of the universal minimal flow play a fundamental role in the algebraic theory of Topological Dynamics. As examples I will discuss the derived group G', the distal group D, and the equicontinuous group E, and their relationship to the Furstenburg structure theorem and the equicontinuous structure relation. (Received March 20, 2017)

1129-37-392 **Mark F Demers*** (mdemers@fairfield.edu), 1073 North Benson Road, Fairfield, CT 06611. *Exponential decay of correlations for Sinai billiard flows.*

While billiard maps for large classes of dispersing billiards are known to enjoy exponential decay of correlations, the corresponding flows have so far resisted such analysis. We describe recent results, based on the construction of function spaces on which the associated transfer operator has good spectral properties, which provide a description of the spectrum of the generator of the semi-group. This construction, together with a Dolgopyat-type cancellation argument to eliminate certain eigenvalues, proves that the generator has a spectral gap and that the Sinai billiard flow with finite horizon has exponential decay of correlations. This is joint work with V. Baladi and C. Liverani. (Received March 20, 2017)

1129-37-426 **Ethan Akin*** (ethanakin@earthlink.net), Department of Mathematics, The City College of New York, Convent Ave at 138th Street, New York, NY 10031. *Approximation Dynamics.* Preliminary report.

We consider the approximation of a continuous map on a p.l. manifold or the Cantor set by one with tractable dynamics. (Received March 20, 2017)

1129-37-439 **Avraham Goldstein*** (avraham.goldstein.nyc@gmail.com), 76-19 168th Street, Flushing, NY 11366. *Plaque Inverse Limit of a Dynamical System - Dynamics, Signatures and Local Topology.* Preliminary report.

Signatures of points in Plaque Inverse Limit of a branched covering self-map of a Riemann surface were introduced by Cabrera, Cherif and Goldstein in "On the topology of the inverse limit of a branched covering over a Riemann surface", shown to be a local invariants of P.I.L. and computed for the invariant lifts of super-attracting, attracting cycles, and certain parabolic cycles. All these signatures have a maximal element.

We show that the local topology of P.I.L. at irregular points differ, depending on the types of signatures at these points. Specifically, the local topology at an irregular point x has a property, that for any small neighborhood V of x there exists a point $y \neq x$ in V such that the open set $V - \{y\}$ consists of an uncountable number of path-connected components, if and only if some signature of x has no maximal element. Additionally, we discuss cases, in which some signature of the invariant lift of a parabolic cycle has no maximal element. Finally, we prove a stronger version of Mañé's Theorem, which asserts that all other irregular points, except the invariant lifts of super-attracting, attracting, and parabolic cycles, have a signature with no maximal element with respect to some recurrent critical point. (Received March 21, 2017)

1129-37-452 **Alica Miller*** (a0mill01@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292. *Some properties of the products of semiflows.* Preliminary report.

We will talk about some properties of the products of semiflows, in particular, about transitivity, mixing properties, sensitivity and mean sensitivity. (Received March 21, 2017)

1129-37-520 **Raluca Tanase*** (raluca.tanase@stonybrook.edu), SUNY at Stony Brook, Stony Brook, NY 11794-3660. *Dynamics of germs of holomorphic diffeomorphisms of* $(\mathbb{C}^n, 0)$.

In this talk we will discuss the dynamics and asymptotic properties of germs of holomorphic diffeomorphisms of $(\mathbb{C}^n, 0)$ with a fixed point at the origin with exactly one neutral eigenvalue. This is based on joint work with T. Firsova, M. Lyubich, and R. Radu. (Received March 21, 2017)

39 ► Difference and functional equations

1129-39-51 **William T Jamieson*** (w.jamieson@snhu.edu), 2500 North River Road, Manchester, NH 03106-1045. *Global Behavior of the Classical Nicholson-Bailey Model.*

In 1935, Nicholson and Bailey proposed the following model for the interaction between the Greenhouse Whitefly and a parasitoid wasp *Encarsia formosa*:

$$\begin{aligned} x_{n+1} &= c\, y_n \left(1 - e^{-a x_n}\right) \\ y_{n+1} &= \lambda\, y_n\, e^{-a x_n} \end{aligned} \tag{1}$$

In system (1), c is the number of viable eggs laid by the parasitoid, a is the searching efficiency of the parasitoid, and λ is the growth rate of the host. A proof that all non-trivial solutions of (1) are unbounded when $\lambda > 1$ will be presented. (Received February 21, 2017)

1129-39-133 **David Timothy McArdle*** (dmcardle@uri.edu), 5 Lippitt Road, Kingston, RI 02881. *Global Dynamics and Boundedness of a 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 $\alpha, \beta, \gamma, \delta$ are nonnegative real numbers, and 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 March 10, 2017)

1129-39-162 **Yevgeniy Kostrov*** (kostrovy@mville.edu), Manhattanville College, 2900 Purchase st, Purchase, NY 10577, and **Zachary Kudlak** (zkudlak@monmouth.edu), Zachary Kudlak, Monmouth University, Department of Mathematics, West Long Branch, NJ 07764,. *On a Second-Order Rational Difference Equation with a Quadratic Term.*

We give the boundedness character, local and global stability of solutions of the following second-order rational difference equation with quadratic denominator,

$$x_{n+1} = \frac{\alpha_\gamma x_{n-1}}{Bx_n + Dx_n x_{n-1} + x_{n-1}}, \quad \text{for } n = 0, 1, \ldots$$

where the coefficients are positive numbers, and the initial conditions x_{-1} and x_0 are nonnegative numbers such that the denominator is nonzero. In particular, we show that in a certain region, the unique equilibrium is globally asymptotically stable, while in another region, the equilibrium is a saddle and there exist prime period-two solutions. (Received March 13, 2017)

1129-39-211 **Gleb Pogudin***, Julius-Raab Str., 10, 140, 4040 Linz, Austria. *On the effective difference Nullstellensatz.*

While modelling a discrete-time system, it is natural to assign a sequence of numbers in which the i-th number is equal to the value of the parameter at the i-th moment in time to every parameter of the system. There are usually several parameters with some relations among them. For every i-th moment in time, these relations can be written as equations in the values of the parameters at this moment and some neighboring moments. It is assumed that these equations are the same for all moments in time up to shifting the indices.

A natural question to ask is whether such an infinite system of equations corresponding to the model has a solution. In this talk, we will describe cases in which this problem can be solved algorithmically using effective upper bounds.

This is joint work with Alexander Levin and Alexey Ovchinnikov. (Received March 16, 2017)

1129-39-233 **Ying Sue Huang*** (yhuang@pace.edu), Department of Mathematics, Pace University, Pleasantville, NY 10570, and **Peter Knopf**. *Convergence of Solutions of the First Order Quadratic-Quadratic Rational Difference Equations.*

Consider the first order difference equations of the form $x_{n+1} = f(x_n)$. The convergence properties are established for a general class of mappings f; where f has at most one critical point. These results can be applied to study the first order quadratic-quadratic rational difference equations of form:

$$x_{n+1} = \frac{Ax_n^2 + Bx_n + C}{\alpha x_n^2 + \beta x_n + \gamma}.$$

The necessary and sufficient conditions are obtained for the convergence of the solutions for all possible choices of non-negative coefficients and positive initial values. (Received March 16, 2017)

1129-39-249 **mustafa r.s. kulenovic***, department of mathematics, university of rhode island, kingston, RI 02881. *KAM theory and time reversal symmetries for certain rational system of difference equations.*

By using the KAM theory and time reversal symmetries we investigate the stability of the equilibrium solutions of the system:

$$\left\{ \begin{array}{lcl} x_{n+1} & = & \frac{a}{x_n + y_n} \\ y_{n+1} & = & \frac{x_n}{y_n} \end{array} \right. , \quad n = 0, 1, 2, \ldots,$$

where the parameter $a > 0$, and initial conditions x_0 and y_0 are positive numbers. We obtain the Birkhoff normal form for this system and prove the existence of periodic points with arbitrarily large periods in every neighbourhood of the unique positive equilibrium. We also use the time reversal symmetry method to find effectively some feasible periods and the corresponding periodic orbits. (Received March 17, 2017)

1129-39-256 **Elliott J. Bertrand*** (ebertrand@uri.edu), Department of Mathematics, University of Rhode Island, 5 Lippitt Road, Kingston, RI 02881, and **M. R. S. Kulenović**. *A Generalization of Lyness' Equation.* Preliminary report.

In their text *Dynamics of Second Order Rational Difference Equations*, Kulenović and Ladas posed an open problem that asked for necessary and sufficient conditions in terms of f so that every positive solution of the generalized Lyness-type difference equation

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

is bounded, where the initial conditions x_{-1} and x_0 are positive numbers and $f \in C[(0,\infty),(0,\infty)]$. We investigate this problem by considering Equation (1) with the function $f(x) = \alpha + x^p$, where $\alpha \geq 0$ and $p \in \mathbb{R}$:

$$x_{n+1} = \frac{\alpha + x_n^p}{x_{n-1}}, \quad n = 0, 1, \ldots. \tag{2}$$

When $p = 1$, Equation (2) is exactly Lyness' equation. We show that for certain values of p, Equation (2) possesses a unique elliptic fixed point. Furthermore, we will attempt to use the KAM theory to prove the stability of this fixed point and show boundedness of solutions for certain values of the parameter p. We will also examine a few special cases of Equation (2), especially those known to possess an invariant. (Received March 17, 2017)

1129-39-259 **Peter M Knopf*** (pknopf@pace.edu), 861 Bedford Rd., Pace University, Department of Mathematics, Pleasantville, NY 10570, and **Ying Sue Huang**, .. *Boundedness Properties of the Difference Equation* $x_{n+1} = \frac{\alpha + x_n}{Cx_{n-1} + x_{n-2}}$. Preliminary report.

We consider the difference equation

$$x_{n+1} = \frac{\alpha + x_n}{Cx_{n-1} + x_{n-2}}$$

with $\alpha > 0$ and $C > 0$. In 2006, Amleh, Camouzis, and Ladas conjectured that if $\alpha C^2 \geq 1$, then for all positive initial conditions the solutions of the difference equations are bounded. If $\alpha C^2 < 1$, then there exists positive initial conditions such that the solutions are unbounded. We completely solve this conjecture. (Received March 17, 2017)

1129-39-349 **Toufik Khyat*** (toufik17@uri.edu), Kingston, RI 02881, and **Mustafa Kulenovic**. *Global Dynamics for Competitive Maps in the Plane.*

In this paper we give some possible dynamic scenarios for general competitive maps in the plane. We apply these results to some cases of second order difference equation

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

which is decreasing in the variable x_n and increasing in the variable x_{n-1}. We illustrate our results with the application to

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

where the initial conditions x_{-1} and x_0 are arbitrary nonnegative numbers and the parameters satisfy $C, D, F, c, d, f \geq 0$, $C + D + F > 0$, $c + d + f > 0, c + D > 0$, and $C + d > 0$. In the special case $D = F = 0$, we characterize completely the global dynamics of this equation with the basins of attraction of its equilibria and periodic solutions.

(Received March 20, 2017)

40 ► Sequences, series, summability

1129-40-433 **Marina Skyers*** (mus61@psu.edu). *Representations of the Simple Random Walk on (0,1).*

In this talk we will investigate representations of the simple random walk on (0,1), S_n, and how to effectively rearrange the sequence of terms $S_n/\sqrt{n}$ in order to achieve almost sure convergence to the standard normal on (0,1). An important question is how much rearranging of the S_n is optimal. One direction attempts to minimize the graph-theoretic complexity of the permutations corresponding to these representations of S_n. One approach would be to minimize the lengths of cycles. (Received March 21, 2017)

41 ► Approximations and expansions

1129-41-28 **Alexander M. Powell***, Department of Mathematics, Vanderbilt University, Nashville, TN 37240, and **Anneliese H. Spaeth**, Department of Mathematics, Huntingdon College, Montgomery, AL 36106. *Nonnegativity constraints for structured complete systems.*

We investigate nonnegativity as an obstruction to various forms of structured completeness in Lp spaces. For example, we prove that if each element of a system of functions in Lp is pointwise nonnegative, then the system cannot be an unconditional basis or unconditional quasibasis (unconditional Schauder frame) for Lp. In particular, in L2 this precludes the existence of nonnegative Riesz bases and frames. On the other hand, there exist pointwise nonnegative conditional quasibases in Lp, and there also exist pointwise nonnegative exact systems and Markushevich bases in Lp. (Received January 23, 2017)

1129-41-204 **B. Currey*** (curreybn@slu.edu), Department of Mathematics and Statistics, Saint Louis University, St. Louis, MO 63103, **H. Fuehr** (fuehr@matha.rwth-aachen.de), Lehrstuhl A fur Mathematik, RWTH Aachen University, D-52056 Aachen, Germany, and **V. Oussa** (voussa@bridgew.edu), Department of Mathematics, Bridgewater State University, Bridgewater, MA 02324. *Classification of continuous wavelet transforms in dimension three.*

We present a full catalogue, up to conjugacy and subgroups of finite index, of all matrix groups $H < \mathrm{GL}(3,\mathbb{R})$ that give rise to a continuous wavelet transform with associated irreducible quasi-regular representation. For each group in this class, coorbit theory allows to consistently define spaces of sparse signals, and to construct atomic decompositions converging simultaneously in a whole range of these spaces. As an application of the classification, we investigate the existence of compactly supported admissible vectors and atoms for the groups. (Received March 15, 2017)

42 ► Fourier analysis

1129-42-23 **Luboš Pick*** (pick@karlin.mff.cuni.cz), KMA MFF UK, Sokolovská 83, 18675 Praha 8, Czech Rep. *How not to leave traces.*

A trace is an important subject in the study of properties of weakly differentiable functions on $\mathbb{R}^n$ and in particular of its applications to boundary value problems. In a generalized sense, a trace represents the restriction of a function to a submanifold of lower dimension, d. While the theory works quite beautifully provided that this d is not too small, things turn into a total havoc when d is smaller than the critical value $n-m$, where m, $m < n$, is the highest order of the weak derivatives involved. A reasonable person would at this stage leave traces and do something more sensible. We do not leave traces. Instead, we develop a new method of dealing with this subcritical case, based on combination of recent potential estimates by Korobkov and Kristensen and a fairly general concept of Frostman measures. This is a joint work with Andrea Cianchi of Firenze and Lenka Slavíková of Columbia, MO. (Received January 17, 2017)

1129-42-68 **John Herr** (jeherr@butler.edu), Department of Mathematics, Indianapolis, IN 46208, **Palle E. T. Jorgensen** (palle-jorgensen@uiowa.edu), Department of Mathematics, Iowa City, IA 52242, and **Eric Weber*** (esweber@iastate.edu), Department of Mathematics, 396 Carver Hall, 411 Morrill Rd., Ames, IA 50011. *Boundary Representations of Reproducing Kernels in the Hardy Space.*

For a singular probability measure μ on the circle, we show the existence of positive matrices on the unit disc which admit a boundary representation on the unit circle with respect to μ. These positive matrices are constructed in several different ways using the Kaczmarz algorithm. Some of these positive matrices correspond to the projection of the Szegő kernel on the disc to certain subspaces of the Hardy space corresponding to the normalized Cauchy transform of μ. Other positive matrices are obtained which correspond to subspaces of the Hardy space after a renormalization, and so are not projections of the Szegő kernel. We show that these positive matrices are a generalization of a spectrum or Fourier frame for μ, and the existence of such a positive matrix does not require μ to be spectral. (Received March 02, 2017)

1129-42-83 **Chun-Kit Lai***, 1600 Holloway Ave, San Francisco, CA 94132-1722, and **Sui Tang** (stang@math.jhu.edu). *Undersampled Windowed Exponentials, Spectra of Toeplitz operators and its Applications.*

We characterize the completeness and frame/basis property of a class of under-sampled windowed exponentials by the spectra of the Toeplitz operators of different symbols. As an application, we answer some open questions in dynamical sampling, phase retrieval and derivative samplings on $\ell^2(\mathbb{Z})$ and Paley-Wiener spaces of bandlimited functions. (Received March 04, 2017)

1129-42-188 **Li-An Daniel Wang*** (daniel.wang@shsu.edu), Dept of Mathematics and Statistics, PO Box 2206, 1900 AVENUE I LDB STE 420, Huntsville, TX 77380, and **David Cruz-Uribe** (dcruzuribe@ua.edu). *Variable Muckenhoupt Weights.* Preliminary report.

The variable L^p spaces allow the exponent p to be a function with values between 1 and infinity. A sizable theory has been developed on these spaces, such as the boundedness of maximal and singular integral operators on these spaces. A natural development is adapting the classical A^p weights to the variable setting. In this talk, we contrast the classical weights and variable weights, and see what properties hold in the variable case. In particular, we have a "reverse factorization" result that allows us to construct variable weights. This is joint work with David Cruz-Uribe (University of Alabama). (Received March 14, 2017)

1129-42-194 **David V. Cruz-Uribe*** (dcruzuribe@ua.edu), Department of Mathematics, Box 870350, University of Alabama, Tuscaloosa, AL 35487-0350, and **Virginia Naibo**. *Kato-Ponce inequalities on weighted and variable Lebesgue spaces.*

We prove fractional Leibniz rules and related commutator estimates in the settings of weighted and variable Lebesgue spaces. Our main tools are uniform weighted estimates for sequences of square-function-type operators and a bilinear extrapolation theorem. Our work extends recent results by Grafakos and Ou, but to get weighted estimates we developed new techniques. If time permits we will also discuss other applications of our extrapolation theorem to prove variable Lebesgue space estimates for certain bilinear multiplier operators and singular integrals; these results are new or improve on results in the literature. (Received March 15, 2017)

1129-42-217 **Michael C. Northington V*** (mcnv3@gatech.edu), **Shahaf Nitzan** and **Alexander Powell**. *Constraints on periodic Fourier Multipliers with applications to the Balian-Low Theorem.* Preliminary report.

The Balian-Low Theorem states that if the integer-lattice Gabor system generated by a square-integrable function forms a Riesz basis for $L^2(\mathbb{R})$, then the function must be poorly localized in either time or frequency. In this talk, I will discuss several sharp results of this nature which hold either for Gabor systems or shift-invariant spaces and where the Riesz basis assumption is replaced by a weaker basis-type property. I will also show that these results follow from a theorem placing constraints on Fourier multipliers between sequence spaces. (Received March 16, 2017)

1129-42-268 **Frank T Burbrink*** (fburbrink@amnh.org), Central Park West at 79th Street, New York, NY 10024-5192, and **Marcelo Gehara** (fburbrink@amnh.org), Central Park West at 79th Street, New York, NY 10024-5192. *The reticulating phylogenetic history of the kingsnakes.* Preliminary report.

While the tree of life is often represented as bifurcating and all downstream comparative approaches also make this assumption, it is clear that gene flow among well-established species is common. It follows then that phylogeny for many groups should be represented as a network. Here we examine phylogenetic history of the New World kingsnakes and milksnakes using genomic data and recently developed computational methods that account for both incomplete lineage sorting and horizontal gene flow. Coupled with several gene interrogation approaches, we show that indeed the evolutionary history of these snakes likely included at least one deep time reticulation. Moreover, expanding comparative methods, we also determine the biogeographic location of these ancient hybridization events. (Received March 17, 2017)

1129-42-269 **Sergey Tikhonov***, Campus de Bellaterra, Edifici C, 08193 Barcelona, Spain. *Polynomial inequalities in weighted Lebesgue spaces.*

We will discuss several polynomial inequalities (Bernstein, Reverse Hölder, Remez) in the weighted L_p spaces. Various conditions on weights will be considered. Partially based on the joint paper with A. Bondarenko (NTNU). (Received March 17, 2017)

1129-42-321 **Steven Hofmann*** (hofmanns@missouri.edu). *Harmonic measure and rectifiability.*

A classical theorem of F. and M. Riesz, proved more than 100 years ago, established mutual absolute continuity of harmonic measure and arc length measure, on the boundary of a simply connected domain in the complex plane with a rectifiable boundary. In this talk, we shall discuss recent progress towards understanding the relationship between absolute continuity properties of harmonic measure in a domain $\Omega \subset \mathbb{R}^d$, and rectifiability of the boundary of Ω. (Received March 19, 2017)

1129-42-445 **Alex Iosevich*** (iosevich@gmail.com), Hylan 909, Rochester, NY 14627. *On Gabor bases and frames in vector spaces over finite fields.*

We shall discuss some recent developments pertaining to the existence of orthogonal Gabor bases in vector spaces over finite fields. (Received March 21, 2017)

1129-42-482 **Wilfredo O Urbina-Romero*** (wurbinaromero@roosevelt.edu), Roosevelt University, Department of Math & Actuarial Sciences, 430 S Michigan Ave, Chicago, IL 60605, **Ebner Pineda** (ebner.pineda@gmail.com), Universidad Centro-Occidental, Lisandro Alvarado Facultad de Ciencias, Departamento de Matemáticas, Barquisimeto, Venezuela, and **Jorge Moreno**, Universidad Centro-Occidental, Lisandro Alvarado Facultad de Ciencias, Departamento de Matemáticas, Barquisimeto, Venezuela. *Topics on Gaussian harmonic analysis on Lp variables spaces.* Preliminary report.

This is a work in progress. We study the boundedness of the Gaussian Hardy-Littlewood maximal function (with generalizations to general probability measures) and the boundedness of the Ornstein-Uhlenbeck semigroup in variable L^p- spaces. It turns out that, different from the classical case, in this context the Ornstein-Uhlenbeck semigroup is not a contractive semigroup and therefore is not hyper-contractive either. (Received March 21, 2017)

1129-42-485 **Guozhen Lu*** (guozhen.lu@uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269, and **Qiaohua Yang** (qhyang.math@gmail.com), School of Mathematical and Statistics, Wuhan University, Wuhan, Hubei , Peoples Rep of China. *Sharp Hardy-Adams inequalities on hyperbolic spaces and Hardy-Sobolev-Maz'ya inequalities for higher order derivatives on half spaces.*

We establish sharp Hardy-Adams inequalities on hyperbolic spaces $\mathbb{B}^n$ in all dimension $n \geq 4$when n is even. Our theorem in dimension four reads as follows: For any $\alpha > 0$ there exists a constant $C_\alpha > 0$ such that

$$\int_{\mathbb{B}^4} (e^{32\pi^2 u^2} - 1 - 32\pi^2 u^2) dV = 16 \int_{\mathbb{B}^4} \frac{e^{32\pi^2 u^2} - 1 - 32\pi^2 u^2}{(1 - |x|^2)^4} dx \leq C_\alpha.$$

for any $u \in C_0^\infty(\mathbb{B}^4)$ with

$$\int_{\mathbb{B}^4} \left(-\Delta_{\mathbb{H}} - \frac{9}{4}\right) (-\Delta_{\mathbb{H}} + \alpha) u \cdot u dV \leq 1.$$

As applications, we obtain an much improved Adams inequality on n-dimensional hyperbolic space and an inequality which improves the classical Adams' inequality and Hardy's inequality simultaneously.

We also establish Hardy-Sobolev-Maz'ya inequalities for higher order derivatives on half spaces. The proof depends on a Hardy-Littlewood-Sobolev inequality on hyperbolic space which is of independent interest. We also give an alternative proof of Benguria, Frank and Loss concerning the sharp constant in the Hardy-Sobolev-Maz'ya inequality in the three dimensional upper half space.

The Fourier analysis on hyperbolic spaces play an important role in our proofs. (Received March 21, 2017)

43 ► Abstract harmonic analysis

1129-43-394 **Joseph W. Iverson*** (jiverson@math.umd.edu), Department of Mathematics, William E. Kirwan Hall, 4176 Campus Dr, College Park, MD 20742. *Zak transform analysis of shift-invariant spaces.*

A subspace $V \subset L^2(\mathbb{R}^n)$ is called *shift invariant* if it is closed under translation by integers. Traditional analysis of shift-invariant spaces relies on the fiberization operator, which applies the Fourier transform for $L^2(\mathbb{R}^n)$ and then examines the cosets of $\mathbb{Z}^n$ on the frequency side. We propose an alternative technique using the Zak transform, which reverses this procedure: it looks at the cosets of $\mathbb{Z}^n$ on the time side, and then applies the Fourier transform for $\ell^2(\mathbb{Z}^n)$. In general, we can replace the pair $(\mathbb{R}^n, \mathbb{Z}^n)$ with (G, H), where G is a locally compact group and H is a closed abelian subgroup. This technique does not require H to be co-compact, or even for G to be abelian. (Received March 20, 2017)

46 ► Functional analysis

1129-46-5 **Hudson Akewe*** (hudsonmolas@yahoo.com), Department of Mathematics, University of Lagos, Yaba, Lagos, Lagos, Nigeria. *Equivalence of Convergence of Jungck-Kirk Type Iterative Schemes for Contrative-like Operators.*

In this paper we prove that the convagences of Jungck-Kirk Mann,Jungck-Ishikawa, Jungck-Kirk Noor and Jungck-Kirk Multistep Iteration Schemes are equivalent for a class to contractive-like Operators. An example is taken to illustrate the applicability of the result. Our result are extension and generalization of several results in literature. (Received October 04, 2016)

1129-46-6 **M Bachar** (mbachar@ksu.edu.sa), Department of Mathematics, King Saud University, Riyadh, Saudi Arabia, and **M A Khamsi*** (mohamed@utep.edu), 500 West University Ave, El Paso, TX 79968. *On nonlinear Fredholm equations in Banach spaces.*

In this talk, we investigate the solutions of the following Fredholm integral equation

$$x(t) = g(t) + \int_I f(t, s, x(s)) ds.$$

This equation may not have a solution in general. Also it may or may not have a unique solution. Throughout this talk, we assume that I is a bounded or unbounded interval of $\mathbb{R}$. (Received November 14, 2016)

1129-46-8 **Shohei Nakamura*** (pokopoko9131@icloud.com), Tokyo, Japan. *Recent development of the weight theory on Morrey spaces.* Preliminary report.

A weight theory is one of important topic on the theory of function spaces and investigated actively. A weight theory on L^p spaces is now well established (Of course, some problems still remain). Meanwhile, we have several generalizations of L^p spaces, especially we will focus on Morrey spaces. It is well known that many facts on L^p spaces can be generalize to Morrey setting in many cases. However, this is not the case when we consider a weight theory because of the structure of Morrey spaces and there is no complete answer even when one weight setting for Morrey spaces. In this talk, we will give recent developments of this problem, one weight theory on Morrey spaces. (Received December 02, 2016)

1129-46-10 **Denny Ivanal Hakim*** (dennyivanalhakim@gmail.com) and **Yoshihiro Sawano**. *Complex Interpolation of Generalized Morrey Spaces.* Preliminary report.

It was shown in [1] that Morrey spaces do not have a good interpolation property. However, there are some recent results on the complex interpolation of Morrey spaces given by Lemarié-Rieusset [2] and Lu et al. [3]. In this talk, we discuss the first and second complex complex interpolation of generalized Morrey spaces. We also present the description of the first and second complex interpolation between L^∞ and the generalized Morrey space $\mathcal{M}_q^\varphi$. Our results can be seen as an extension of the complex interpolation of Morrey spaces in [2, 3]. This is joint work with Yoshihiro Sawano (Tokyo Metropolitan University).

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(Received December 06, 2016)

1129-46-13 **Monther Rashed Alfuraidan*** (monther@kfupm.edu.sa), P O Box 1285, Dhahran, Eastern 31261, Saudi Arabia. *Topological aspects of weighted graphs with application to fixed point theory.*

In this talk, we introduce new concepts of G-monotone sequences, G-bounded and G_τ-compact nonempty subsets of the set of vertices of a weighted digraph G, where τ is a sequential convergence. We also provide an application to metric fixed point theory.
(Received December 25, 2016)

1129-46-24 **Ryan M Causey*** (causeyrm@miamioh.edu), 2265 Joshua Circle, Middletown, OH 45044. *Asplund operators and renormings.*

We discuss asymptotically uniformly smooth and asymptotically uniformly convex operators, as well as transfinite generalizations of these notions. We discuss duality, renormings, ideal properties, and non-linear characterizations associated with classes of ξ-asymptotically uniformly smooth and ξ-asymptotically uniformly convex operators.
(Received January 18, 2017)

1129-46-43 **Igor V. Nikolaev*** (igor.v.nikolaev@gmail.com), St. John's University, 8000 Utopia Parkway, New York, NY 11439. *Cluster C*-algebras and knot polynomials.* Preliminary report.

We construct a representation of the braid groups in a cluster C*-algebra coming from a triangulation of the Riemann surface S with one or two cusps. It is shown that the Laurent polynomials attached to the K-theory of such an algebra are topological invariants of the closure of braids. In particular, the Jones and HOMFLY polynomials of a knot correspond to the case S being a sphere with two cusps and a torus with one cusp, respectively. Reference: arXiv:1603.01180 (Received February 06, 2017)

1129-46-66 **Alexander A Katz*** (katza@stjohns.edu), St. John's University, SJC, Dep. of Math & CS, 8000 Utopia Parkway, SJH-334-G, Queens, NY 11439. *On C*-algebras over Stone algebras.*

We discuss Banach-Kantorovich complex *-algebras over Stone algebras (the algebras of continuous complex-valued functions on Stonean compact Hausdorff spaces, taking infinite values on nowhere dense subsets only), their basic properties and applications. (Received March 01, 2017)

1129-46-70 **Mishko Mitkovski** and **Aaron E Ramirez Flores*** (aeramir@g.clemson.edu). *Density results for continuous frames.*

We derive necessary conditions for localization of two continuous frames in terms of generalized Beurling densities, where the localization is understood as follows: for any $\epsilon > 0$ there exists $R > 0$ such that

$$\left| \int_{B^c} \int_B \langle g_x, f_y \rangle \left\langle \widetilde{f_y}, \widetilde{g_x} \right\rangle d\mu(y) d\nu(x) - \int_{B^c} \int_B \langle g_x, f_y \rangle \left\langle \widetilde{f_y}, \widetilde{g_x} \right\rangle d\nu(x) d\mu(y) \right| < \epsilon(\mu + \nu)(B)$$

for all $r \geq R$ and all $B = B(a, r)$.

As an important application we provide necessary density conditions for sampling and interpolation in a very large class of reproducing kernel Hilbert spaces. (Received March 02, 2017)

1129-46-71 **Oleg Friedman*** (friedman001@yahoo.com), Lander College for Men / Touro College, Department of Mathematics, 75-31 150th Street, Kew Gardens Hills, NY 11367, and **Alexander A Katz** (katza@stjohns.edu), St. John's University, SJC, Department of Math & CS, 8000 Utopia Parkway, SJH-334-G, Queens, NY 11439. *On Real and Jordan Structures in Locally C*-algebras.*

We discuss real locally C*- and locally JB-algebras, their structure theory and representstions, and relation to the theory of complex locally C*-algebras. (Received March 02, 2017)

1129-46-82 **Sofya S Masharipova*** (smasharipova@saumag.edu), 100 E. University, MSC 9243, Dept of Math and CS, Magnolia, AR 71753, and **Shukhrat M Usmanov** (shukhrat.usmanov@waldorf.edu), 106 South 6 Street, Waldorf University, Dept of Mathematics, Forest City, IA 50436. *Positivity and geometry of unit balls in operator algebras on Pontryagin space* Π_1. Preliminary report.

In the work we study the positivity for operators and linear mappings on symmetric algebras of bounded linear operators on Pontryagin space Π_1. Consideration of all possible cases is based on structure of cones of positive linear operators. Geometry of unit balls of symmetric algebras of operators on Pontryagin space π_1 is studied. Connection with V. S. Shulman's types of such algebras is described (see Math. Sbornik, 1972, No 2). (Received March 03, 2017)

1129-46-88 **Kasper Green Larsen** and **Jelani Nelson*** (minilek@seas.harvard.edu), Maxwell Dworkin 125, 33 Oxford Street, Cambridge, MA 02138. *Optimality of the Johnson-Lindenstrauss lemma.*

We consider the question: given integers $n, d > 1$, and some $0 < \varepsilon < 1$, what is the minimum value of m such that for all n-point subsets $X \subset \ell_2^d$, there exists an embedding $f : X \to \ell_2^m$ with distortion at most $1 + \varepsilon$? We show that for nearly the full range of interest for the parameters n, d, and ε, the Johnson-Lindenstrauss lemma is tight: there exists an n-point subset of d-dimensional Euclidean space such that any such f must have $m \gtrsim \varepsilon^{-2} \log n$. (Received March 05, 2017)

1129-46-94 **J. Alejandro Chávez-Domínguez***, Department of Mathematics, University of Oklahoma, Norman, OK 73019-3103. *An Ando-Choi-Effros lifting theorem respecting subspaces.*

We prove a version of the Ando-Choi-Effros lifting theorem respecting subspaces, which in turn relies on Oja's principle of local reflexivity respecting subspaces. To achieve this, we first develop a theory of pairs of M-ideals. As a first consequence we get a version respecting subspaces of the Michael-Pełczyński extension theorem. Other applications are related to linear and Lipschitz bounded approximation properties for a pair consisting of a Banach space and a subspace. We show that in the separable case, the BAP for such a pair is equivalent to the simultaneous splitting of an associated pair of short exact sequences given by a construction of Lusky. We define a Lipschitz version of the BAP for pairs, and study its relationship to the (linear) BAP for pairs. The two properties are not equivalent in general, but they are when the pair has an additional Lipschitz-lifting property in the style of Godefroy and Kalton. We also characterize, in the separable case, those pairs of a metric space and a subset whose corresponding pair of Lipschitz-free spaces has the BAP. (Received March 06, 2017)

1129-46-109 **R. M. Causey**, Department of Mathematics, Miami University, Oxford, OH 45056, and **S. J. Dilworth***, Department of Mathematics, University of South Carolina, Columbia, SC 29208. *Metric Characterizations of Super Weakly Compact Operators.*

We define the notion of factorization of a family of metric spaces through a bounded, linear operator between Banach spaces. This notion serves as the analogue of uniform bi-Lipschitz embeddings of this family of metric spaces into a given Banach space. We prove operator versions of well-known non-linear characterizations of superreflexivity due to Bourgain, Johnson and Schechtman, and Baudier. More precisely, we give a non-linear characterization of non-super weakly compact operators as those through which the binary tree, diamond, and Laakso graphs may be factored with uniform distortion. (Received March 08, 2017)

1129-46-114 **Anatoly G Baskakov** and **Ilya A Krishtal*** (ikrishtal@niu.edu), Northern Illinois University, Department of Mathematical Sciences, Watson Hall 320, DeKalb, IL 60115. *Bounded uniform partitions of unity, localization, and approximation.*

The talk illustrates how bounded partitions of unity and related systems of functions may be used to define various subspaces and submodules of Banach function spaces that possess useful localization and/or approximation properties. For example, we will describe the subspace of functions with absolutely summable spectrum which is a generalization of the Wiener algebra. We will also describe versions of Wiener's Lemma and Paley-Wiener's theorem that can be obtained in this setting. (Received March 08, 2017)

1129-46-121 **Shukhrat Usmanov*** (shukhrat.usmanov@waldorf.edu), Waldorf University, Department of Mathematics, 106 South 6th Street, Forest City, IA 50436, and **Sofya Masharipova**. *Flows of weights on real factors of type III.*

In the work we define and study a flow of weights in sense of Connes-Takesaki on real von Neumann factors of type III. It is well know that there exist non-isomorphic real factors of type III_λ, such that its generating isomorphic enveloping (complex) factors. We show that σ-finite non-isomorphic real factors of type $III_\lambda, 0 < \lambda \leq 1$, have non-isomorphic smooth flows of weights. (Received March 09, 2017)

1129-46-131 **Konstantin Makarychev** (konstantin@northwestern.edu) and **Yury Makarychev*** (yury@ttic.edu). *A Union of Euclidean Metric Spaces is Euclidean.*

Suppose that a metric space X is the union of two metric subspaces A and B that embed into Euclidean space with distortions D_A and D_B, respectively. We prove that then X embeds into Euclidean space with a bounded distortion (namely, with distortion at most $7D_AD_B + 2(D_A + D_B)$). Our result settles an open problem posed by Naor. Additionally, we present some corollaries and extensions of this result. (Received March 10, 2017)

1129-46-146 **Anna H Kaminska*** (kaminska@memphis.edu) and **Hyung-Joon Tag**. *Diameter of weak neighborhoods and the Radon-Nikodým property in Orlicz-Lorentz spaces.*

Given an Orlicz convex function φ and a positive weight w we present criteria of diameter two property and of Radon-Nikodým property in the Orlicz-Lorentz function and sequence spaces, $\Lambda_{\varphi,w}$ and $\lambda_{\varphi,w}$, respectively. We show that in the spaces $\Lambda_{\varphi,w}$ or $\lambda_{\varphi,w}$ equipped with the Luxemburg norm, the diameter of any relatively weakly subset of the unit ball in these spaces is two if and only if φ does not satisfy the appropriate growth condition Δ_2, while they do have the Radon-Nikodým property if and only if φ satisfies the appropriate condition Δ_2. (Received March 11, 2017)

1129-46-158 **Florent P Baudier*** (florent@math.tamu.edu), Department of Mathematics, College Station, TX 77843-3368, and **Ryan Causey** (causeyrm@miamioh.edu), **Steve Dilworth** (dilworth@math.sc.edu), **Denka Kutzarova** (denka@math.uiuc.edu), **Nirina L Randrianarivony** (nrandria@slu.edu), **Thomas Schlumprecht** (schlump@math.tamu.edu) and **Sheng Zhang** (sheng@home.swjtu.edu.cn). *Geometry of the diamond graphs: what's new and what's next.*

Recently, the geometry of finite and infinite diamond graphs has been better understood. As is well known, the Lipschitz geometry of these graphs turned out to be fundamental regarding the dimension reduction problem in ℓ_1. In this talk we will review what is known about the embeddability of the diamond graphs into classical, and more general, Banach spaces. In particular we will discuss the recent work of the speaker and his collaborators (R. Causey, S. Dilworth, D. Kutzarova, N. L. Randrianarivony, Th. Schlumprecht, S. Zhang) about the geometry of the countably branching diamond graphs, and the work of B. Randrianantoanina and M. I. Ostrovskii on the finitely branching diamond graphs. Some open problems will be mentioned. (Received March 12, 2017)

1129-46-163 **Anthony Weston*** (westona@canisius.edu), 2001 Main St, Buffalo, NY 14208. *The geometry of two-valued subsets of L_p-spaces.*

The purpose of this talk will be to examine negative type properties of two-valued subsets of L_p-spaces. By definition, a set $B \subset L_p(\Omega, \mu)$ is *two-valued* if $|B| > 1$ and the essential range of each $f \in B$ is a subset of $\{0, 1\}$. This study was motivated by the following theorem of Mathav Murugan:

> Suppose $k, n \geq 1$. A subset $B = \{\mathbf{x}_0, \mathbf{x}_1, \ldots, \mathbf{x}_k\}$ of the Hamming cube $\{0, 1\}^n \subset \ell_1^{(n)}$ is affinely independent if and only if B has strict 1-negative type.

In this talk we will discuss how to generalize Murugan's theorem to the setting of arbitrary two-valued subsets of L_p-spaces. Our results are valid for all $p \in (0, \infty)$ and they are particularly surprising in the case $p > 2$. It is noteworthy that our techniques are completely different to those of Murugan. Time permitting we may also discuss asymptotic negative type properties of finite ultrametric spaces. (Received March 13, 2017)

1129-46-164 **Gilles Lancien*** (gilles.lancien@univ-fcomte.fr), Laboratoire de Mathématiques de Besancon, Univ. Bourgogne franche-Comté, 16, route de Gray, 25115 Besancon, France, and **Matias Raja**. *Asymptotic and coarse Lipschitz structures of quasi-reflexive Banach spaces.*

In a paper published in 2008, N. Kalton and L. Randrianarivony introduced a special family of graphs, for which they proved a fundamental property about Lipschitz maps from these graphs into reflexive Banach spaces with an asymptotically uniformly smooth norm. From this they derived important properties of the Banach spaces that can be coarse Lipschitz embedded into reflexive Banach spaces with an asymptotically uniformly smooth norm (see also the recent work of B.M. Braga for other applications). In this talk, we will explain how to produce a version of Kalton-Randrianarivony's result for maps into quasi-reflexive Banach spaces with an asymptotically uniformly smooth norm and deduce similar consequences.
This talk is based on a joint work with M. Raja. (Received March 13, 2017)

1129-46-165 **Vít Musil*** (musil@karlin.mff.cuni.cz) and **Andrea Cianchi** (andrea.cianchi@unifi.it). *Optimal domain spaces in Orlicz-Sobolev embeddings.*

We deal with Orlicz-Sobolev embeddings in open subsets of $\mathbb{R}^n$. A necessary and sufficient condition is established for the existence of an optimal, i.e. largest possible, Orlicz-Sobolev space continuously embedded into a given Orlicz space. Moreover, the optimal Orlicz-Sobolev space is exhibited whenever it exists. Parallel questions are addressed for Orlicz-Sobolev embeddings into Orlicz spaces with respect to a Frostman measure, and, in particular, for trace embeddings on the boundary. (Received March 13, 2017)

1129-46-193 **Alexandr Andoni**, **Robert Krauthgamer** and **Ilya Razenshteyn*** (ilyaraz@mit.edu), 27 Park Drive apt 17, Boston, MA 02215. *Sketching and Embedding are Equivalent for Norms.*

Imagine the following communication task. Alice and Bob each have a point from a metric space. They want to transmit a few bits and decide, whether their points are close to each other or are far apart. Of particular interest are sketching protocols: Alice and Bob both compute short summaries of their inputs and then a referee, given these summaries, makes the decision; sketches are very useful for various algorithms for massive datasets. Indyk (FOCS 2000) showed that for the ℓ_p spaces with $0 < p \leq 2$ the above problem allows a very efficient sketching protocol. Consequently, any metric that can be embedded into the ℓ_p space with small distortion has a good protocol as well.

I will show that for normed spaces embedding into ℓ_p is the only possible technique for solving the communication problem. Slightly more formally, we show that any normed space that admits a good communication (in particular, sketching) protocol for distinguishing close and far pairs of points embeds well into ℓ_p with p being close to 1.

As a corollary, we will see communication lower bounds for the planar Earth Mover's Distance and for the trace norm by deriving them from the (known) non-embeddability theorems and (the contrapositive of) our result. (Received March 15, 2017)

1129-46-203 **Lyonell Boulton*** (l.boulton@hw.ac.uk), Department of Mathematics, Heriot-Watt University, Edinburgh, Scotland EH14 4AS, United Kingdom. *Computable criteria for Schauder bases of dilated periodic functions.*

We examine a computable criterion for determining whether families of dilated periodic functions form a Schauder basis of $L^r(0,1)$ for all $r > 1$. We illustrate the rich structure behind this problem, by applying this criterion to various families of functions. Two of these families are the p-sine and the p-cosine functions. For them we find improved thresholds $1 < p_1 < p_2 < \infty$, such that a Schauder basis is guaranteed for all $p \in [p_1, p_2]$. (Received March 15, 2017)

1129-46-208 **D. Freeman**, **E. Odell**, **B. Sari** and **Bentuo Zheng*** (bzheng@memphis.edu). *Banach spaces with spreading bases.*

In this talk, we will present the structure of Banach spaces with a conditional spreading basis. The geometry of such spaces exhibit a striking resemblance to the geometry of James' space. Further, we show that the averaging projections onto sub- spaces spanned by constant coecient blocks with no gaps between supports are bounded. As a consequence, every Banach space with a spreading basis contains a complemented subspace with an unconditional basis. This gives an armative answer to a question of H. Rosenthal. (Received March 15, 2017)

1129-46-218 **Andrew T. Swift*** (ats0@math.tamu.edu). *Coarse embeddability of Banach spaces into superstable Banach spaces.*

We will show how the methods of Krivine and Maurey and Raynaud can be used to find a necessary condition for a Banach space to be coarsely embeddable into a superstable Banach space. Specifically, a Banach space that coarsely embeds into a superstable Banach space must contain an ℓ_p spreading model for some $p \in [1, \infty)$. This implies that not every reflexive Banach spaces is coarsely embeddable into a superstable Banach space. This is joint work with B.M. Braga. (Received March 16, 2017)

1129-46-247 **Aleš Nekvinda*** (ales.nekvinda@cvut.cz), Thákurova 7, Prague 6, Czech Rep. *Characterization of function with zero traces in variable Sobolev spaces.*

Consider a variable Sobolev space W with log-Holder continuous exponent. A characterization of functions with zero trace on the boundary from W will be given via a distance function from the boundary. Moreover, assumptions to the boundary are required much more weak than Lipschitz boundary. (Received March 17, 2017)

1129-46-275 **Marat V. Markin*** (mmarkin@csufresno.edu), Department of Mathematics, California State University, Fresno, 5245 North Backer Avenue, M/S PB108, Fresno, CA 93740-8001. *On the Mean Ergodicity of Weak Solutions of an Abstract Evolution Equation.* Preliminary report.

Found are conditions of rather general nature sufficient for the existence of the limit at infinity of the *Cesàro means*

$$\frac{1}{t}\int_0^t y(s)\,ds$$

for every *bounded weak solution* $y(\cdot)$ of the abstract evolution equation

$$y'(t) = Ay(t),\ t \geq 0,$$

with a closed linear operator A in a Banach space X. (Received March 17, 2017)

1129-46-302 **Lenka Slavíková*** (slavikoval@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Banach algebras of weakly differentiable functions.*

It is well known that classical Sobolev spaces on domains with the cone property are Banach algebras under pointwise multiplication of functions if and only if they are embedded into the space of essentially bounded functions. An example of a very irregular two-dimensional domain due to Maz'ya and Netrusov shows, however, that one cannot expect this phenomenon to hold for all Euclidean domains.

We address the question of when a Sobolev space is a Banach algebra in the very general setting of Sobolev spaces built upon any rearrangement-invariant norm, over a variety of Euclidean domains described in terms of their isoperimetric function. In particular, we show that the above mentioned equivalence continues to hold not only for a large class of regular Euclidean domains (John domains), but also for several irregular domains, including domains with cusps. This is a joint work with Andrea Cianchi (Florence, Italy) and Luboš Pick (Prague, Czech Republic). (Received March 19, 2017)

1129-46-308 **Daniel Freeman*** (dfreema7@slu.edu) and **Darrin Speegle**. *The discretization problem for continuous frames.*

There is a long history of creating frames for Hilbert spaces by sampling continuous frames. For instance, Gabor frames are formed by sampling the short time Fourier transform at a lattice. Continuous frames often arise naturally in mathematics and physics, but the sampled frames are usually more useful for applications and computations. Using the results of Marcus-Spielman-Srivastava in their solution of the Kadison-Singer problem, we solve the discretization problem for continuous frames by characterizing exactly when a continuous frame may be sampled to obtain a frame. In particular, we prove that every bounded continuous frame may be sampled to obtain a frame. (Received March 19, 2017)

1129-46-312 **Gerard Buskes*** (mmbuskes@olemiss.edu). *AM-spaces and AL-spaces of homogeneous polynomials on Banach lattices.*

We present results that characterize when certain spaces of multilinear maps and homogeneous polynomials on Banach lattices are AM-spaces or AL-spaces. This is joint work with Q. Bu and Y. Li. (Received March 19, 2017)

1129-46-327 **S. A. Argyros** and **P. Motakis***, Texas A&M University, and **B. Sari**. *A study of conditional spreading sequences.*

The notion of a spreading model plays a central role in the linear theory of Banach spaces and it concerns the asymptotic behavior of linear combinations of sequences in such spaces. It has been used in a variety of ways, e.g. to study the behavior of finite block sequences of Schauder bases and even to study properties of bounded linear operators on certain Banach spaces. A notion that goes hand in hand with spreading models is that of a spreading sequence. We analyze the norm behavior of conditional spreading sequences and break them up into two basic components that are very well behaved, namely one that is equivalent to all its convex block sequences and one that is subsymmetric. We apply this analysis to study the structure of spaces with conditional spreading bases and to prove results such as the fact that every conditional spreading sequence is admitted as a spreading model of a quasi-reflexive Banach space and the fact that $C(\omega^\omega)$ admits all possible spreading models, i.e. both the conditional and the unconditional ones. (Received March 19, 2017)

1129-46-364 **Dale Alspach**, **Koshal Dahal** and **Bunyamin Sari***, 1155 Union Circle #311430, Denton, TX 76203-5017. *$C(\Delta)$-trees on $C(\alpha)$.* Preliminary report.

We will speak on a new approach to some of the classical facts about the structure of $C(K)$ spaces for K countable compact. The new approach involves what we call $C(\Delta)$-trees which are the $p = \infty$ case of L_p index trees defined (but not studied) by Bourgain, Rosenthal and Schechtman. Among other things, we will compute the $C(\Delta)$ ordinal index of $C(\alpha)$ spaces, and as an application give a "textbook calculation" for the Banach-Mazur distance $d(c_0, c)$. (Received March 20, 2017)

1129-46-368 **Kevin James Beanland*** (`beanlandk@wlu.edu`), 1930 Floyd Ave, Richmond, VA 23220. *Quantitative Factorization of weakly compact, Rosenthal and Banach-Saks operators.*

In the spirit of the famous Davis-Figiel-Johnson-Pelczynski factorization theorem for weakly compact operators, we establish many quantitative factorization theorems for weakly compact, Rosenthal and Banach-Saks operators. (Received March 20, 2017)

1129-46-398 **J. Alejandro Chávez-Domínguez***, Department of Mathematics, University of Oklahoma, Norman, OK 73019, and **Daniel Freeman** and **Keri Kornelson**. *Finite unit norm tight frames for Banach spaces via a frame potential.* Preliminary report.

Frames for Hilbert spaces, as overcomplete versions of bases, are quite useful in applications because they provide decompositions that are more robust. Those frames that consist of vectors of norm one and are additionally tight have even more computational advantages, e.g. they provide fast convergence for said decompositions.

Benedetto and Fickus have developed a *frame potential*, a numerical quantity that can be assigned to a collection of finitely many vectors in a Hilbert space, which characterizes unit norm tight frames as follows: a sequence of k norm-one vectors in an n-dimensional Hilbert space (where $k \geq n$) has frame potential at least k^2/n, with equality if and only if the sequence is a tight frame (and there always exist frames achieving this bound).

The main result of this paper is a generalization of the aforementioned result to the context of finite-dimensional Banach spaces. We define a frame potential for a sequence of k norm-one vectors in an n-dimensional Banach space (where $k \geq n$), which generalizes the Hilbert-space notion. This generalized potential is also bounded below by k^2/n, with equality if and only if we the sequence is a tight frame. For a wide class of spaces, we show that the equality case does occur. (Received March 20, 2017)

1129-46-416 **Jan Lang***, Department of Mathematics, The Ohio State University, 231 West 18th Avenue, Columbus, OH 43210-1174, and **D E Edmunds**. *Series representation of compact linear operators in Banach spaces.*

Let $T : X \to Y$ be a compact map between uniformly convex and uniformly smooth Banach spaces. When X and Y are Hilbert spaces then E. Schmidt result guaranties that T can be represent in form of series, i.e. $Tf(x) = \sum \alpha_Y(x) y_n$ where $\alpha_Y \in Y^*$ and $y_n \in Y$. From Enflo's result follows that such representation of the compact map T is, generally, not possible on Banach spaces. In this talk we will discuses conditions under which we can obtain Banach-space version of the well-known Hilbert-space result of E. Schmidt (talk is based on joint papers with D.E.Edmunds). (Received March 20, 2017)

1129-46-431 **Bruno de Mendonça Braga*** (`demendoncabraga@gmail.com`). *Asymptotic structure and coarse Lipschitz geometry of Banach spaces.*

I will talk about nonlinear embeddings between Banach spaces. More specifically, I will present some results concerning the coarse Lipschitz geometry of Banach spaces with certain asymptotic properties. (Received March 21, 2017)

1129-46-434 **S. J. Dilworth**, **Denka Kutzarova**, **N. Lovasoa Randrianarivony*** (nrandria@slu.edu) and **Matthew Romney**. *Sums of AMUC spaces.*

Asymptotic midpoint uniform convexity was introduced in 2015 as one asymptotization of uniform convexity. In this talk, we explore the transfer of the AMUC property through taking infinite direct sums of Banach spaces. (Received March 21, 2017)

1129-46-499 **Małgorzata M Czerwińska** and **Anna H. Kaminska*** (kaminska@memphis.edu), Department of Math Sciences, Memphis, TN 38152. *Banach envelopes in symmetric spaces of measurable operators.*

We study Banach envelopes for commutative symmetric sequence or function spaces, and noncommutative symmetric spaces of measurable operators. We characterize the class (HC) of quasi-normed symmetric sequence or function spaces E for which their Banach envelopes $\widehat{E}$ are also symmetric spaces. The class of symmetric spaces satisfying (HC) contains but is not limited to order continuous spaces. Let $\mathcal{M}$ be a non-atomic, semifinite von Neumann algebra with a faithful, normal, σ-finite trace τ and E be as symmetric function space on $[0, \tau(1))$ or symmetric sequence space. We compute Banach envelope norms on $E(\mathcal{M}, \tau)$ and C_E for any quasi-normed symmetric space E. Then we show under assumption that $E \in (HC)$ that the Banach envelope $\widehat{E(\mathcal{M}, \tau)}$ of $E(\mathcal{M}, \tau)$ is equal to $\widehat{E}(\mathcal{M}, \tau)$ isometrically. We also prove the analogous result for unitary matrix spaces C_E. (Received March 21, 2017)

1129-46-523 **Osvaldo Mendez*** (osmendez@utep.edu), 500W University Ave., 124 Bell Hall, El Paso, TX 79968, and **Jan Lang**. *A Sobolev Embedding for Sobolev-Musielak-Orlicz spaces.* Preliminary report.

Let φ be a Musielak-Orlicz function on a bounded domain Ω. We prove that under natural necessary conditions of φ, the Sobolev Embedding $W_0^{1,\varphi}(\Omega) \to L^{\varphi}(\Omega)$ is compact. (Received March 22, 2017)

1129-46-526 **Sudeshna Basu*** (sbasu@gwu.edu), Department of Mathematics, Phillips Hall Room 739, George Washington University, District of Columbia, DC 20052. *On Small Combination of Slices in Banach Spaces.*

The notion of Small Combination of Slices (SCS) in the unit ball of a Banach space was first introduced in N. Ghoussoub, G. Godefroy, B. Maurey, W. Schachermayer, and subsequently analyzed in detail by H.P. Rosenthal, W. Schachermayer. In this work, we introduce the notion of Ball SCS- Property (BSCP), which can be seen as a generalization of dentability in terms of SCS. We study certain stability results for the w^*-BSCSP leading to a discussion on BSCSP in the context of ideals of Banach spaces. We prove that the w^*-BSCSP can be lifted from a M-ideal to the whole Banach Space. We also prove similar results for strict ideals and U-subspaces of a Banach space. We note that the space $C(K, X)^*$ has w^*-BSCSP when K is dispersed and X^* has the w^*-BSCSP. (Received March 22, 2017)

47 ► Operator theory

1129-47-57 **Genady Ya Grabarnik*** (grabarng@stjohns.edu), Queens, NY 11439. *Mean ergodic theorems in non commutative symmetric spaces.* Preliminary report.

We show embedding theorem and give necessary and sufficient conditions for mean ergodic theorem to hold for double contractions. (Received February 27, 2017)

1129-47-279 **Fumio Hiroshima** (hiroshima@math.kyushu-u.ac.jp), 744 Motooka, Nishiku, Fukuoka, Fukuoka 8190385, Japan, and **Susumu Osawa*** (susumu_osawa@kyudai.jp), 744 Motooka, Nishiku, Fukuoka, Fukuoka 8190385, Japan. *Mass Renormalization in the Nelson Model.*

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

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

with some constants C, C_1 and C_2. (Received March 18, 2017)

49 ► Calculus of variations and optimal control; optimization

1129-49-59 **Youssef Qranfal*** (qranfaly@wit.edu), 550 Huntington Avenue, Boston, MA 02115.
Recent Advances in Medical Imaging.

Images and visualization have become increasingly important in many areas of science and technology. Advances in hardware and software have allowed computerized image processing to become a standard tool in many scientific applications, including medical imaging. In this talk, we see how we model and solve the inverse problem of reconstructing a dynamic medical image where the signal strength changes substantially over the time required for data acquisition. We use a stochastic approach based on a Markov process to model the problem. We introduce a novel proximal approach and apply it during the Kalman filter algorithm to ensure positivity and spatial regularization. We test our method for the case of image reconstruction in time-dependent single photon emission computed tomography (SPECT). Numerical results corroborate the effectiveness of our approach. (Received February 27, 2017)

1129-49-309 **Stan Alama*** (alama@mcmaster.ca), Department of Mathematics & Statistics, McMaster University, 1280 Main St West, Hamilton, ON L8S 4K1, Canada, and **Lia Bronsard** and **Ihsan Ata Topaloglu**. *Energy minimizing patterns for a copolymer model with confinement.*

We identify the Γ-limit of an energy related to nanoparticle/block copolymer blends, in a limit of a large number of nanoparticles occupying a vanishingly small volume in the copolymer sample. The limiting energy consists of two terms: the perimeter of the interface separating the phases and a confinement term representing the effect of the nanoparticles, which attract one of the two stable phases. Our interest is in studying how the confinement term affects the phase transition morphology. We prove that local minimizers of the limiting energy admit regular phase boundaries and derive the first and second variations of the limiting energy functional. Finally we discuss possible critical and minimizing patterns in two dimensions and how these patterns vary from global minimizers of the purely local isoperimetric problem. (Received March 19, 2017)

51 ► Geometry

1129-51-32 **Christopher Allen Manon***, 4400 University Drive MS: 3F2, Fairfax, VA 22030.
Contraction of a Hamiltonian K-space with applications to free group character varieties.

I will describe how to construct the contraction X_0 of a Hamiltonian K-space X. The contraction X_0 manages to be very close to X yet it comes equipped with a Hamiltonian $K \times T$ action for $T \subset K$ a maximal torus. Contraction emerges algebraically from the horospherical contraction operation of Popov, and it has a close relationship to recent work of Harada and Kaveh on Newton-Okounkov bodies. As an application I show how the free group SL_2 character varieties are very close to being toric varieties in an infinite number of ways in bijection with the facets of Culler and Vogtmann's outer space. Some of this is joint work with Joachim Hilgert and Johan Martens. (Received January 25, 2017)

1129-51-118 **Irene Pasquinelli***, Dept of Mathematical Sciences Durham Univers, Lower Mountjoy Stockton Road, Durham, United Kingdom. *Deligne-Mostow lattices and cone metrics on the sphere.*

Finding lattices in PU(n,1) has been one of the major challenges of the last decades. One way of constructing lattices is to give a fundamental domain for its action on the complex hyperbolic space.

One approach, successful for some lattices, consists of seeing the complex hyperbolic space as the configuration space of cone metrics on the sphere and of studying the action of some maps exchanging the cone points with same cone angle.

In this talk we will see how this construction of fundamental polyhedra can be extended to almost all Deligne-Mostow lattices with three folding symmetry. (Received March 09, 2017)

1129-51-147 **Christian Millichap** and **William Worden*** (william.worden@temple.edu). *Hidden Symmetries and Commensurability of 2-bridge link complements.*

The canonical triangulations and symmetry groups of 2-bridge link complements are well understood and relatively easy to describe. We leverage this fact to show that non-arithmetic 2-bridge link complements have no hidden symmetries (i.e., symmetries of a finite cover that do not descend to symmetries of the link complement itself), and are pairwise incommensurable. This is joint work with Christian Millichap. (Received March 11, 2017)

1129-51-307 **Benoit Cadorel*** (benoit.cadorel@univ-amu.fr), Centre de Mathematiques et d'Informatique, Technopole Chateau-Gombert, 39, rue F. Joliot Curie, 13013 Marseille, France. *Symmetric differentials on hyperbolic manifolds with cusps.*

Given a smooth compactification of a quotient of a bounded symmetric domain, we want to study the usual notions of positivity of its logarithmic and standard cotangent bundles. To this end, we prove a metric criterion of bigness of the cotangent bundle, relevant on any smooth log-pair. Then, we can show that the logarithmic cotangent bundle of the previous compactification is always big, which gives back a result of Y. Brunebarbe.

In the case of a ball quotient, we are interested in the ramified covers of the compactification, étale on the inside. Using recent results of Bakker and Tsimerman, our criterion can be applied to give effective ramification orders, beyond which all the subvarieties of such a cover, if they are not included in the boundary, will have nef, or big, cotangent bundle. (Received March 19, 2017)

1129-51-410 **Max Glick*** (max.glick@uconn.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 March 20, 2017)

52 ► Convex and discrete geometry

1129-52-324 **Assaf Naor*** (naor@math.princeton.edu), Princeton University, Department of Mathematics, Fine Hall, Washington Road, Princeton, NJ 08544-1000. *A spectral gap precludes low-dimensional embeddings.*

We prove that if an n-vertex $O(1)$-expander graph embeds with average distortion D into a finite dimensional normed space X, then necessarily the dimension of X is at least $n^{c/D}$ for some universal constant $c > 0$. This is sharp up to the value of the constant c, and it improves over the previously best-known estimate $\dim(X) > c(\log n)^2/D^2$. (Received March 19, 2017)

1129-52-454 **Johannes Hofscheier**, **Lukas Katthän*** (katth001@umn.edu) and **Benjamin Nill**. *Ehrhart Theory for spanning lattice polytopes.*

A lattice polytope is called spanning if its lattice points affinely span the ambient lattice. In this talk we describe a new result in the Ehrhart theory of lattice polytopes that implies that the h^*-vector of a spanning lattice polytope has no no inner zeros. This generalizes a recent theorem by Blekherman, Smith, and Velasco, and implies a polyhedral consequence of the Eisenbud-Goto conjecture. We also discuss how this relates to unimodality questions of lattice polytopes and previously achieved results on lattice polytopes of given degree. (Received March 21, 2017)

53 ► Differential geometry

1129-53-26 **Dan Cristofaro-Gardiner**, **Tara Holm**, **Alessia Mandini** and **Ana Rita Pires*** (apissarrapires@fordham.edu). *Symplectic embeddings and infinite staircases.* Preliminary report.

McDuff and Schlenk studied an embedding capacity function, which describes when a 4-dimensional ellipsoid can symplectically embed into a 4-ball. The graph of this function includes an infinite staircase related to the odd index Fibonacci numbers. Infinite staircases have been shown to exist also in the graphs of the embedding capacity functions when the target manifold is a polydisk or the ellipsoid E(2,3). This talk describes joint work with Cristofaro-Gardiner, Holm, and Mandini, in which we use ECH capacities and Ehrhart polynomials to show that infinite staircases exist for these and a few other target manifolds. I will also explain why we conjecture that these are the only such target manifolds. (Received January 19, 2017)

1129-53-198 **Mark A Stern*** (stern@math.duke.edu) and **Michael Lipnowski**. *Spectral geometry of the 1 form Laplacian on hyperbolic manifolds.*

Motivated by questions arising in analytic torsion, we give geometric lower bounds for the first nonzero eigenvalue of the 1 form Laplacian on hyperbolic 3 manifolds and discuss associated betti number bounds. (Received March 15, 2017)

1129-53-216 **David N Pham*** (dnpham@qcc.cuny.edu). *$\mathfrak{g}$-quasi-Frobenius Lie algebras.*

For a finite group G, V. Turaev showed that crossed G-algebras (or G-Frobenius algebras) are the algebraic structures which classify 2-dimensional homotopy quantum field theories where the target space is a $K(G,1)$-space. In this talk, we propose a Lie version of a G-Frobenius algebra which is motivated by a somewhat recent categorical formulation of G-Frobenius algebras as commutative Frobenius objects in the braided monoidal category of left $D(k[G])$-modules, where $D(k[G])$ is the Drinfeld double of the group algebra $k[G]$ with its standard Hopf structure. We call the aforementioned structures $\mathfrak{g}$-quasi-Frobenius Lie algebras (for $\mathfrak{g}$ a finite dimensional Lie algebra). The geometry of these structures is discussed and some examples are presented. (Received March 16, 2017)

1129-53-219 **Jo Nelson***, mathochist@gmail.com, and **Katherine Christianson**. *Symplectic embeddings of four-dimensional polydisks into balls.*

I will talk about recent joint work with Katherine Christianson, which yields new sharp obstructions to symplectic embeddings of the four-dimensional polydisk into the ball, extending results of Hind-Lisi, Hutchings, and Schlenk. Our proof relies on connections between combinatorial toric geometry and embedded contact homology by way of a necessary criterion for one "convex toric domain" to symplectically embed into another, which was introduced by Hutchings in 2015. (Received March 16, 2017)

1129-53-231 **Fernando Coda Marques***, Fine Hall, Princeton University, Princeton, NJ 08544. *The space of cycles, a Weyl's law and Morse index estimates.*

The space of cycles in a compact Riemannian manifold has very rich topological structure. The space of hypercycles, for instance, taken with coefficients modulo two, is weakly homotopically equivalent to the infinite dimensional real projective space. This structure leads to a proof of the existence of infinitely many closed minimal hypersurfaces in manifolds with positive Ricci curvature. We will discuss a proof of a Weyl's law conjectured by Gromov (joint work with Liokumovich and Neves) in which the eigenvalues of the Laplacian are replaced by the areas of minimal hypersurfaces constructed by minimax methods. We will also discuss current work with Neves about the first Morse index bounds of the theory and the problem of multiplicity. (Received March 16, 2017)

1129-53-333 **Ruobing Zhang*** (ruobing.zhang@stonybrook.edu). *Non-local Curvature and Topology of Locally Conformally Flat Manifolds.*

In this talk, we focus on the geometry of conformally flat manifolds (M^n, g) with positive scalar curvature. Schoen-Yau proved that its universal cover is conformally embedded in S^n such that M^n is a Kleinian manifold. Moreover, the associated limit set has Hausdorff dimension $< (n-2)/2$. If additionally we assume that the non-local curvature $Q_{2\gamma} > 0$ for some $1 < \gamma < 2$, then the upper bound of the Hausdorff dimension is improved to $(n-2\gamma)/2$. In fact, the above upper bound is sharp. As applications, we obtain some topological rigidity and classification theorems in lower dimensions. Also I will show some applications in the fractional Yamabe problem. (Received March 19, 2017)

1129-53-344 **Schlenk Felix*** (schlenk@unine.ch), Rue Emile Argand 14, 2000 Neuchatel, Switzerland. *Several combinatorial descriptions of the problem of symplectically embedding a 4-dimensional ellipsoid into a ball.*

The problem of symplectically embedding a 4-dimensional ellipsoid E(a,b) into a 4-ball as small as possible can be described in many ways: in terms of Fibonacchi numbers, in terms of solutions of a Diophantine system coming from special holomorphic spheres in multiple blow-ups of the complex projective plane, by a combinatorial algorithm involving the Cremona transform, and by lattice point counting in a rectangular triangle. The last description gives rise to new examples of period collapse and to first steps of an irrational Ehrhart theory. This talk is based on results of Dan Cristofaro-Gardiner, David Frenkel, Aaron Kleinman, Dusa McDuff and myself. (Received March 20, 2017)

1129-53-407 **Tara S Holm*** (tsh@math.cornell.edu), Cornell University, Department of Mathematics, Ithaca, NY 14853-4201, and **Liat Kessler**. *The Topology of Symplectic Manifolds.* Preliminary report.

In symplectic geometry, a Hamiltonian group action gives rise to the momentum map, a key tool in studying topological invariants of symplectic manifolds. On the other hand, pseudoholomorphic curves provide strong analytic tools to study symplectic invariants of these spaces. A fundamental problem in symplectic geometry is to relate the geometry and topology of a Hamiltonian group action to the discrete geometry of the momentum polytope. I will give an overview of these ideas, and explain some of my recent work with Liat Kessler. (Received March 20, 2017)

55 ► Algebraic topology

1129-55-20 **M. Bendersky*** (mbenders@hunter.cuny.edu), 695 Park Ave, New York, NY 10065, and **A. Bahri**, **F. Cohen** and **S. Gitler**. *Cohomology of Polyhedral Products.*

The polyhedral product is a functor of a simplicial complex and pairs of CW complexes indexed by the vertices of the complex. I will talk about a spectral sequences which converges to the cohomology of the polyhedral product. If the CW complexes satisfy suitable freeness conditions we can compute the differentials and give a description of the cohomology groups. The ring structure is given in terms of the cohomology of the CW complexes and the the cohomology of the simplicial complex. (Received January 12, 2017)

1129-55-29 **Yury Ustinovskiy***, Fine Hall, Washington Road, Princeton, NJ 08544. *Face numbers of flag simplicial complexes and toric topology.*

Denham and Suciu in the paper "Moment-angle complexes, monomial ideals and Massey products", 2007 and Panov and Ray in the paper "Categorical aspects of toric topology", 2008 computed ranks of homotopy groups and Poincaré series of a moment-angle-complex $Z(K)$ / Davis-Januzskiewicz space $DJ(K)$ associated to a flag simplicial complex K. In this talk we revisit these results and interpret them as polynomial bounds on the face numbers of an arbitrary simplicial flag complex. (Received January 24, 2017)

1129-55-31 **Cihan Okay*** (cokay@uwo.ca), Department of Mathematics, Middlesex College, London, ON N6A 5B7, Canada. *Filtrations of classifying spaces.*

Adem, Cohen, and Torres-Giese introduced a natural filtration of the classifying space BG of a group G using descending central series of free groups. The spaces $B(q,G)$ in the filtration are defined simplicially from the spaces of homomorphisms from nilpotent quotients of free groups to G. I will talk about homotopical properties of $B(q,G)$ when $q=2$. For extraspecial p-groups $B(2,G)$ has interesting properties which have potential applications in quantum physics. (Received January 25, 2017)

1129-55-33 **Elizabeth Vidaurre*** (elizabeth.vidaurre@rochester.edu), 140 Trustee Road, Mathematics Department, University of Rochester, Rochester, NY 14627, and **Jelena Grbic**, **Michele Intermont** and **Isabelle Laude**. *A Homotopical Generalisation of the Bestvina-Brady Construction.*

Using polyhedral products $(\underline{X},\underline{A})^K$, we recognise the Bestvina-Brady construction as the fundamental group of the fibre of $(S^1,*)^L \to (S^1,*)^K = S^1$, where L is a flag complex and K is a one vertex complex. We generalise their construction by studying the homotopy fibre F of $(S^1,*)^L \to (S^1,*)^K$ for an arbitrary simplicial complex L and K an $(m-1)$-dimensional simplex. We describe the homology of F, its fixed points, and maximal invariant quotients for coordinate subgroups of $\mathbb{Z}^m$. This generalises the work of Leary and Saadetoğlu who studied the case when $m=1$. (Received January 26, 2017)

1129-55-34 **Alexander I. Suciu*** (a.suciu@neu.edu), Department of Mathematics, Northeastern University, Boston, MA 02115. *Representation varieties and polyhedral products.*

Given a finitely generated group π and a complex, linear algebraic group G, the representation variety $\mathrm{Hom}(\pi,G)$ has a natural filtration by the cohomology jump loci associated to a rational representation $G \to \mathrm{GL}(V)$. The infinitesimal counterpart of the representation variety around the trivial representation is the space of $\mathfrak{g}$-valued flat connections on an appropriate commutative, differential graded algebra (A,d). This space admits a corresponding filtration by the resonance varieties associated to the tangential representation $\mathfrak{g} \to \mathfrak{gl}(V)$ of the Lie algebra of G. In this talk, I will explain how one can understand the local behavior of all these varieties, at least in some favorable situations of geometric interest. This approach works very well in the case when $G=\mathrm{SL}(2,\mathbb{C})$ or one of its standard subgroups, and π is a right-angled Artin group, that is, the fundamental group of a polyhedral product of the form $\mathcal{Z}_K(S^1,*)$, for some finite simplicial graph K. (Received January 27, 2017)

1129-55-35 **Alejandro Adem*** (adem@math.ubc.ca). *Infinite loop spaces arising from spaces of representations.*

We discuss joint work with J.Gomez, J.Lind and U.Tillmann showing how spaces of representations can be assembled to form new infinite loop spaces that naturally filter classical loop spaces such as BU and BO. We discuss the notion of nilpotent K-theory associated to them as well as recent results about the ring of coefficients for commutative complex K-theory (obtained by S.Gritschacher). (Received January 30, 2017)

1129-55-37 **Patrick Papadopulos*** (pgpsma@rit.edu). *On Configuration Spaces of graphs and toric topology.*

In this talk we will discuss recent results on configuration spaces of certain types of graphs and their relationships to toric topology. (Received January 31, 2017)

1129-55-339 **David Allen*** (dtallen@bmcc.cuny.edu), David Allen, Mathematics Dept (N599), 199 Chambers Street, New York, NY 10007. *Applications of Homotopy Theory to Torus Actions.*

In this talk I will describe explicit calculations of the higher derived functor of the indecomposable functor, L_iQA (or dually, $R^iP(-)$)for an augmented simplicial algebra A over a commutative ring. In certain degrees there are concrete representations that facilitate explicit calculations. These computations allow one to translate statements concerning torus actions on Quastitoric manifolds into statements concerning the orbits, which can then be analyzed using unstable methods. There is an interplay between the combinatorics, simplicial methods and commutative algebra that produces isomorphisms of these derived functors. A few applications will be discussed, the first answers in the negative a question posed by Bendersky on the existence of certain "nice" torus actions. These methods also provide additional insight into questions regarding cohomological rigidity including notions such as *C-rigid* polytopes recently studied by Panov and his collaborators. Time permitting I will discuss recent results regarding the Unstable $K(1)$ completion of a certain family of Toric Spaces.

This work is done in collaboration with Jose La Luz and Peter Gregory. (Received March 20, 2017)

1129-55-423 **Cristian Lenart*** (clenart@albany.edu), State University of New York at Albany, **Kirill Zainoulline**, University of Ottawa, Canada, and **Changlong Zhong**, State University of New York at Albany. *Schubert calculus beyond K-theory.*

Modern Schubert calculus has been mostly studying the cohomology and K-theory (including their equivariant and quantum generalizations) of flag manifolds. The basic results for an arbitrary oriented cohomology theory have only been obtained recently; additional complexity is due to the dependence of the classes associated to Schubert varieties on their Bott-Samelson desingularizations. Our work in this area focuses on torus equivariant hyperbolic cohomology (a stalk version of elliptic cohomology). First, we generalize certain formulas for the equivariant Schubert classes in cohomology and K-theory. We also construct and study a canonical replacement of the Schubert basis (for partial flag varieties), using the Kazhdan-Lusztig basis of a certain Hecke algebra. As a byproduct, we give a new interpretation of several results in Kazhdan-Lusztig theory. (Received March 20, 2017)

57 ► Manifolds and cell complexes

1129-57-44 **Jozef H Przytycki** (przytyck@gwu.edu), Phillips Hall, Washington, DC 20052, and **Adam S. Sikora*** (asikora@buffalo.edu), 244 Math Bldg, SUNY Buffalo, Buffalo, NY 14260. *On algebraic properties of skein algebras of surfaces.*

Skein algebras are non-commutative deformations of SL(2)-character varieties of surfaces, whose construction is motivated by quantum topology. We will discuss various aspects of the algebraic structure of skein algebras, including zero-divisors, central elements, and the properties of the filtrations induced by pants decompositions of surfaces. (Received February 10, 2017)

1129-57-52 **Ina Petkova** (ina.petkova@dartmouth.edu) and **C.-M. Michael Wong*** (cmmwong@math.columbia.edu). *An unoriented skein relation for tangle Floer homology.*

Knot Floer homology, a link invariant with rich applications defined by Ozsváth–Szabó and Rasmussen, was shown by Manolescu to satisfy an unoriented skein exact triangle. A combinatorial proof was later provided by the second author. More recently, inspired by the work of Lipshitz–Ozsváth–Thurston on bordered Floer homology, Vértesi and the first author have defined tangle Floer homology, a tangle invariant that satisfies a pairing theorem, recovering the knot Floer homology of a link obtained by gluing tangles. In this talk, we prove that an analogous skein relation is satisfied by tangle Floer homology, which together with the pairing theorem recovers a version of Manolescu's result. The proof is reminiscent of the combinatorial proof for knot Floer homology mentioned above. No prior knowledge is necessary for the talk, as a brief introduction to tangle Floer homology will be given. (Received February 22, 2017)

1129-57-110 **Min Hoon Kim**, **David Krcatovich** and **JungHwan Park*** (jp35@rice.edu), 2630 Bissonnet st a2107, Houston, TX 77005. *Links with non-trivial Alexander polynomial.*

We give infinitely many 2-component links with unknotted components which are topologically concordant to the Hopf link, but not smoothly concordant to any 2-component link with trivial Alexander polynomial. This is joint work with Min Hoon Kim and David Krcatovich. (Received March 08, 2017)

1129-57-113 **Jennifer Hom**, **Adam Simon Levine*** (asl2@math.princeton.edu) and **Tye Lidman**. *Concordance of knots in homology 3-spheres.*

While not every knot in the 3-sphere bounds a smoothly embedded disk in the 4-ball, every such knot bounds a non-locally-flat PL disk. For knots in the boundaries of other contractible 4-manifolds, however, even this weaker statement need not hold; the second author gave the first examples of knots in homology spheres that cannot bound PL disks in any homology 4-ball. In other words, the group of knots in homology 3-spheres that bound homology 4-balls, modulo non-locally-flat PL concordance in homology cobordisms, is nontrivial. In the present talk, we shall show that this group has infinite order. (Received March 08, 2017)

1129-57-115 **BoGwang Jeon*** (bogwang.jeon@gmail.com), 2990 Broadway, New York, NY 10027. *The Pink-Zilber conjecture and the generalized Cosmetic Surgery Conjecture.* Preliminary report.

The following is a well-known conjecture of C. Gordon: Let M be a 1-cusped hyperbolic 3-manifold and M(p/q) and M(p'/q') be its p/q and p'/q'- Dehn filled manifolds (respectively) which are all hyperbolic. Then M(p/q) is isometric to M(p'/q') if and only if p/q=p'/q'. In this talk, I will explain how one can generalize this conjecture to an n-cusped hyperbolic 3-manifold by assuming another well-known conjecture in number theory, so called the Pink-Zilber Conjecture. (Received March 08, 2017)

1129-57-117 **Joseph A. Quinn*** (josephanthonyquinn@gmail.com), Av. Universidad s/n., Col. Lomas Chamilpa, 62210 Cuernavaca, Morelos, Mexico, and **Alberto Verjovsky** (alberto@matcuer.unam.mx), Av. Universidad s/n., Col. Lomas Chamilpa, 62210 Cuernavaca, Morelos, Mexico. *Quaternionic Hilbert modular varieties.* Preliminary report.

Hilbert modular varieties arise from the discrete action of a group $\mathrm{PSL}_2(R)$ on a product of hyperbolic planes, where R is the ring of integers of a totally real number field. We investigate a generalization of this to the discrete action of a group $\mathrm{PSL}_2(\mathcal{O})$ on a product of hyperbolic 4-spaces, where $\mathcal{O}$ is an order in a definite quaternion algebra over a totally real number field. We observe some topological properties of the resulting orbifolds via some examples. (Received March 09, 2017)

1129-57-127 **Colin Adams*** (cadams@williams.edu), Bronfman Science Center, 18 Hoxsey St., Williamstown, MA 01267, and **Rose Kaplan-Kelly**, **Michael Moore**, **Brandon Shapiro**, **Shruthi Sridhar** and **Joshua Wakefield**. *Densities of hyperbolic cusp invariants.*

We find that cusp densities of hyperbolic knots in S^3 are dense in $[0, 0.6826\dots]$ and those of links are dense in $[0, 0.853\dots]$. We define a new invariant associated with cusp volume, the cusp crossing density, as the ratio between the cusp volume and the crossing number of a link, and show that cusp crossing density for links is bounded above by $3.1263\dots$. Moreover, there is a sequence of links with cusp crossing density approaching 3. The least upper bound for cusp crossing density remains an open question. For two-component hyperbolic links, cusp crossing density is shown to be dense in the interval $[0, 1.6923\dots]$ and for all hyperbolic links, cusp crossing density is shown to be dense in $[0, 2.120\dots]$. (Received March 10, 2017)

1129-57-132 **Daryl Cooper** and **David Futer*** (dfuter@temple.edu). *Ubiquitous quasifuchsian surfaces in finite-volume hyperbolic 3-manifolds.*

I will discuss a proof that every finite volume hyperbolic 3-manifold M contains a very large collection of immersed, π_1-injective surfaces. These surfaces are *ubiquitous* in the sense that their preimages in the universal cover separate any pair of disjoint geodesic planes. The proof relies in a major way on the corresponding theorem of Kahn and Markovic for closed 3-manifolds. As a corollary, we recover Wise's theorem that the fundamental group of M is acts properly and cocompactly on a cube complex. This is joint work with Daryl Cooper. (Received March 10, 2017)

1129-57-142 **Christine Ruey Shan Lee*** (clee@math.utexas.edu). *Jones slope and coarse volume of near-alternating links.*

We consider near-alternating links admitting a diagram where the number of crossing changes needed to obtain an alternating diagram is small compared to the number of the rest of the crossings. We show that with a mild diagrammatic condition, the Jones slopes of a near-alternating knot are realized by state surfaces, thereby verifying the Strong Slope Conjecture for these knots. In addition, we show that the colored Jones polynomial of a near-alternating knot has stable coefficients, and we discuss geometric estimates on the knot complement from the first and second stable coefficients similar to those for an alternating knot. (Received March 11, 2017)

1129-57-150 **E Kalfagianni*** (kalfagia@math.msu.edu), Department of Mathrmatics, MSU, E. Lansing, MI 48824. *Jones and Normal surfaces of Knots.* Preliminary report.

A Jones surface of a knot is an "essential" surface in the knot complement with boundary slope and Euler characteristic determined by the colored Jones polynomial of the knot. After giving the definitions and reviewing related conjectures we will outline an algorithm for finding Jones surfaces (joint work with Christine Lee). (Received March 12, 2017)

1129-57-182 **Michelle Chu*** (mchu@math.utexas.edu), University of Texas at Austin. *Special subgroups of Bianchi groups.* Preliminary report.

Every cusped arithmetic hyperbolic 3-manifolds is commensurable to the quotient of $\mathbb{H}^3$ by a Bianchi group. The Bianchi groups are the Kleinian groups $\mathrm{PSL}_2(\mathcal{O}_d)$ where $\mathcal{O}_d$ is the ring of integers in an imaginary quadratic field $\mathbb{Q}(\sqrt{-d})$. Recently there has been interest in determining the index of special subgroups of virtually special Kleinian groups. For the Bianchi groups $\mathrm{PSL}_2(\mathcal{O}_d)$, we determine a special congruence subgroup, compute its index, and give an upper bound independent of d for the smallest index of a special subgroup. (Received March 14, 2017)

1129-57-250 **Sean Cleary*** (cleary@sci.ccny.cuny.edu), **Joel Hass** and **Katherine St. John**. *Finding geodesics in Billera-Holmes-Vogtmann treespace via curve shortening.* Preliminary report.

We describe an approach for finding geodesics in Billera-Holmes-Vogtmann treespace based upon iterative curve shortening in the relevant CAT(0) cube complex. (Received March 17, 2017)

1129-57-271 **Christopher W Davis**, **Matthias Nagel**, **JungHwan Park** and **Arunima Ray*** (aruray@brandeis.edu), Waltham, MA 02453. *Concordance of knots in $S^1 \times S^2$.*

We give a collection of results on topological and smooth concordance and sliceness of knots in $S^1 \times S^2$. For example, we show that there is a unique smooth concordance class of knots in $S^1 \times S^2$ with winding number one. This is joint work with Chris Davis, Matthias Nagel, and JungHwan Park. (Received March 17, 2017)

1129-57-286 **Charles D Frohman** and **Joanna Kania-Bartoszynska***, jkaniaba@nsf.gov, and **Thang Le**. *Unicity for representations of the Kauffman bracket skein algebra.*

Given an oriented surface F, its Kauffman bracket skein algebra is formed by taking linear combinations of framed links in a cylinder over F and modding out by the Kauffman bracket skein relation. Multiplication is given by stacking. We characterize the center of the Kauffman bracket skein algebra of any orientable surface, where the parameter in the Kauffman bracket skein relation is any root of unity. We also resolve the unicity conjecture of Bonahon and Wong, by proving that the irreducible representations of a prime affine algebra over an algebraically closed field that has a finite rank over its center are generically characterized by their central characters. (Received March 18, 2017)

1129-57-354 **Thang Le** (letu@math.gatech.edu), Atlanta, NY 30332, and **Adam Sikora*** (asikora@buffalo.edu), 244 Math Bldg, SUNY Buffalo, Buffalo, NY 14260. *From character varieties to quantum groups.* Preliminary report.

We will discuss a deformation-quantization of character varieties that underlines the Witten-Reshetikhin-Turaev topological quantum field theory. In particular, we will reveal its interesting algebraic properties, and show how it leads to a novel point of view on quantum groups. (Received March 20, 2017)

1129-57-360 **Kate Petersen*** (petersen@math.fsu.edu). *SL(2,C) representations of knot groups.* Preliminary report.

I'll talk about some interesting representations of knot groups. (Received March 20, 2017)

1129-57-366 **Rochy Flint*** (rochyflint@gmail.com). *Intercusp Geodesics and Cusp Shapes of Fully Augmented Links.*

We study the geometry of fully augmented link complements in S^3 by looking at their link diagrams. We extend the method introduced by Thistlethwaite and Tsvietkova to fully augmented links and define a system of algebraic equations in terms of parameters coming from edges and crossings of the link diagrams. Combining it with the work of Purcell, we show that the solutions to these algebraic equations are related to the cusp shapes of fully augmented link complements. As an application we use the cusp shapes to study commensurability classes of fully augmented links. (Received March 20, 2017)

1129-57-372 **Patricia Cahn*** (pcahn@smith.edu) and **Alexandra Kjuchukova** (kjuchukova@wisc.edu). *Computing the signature of a dihedral cover of a four-manifold with a singular branching set.*

We describe an algorithm for computing the signature of a 3-fold dihedral cover of a four-manifold, when the branching set is embedded and has a isolated singularity modeled on the cone over a knot K in the three-sphere. The computation uses a formula of Kjuchukova, together with an algorithm for computing linking numbers of curves in a 3-fold dihedral cover of the three-sphere branched along K. The later generalizes an algorithm due to Perko for computing the linking numbers of the branch curves in such a cover. (Received March 20, 2017)

1129-57-383 **Thomas Kindred*** (thomas-kindred@uiowa.edu), Department of Mathematics, 14 MacLean Hall, Iowa City, IA 52242. *Alternating links have representativity 2.*

We prove that if L is a non-trivial alternating link embedded (without crossings) in a closed surface $F \subset S^3$, then F has a compressing disk whose boundary intersects L in no more than two points. Moreover, whenever the surface is incompressible and ∂-incompressible in the link exterior, it can be isotoped to have a standard tube at some crossing of any reduced alternating diagram. (Received March 20, 2017)

1129-57-421 **Cody W Armond*** (armond.2@osu.edu), Ohio State University at Mansfield, Mansfield, OH 44906. *Determining the lowest degree terms of the tail of the colored Jones polynomial from the reduced B-graph.* Preliminary report.

The colored Jones polynomial is a sequence of Laurent polynomials. For alternating knots, the sequence of leading coefficients stabilize to produce a power series called its tail. It is known that this tail depends only on the reduced B-graph of the knot. It is conjectured that the coefficients are determined by counting certain types of subgraphs of sizes less than or equal to the degree of the term in question. We will discuss the case when looking at a term whose degree is less than or equal to the size of the smallest cycle in the graph. (Received March 20, 2017)

1129-57-422 **Daniel S. Silver** (silver@southalabama.edu) and **Susan G. Williams*** (swilliam@southalabama.edu), AL. *Alexander polynomials and Laplacian matrices.*

We generalize a theorem of Murasugi and Stoimenow (2003) by showing that the Alexander polynomial of any knot K is the sum of weights of spanning trees of an even-valence Tait graph of K, with an appropriate weighting scheme. Such a graph corresponds to a "special diagram" of the knot. We then use an idea of Louis Kauffman to extend the theorem for arbitrary diagrams. The proofs are relatively simple, making use of the Laplacian matrix of a graph. (Received March 20, 2017)

1129-57-448 **Roman Aranda** and **Seungwon Kim*** (math751@gmail.com), New York, NY 10016, and **Maggy Tomova**. *A representativity of certain cable knots.* Preliminary report.

Let K be a knot embedded in a closed surface F embedded in S^3. The representativity $r(F,K)$ of a pair (F,K) is the minimal intersection number of K and ∂D where D ranges over all compressing discs of F. The representativity $r(K)$ of K is the maximal number of $r(F,K)$ over all embedded closed surfaces F which contain K. We showed that with certain conditions, the representativity of a cable knot is same as its index. (Received March 21, 2017)

1129-57-461 **Harrison Chapman*** (hchaps@gmail.com) and **Andrew Rechnitzer**. *A Markov chain sampler for knot diagrams.*

By taking as transitions the "flat" Reidemeister moves with appropriate weights, we construct a Markov chain on the space of knot shadows (i.e. immersed plane curves) which limits, for a fixed number of crossings, on the uniform distribution. This provides a new way to sample random knot diagrams and examine their knot types and invariants. We discuss how classical questions—such as the number of Reidemeister moves required to change one diagram into another—play into our understanding of this process. (Received March 21, 2017)

58 ► Global analysis, analysis on manifolds

1129-58-84 **R. A. Lowry*** (lowryr@sunysuffolk.edu), (SUNY) Suffolk County Community College, Department of Mathematics & Computer Science, 533 College Road, Selden, NY 11784. *A Survey of Geometric Principal Fiber Bundles with Applications.* Preliminary report.

In this talk we will survey the basic concept of a geometric principal fiber bundle (GPFB). The notion of a GPFB arose from previous work of Arthur E. Fischer (University of California, Santa Cruz) and collaborators working in general relativity, gauge field theories, the study of Teichmüller space, and geometric mechanics. These separate fields of mathematics share a similarity in the nonlinear function spaces which underly their structure: that of an infinite dimensional principal fiber bundle (PFB) endowed with a natural geometric structure (weak Riemannian, almost complex, symplectic, etc) which is compatible with the group action of the PFB. The concept of a GPFB enables one to unify the analysis of the relationships between the PFB structure and various differential geometric structures into a single formalism. We'll also discuss the application of the GPFB program to the mechanics of fluids and general relatvity. (Received March 04, 2017)

1129-58-356 **Onur Alper*** (alper@cims.nyu.edu), 251 Mercer Street, New York, NY 10012. *Defects of liquid crystals with variable degree of orientation.*

We will discuss the structure of line defects in minimizing configurations of the modified Ericksen model for nematic liquid crystals. Firstly, we will focus on a joint work with Fang-Hua Lin and Robert Hardt regarding the topological structure of defects. If time permits, we will also discuss a more recent result: that the line defects in this context have locally finite length. (Received March 20, 2017)

60 ► Probability theory and stochastic processes

1129-60-21 **Louis V QUINTAS*** (lvquintas@gmail.com), Mathematics Department, Pace University, New York, NY 10038, and **Edgar G. DuCasse** (educasse@pace.edu), Mathematics Department, Pace University, New York, NY 10038. *Random processes with transition digraphs whose nodes are graphs.* Preliminary report.

Let Cl denote a class of unlabeled graphs of order n. A graph G(0) in Cl is called an initial graph in Cl , if the deletion of any edge of G(0) produces a graph not in Cl. Then, starting at any G(0) in Cl , randomly add an edge uv to start a random walk (G(i)) such that at each step G(i + 1) = G(i) U uv is in Cl for all i greater than or equal to 0.

The probability that edge uv is selected is 1/N, where N not equal to 0 is the number of edges such that G(i + 1) = G(i) U uv is in Cl. If N = 0, then the graph G(i) is called a terminal graph.

The transition digraph for this random process is the directed graph made up of the union of all such random walks. Each random walk is a Markov chain.

Old and new random processes of this type are studied yielding new results and observations concerning these processes. Obtained are properties of their transition digraphs and their underlying graphs. (Received January 15, 2017)

1129-60-202 **Moumanti Podder*** (mp3460@nyu.edu), 226-230 East 12th Street, Apartment 11B, New York, NY 10012. *The Strange Logic of Galton-Watson Trees.*

This talk will focus on the rooted Galton-Watson (GW) tree with Poisson(λ) offspring distribution, though most of the results can be extended to very general distributions. I shall discuss first the analysis of first order (FO) properties: these capture the local structures inside a tree. I give a complete description of the probabilities $P_\lambda[A]$ of all possible FO sentences A conditioned on the survival of the GW tree. There are, up to tautology, only a finite number of FO sentences of given quantifier depth k. For an arbitrary k, I introduce a natural distributional recursion Ψ_k, such that the probabilities of these sentences form a fixed point of Ψ_k. I further show that Ψ_k is a contraction, and that its fixed point is unique and analytic in λ.

Time permitting, I shall gloss over some recently finished results concerning existential monadic second order (EMSO) properties of trees. I define the notion of *interpretation* of fixed points derived from *tree automata*, and discuss a bit about *rogue fixed points*, the ones that do not admit any interpretation. I illustrate these via a nice example of an EMSO. I shall end with speculations and conjectures that hopefully the audience will find fascinating. (Received March 15, 2017)

1129-60-357 **Yuri Bakhtin*** (bakhtin@cims.nyu.edu), 251 Mercer St, New York, NY 10012. *Ergodic theory of the Burgers equation with random forcing.*

The Burgers equation is a basic nonlinear evolution PDE of Hamilton–Jacobi type related to fluid dynamics and growth models. I will talk about the ergodic theory of randomly forced Burgers equation in noncompact setting. The basic objects are one-sided infinite minimizers of random action (in the inviscid case) and polymer measures on one-sided infinite trajectories (in the positive viscosity case). This is joint work with Eric Cator, Kostya Khanin, and Liying Li. (Received March 20, 2017)

1129-60-367 **Kavita Ramanan*** (kavita_ramanan@brown.edu). *Tales of Random Projections: where Geometry meets Probability Theory.*

The structure of high-dimensional measures is a fascinating subject whose study leads to an interesting interplay between geometry and probability. Classical theorems in probability theory such as the central limit theorem and Cramér's theorem can be viewed as providing information about certain scalar projections of high-dimensional product measures. This talk will focus on the behavior of random projections of more general (non-product) high-dimensional measures, which are of interest in diverse fields, ranging from asymptotic convex geometry to high-dimensional statistics. Although the study of (typical) projections of high-dimensional measures dates back to Borel, only recently has a theory begun to emerge that identifies the role of certain geometric assumptions that lead to better behaved projections. We will review past work on this topic, including a striking central limit theorem for convex sets, and show how it leads naturally to questions on the tail behavior of random projections, and the study of large deviations on the Stiefel manifold. We will describe our recent results in this direction, their implications and several open questions. (Received March 20, 2017)

1129-60-417 **Gideon Simpson*** (grs53@drexel.edu), Philadelphia, PA 19123. *Spin-Diffusions and Diffusive Molecular Dynamics.*

Diffusive Molecular Dynamics (DMD) is a novel approach to problems in molecular dynamics that aims to reach the diffusive time scale of milliseconds and beyond. To accomplish this, DMD "averages out" the vibrational time scale of femtoseconds and evolves probability densities at atomistic sites. This requires the approximation of a probability distribution in an extended state space by a synthetic approximate distribution, which can easily be sampled. The mean occupancy at the atomic sites are then evolved according to a system of coupled ODEs, under a so-called Master Equation, but no underlying stochastic process is given in the current formulation. In this work, we propose and examine a stochastic process, coupling a diffusion to a spin model, which gives rise to similar dynamics as DMD. This primitive model also offers a way to connect DMD to a more traditional MD. (Received March 20, 2017)

62 ► Statistics

1129-62-234 **Amy Willis*** (amy.willis7@gmail.com), Department of Statistical Science, Comstock Hall, ITHACA, NY 14853. *Confidence sets for phylogenetic trees.*

Phylogenetic trees represent evolutionary histories and have many important applications in biology, anthropology and criminology. The branching structure of the tree encodes the order of evolutionary divergence, and the branch lengths denote the time between divergence events. The target of interest in phylogenetic tree inference is high-dimensional, but the real challenge is that both the discrete (tree topology) and continuous (branch lengths) components need to be estimated. While decomposing inference on the topology and branch lengths has been historically popular, the mathematical and algorithmic developments of the last 15 years have provided a new framework for holistically treating uncertainty in tree inference. I will discuss how we can leverage these developments to construct a confidence set for the Fréchet mean of a distribution with support on the space of phylogenetic trees. The sets have good coverage and are efficient to compute. Time permitting, I will discuss the procedure in the context of an HIV forensics investigation, and to assess confidence in the geographical origins of the Zika virus. (Received March 16, 2017)

65 ► Numerical analysis

1129-65-143 **Yi Grace Wang*** (ywang392@syr.edu), 215 Carnegie Hall, Syracuse, NY 13244, and **Ingrid Daubechies** and **Hau-Tieng Wu**. *ConceFT: Concentration of Frequency and Time via a multitapered synchrosqueezed transform.*

Time-frequency representations provide a powerful tool for the analysis of time series signals. Techniques that decompose the time-dependent signals into multiple oscillatory components, with time-varying amplitudes and instantaneous frequencies are very appealing and have been shown to be useful in a wide range of applications including geophysics, biology, medicine, finance and social dynamics. In this talk, I'll give an introduction to time-frequency representations and review existing methods for the previously described decomposition. Then I'll present a new method that applies the multitapering with synchrosqueezed transform. Numerical experiments as well as a theoretical analysis will be demonstrated to assess its effectiveness. (Received March 11, 2017)

1129-65-205 **Noel J Walkington*** (noelw@andrew.cmu.edu), Carnegie Mellon University, 5000 Forbes Ave, Pittsburgh, PA 15213. *Numerical Approximation of Complex Fluids.*

Many models of polymers, liquid crystals, and fluids with multiple phases, consist of the momentum equation coupled to equations for internal variables which characterize fine scale structures and phases formation. Examples include the Ericksen–Leslie model of liquid crystals with nematic and isotropic regions and the Oldroyd–B fluid. The variational structure of these equations models the subtle balance between inertia, transport, and dissipation. This talk will illustrate how the underlying variational structure of these equations can be used to develop stable numerical schemes to simulate these systems and the corresponding numerical analysis. (Received March 15, 2017)

1129-65-228 **Erin Claire Carson*** (erin.carson@nyu.edu). *Communication-Avoiding Krylov Subspace Methods.*

Solvers for sparse linear algebra problems, ubiquitous throughout scientific codes, often limit application performance due to a low computation/communication ratio. In this talk, we present work in the development of parallel communication-avoiding Krylov subspace methods, which can yield performance improvements in a wide variety of scientific applications. Focusing on the conjugate gradient method, we discuss convergence and stability properties in finite precision as well as tradeoffs between performance and accuracy that arise due to both machine parameters and the numerical properties of the problem. We conclude with recommendations on when we expect communication-avoiding variants to be beneficial in practice. (Received March 16, 2017)

1129-65-277 **Vira Babenko***, Department of Mathematics, Ithaca College, Ithaca, NY 14850. *A generalized approach to the numerical analysis of set-valued and fuzzy-valued functions.*

A wide variety of questions which range from social and economic sciences to physical and biological sciences lead to functions with values that are sets in finite or infinite dimensional spaces, or that are fuzzy sets. With the fast-moving development of uncertainty quantification and set-valued optimization, such set-valued and fuzzy-valued functions attract recently a lot of attention. In this talk we consider a generalized concept of such functions, that of functions with values in so-called L-space, that encompasses set-valued and fuzzy functions as special cases and allow to investigate them from the common point of view. We will discuss several problems of Numerical Analysis for functions with values in L-spaces. In particular numerical methods of solution of Fredholm and Volterra integral equations for such functions will be presented. (Received March 17, 2017)

1129-65-317 **Eric Joseph Hall*** (hall@math.umass.edu), Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003, and **Markos A. Katsoulakis** (markos@math.umass.edu), Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003. *Goal-oriented information divergences for quantifying model-form uncertainty in subsurface flow.* Preliminary report.

Elliptic random partial differential equations arise in many applications of time-independent subsurface flow, including hydrology, carbon sequestration, petroleum engineering, and composite biological materials. A key challenge in these problems is the quantification of uncertainties in observables or quantities of interest. In this talk we derive information theoretic divergences for observables that distinguish between different sources of uncertainty with a view toward robust prediction and risk management. We demonstrate an application to sensitivity analysis for parametric model-form uncertainty in time-independent groundwater flow. (Received March 20, 2017)

1129-65-420 **Ilija Jegdic*** (ilija.jegdic@tsu.edu), 3100 Cleburne St, Houston, TX 77004. *Overlapping grids for one-dimensional conservation laws.*

We consider a numerical method for overlapping grids for conservation laws based on a finite volume method. We present convergence analysis in one-dimensional case and we prove that if numerical solutions converge boundedly almost everywhere then they converge to the entropy solution. The idea of overlapping grids is important for practical applications and we illustrate the method on several examples involving shocks and rarefaction waves. (Received March 20, 2017)

1129-65-425 **Tatyana Sorokina*** (tsorokina@towson.edu). *Continuous piecewise divergence-free spline vector fields on Alfeld refinement of simplicial partitions.*

Dimension and a minimal determining set for continuous piecewise divergence-free spline fields on the Alfeld split of a simplex in $\mathbb{R}^n$ are obtained using new Bernstein-Bézier techniques, as well as the dimension formula for continuous piecewise divergence-free splines on the Alfeld refinement of an arbitrary simplicial partition in $\mathbb{R}^n$. (Received March 20, 2017)

68 ► Computer science

1129-68-287 **B Mishra*** (mishra@nyu.edu), 251 Mercer St, New York, NY 10012. *Causality, Kernels and Clocks in Cancer: A Cook's Tour.*

"What if doctors could call up a computerized map that would show them how a case of cancer is likely to progress? Tumor cells can mutate in unexpected ways. And cancers can suddenly grow. For doctors, anticipating cancer's next moves can help guide timely, effective patient treatment. A mapping program, developed by an international team of mathematicians and computer scientists, aims to help physicians in staying a step ahead of cancer and preparing long-term treatment plans with fewer elements of surprise. How does it work?" We will provide a Cook's tour of the mathematical tools used for this, building upon probabilistic temporal logic models of somatic evolution of tumorigenesis. We will also compare our tools to others building upon phylogeny of tumor cell populations. (Received March 18, 2017)

1129-68-316 **Alexandr Andoni*** (andoni@cs.columbia.edu), 450 Computer Science Building, 1214 Amsterdam Avenue, Mail Code 0401, New York, NY 10027, and **Huy Nguyen**, **Aleksandar Nikolov**, **Ilya Razenshteyn** and **Erik Waingarten**. *Embeddings of symmetric normed spaces with applications.*

High-dimensional Nearest Neighbor Search (NNS) problem is a classic problem at the crossroads of theoretical computer science and machine learning. In one variant of it, we are given a high-dimensional pointset P, and we are to find the closest pair of points inside P, i.e., a pair at the smallest distance. The main objective is to obtain algorithms running faster than simply enumerating all pairs of points in P, perhaps at the expense of outputting only an approximately-closest pair. Past research has shown efficient approximate algorithms for standard distances such as the Euclidean or the ℓ_p norms.

We give an algorithm for the general problem of NNS under an *arbitrary high-dimensional symmetric norm*. The crux of the algorithm is a near-isometric embedding of an arbitrary symmetric norm into an universal norm, whose dimension is only polynomially-bounded in the dimension of the original symmetric norm. This universal norm is a product space of simpler norms, namely of ℓ_p's and the top-k norm, for which we have (or design new) efficient algorithms. (Received March 19, 2017)

1129-68-389 **Anastasios Sidiropoulos*** (sidiropoulos.1@osu.edu), **Dingkang Wang** (wang.6150@buckeyemail.osu.edu) and **Yusu Wang** (yusu@cse.ohio-state.edu). *Metric embeddings with outliers.*

We initiate the study of metric embeddings with outliers. Given some finite metric space we wish to remove a small set of points and to find either an isometric or a low-distortion embedding of the remaining points into some host metric space. This is a natural problem that captures scenarios where a small fraction of points in the input corresponds to noise.

We present polynomial-time approximation algorithms for computing outlier embeddings into Euclidean space, trees, and ultrametrics. In the case of isometric embeddings the objective is to minimize the number of outliers, while in the case of non-isometries we have a bi-criteria optimization problem where the goal is to minimize both the number of outliers and the distortion. We complement our approximation algorithms with NP-hardness results for these problems. (Received March 20, 2017)

1129-68-469 **BENOIT MONIN*** (`benoit.monin@gmail.com`), 75019 Paris, France. *Asymptotic density and error correcting codes.*

Andrews, Cai, Diamondstone, Jockusch and Lempp assigned in "Asymptotic density, computable traceability and 1-randomness" a value gamma (with lower case 'g') to each set of natural numbers, which indicates how far the set is from being coarse-computable. They used this to assign a value Gamma (with upper case 'G') to each Turing degree, which indicates how far the degree is from being coarse-computable. They proved that the Gamma values of 0, 1/2 and 1 can be realized. They also proved that if a Turing degree has a Gamma value strictly larger than 1/2, then it is the computable degree and its Gamma value in fact equals 1. They asked whether a Turing degree can have a Gamma value strictly in between 0 and 1/2.

Using notions from computability theory, developped by Monin and Nies, together with some techniques from the field of error-correcting codes, we are able to give a negative answer to this question: The only Gamma values that can be realized by a Turing degrees are $0, 1/2$ and 1. (Received March 21, 2017)

70 ► Mechanics of particles and systems

1129-70-411 **Miranda Holmes-Cerfon***, holmes@cims.nyu.edu, and **Yoav Kallus**. *The statistical mechanics of singular sphere packings.*

What are all the ways to arrange N hard spheres to form a rigid cluster? The answer brings insight to a number of phenomena in materials science, from nucleation, to emergence, to self-assembly. We enumerate packings of $N \leq 19$ spheres using a deterministic numerical algorithm, whose completeness could be addressed using geometrical methods.

We next ask: what is the free energy of the clusters when the spheres interact with a very short-range potential? For all so-called "regular' clusters, this can be evaluated using a harmonic approximation for the energy. However, the list contains a great many "singular' clusters, which correspond to singular solutions to a set of algebraic equations. These are also the clusters one sees with unusually high probability in experiments. We show how to compute the leading-order contribution to their free energy, and discuss implications for problems in materials science. (Received March 20, 2017)

74 ► Mechanics of deformable solids

1129-74-350 **Mallikarjunaiah S Muddamallappa*** (`msmuddamallappa@wpi.edu`), 100 Institute Road, Worcester, MA 01609, and **Christopher Larsen** and **Marcus Sarkis**. *On an adaptive finite element phase-field dynamic fracture model:a single anti-plane shear crack.*

In this talk we describe an efficient finite element treatment of a variational, time-discrete model for dynamic brittle fracture. We start by providing an overview of an existing dynamic fracture model that stems from Griffith's theory and based on the Ambrosio-Tortorelli crack regularization. We propose an efficient numerical scheme based on the bilinear finite elements. For the temporal discretization of the equations of motion, we use generalized α-time integration algorithm, which is implicit and unconditionally stable. To accommodate the crack irreversibility, we use a primal-dual active set strategy, which can be identified as a semi-smooth Newton's method. It is well known that to resolve the crack-path accurately, the mesh near the crack needs to be very fine, so it is common to use adaptive meshes. We propose a simple, robust, local mesh-refinement criterion to reduce the computational cost. We show that the phase-field based variational approach and adaptive finite-elements provides an efficient procedure for simulating the complex crack propagation including crack-branching. (Received March 21, 2017)

76 ► Fluid mechanics

1129-76-376 **Cecilia F Mondaini*** (`cfmondaini@gmail.com`). *Analysis of a feedback-control data assimilation algorithm.*

The purpose of this talk is to present some analysis results concerning a feedback-control (nudging) approach for data assimilation that works for a general class of dissipative dynamical systems and observables. In particular, we first show how to treat the case of discrete in time measurements with systematic errors. Later, we show how to obtain an analytical estimate of the error committed when using a numerical approximation of the feedback-control equation given by the Postprocessing Galerking method. Most importantly, the error estimate obtained in this latter result is uniform in time, which reflects the global stability of the system. This talk is based on joint works with C. Foias and E. S. Titi. (Received March 20, 2017)

1129-76-462 **Qi Wang***, Department of Mathematics, Columbia, SC 29208. *Active Liquid Crystals and their Applications to Cell Motility.*

I will discuss a set of models for active liquid crystals that are derived following the generalized Onsager principle. Their predictions in various confined geometries will be discussed briefly. Then, I will apply these models to study cell motility. A multiphase complex fluid model incorporating the active liquid crystal as one of the active matter layer will be introduced and discussed. Numerical simulations using the model for cell migration on patterned substrates will be presented. (Received March 21, 2017)

1129-76-471 **Ruhai Zhou*** (rzhou@odu.edu), Department of Mathematics & Statistics, Old Dominion University, Norfolk, VA 23529, and **M Gregory Forest** and **Qi Wang**. *Phase diagram of kinetic attractors of active nematic suspensions.*

Based on the kinetic model for active suspensions of nematic polymers, we present some numerical simulation results to show various attractors and their transitions. These attractors include both 1D banded and 2D cellular, stationary and strong oscillatory states. A phase diagram is given in the parameter space of nematic strength and activation strength. Some properties of these attractors will be examined in detail. (Received March 21, 2017)

1129-76-475 **Carme Calderer***, School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *Liquid Crystal Electrokinetics.*

We consider flow of liquid crystals containing ionic charges and driven by an applied electric field. Recent experiments show remarkable new features resulting from coupling between flow anisotropy, especially defects, and electric charge [O.D.Lavrentovich, 2014]. We present the Ericksen-Leslie equations of electrokinetics and discuss their well-posedness. We give examples of charge separation in connection with line defects in Poiseuille flow. The research is aimed at understanding phenomena of nonlinear electrophoresis in liquid crystal flow environment. (Received March 21, 2017)

1129-76-516 **Daniel Fusca*** (dfusca@math.toronto.edu), Department of Mathematics, University of Toronto, 40 St. George St., Room 6290, Toronto, Ontario M5S 2E4, Canada. *Lie algebroid and a rigid body in a fluid.*

In the '60s, Arnold framed the motion of an incompressible fluid as the Euler-Poincare equations on the dual of the Lie algebra of divergence-free vector fields. If a free rigid body is present in the fluid, it turns out that the corresponding phase space becomes (the dual of) a certain Lie algebroid, rather than the Lie algebra of vector fields. In this talk we outline how the equations of motion for a rigid body in an incompressible fluid may be derived as Euler-Poincare equations on the dual of a naturally chosen Lie algebroid. (Received March 21, 2017)

81 ► Quantum theory

1129-81-41 **Dr. Lia Leon Margolin*** (lmargolin@mmm.edu), 221 East 71 Street, New York, NY 07030. *Model- Independent Approaches for the Description of Quantum Systems.*

The main problem that arises when investigating dynamics of quantum systems is the problem of kinematic rotations under particle permutations. When number of particles increases, kinematic rotations include not only particle permutations but also transitions between different possible configurations, and mathematical calculations using complex general formula become impossible. Proposed model-independent approach for the description of N particle quantum systems in multidimensional momentum space solves this problem by using the Parentage Scheme of Summarization to the N-body symmetrized basis construction, necessary for the description of the structural characteristics and decay reactions of quantum systems with arbitrary amount of particles. Generalized mathematical formalism to the construction of N-particle fully symmetrized hyperspherical functions on the basis of the N-particle hyperspherical functions symmetrized with respect to N-1 particles is applied to the solution of few-body problem in hypernuclear physics. Wave functions are expanded in a complete set of symmetrized N-1 particle hyperspherical functions. Good convergence for the ground state energy in the number of included harmonics is obtained. (Received February 04, 2017)

82 ► *Statistical mechanics, structure of matter*

1129-82-384 **Maxim O Lavrentovich*** (lavrentm@gmail.com), 209 S 33rd St, Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, PA 19104. *Putting Patterns on Cholesteric Shells.*

Intricate patterning, reminiscent of the structures observed on the surfaces of pollen grains, occurs on the surface of cholesteric liquid crystal (CLC) shells under the appropriate anchoring conditions. We discuss how to control the CLC shell pattern through anchoring and confinement. When patterns such as stripes or hexagonal tilings form on a spherical surface, topology forces in defects in the patterns. These defects, then, have an interplay with the defects in the orientational order of the CLC as we change the anchoring conditions. We discuss these features and compare experiments to Landau-de Gennes modelling of the CLC shells. We also discuss general features of transitions to phases in which a pattern with a characteristic wavelength (set by the pitch in the CLC) must tile a sphere, and how such a transition may manifest in pollen grain development. (Received March 20, 2017)

1129-82-457 **Sookyung Joo*** (sjoo@odu.edu), Department of Mathematics and Statistics, Old Dominion University, Norfolk, VA 23508, and **Andres Contreras**, **Carlos Garcia-Azpeitia** and **Carlos Garcia-Cervera**. *External field response of smectic A liquid crystals in three dimensions.*

We study the Landau-de Gennes free energy to describe the undulatory instability in smectic A liquid crystals subjected to magnetic fields. We prove this phenomena by the bifurcation theory to the nonlinear system of Landau-de Gennes model. The bifurcation at the onset of undulation in 3D is not simple. We identify the irreducible representations for natural actions on the functional that take into account the invariances of the problem thus allowing for reducing the bifurcation analysis to a subspace with symmetries. A reduced 2D model provides a qualitative structure of the minimizer. We also perform numerical simulations to illustrate the results of our analysis. (Received March 21, 2017)

90 ► *Operations research, mathematical programming*

1129-90-506 **Yun Lu*** (lu@kutztown.edu), Mathematics Department, Kutztown University, Kutztown, PA 19530. *Improved Teaching-Learning-Based Optimization Metaheuristic for Multiple-Choice Multidimensional Knapsack Problems.*

In this paper, we improve the performance of the teaching-learning-based optimization (TLBO) method by introducing 'teacher training' before the teaching phase of TLBO. That is, before the teaching phase of TLBO, we perform a local neighbourhood search on the best solution (the teacher) in the current population. The effectiveness of teacher training (TT) in terms of both solution quality and convergence rate will be demonstrated by using this approach (TT-TLBO) to solve a large (393) number of problem instances from the literature for the important (NP-Hard) multiple-choice multidimensional knapsack problem (MMKP). Furthermore, we will demonstrate that TLBO outperforms the best published solution approaches for the MMKP. (Received March 21, 2017)

91 ► *Game theory, economics, social and behavioral sciences*

1129-91-496 **Gwen M Spencer***, Burton Hall, Smith College, Northampton, MA 01063. *Economic spread in networks: theorems, measurements, and uncertainty.* Preliminary report.

Network seeding, or selecting a seed set of "high influence" in a network, is a famous problem in combinatorial optimization. Unfortunately, there is a significant disconnect between spread models where algorithmic guarantees have been proved and those that resemble rational (or behaviorally-observed) economic spread. We will mention some provable results on convergence times and measurements of robustness in the face of link-uncertainty. Computational investigation exposes some strong contrasts with the typical submodular spread mechanism. (Received March 21, 2017)

92 ► Biology and other natural sciences

1129-92-100 **Colby Long*** (long.1579@mbi.osu.edu) and **Daniel Irving Bernstein**. *L-infinity optimization to linear spaces and phylogenetic trees.*

Given a distance matrix consisting of pairwise distances between taxa, a distance-based phylogenetic reconstruction method returns a tree metric or equidistant tree metric (ultrametric) that best fits the data. We investigate distance-based phylogenetic reconstruction using the l^{∞}-metric. In particular, we will present results on the dimension of the set of l^{∞}-closest ultrametrics or tree metrics to an arbitrary dissimilarity map. We will show that these sets often contain points representing many different tree topologies. Our approach is to first address uniqueness issues arising in l^{∞}-optimization to linear spaces. We show that the l^{∞}-closest point in a linear space is always unique if and only if the underlying matroid of the linear space is uniform. Finally, we will discuss some of the implications of these results for phylogenetic reconstruction using the l^{∞}-metric. (Received March 06, 2017)

1129-92-130 **Chong Wang*** (chongwang@gwu.edu), 532 20TH ST NW, Apt 705, Washington, DC 20006, and **Yanxiang Zhao** and **Xiaofeng Ren**. *Pattern formation – on the modeling of multi-constituent inhibitory systems.*

Skin pigmentation, animal coats and block copolymers, which can be considered as multi-constituent inhibitory systems, are all around us. Theoretical analysis and numerical simulation of multi-constituent inhibitory systems will be provided here. An inhibitory system is studied as a nonlocal geometric variational problem. The free energy of the system is the sum of two terms: the total size of the interfaces separating the constituents, and a longer ranging interaction energy that inhibits micro-domains from unlimited growth. We establish that in different parameter ranges there are corresponding assemblies of certain patterns that exist as the stationary sets of the free energy functional. Numerically, a diffusive interface model is proposed and many self-assembly processes, which form various patterns, are vividly showed here. Different numerical schemes are compared and a new technique is introduced to be consistent with the Euler-Lagrange equation in the sharp interface model. (Received March 10, 2017)

1129-92-223 **Ruth E. Davidson*** (redavid2@illinois.edu), Department of Mathematics, 1409 W. Green Street, Urbana, IL 61801, and **Joseph Rusinko**, **Zoe Vernon** and **Jing Xi**. *Mining Abundant Public Genome Data to Recover Statistical Trends using Geometry.*

Websites such as TreeBASE.org and datadryad.org provide public access to a wealth of genomic data. Phylogenomics-the recovery of tree-like trends in the common evolutionary history of a group of species-is a basic area of research that is consumed by myriad fields such as ecology and medicine. We present a project that provides a baseline framework for studying statistical trends in public genomic data that relies on geometric combinatorics. Further, we will outline future research directions that will (1) build on this baseline framework to inform the development of new theory and methods for model-testing, and (2) improve the understanding of trends in phylogenomic data in the systematic biology, computer science, statistics, and mathematics communities. (Received March 16, 2017)

1129-92-355 **Angelika Manhart*** (angelika.manhart@cims.nyu.edu), **Pierre Degond** and **Hui Yu**. *Traveling Waves in Myxobacteria.*

Myxobacteria are social bacteria, that can glide in 2D and form counter-propagating, interacting waves. In this talk I will present a novel age-structured, continuous macroscopic model for the movement of myxobacteria. The derivation is based on microscopic interaction rules that can be formulated as a particle-based model and set within the SOH (Self-Organized Hydrodynamics) framework. The strength of this combined approach is that microscopic knowledge or data can be incorporated easily into the particle model, whilst the continuous model allows for easy numerical analysis of the different effects. This allows to analyze the influence of a refractory (insensitivity) period following a reversal of movement. Our analysis reveals that the refractory period is not necessary for wave formation, but essential to wave synchronization, indicating separate molecular mechanisms. (Received March 20, 2017)

1129-92-401 **R Davidson**, **M Lawhorn**, **J Rusinko*** (rusinko@hws.edu) and **N Weber**. *Efficient Quartet Systems.*

Quartet trees displayed by larger phylogenetic trees have long been used as inputs for species tree and supertree reconstruction. Computational constraints prevent the use of all displayed quartets in many practical problems with large numbers of taxa. We introduce the notion of an Efficient Quartet System to represent a phylogenetic tree with a subset of the quartets displayed by the tree. Using performance tests on simulated datasets, we demonstrate that using an Efficient Quartet System to reduce the number of quartets in both summary method pipelines for species tree inference as well as methods for supertree inference results in only small reductions in accuracy. (Received March 20, 2017)

1129-92-405 **Francesca M Falzon*** (fmf19@scarletmail.rutgers.edu), Hill Center for the Mathematical Sciences, 110 Frelinghuysen Road, Rutgers University, Piscataway, NJ 08854. *On the Complexity of the Rooted-Triples Closure Problem.* Preliminary report.

The study of binary trees arises naturally from phylogenetics. By examining evolutionary relationships as rooted triples on three leaves, we aim to prove or disprove the existence of an efficient algorithm for determining all relationships implied by a set of triples. Given a set of rooted triples, R, on a set of species, S, can we determine all new triples inferred by the initial set, R, (i.e. the closure) in polynomial time? This question was originally posed by Mike Steel in 2007. We look at a reduction from the Hamiltonian Path Problem in directed acyclic graphs.

This is joint work with Zara Adamou, Yulia Alexandr, Jeremy Alexandre, Abigail Banting, Jona Kerluku, Megan Owen, Edgar Palaquibay, Katherine St. John, Arnav Sood, Emre Tetik, and Moshiyakh Tokov as part of the Fall 2016 Treespace REU at Lehman College, CUNY. (Received March 20, 2017)

1129-92-427 **Sarah Feldt Muldoon*** (smuldoon@buffalo.edu), **Fabio Pasqualetti**, **Shi Gu**, **Matthew Cieslak**, **Scott T Grafton**, **Jean M Vettel** and **Danielle S Bassett**. *Data-driven modeling of brain dynamics: stimulation and control.*

Representing the brain as a complex network of interacting components allows for insight into brain function, and computational modeling provides a controlled environment to test theoretical predictions of brain network structure. Here, we use a data-driven computational model of brain dynamics to test the relationship between regional network controllability calculations and the ability of stimulation to impart change in functional network configurations. The model is built on structural brain networks derived from diffusion spectrum imaging data, and regional brain dynamics are modeled using biologically motivated nonlinear Wilson-Cowan oscillators. Through the systematic application of a regional stimulation protocol, we observe that stimulation of brain regions within different cognitive systems differentially impacts local and global brain dynamics. In particular, regions within the default mode system are capable of imparting large global change despite being highly constrained by structural connectivity. By elucidating the link between regional stimulation and system effects, our modeling approach provides insight into how single regions drive global brain dynamics and opens the door for the development of novel stimulation protocols for personalized medical treatments. (Received March 20, 2017)

1129-92-470 **Ward C Wheeler*** (wheeler@amnh.org), Division of invewrtebrate Zoology, American Museum of Natural History, 200 Central Park West, New Yok, NY 10024. *Improvements in Tree and Network Alignment Algorithms.* Preliminary report.

Tree-Alignment (sensu Sankoff) has been known to be NP-hard for some time. Recent improvements in both the quality (in terms of optimality score) and time complexity of heuristic approaches to this problem are discussed in the context of soft-wired networks. The effectiveness of these approaches to both simulated and real data sets are discussed. (Received March 21, 2017)

1129-92-503 **Sakellarios Zairis***, 1130 St. Nicholas Avenue, New York, NY 10032, and **Hossein Khiabanian**, **Andrew J Blumberg** and **Raul Rabadan**. *Genomic data analysis in tree spaces.*

Accelerating collection of genomic data has highlighted the need for both statistical comparison and intuitive visualization of high-dimensional clonal processes. In biomedical applications, we are often interested in classifying distinct evolutionary patterns by understanding the relative lengths of edges in a phylogenetic tree: rescaling edge lengths should not change the relationship between branches. Motivated by this consideration, and building upon the metric geometry of tree spaces, we define a moduli space of phylogenetic trees with unit sum of branch lengths. This projective tree space enables direct visualization of evolutionary patterns in collections of longitudinal sequencing data. For settings of long and densely sampled clonal processes, such as influenza surveillance, we introduce tree dimensionality reduction (TDR), a stable approach for mapping large phylogenetic trees to distributions of smaller ones. These distributions of subtrees are amenable to statistical summarization, since inter-tree distance calculations are polynomial in the number of leaves in BHV tree spaces. We apply TDR to 23 seasons of H3N2 hemagglutinin sequences, and observe that the variance in the distributions of subtrees correlates negatively with future influenza vaccine effectiveness. (Received March 21, 2017)

1129-92-525 **Rolf J Ryham*** (rryham@fordham.edu), 441 E Fordham Rd, Bronx, NY 10458.
Calculating Energy Barriers and Activation States for Steps of Fusion.

Fusion between biological membranes is a widespread cellular process, responsible for events as varied as secretion of neurotransmitters and fertilization of egg by sperm. Molecularly, fusion is the merger of two lipid bilayer membranes, and this merger proceeds through several key intermediates states. But the transition energy barriers that separate these intermediates have not been determined. Using the string method, we calculate a least energy pathway and the activation states between intermediates for the entire fusion process. The bilayer energetics are based on a modified Helfrich Hamiltonian that accounts for long range interactions between bilayers, and a novel field theoretic treatment of hydrophobic potentials. Through the energetic analysis, we conclude that lipid de-mixing is required for the transition from a stalk to a hemifusion diaphragm, and that complete fusion is possible provided pore formation is initiated while the diaphragm is small. The calculations provide a movie of individual lipid deformations, as the membrane geometry and topology evolve over time. (Received March 22, 2017)

94 ► Information and communication, circuits

1129-94-90 **Vladimir Shpilrain*** (shpil@groups.sci.ccny.cuny.edu), Department of Mathematics, The City College of New York, New York, NY 10031, and **Dima Grigoriev** and **Laszlo B. Kish**. *Yao's millionaires' problem and public-key encryption.*

We offer efficient and practical solutions of Yao's millionaires' problem without using any one-way functions. Some of the solutions involve physical principles, while others are purely mathematical. One of our solutions (based on physical principles) yields a public-key encryption protocol secure against (passive) computationally unbounded adversary. In that protocol, the legitimate parties are not assumed to be computationally unbounded.
(Received March 06, 2017)

1129-94-180 **Benjamin Fine*** (fine@fairfield.edu), Department of Mathematics, Fairfield University, Fairfield, CT 06824, **Anja Moldenhauer**, Department of Mathematics, Florida Stlantic University, Boca Rtaon, FL , and **Gerhard Rosenberger**, Fachebriech Mathematik, University of Hamburg, Hamburg, Germany. *An Analysis of the Closest Vector Secret Sharing Scheme.*

Abstract:

An (n,t) secret sharing scheme with $t \leq n$ is a crypotgrapic protocol designed to allow a secret to be shared among n participants in such a way that any t can access the secret but not less than t. The gold standard in secret sharing is a beautiful method due to Shamir based on polynomial interpolation. In this talk we discuss a geometric alternative to the Shamir scheme given by Chum, Fine, Rosenberger and Zhang based on the closest vector theorem. We show hos this method can be implemented and show that it has several advantages over the Shamir scheme. (Received March 14, 2017)

1129-94-186 **Chi Sing Chum** and **Xiaowen Zhang*** (xiaowen.zhang@csi.cuny.edu), 2800 Victory Blvd, 1N-215, Department of Computer Science, College of Staten Island, Staten Island, NY 10314. *Bloom filters and their applications in searchable encryption schemes.*

Bloom filter is a probabilistic data structure and a space-efficient tool for testing set membership with a lot of practical applications. It can be used to store indexes of documents in large databases to facilitate the search. It has been used in searchable encryption schemes in which both documents and indexes are encrypted. But false positive exists. We propose a new Bloom filter structure to cut down both false positive rate and filter size meanwhile fulfilling the user requirements. (Received March 15, 2017)

1129-94-335 **Akram Aldroubi***, Mathematics/Vanderbilt, and **Ilya Krishtal** and **Sui Tang**.
Phaseless reconstruction from space-time samples.

Phaseless reconstruction from space-time samples is the nonlinear problem of recovering a function x in a Hilbert space $\mathcal{H}$ from the absolute values of linear measurements $\{|\langle x, \phi_i\rangle|, \ldots, |\langle A^{L_i}x, \phi_i\rangle| : i \in \mathcal{I}\}$, where $\{\phi_i; i \in \mathcal{I}\} \subset \mathcal{H}$ is a set of functionals on $\mathcal{H}$, and A is a bounded operator on $\mathcal{H}$ that acts as an evolution operator. In this talk, we present various sufficient or necessary conditions for solving this problem. (Received March 19, 2017)

1129-94-486 **Delaram Kahrobaei**, PhD Program in Computer Science, Office 4410, 365 Fifth Avenue, New York, NY 10016, **Dmytro Savchuk*** (savchuk@usf.edu), 4202 E Fowler ave, CMC 342, Tampa, FL 33620, and **Vladimir Shpilrain**, Department of Mathematics, The City College of New York, Convent Ave at 138th Street, New York, NY 10031.
Non-commutative polly cracker-type cryptosystem. Preliminary report.

We present a variant of a polly cracker type cryptosystem based on polynomials over non-commutative matrix rings. The problems on which the security of the system is based will be discussed. (Received March 21, 2017)

1129-94-524 **Katie Haymaker*** (kathryn.haymaker@villanova.edu), **Gretchen Matthews** and **Beth Malmskog**. *Relating distance and availability in locally recoverable codes with multiple recovery sets.*

Locally recoverable codes are error-correcting codes in which any given codeword symbol can be recovered by accessing at most r other (uncorrupted) symbols. The positions that that are used to recover a symbol are called its recovery set. In this talk we will relate the number of recovery sets t in an LRC with multiple recovery sets to the minimum distance of the code. (Received March 22, 2017)

2010 MATHEMATICS SUBJECT CLASSIFICATION

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00 General
01 History and biography
03 Mathematical logic and foundations
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General algebraic systems
11 Number theory
12 Field theory and polynomials
13 Commutative rings and algebras
14 Algebraic geometry
15 Linear and multilinear algebra; matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory; homological algebra
19 *K*-theory
20 Group theory and generalizations
22 Topological groups, Lie groups
26 Real functions
28 Measure and integration
30 Functions of a complex variable
31 Potential theory
32 Several complex variables and analytic spaces
33 Special functions
34 Ordinary differential equations
35 Partial differential equations
37 Dynamical systems and ergodic theory
39 Difference and functional equations
40 Sequences, series, summability
41 Approximations and expansions
42 Fourier analysis
43 Abstract harmonic analysis
44 Integral transforms, operational calculus
45 Integral equations
46 Functional analysis
47 Operator theory
49 Calculus of variations and optimal control; optimization
51 Geometry
52 Convex and discrete geometry
53 Differential geometry
54 General topology
55 Algebraic topology
57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
65 Numerical analysis
68 Computer science
70 Mechanics of particles and systems
74 Mechanics of deformable solids
76 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
85 Astronomy and astrophysics
86 Geophysics
90 Operations research, mathematical programming
91 Game theory, economics, social and behavioral sciences
92 Biology and other natural sciences
93 Systems theory; control
94 Information and communication, circuits
97 Mathematics education

0192-5857(2017)38:2;1-I