ABSTRACTS

of Papers Presented to the American Mathematical Society

Volume 36, Number 4, Issue 182 Fall 2015

Abstracts for

ISSN 0192-5857 Pages 1049–1183

AMS

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* Indicates who will present the paper at the meeting.

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Abstracts of Papers Presented to the American Mathematical Society (ISSN 0192-5857) is published four times a year by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2294. The subscription price for Volume 36 (2015) is US$174.00 list, US$139.20 institutional member, US$104.40 individual member. Please add US$5 for delivery within the United States; US$11 for delilvery outside the United States. Subscription renewals are subject to late fees. See `www.ams.org/customers/macs-faq.html#journal` for more information. Periodicals postage paid at Providence, RI. POSTMASTER: Send address change notices to Abstracts of Papers Presented to the American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294 USA.

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PAPERS PRESENTED AT MEETINGS

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

MEETING #	DATE	PLACE	ABSTRACT DEADLINE	ABSTRACT ISSUE
1116	January 6–9, 2016	Seattle, WA	EXPIRED	Vol 37, No. 1
1117	March 5–6, 2016	Athens, GA	January 19	Vol 37, No. 2
1118	March 19–20, 2016	Stony Brook, NY	February 2	Vol 37, No. 2
1119	April 9–10, 2016	Salt Lake City, UT	February 16	Vol 37, No. 2
1120	April 16–17, 2016	Fargo, ND	February 23	Vol 37, No. 2
1121	September 24–25, 2016	Brunswick, ME	July 19	Vol 37, No. 3
1122	October 8–9, 2016	Denver, CO	August 16	Vol 37, No. 3
1123	October 28–30, 2016	Minneapolis, MN	August 30	Vol 37, No. 4
1124	November 12–13, 2016	Raleigh, NC	September 13	Vol 37, No. 4
1125	January 4–7, 2017	Atlanta, GA	TBA	Vol 38, No. 1
1126	March 10–12, 2017	Charleston, SC	TBA	TBA
1127	April 1–2, 2017	Bloomington, IN	TBA	TBA
1128	April 22–23, 2017	Pullman, WA	TBA	TBA
1129	May 6–7, 2017	New York, NY	March 21	TBA
1130	July 24–28, 2017	Montréal, Canada	TBA	TBA

FULLERTON, CA, October 24–25, 2015

Abstracts of the 1114th Meeting.

00 ► General

1114-00-69 **Matthias Kawski*** (kawski@asu.edu), School of Mathematical & Statistical Sciences, Tempe, AZ 85287, and **Henry Kierstead** (kierstead@asu.edu), School of Mathematical & Statistical Sciences, Tempe, AZ 85287. *Math Circle at ASU Tempe.* Preliminary report.

Founded after the first Circle on the Road Conference (held in Tempe in 2010), the Math Circle at ASU Tempe connects high school age students with research mathematicians.

We report on organizational challenges, and guiding ideas behind typical activities. Striving to be orthogonal to school curricula, the most valued activities start with compelling questions accessible to school age students and develop into lines of inquiry that connect with advanced research, some of which won Abel and Nobel prizes. (Received August 21, 2015)

1114-00-103 **Alessandra Pantano*** (apantano@uci.edu), University of California, Irvine, Department of Mathematics, Irvine, CA 92697, and **Li-Sheng Tseng** (lstseng@math.uci.edu), University of California, Irvine, Department of Mathematics, Irvine, CA 92697. *The Expanding Circle.*

In this talk, we will describe the expansion and evolution of the UCI Math Circle, from a relatively small high school circle in Spring 2012 to a large-scale community educational outreach in 2015. In particular, we will emphasize the increased involvement of pre-service teachers, the push for diversity, the funding and the collaborations that made the program flourish. (Received August 26, 2015)

1114-00-141 **Arlo Caine***, Cal Poly Pomona, Mathematics, 3801 W. Temple Ave., 8-113, Pomona, CA 91786. *Build up or Dive In? Two approaches to Linear Algebra/Advanced Calculus for the CSU PUMP Summer Program.*

Cal Poly Pomona hosted the Summer Program for the CSU Alliance for PUMP (Preparing Undergraduates through Mentoring towards PhDs) in summers '14 and '15. Each year, 24 math majors from the alliance

campuses were selected to: live on campus for the month of July; attend advanced courses and problem sessions 6 days per week, working collaboratively on problems and projects to form a community; and become informed by speakers about the culture of advanced study, the excitement of mathematical discovery, and career paths in mathematics. In this talk, I will compare my two different approaches to the Linear Algebra/Advanced Calculus course and offer some personal reflections on the role of this outreach program in my own growth as a mathematician. (Received August 21, 2015)

1114-00-148 **John A Rock*** (jarock@cpp.edu), Mathematics and Statistics, Cal Poly Pomona, Pomona, CA 91768. *The National and Pacific Math Alliances.*

The Math Alliance (that is, The National Alliance for Doctoral Studies in the Mathematical Sciences) is a community of students, faculty, and staff in mathematics with a simple common goal: to ensure that every underrepresented or underserved American student with the talent and the ambition has the opportunity to earn a doctoral degree in a mathematical science. The Pacific Math Alliance is a regional branch of this important community, and this talk will feature the experiences of an Alliance Mentor (math faculty) and the work done with various Alliance Scholars (students) and other students and faculty in order to encourage the pursuit a graduate degrees in mathematics by students in the Southern California area. (Received August 22, 2015)

1114-00-157 **Alvin Kim*** (alvin.kim@live.com), 22529 Kent Avenue, Torrance, CA 90505. *Exploring Inequalities.*

We all probably know the basic inequality relationships: QM (or RMS)-AM-GM-HM, rearrangement inequality, and Cauchy-Schwarz inequality. I will show that we can manipulate these simply-seeming relationships for proving problems that look complicated, with hardly any use of other relationships. The majority of the problems come from the Gazeta matematica and have been distributed during the workshops of Fullerton Mathematical Circle. Also included in the talk, is an inequality that I managed to generalize and successfully proved, using only the basic inequality relationships as building blocks. (Received August 24, 2015)

1114-00-184 **Jesse Elliott*** (jesse.elliott@csuci.edu), One University Drive, Camarillo, CA 93012. *Monism, pluralism, and the axiom of constructibility.*

The axiom of constructibility is argued for on monist grounds but rejected on pluralist grounds. Dualism is put forward to reconcile the two. (Received August 26, 2015)

1114-00-194 **Mark L Huber*** (autotomic@gmail.com), 850 Columbia Avenue, Claremont, CA 91711. *What is Humanistic Mathematics?* Preliminary report.

Mathematics has long been indispensable to science, but the connections to art, music, and literature go back equally far. Humanistic mathematics is about exploring the human side of the mathematical process. This can come through in a myriad of ways. A writer might use mathematical themes in fiction or poetry. Artists might employ mathematics in creating their vision. Coming from the other direction, a mathematician might try to use their mathematical knowledge to unpack why a favorite painting or song has the impact that it does. Teachers might try to build students' understanding of mathematics not as a sterile set of facts to be memorized, but as an interactive process where the context matters. Mathematics has impacted how we think about history and philosophy, and philosophy has in turn influenced mathematics. This talk will discuss examples of all these ways of thinking. (Received August 26, 2015)

1114-00-243 **Laura M Smith*** (lausmith@fullerton.edu), 800 N State College Blvd, Department of Mathematics, Fullerton, CA 92831, and **Linhong Zhu**, **Kristina Lerman** and **Allon G. Percus**. *Partitioning Networks with Node Attributes by Compressing Information Flow.*

Real-world networks are often organized as modules or communities of similar nodes that serve as functional units. These networks are also rich in content, with nodes having distinguishing features or attributes. In order to discover a network's modular structure, it is necessary to take into account not only its links but also node attributes. We describe an information-theoretic method that identifies modules by compressing descriptions of information flow on a network. Our formulation introduces node content into the description of information flow, which we then minimize to discover groups of nodes with similar attributes that also tend to trap the flow of information. The method has several advantages: it is conceptually simple and does not require ad-hoc parameters to specify the number of modules or to control the relative contribution of links and node attributes to network structure. We apply the proposed method to partition real-world networks with known community structure. We demonstrate that adding node attributes helps recover the underlying community structure in content-rich networks more effectively than using links alone. In addition, we show that our method is faster and more accurate than alternative state-of-the-art algorithms. (Received August 28, 2015)

1114-00-275 **Kent G. Merryfield*** (kent.merryfield@csulb.edu), Department of Mathematics and Statistics, California State University, Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840. *Adventures in the World of Mathematical Competitions.* Preliminary report.

In a personal reminiscence, one mathematician looks back on over 15 years of involvement in high school mathematics competitions. We will explore the motivations for such competitions, describe the variety of such competitions, and give examples of the type of mathematics encountered. We will pay particular attention to ARML (American Regions Math League) and its role in fostering teamwork and personal connections among students from different schools. This is all from a Southern California perspective. (Received August 30, 2015)

1114-00-343 **Emily K Bice*** (emily.k.bice@boeing.com). *Enhancing Inertial Navigation.*

Inertial navigation is still a widely-used technique to provide position, orientation, and velocity of a moving object. An inertial navigation system is a (nearly) self-contained system that primarily relies on dead-reckoning from inertial instruments, rather that external signals such as GPS, to navigate. Two types of inertial navigation are the gimbaled inertial navigator and strap-down inertial navigator. Modern inertial instruments such as the fiber-optic gyro have inherent stochastic properties which necessitate sophisticated mechanizations and techniques in order to design a high-accuracy system. In this presentation, an overview of inertial navigation is provided, with an emphasis on marine systems. Then, a discussion of mathematical and statistical applications to improve the navigation solution is given. (Received September 01, 2015)

01 ► History and biography

1114-01-7 **Gun-Won Lee*** (lgnwn7@gmail.com), Rm 101 Yihwa Apt, 9-8 Yihwa-dong Jongro-ku, Seoul, 110-500, South Korea. *The division and calculus in the Chinese Remainder Theorem.* Preliminary report.

From the arbitrary division d1 into 2 from 49 sticks, we have say 19 in the left hand and 30 in the right. This is one of 48 possible divisions. Then the arbitrary division d2 into 2 from say the 44 which is the remainder of d1, say 8 in the left hand and 36 in the right. This d2 is one of 43 possible divisions. Again the 36 which is the remainder of d2, we have 5 in the left hand and 31 in the right by d3. Then we have a stick - - yin or _yang , which is a hi possible divisions: hi = d1*d2*d3. The example was h1 = 72,240 = 48*43*35. We have 18 dividions to have a hexagram, so the possible divisions to have a hexagram H shall be as follows: H = h1*h2*h3*h4*h5*h6. The choice is H in having a hexagram in the Chinese Remainder Theorem with the given way to calculate, I think. (Received February 26, 2015)

1114-01-34 **Shirley B. Gray, Ph.D.*** (sgray@calstatela.edu), Dept. of Mathematics, California State University, 5151 State University Drive, Los Angeles, CA 90032. *Archimedes Redux Eureka Meets Mathematica, MATLAB & a 3-D Printer in 2015.*

No area of mathematics has attracted more international attention in the past decade than the Palimpsest of Archimedes. The 1998 auction at Christie's, followed by collaborative work centered at the Walters Art Museum led to traveling museum exhibits, newspaper articles, television specials, and dozens of presentations. Mathematicians and other scholars attracted a new and significant audience. The singed, battered, faded, mildewed, damaged 10th century manuscript - the world's oldest copy of The Method of Archimedes - sold for $2 million "under the hammer." Mathematicians and classical scholars have long wondered just how close Archimedes (287-212 BC), a mechanical genius, had come to formulating modern calculus. The clues would surely lie in Propositions 13 and 14, if only they could be read. Though now transcribed, the content may contain copyists' errors. In the true Archimedean experimental tradition, we decided to avail ourselves of the opportunity to look not retrospectively at the content of propositions in The Method but rather in terms of 21st century mathematics and technology. Moreover, we believe we participated in every scholar's quest to have a Eureka moment - we found the Golden Ratio in our attempts to image the footprint of Archimedes. (Received June 27, 2015)

1114-01-38 **Isabel M. Serrano*** (iserrano@csu.fullerton.edu), 800 N State College Blvd, 154 McCarthy Hall, Fullerton, CA 92620-0290, **Bogdan D Suceavă** (bsuceava@fullerton.edu), 800 N. State College Road, 154 McCarthy Hall, Fullerton, CA 92620-0290, and **Lucy H. Odom**, Daly City, CA. *Quadrivium: The Structure of Mathematics as Described in Isidore of Seville's Ethymologies.*

Isidore's *Etymologies* enjoyed a wide audience during the medieval period. We examine the structure of mathematics, as it is described in the *Etymologies*, and we discuss the sources on which Isidore relied when he collected

his etymological definitions. We remark that for Isidore, mathematics is described as "the science of learning", and among his sources there have been the classical Greek authors, most likely available in Boethius and Cassiodorus Latin translations performed in the early 6th century. (Received July 11, 2015)

1114-01-66 **James T. Smith*** (smith@sfsu.edu). *Geometry and the Incongruous Crow.*
Searching for a spectacular illustration to introduce a background chapter on projective geometry for a coauthored book on Mario Pieri's logic and geometry, I found that the Palace of the Legion of Honor in San Francisco has acquired Laurent de La Hyre's huge 1649 *Allegory of Geometry*. I will show and describe that and its relationship to Girard Desargues, one of the pioneers in the field. This painting was one of a series. I found another, the *Allegory of Dialectics*, to introduce a chapter on logic. And there perches the incongruous crow, begging for explanation! (Received August 06, 2015)

1114-01-87 **Glen R Van Brummelen*** (gvb@questu.ca), Quest University, 3200 University Boulevard, Squamish, BC V8B 0N8, Canada. *Astronomical Algorithms in Medieval Islam: Geometry, Arithmetic, and the Unbridgeable Chasm.*
From the tenth century onward, Islamic mathematical astronomy was inspired by Greek geometry. This led astronomers to a particular interpretation of the classical tradition of analysis and synthesis, which affected the way they shaped their algorithms and arguments. Awareness of this context allows us to understand some otherwise baffling passages about the computability of certain quantities. We conclude with a comparison of Jamshīd al-Kāshī's two methods of determining $\sin 1^\circ$: the first firmly within the geometric tradition, and the second startlingly inspired by methods derived from number theory. (Received August 12, 2015)

1114-01-99 **Stephan Ramon Garcia*** (stephan.garcia@pomona.edu), Department of Mathematics, Pomona College, 610 N College Ave, Claremont, CA 91711. *Wetzel's problem, Paul Erdős, and the continuum hypothesis: a mathematical mystery.*
In 1963, Paul Erdős provided a stunning solution to Wetzel's Problem in complex variables. But who was Wetzel and how did his problem find its way to Erdős? Tracing the path that this problem took, from its birth to its resolution, was a mathematical mystery. A burnt out car on the streets of Chicago appeared to mark the end of the trail. An enigmatic manuscript, written by unknown hands, prompted even more questions... (Joint work with Amy L. Shoemaker). (Received August 15, 2015)

1114-01-146 **Judith R Goodstein*** (jrg@caltech.edu), California Institute of Technology, Einstein Papers Project, 20-7, Pasadena, CA 91125. *Recognizing Ricci.* Preliminary report.
The names of the Italian mathematicians Ricci and Levi-Civita have been enshrined in the theory of general relativity since Einstein seized on the absolute differential calculus as the indispensable mathematical tool for expressing his uniquely determined gravitational equations. The physicist's long-standing indifference to mathematics changed abruptly as he struggled with the theory, methods, and notation of the calculus developed and refined by Gregorio Ricci-Curbastro, together with Tullio Levi-Civita at the University of Padua, before the end of the nineteenth century. While mathematicians and physicists are familiar with the Ricci tensor, by and large they know very little else about the mathematician for whom this symbol in differential geometry is named. This talk is a brief introduction to the story of his life. (Received August 22, 2015)

1114-01-162 **Elena Anne Corie Marchisotto*** (emarchisotto@csun.edu). *Insights into Bézout's theorem from Descartes to Pieri.* Preliminary report.
A famous theorem of Étienne Bézout (1730-1783)enumerates the points of intersection of two plane curves. It has been proved in various ways. One way uses algebraic techniques to solve equations by eliminating variables. Another uses geometric techniques of Intersection Theory in Algebraic Geometry.

Within these two contexts, I will discuss, in addition to Bézout, three contributors to the rich conversation about proofs of the theorem: René Descartes (1596-1650), Michel Chasles (1793-1880) and Mario Pieri (1860-1913). (Received August 24, 2015)

1114-01-193 **Rebecca Lea Morris***, Department of Philosophy, Baker Hall 161, Carnegie Mellon University, Pittsburgh, PA 15213. *Motivated Proofs.*
In his 1949 paper "With, or without, motivation?" that appeared in the *Monthly*, Pólya illustrated how a proof can be perfectly correct but fail to satisfy the reader. In his discussion, he suggested that we desire two things from proofs: to recognize the correctness of the proof steps and to recognize how they advance the argument. I suggest that, in addition, we desire to recognize where the proof steps come from. Proofs which meet all three of these conditions have a number of important benefits, promoting understanding and fostering more effective

reuse of mathematical ideas. Further, there are general methods that we can use to help ensure our proofs meet these desiderata. I will illustrate my discussion of these issues with examples from the history of number theory.

References George Pólya, "With, or without, motivation?", The American Mathematical Monthly, 56(10): 684-691, 1949. (Received August 26, 2015)

1114-01-272 **Janet L Beery*** (janet_beery@redlands.edu). *Mathematical communities in the photographs of Paul Halmos.*

Mathematician Paul Halmos (1916-2006) is well-known and warmly remembered for many things, including his delight in snapping a photograph of nearly every mathematician he met during the 1950s through 1980s. From a collection digitized by the MAA, we focus on images illustrating (1) Halmos and his PhD advisor and fellow students, (2) the 1958 ICM, (3) women in mathematics, (4) functional analysis at Oberwolfach, and (5) mathematicians behind the Iron Curtain. (Received August 30, 2015)

1114-01-335 **William B Gearhart***, Mathematics Department, California State University, Fullerton, CA, and **Charles H Lee** and **Angel R Pineda**. *Overview of the Applied Math Program at CSUF.*

We present an overview of the history and evolution of the Graduate Program in Applied Mathematics at California State University, Fullerton with a special emphasis on the contributions of John (Greg) Pierce. We also highlight the role of the academic-industrial collaborations in the applied math projects with specific examples in the aerospace and medical imaging areas. (Received September 01, 2015)

03 ► Mathematical logic and foundations

1114-03-23 **Mark Balaguer*** (mbalagu@calstatela.edu), Mark Balaguer, Department of Philosophy, Cal State L.A., Los Angeles, CA 90032. *Platonism and Humanism.*

Mathematical platonism is the view that (a) there exist abstract mathematical objects (i.e., mathematical objects that are objective, non-physical, non-mental, and non-spatiotemporal) and (b) our mathematical theories provide true descriptions of these objects. Weak mathematical humanism is the idea that mathematics is a broadly human endeavor. Strong mathematical humanism is that human practices or thought somehow determine which mathematical sentences are correct. While platonism is obviously compatible with weak humanism, it might seem that it's incompatible with strong humanism. But this paper argues that platonism and strong humanism are compatible. In fact, it argues that the best versions of platonism involve a commitment to strong humanism. (Received May 18, 2015)

1114-03-216 **Shosaku Matsuzaki*** (shosaku@aoni.waseda.jp), #405 5-17-5, honcho, shiki, Saitama 3530004, Japan. *Arrangements of spatial graphs on surfaces arranged in* $\mathbb{R}^3$.

A finite set composed of connected two-dimensional manifolds embedded in the three-dimensional Euclidean space is called an *arrangement of surfaces*. We call an arrangement $\mathcal{F}$ of surfaces an arrangement of planes if every element of $\mathcal{F}$ is a "flat plane" and no two of them are parallel. A spatial graph G is said to be *arrangeable* on an arrangement $\mathcal{F}$ of surfaces if there exists a spatial graph G' which is ambient isotopic to G such that each component of G' is contained in a surface belonging to $\mathcal{F}$. We consider the following problems. (1) Given an arrangement of surfaces, determine spatial graphs which can be arrangeable on it. (2) Given a spatial graph, determine arrangements of surfaces on which the spatial graph is arrangeable. I will talk about partial answers to the problems. For example, I will introduce the following result. Every spatial graph composed of n trivial planar graphs is arrangeable on every arrangement of planes with n planes. (Received August 28, 2015)

1114-03-323 **John Mumma*** (jmumma@csusb.edu), CA. *Mathematical rigor, modern logic, and elementary geometry.*

The rigor of a mathematical proof is commonly thought to require that the conclusion of the proof be *logically* deducible from its premises. Such a principle underlies, for instance, the widespread assessment of Euclid's *Elements* as lacking in rigor in comparison to Hilbert's *Foundations of Geometry*. In my talk I examine the extent to which the principle is called into question by a recent analysis of Euclid's diagrammatic method in precise formal terms. The analysis points to the possibility of understanding Euclid's proofs as rigorous relative to a notion of *geometric consequence*. Accordingly, even though Euclid's conclusions are not deducible from his premises via universal rules of logic, they are deducible from his premises via rules valid in the domain of elementary geometry. (Received August 31, 2015)

1114-03-331 **Victor L. Sciortino*** (vicphysics@yahoo.com), 13141 Yakima Rd, Apple Valley, CA 92308. *Beyond ZFC: The Road to solving the Continuum Problem.* Preliminary report.

Zermelo and Fraenkel's axiomatic set theory with the axiom of choice (ZFC) is widely accepted as the usual foundation for set theory. It was considered a great triumph when Paul Cohen established the independence of the Continuum Hypothesis (CH) from ZFC using his method of forcing. Pluralists, like Cohen, thought this settled the question. It was supposedly impossible to find a proof of the CH or the Generalized Continuum Hypothesis (GCH). Non-pluralists, like Kurt Goedel, believed a solution to the continuum problem was still possible outside of ZFC. It has been argued by J.D. Hamkins that a "dream solution" to this problem is not attainable by introducing a new axiom to ZFC. Too many have experienced universes where CH is true and others where it has been false. Anyone wishing to propose an alternate solution to this problem must explain the illusion of our experience with the contrary hypothesis. I will discuss a possible explanation for why ZFC may give rise to the illusion of universes where CH is false, and well as a road outside of ZFC we can follow to actually settle this question. (Received September 01, 2015)

05 ► Combinatorics

1114-05-65 **M M Jaradat*** (mmjst4@qu.edu.qa), Department of Mathematics, P.O.Box 2713, Doha, Qatar. *On the basis number of the Wreath product of graphs and some related problem.*

For a given graph G, the set $\mathcal{E}$ of all subsets of $E(G)$ forms an $|E(G)|$-dimensional vector space over Z_2 with vector addition $X \oplus Y = (X \backslash Y) \cup (Y \backslash X)$ and scalar multiplication $1.X = X$ and $0.X = \emptyset$ for all $X, Y \in \mathcal{E}$. The cycle space, $\mathcal{C}(G)$, of a graph G is the vector subspace of $(\mathcal{E}, \oplus, .)$ spanned by the cycles of G. Traditionally there have been two notions of minimalls among bases of $\mathcal{C}(G)$. The *basis number*, $b(G)$, of G is the least non-negative integer d such that each edge of G appears in at most d edges of the basis. Second, a basis $\mathcal{B}$ is called *a minimum cycle basis* if its total length is minimum among all bases of $\mathcal{C}(G)$.

The Wreath product $G\rho H$ has the vertex set is$V(G) \times V(H)$ and the edge set is $\{(u_1, v_1)(u_2, v_2) | u_1 = u_2$ and $v_1 v_2 \in E(H)$, or $u_1 u_2 \in E(G)$ and *there is* $\alpha \in Aut(H)$ *such that* $\alpha(v_1) = v_2\}$. In this work, we investigate the basis number for the wreath product of some graphs. Moreover, in a related problem, we construct a minimum cycle bases of the wreath product of the same. (Received August 06, 2015)

1114-05-105 **Thu Dinh*** (tndinh@cpp.edu), 3301 Yorba Linda Blvd, Apt 236, Fullerton, CA 92831. *The Repeated Sums of Integers.*

Abstract: It is well-known that the sum of integers from 1 to n is

$$1 + 2 + ... + n = \frac{n(n+1)}{2}$$

But what happens when we add these sums together? Do we have a closed form formula for $\sum_{i=1}^{n} \sum_{j=1}^{i} j = 1 + 3 + 6 + ... \frac{1}{2} n(n+1)$? Moreover, what happens if we keep taking the sum of the sums? In general, we will attempt to find a closed form formula for

$$\sum_{a_1=1}^{n} \sum_{a_2=1}^{a_1} ... \sum_{a_m=1}^{a_{m-1}} a_m$$

We will then look at higher power of integers and repeat the process. Would we have a nice closed form formula for

$$\sum_{a_1=1}^{n} \sum_{a_2=1}^{a_1} ... \sum_{a_m=1}^{a_{m-1}} a_m^k$$

for any positive power k? The technique used in finding these sums can be used to find a formula for the partial sum of many well-known sequences. It can also be used to count the number of lattice paths under some special conditions. (Received August 16, 2015)

1114-05-114 **Kyungpyo Hong*** (kphong@nims.re.kr), 70 Yuseong-daero 1689-gil, Yuseoung-gu, Daejeon, 34047, South Korea. *Results of some kinds of stick numbers of knots.*

The stick number $s(K)$ of a knot or a link K is defined to be the minimum number of sticks required to construct a polygonal representation of the knot or link. In particular, the lattice stick number $s_L(K)$ of a knot or a link K is defined to be the minimum number of sticks in the cubic lattice $\mathbb{Z}^3 = (\mathbb{R} \times \mathbb{Z} \times \mathbb{Z}) \cup (\mathbb{Z} \times \mathbb{R} \times \mathbb{Z}) \cup (\mathbb{Z} \times \mathbb{Z} \times \mathbb{R})$. The minimum lattice length $Len(K)$ of a knot or a link K is defined to be the minimum number of edges which are line segments of unit length joining two nearby lattice points in $\mathbb{Z}^3$. In this time, I will introduce our results

related to above three invariants of knot. I provide upper bounds of them in terms of its crossing number $c(K)$. And I find the exact values of them for small knots or links. (Received August 17, 2015)

1114-05-136 **Harrison Chapman*** (hchapman@math.uga.edu). *Asymptotics of random knot diagrams.*
We consider a model of random knots akin to the one proposed by Dunfield et. al.; a random knot diagram is a random immersion of the circle into the sphere with randomly assigned crossings. By studying diagrams as annotated combinatorial maps, we are able to show that any given tangle diagram almost certainly occurs many times in a random knot diagram with sufficiently many crossings. Thus, in this model, it is exponentially unlikely for a diagram with n crossings to represent an unknot as $n \to \infty$. This asymptotic behavior is similar to that seen in other models of random knots such as random lattice walks and random polygons. (Received August 20, 2015)

1114-05-330 **Glenn Tesler*** (gptesler@math.ucsd.edu), Department of Mathematics, University of California, San Diego, 9500 Gilman Dr, La Jolla, CA 92093-0112. *Computing probabilities of repeated words in a string using the string correlation lattice.* Preliminary report.
The distribution of the number of occurrences of a word w over random strings depends not just on the length of w, but also on how occurrences of w may overlap. This is characterized by the *string autocorrelation* structure of w (Guibas and Odlyzko, 1981). We introduce the *string correlation lattice*: a partially ordered set with a lattice structure, whose elements characterize overlaps among collections of words. We use it to study:

(1) What is the probability that a random string of length n over an alphabet of size q has some k-mer (length k word) occurring at least m times?

(2) We consider the same problem with occurrences of each k-mer counted in both forwards and reverse directions.

(3) In DNA sequences over the alphabet $\{A, C, G, T\}$, we may count occurrences of each k-mer in both the forwards and *reverse complement* directions: reverse the letters and substitute $A \leftrightarrow T$, $C \leftrightarrow G$; e.g., $AACTC \to GAGTT$. We also generalize reverse complements to other alphabets.

(4) We also consider these problems for random strings generated by a biased q-sided die (e.g., modeling GC content in a DNA sequence). The results are in terms of symmetric functions of probabilities of symbols in the alphabet. (Received September 01, 2015)

11 ► Number theory

1114-11-18 **Hashem Sazegar*** (h.sazegar@gmail.com), 91777 Mashhad, Khorasan R, Iran. *A Proof for Goldbach's Conjecture.*
In 1742, Goldbach claimed that each even number can be shown by two primes. In 1937, Vinograd of Russian Mathematician proved that each odd large number can be shown by three primes. In 1930, Lev Schnirelmann proved that each natural number can be shown by M-primes. In 1973, Chen Jingrun proved that each odd number can be shown by one prime plus a number that has maximum two primes. In this article, we state one proof for Goldbach's (Received March 30, 2015)

1114-11-20 **Cindy Tsang*** (cindytsy@math.ucsb.edu). *On the Galois Module Structure of the Square Root of the Inverse Different in Abelian Extensions.* Preliminary report.
Let K be a number field with ring of integers $\mathcal{O}_K$ and let G be a finite group of odd order. Given a finite Galois extension L/K with $\mathrm{Gal}(L/K) \simeq G$, Hilbert's formula implies that there exists a fractional ideal $A_{L/K}$ in L whose square is the inverse of the different ideal of L/K. A theorem of Erez states that $A_{L/K}$ is locally free over $\mathcal{O}_K G$ if and only if L/K is weakly ramified, in which case it defines a class $[A_{L/K}]$ in the locally free class group $\mathrm{Cl}(\mathcal{O}_K G)$ of $\mathcal{O}_K G$. In this paper, we show that

$$\mathcal{A}^t(\mathcal{O}_K G) := \{[A_{L/K}] : L/K \text{ is a tame Galois extension with } \mathrm{Gal}(L/K) \simeq G\}$$

is a subgroup of $\mathrm{Cl}(\mathcal{O}_K G)$ when G is abelian. Moreover, we will study the difference between $\mathcal{A}^t(\mathcal{O}_K G)$ and the set

$$\mathcal{A}(\mathcal{O}_K G) := \{[A_{L/K}] : L/K \text{ is a weakly ramified Galois extension with } \mathrm{Gal}(L/K) \simeq G\}$$

of all such classes. (Received May 19, 2015)

1114-11-61 **Sug Woo Shin*** (sug.woo.shin@berkeley.edu), 901 Evans Hall, Berkeley, CA 94720. *From Langlands-Rapoport conjecture to cohomology of Shimura varieties.*
Kisin proved the Langlands-Rapoport conjecture for Shimura varieties of abelian type (under a very mild condition). The conjecture describes the special fibers of Shimura varieties at primes of good reduction with natural

group actions. So it should in principle lead to the description of the cohomology with such actions, which is one of the central problems in the Langlands program. I will explain how this is done based on work of Langlands-Rapoport, Kottiwtz and Milne as well as my work in progress with Mark Kisin and Yihang Zhu. (Received August 04, 2015)

1114-11-100 **Stephan Ramon Garcia*** (stephan.garcia@pomona.edu), Department of Mathematics, Pomona College, 610 N College Ave, Claremont, CA 91711. *The graphic nature of Gaussian periods.*

At the age of eighteen, Gauss established the constructibility of the 17-gon, a result that had eluded mathematicians for two millennia. At the heart of his argument was a keen study of certain sums of complex exponentials, known now as *Gaussian periods*. It turns out that these classical objects, when viewed appropriately, exhibit dazzling array of visual patterns of great complexity and remarkable subtlety. (Joint work with Bill Duke, Trevor Hyde, and Bob Lutz). (Received August 15, 2015)

1114-11-121 **A. Agboola*** (agboola@math.ucsb.edu), Department of Mathematics, University of California, Santa Barbara, CA 93106, and **L. R. McCulloh**. *Relative Galois module structure of rings of integers in tame extensions.*

Let F be a number field, with ring of integers O_F, and let G be a finite group. We shall describe a K-theoretic approach to studying the set of realisable classes in the locally free class group of $O_F[G]$. When G is nilpotent, we show that the set of realisable classes is a subgroup of this locally free class group. This may be viewed as being an analogue of a classical theorem of Scholz and Reichardt on the inverse Galois problem for nilpotent groups in the setting of Galois module theory. (Received August 19, 2015)

1114-11-142 **Xinyi Yuan*** (yxy@math.berkeley.edu), Berkeley, CA 94702. *On the Averaged Colmez Conjecture.*

The Colmez conjecture expresses the Faltings height of a CM abelian variety in terms of the logarithmic derivatives of certain Artin L-functions. In this talk, I will present an averaged version of the conjecture proved in my joint work with Shou-Wu Zhang. Combining with the recent work of Jacob Tsimerman, the Andre-Oort conjecture for Shimura varieties of abelian type is confirmed. A slightly weaker version of the averaged conjecture is proved by Andreatta, Goren, Howard and Madapusi-Pera. (Received August 22, 2015)

1114-11-190 **Jaclyn A. Lang*** (jaclynlang@math.ucla.edu). *Images of Galois representations associated to Hida families.*

Fix a prime $p > 2$. Let ρ be the Galois representation coming from a non-CM irreducible component $\mathbb{I}$ of Hida's p-ordinary Hecke algebra. Assume the residual representation $\bar{\rho}$ is absolutely irreducible. Under a minor technical condition, we identify a subring $\mathbb{I}_0$ of $\mathbb{I}$ containing $\mathbb{Z}_p[[T]]$ such that the image of ρ is large with respect to $\mathbb{I}_0$. That is, the image of ρ contains $\ker(\mathrm{SL}_2(\mathbb{I}_0) \to \mathrm{SL}_2(\mathbb{I}_0/\mathfrak{a}))$ for some non-zero $\mathbb{I}_0$-ideal $\mathfrak{a}$. This paper builds on recent work of Hida who showed that the image of such a Galois representation is large with respect to $\mathbb{Z}_p[[T]]$. Our result is an $\mathbb{I}$-adic analogue of the description of the image of the Galois representation attached to a non-CM classical modular form obtained by Ribet and Momose in the 1980s. (Received August 26, 2015)

1114-11-225 **Mirela Ciperiani*** (mirela@math.utexas.edu). *Supersingular elliptic curves over $\mathbb{Z}_p$-extensions.*

We will discuss the structure of points and Tate-Shafarevich groups of supersingular elliptic curves over $\mathbb{Z}_p$-extensions. (Received August 28, 2015)

1114-11-260 **Daniel A Goldston*** (daniel.goldston@sjsu.edu), Department of Mathematics and Statistics, San Jose, CA 95192-0103. *Sums and Differences of Pairs of Primes.* Preliminary report.

The Goldbach Conjecture states that every even number greater than 2 can be written as a sum of two primes. We can ask more generally how many such representations each even number has. While the Goldbach Conjecture remains unproved and inaccessible, we can examine the average situation by considering the sums of all pairs of primes in various ways. One application due to Montgomery and Vaughan in 1973 is a limitation on the accuracy of any asymptotic formula for the number of Goldbach representations.

The corresponding problem for differences between pairs of primes can be examined in a similar way. Hardy and Littlewood in 1922 conjectured an asymptotic formula for the number of pairs of primes both less than x that differ by a given number d. However the method used for sums of primes to obtain limitations in accuracy in this formula breaks down, and a satisfactory answer is not yet known.

Much work has been done on problems concerning the difference between consecutive primes, which is usually a more delicate situation than problems involving the difference between pairs of primes which may or may not be consecutive. We will discuss a problem where this is both true and false at the same time. (Received August 30, 2015)

1114-11-276 **Nathan Kaplan*** (nckaplan@math.uci.edu), Department of Mathematics, University of California, Irvine, Irvine, CA 92697. *Rational Point Counts for Varieties over Finite Fields.*

We discuss several questions in arithmetic statistics about families of varieties over a fixed finite field $\mathbb{F}_q$. For example, what is the average number of $\mathbb{F}_q$-rational points on an elliptic curve with a rational 5-torsion point? What is the probability that two plane cubic curves intersect in exactly 9 $\mathbb{F}_q$-points? How many collections of 10 points in $\mathbb{P}^2(\mathbb{F}_q)$ have no three on a line? We will also discuss connections to coding theory and the Eichler-Selberg trace formula. (Received August 30, 2015)

1114-11-302 **Kenneth A. Ribet*** (ribet@berkeley.edu). *The Eisenstein ideal and the cuspidal group.* Preliminary report.

We present joint work with Bruce Jordan and Anthony Scholl on the Jacobian J of the modular curve $X = X_0(N)$, where N is a positive integer.

Let $\tilde{\mathbf{T}}$ be the ring of Hecke operators on the space of modular forms of weight 2 for $\Gamma_0(N)$, and let $\mathbf{T}$ be the image of $\tilde{\mathbf{T}}$ in the endomorphism ring of J. The Eisenstein ideal of $\mathbf{T}$ is the ideal of those $t \in \mathbf{T}$ that lift to an operator $\tilde{t} \in \tilde{\mathbf{T}}$ such that $\tilde{t}$ vanishes on the space of Eisenstein series.

Let C be the cuspidal subgroup of J. Because we have $I \subseteq \mathrm{Ann}_{\mathbf{T}} C$, it is natural to ask whether $I = \mathrm{Ann}_{\mathbf{T}} C$.

We prove this equality locally at prime numbers that are prime to the product $6N$ and expect to be able to consider more generally primes (including 2 and 3) whose squares do not divide N.

Let $\mathcal{C}$ be the *formal cuspidal group* for J, the group of degree-0 divisors on X with support on the cusps. There is a natural map $\mathcal{C} \to J$ whose image is C; we regard this map as a 1-motive $[\mathcal{C} \to J]$. Consideration of the cohomology of this 1-motive reveals the desired connection between the Eisenstein ideal and the cuspidal group of J. (Received September 01, 2015)

1114-11-337 **Lisa Joy Mueller*** (exceedinglyhappy@csu.fullerton.edu), 1981 Berkshire Drive, Fullerton, CA 92833, and **Nick Bohall**, **Kajal Chokshi**, **Jackie Emrich** and **Abdollah Khodkar**. *Edge-Magic Total Labelings.*

A graph with v vertices and e edges has an edge-magic total labeling if the vertices and edges can be labeled with the numbers 1 through $v + e$ such that the sum of any edge and its two adjacent vertices adds up to the same number. The main focus for this research project has been to explore different types of graphs to see which are edge-magic in general or for an entire spectrum of possible sums according to how many vertices and edges a given graph contains. (Received September 01, 2015)

1114-11-338 **Lisa Joy Mueller*** (exceedinglyhappy@csu.fullerton.edu), 1981 Berkshire Drive, Fullerton, CA 92833, and **Oliver Sawin**, **WonHyuk "Harry" Choi** and **Abdollah Khodkar**. *Study on Oddly Bipancyclic Graphs and Other N-Pancyclic Graphs.*

A graph of n vertices with a Hamiltonian cycle of length n is called a uniquely pancyclic cycle if it contains exactly one cycle of length $m \forall 3 \leq m \leq n$. Similarly, a uniquely bipancylic cycle is one with cycle lengths of all even cycles of length $2m \forall 2 \leq m \leq n/2$ where $n = 2k$. In this paper, we expand on these definitions to find a new type of uniquely pancyclic graphs, an uniquely oddly bipancyclic graph, which has n vertices with a Hamiltonian cycle of length $n - 1$ where $n = 2k + 1$; additionally, it contains exactly cycles of length $2m \forall 2 \leq m \leq (n - 1)/2$. We provide the 6 non-isomorphic uniquely oddly bipancyclic graphs with 5 or less chords. We also present additional information on k-panyclic graphs, which contain exactly k cycles of length 3 through degree n. (Received September 01, 2015)

1114-11-360 **Amita Malik*** (amalik10@illinois.edu), 1409 W Green Street, Urbana, IL 61801, and **Armin Straub**. *Sporadic Apéry-like sequences in the p-adic universe.*

In 1982, Gessel showed that the Apéry numbers associated to the irrationality of $\zeta(3)$ satisfy Lucas congruences. In this talk, we discuss the corresponding congruences for all sporadic Apéry-like sequences. In several cases, we are able to employ approaches due to McIntosh, Samol-van Straten and Rowland-Yassawi to establish these congruences. However, for the sequences often labeled s_{18} and η, we require a finer analysis. As an application, we investigate modulo which numbers these sequences are periodic. We also investigate primes which do not divide any term of a given Apéry-like sequence. This is joint work with Armin Straub. (Received September 01, 2015)

13 ► Commutative rings and algebras

1114-13-84 **Adam Boocher*** (boocher@math.utah.edu), **Alessio D'Alí**, **Eloísa Grifo**, **Jonathan Montaño** and **Alessio Sammartano**. *Deviations of Graded Algebras.*

The deviations of a graded algebra are a sequence of integers that determine the Poincaré series of its residue field and arise as the number of generators of certain DG algebras. In a sense, deviations measure how far the ring is from being a complete intersection. We study extremal deviations among those of algebras with a fixed Hilbert series. We prove that, like the Betti numbers, deviations do not decrease when passing to initial and lex-segment ideals. We also prove that deviations grow exponentially for Golod rings and for algebras presented by certain edge ideals. Combinatorial considerations, including some open questions will be discussed. (Received August 12, 2015)

1114-13-117 **Sean Sather-Wagstaff***, Clemson University, and **Richard Wicklein**, MacMurray College. *adic semidualizing modules.*

Over a commutative noetherian ring R, dualities with respect to R and with respect to a dualizing module (when one exists) are classical notions. Duality with respect to a semidualizing R-module encompasses both of these notions, but it misses other important dualities, e.g., Matlis duality. In this talk, we present a single notion that encompasses all of these dualities simultaneously. (Received August 18, 2015)

1114-13-120 **Katharine Shultis*** (shultis@gonzaga.edu), Department of Mathematics, 502 E. Boone Ave, MSC 2615, Spokane, WA 99258. *Systems of parameters of modules and the Cohen-Macaulay property.* Preliminary report.

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. I will discuss the structure of $\mathrm{Hom}_R(R/\mathfrak{a}, M/\mathfrak{b}M)$ for general M. (Received August 18, 2015)

1114-13-150 **Saeed Nasseh*** (snasseh@georgiasouthern.edu) and **Yuji Yoshino** (yoshino@math.okayama-u.ac.jp). *AB Rings And Homogenization Functor.* Preliminary report.

In this talk, we define the homogenization of a module over a $\mathbb{Z}$-graded commutative noetherian ring and discuss some problems that are related to the localization problem of AB rings. (Received August 23, 2015)

1114-13-160 **Maral Mostafazadehfard*** (maral@math.utah.edu) and **Aron Simis**. *Homaloidal Determinants.*

Let $R = k[x_0, \cdots, x_n]$ be a polynomial ring over a field of characteristic zero. A birational transformation of P^n is called a Cremona transformation. An important class of Cremona maps comes off Polar maps, That is, the rational map $\triangledown f : P^n \dashrightarrow P^n$ of the hypersurface $D = V(f)$ given by partial derivatives of f, where f is a homogeneous polynomial. The polynomial f or the hypersuface D is homaloidal when its polar map is a cremona transformation.

In this talk the focus is on the determinant of a generic Hankel matrix and one of its degenerations. We show that the first has nonvanishing Hessian (hence its polar map defines a dominant rational map) but it is non-homaloidal. In the degeneration case we determine the ideal theoretic and numerical invariants of the corresponding gradient (polar) ideal, as well as its homological nature. Moreover, a conjecture of Ciliberto-Russo-Simis(2008) is proved. We also bring out the determinant of a circulant matrix, which is also homaloidal. All results draw on some nontrivial underlying commutative algebra. All cases of study are saturated non Cohen-Macaulay polar ideals but up to radical they are perfect of codimension 2 or 3. (Received August 24, 2015)

1114-13-161 **Hamid Seyed Hassanzadeh*** (hamid@math.utah.edu), UT 84102, and **Jose Naeliton**. *Annihilator of Koszul Homologies.*

Despite a long history of Koszul complex, still there exist many mysterious and unknown facts about its structure, for examples ANNIHILATORS OF ITS HOMOLOGIES!. In this talk we reveal some connections between Koszul annihilators and RESIDUAL INTERSECTION. After introducing the concepts, we show how SLIDING DEPTH CONDITIONS provide non-trivial annihilators for Koszul homologies. To this end, we present a family of approximation complexes for residual intersctions. The main theorem we'll discuss is the following

Theorem Let $(R, \mathfrak{m})$ be a CM local ring of dimension d, I satisfy Sliding Depth, and depth $(R/I) \geq d - s$. Let $J = (\mathfrak{a} : I)$ be an s-residual intersection and use $H_j(\mathfrak{a})$ to denote the j'th Koszul homology module with respect to a minimal generating set of $\mathfrak{a}$. Then

$$I \subseteq \bigcap_{j \geq 1} \operatorname{Ann}(H_j(\mathfrak{a})).$$

Surprisingly, this result contradicts one of the old (unpublished) results of G. Levin. (Received August 24, 2015)

1114-13-177 **Mark Blumstein*** (mark.blumstein@gmail.com). *Multiplicity of Graded Modules.*

The purpose of this talk is to define a multiplicity in a certain category of graded modules and investigate its properties. For a graded module over the "standard" graded ring, the module's multiplicity is given by the leading term of its Hilbert polynomial. The category of interest in this talk includes non-standard gradings as well, so we need to define a replacement multiplicity for when the Hilbert polynomial does not exist.

Given a homogeneous system of parameters we define such a multiplicity in two equivalent ways: first as the leading coefficient of the Samuel polynomial for the given homogeneous system, and second using Koszul complexes and their Euler characteristics.

The main theorem highlights a link between grading and multiplicity. In particular, the multiplicity discussed above is related directly to the Poincare series of the module, scaled by the product of the degrees of elements in a homogeneous system of parameters.

Some nice examples of the main theorem are provided by the cohomology of p-groups. Ongoing research is being conducted to relate the main theorem to work done by Quillen (1971) and R. Lynn (2013), where relations between the group structure and the algebraic/geometric structures of the equivariant cohomology ring are explored. (Received August 25, 2015)

1114-13-219 **Rebecca R.G.*** (rirg@umich.edu). *Closure operations that give big Cohen-Macaulay modules and algebras.* Preliminary report.

Geoffrey Dietz introduced a set of axioms for a closure operation on a complete local domain R such that the existence of a closure operation satisfying the axioms is equivalent to the existence of a big Cohen-Macaulay module. These are called Dietz closures. In characteristic $p > 0$, solid closure, tight closure, and plus closure all satisfy the axioms. Some closures based on properties of local cohomology have been proposed as possible Dietz closures in mixed characteristic.

I will show that under mild conditions, a ring R is regular if and only if all Dietz closures on R are trivial. In particular, if R is not regular, a module of syzygies gives a nontrivial Dietz closure. I will also discuss a new axiom for a closure operation such that the existence of a Dietz closure satisfying this additional axiom is equivalent to the existence of a big Cohen-Macaulay algebra. (Received August 28, 2015)

1114-13-220 **Thomas Marley** and **Marcus Webb*** (webbm@sfasu.edu). *Minimal flat resolutions in characteristic p.*

In this talk, we will study the action of the Frobenius functor on flat resolutions. We will show that a classical result of Peskine and Szpiro concerning the action of the Frobenius functor on finite projective resolutions of finitely generated modules extends to finite flat resolutions. The proof makes use of the theory of minimal flat resolutions developed by Enochs and Xu, and we will summarize the relevant potions of their results. (Received August 28, 2015)

1114-13-256 **Alexander Pavlov*** (apavlov@msri.org), 17 Gauss way, Berkeley, CA 94720. *Betti Tables of Maximal Cohen-Macaulay Modules over the Cones of Cubic Curves.*

Graded Betti numbers are classical invariants of finitely generated modules describing the shape of a minimal free resolution. We show that for maximal Cohen-Macaulay modules over a homogeneous coordinate rings of smooth Calabi-Yau varieties X computation of Betti numbers can be reduced to computations of dimensions of certain Hom groups in the bounded derived category $D^b(X)$.

In the simplest case of a smooth elliptic curve embedded into projective plane as a cubic we use our formula to get explicit answers for Betti numbers. In this case we show that there are only four possible shapes of the Betti tables up to a shifts in internal degree, and two possible shapes up to a shift in internal degree and taking syzygies. (Received August 29, 2015)

1114-13-261 **Eliana M Duarte***, 1409 W. Green Street, Urbana, IL 61801, and **Hal Schenck**. *Tensor product surfaces and linear syzygies.*

A tensor product surface is the image of a rational map $\mathbb{P}^1 \times \mathbb{P}^1 \to \mathbb{P}^3$. Such surfaces arise in geometric modeling and in this context it is useful to know the implicit equation of the closure of the image. In this talk I will explain how the existence of a linear syzygy between the defining polynomials of the map is sufficient to obtain its implicit equation. (Received August 30, 2015)

1114-13-263 **Hannah Altmann*** (haltmann@morris.umn.edu). *Semidualizing DG Modules over Tensor Products.*

Let R be a commutative, noetherian ring with identity. A finitely generated R-module C is *semidualizing* if the homothety map $\chi_C^R : R \to \mathrm{Hom}_R(C, C)$ is an isomorphism and $\mathrm{Ext}^i_R(C, C) = 0$ for all $i > 0$. For example, R is semidualizing over R, as is a dualizing module, if R has one. In some sense the number of semidualizing modules measures the severity of the singularity of R. We are interested in that number. We can extend this idea to semidualizing complexes of R and generalize even further over Differential Graded (DG) algebras. We will discuss constructing semidualizing DG modules over tensor products of algebras over a field. In particular, this gives us a lower bound on the number of semidualizing DG modules over the tensor product. (Received August 30, 2015)

1114-13-265 **Greg Piepmeyer*** (gpiepmeyer@columbiabasin.edu). *Current problems in Gorenstein homological algebra.*

Recent work, particularly coming from Emmanouil, and with my coauthors Celikbas/Christensen/Li, has highlighted the roles of Gorenstein flat and projective modules in stable homology. A few key questions remain. This talk will discuss these, the primary obstacles within these problems, and some possible routes of attack. (Received August 30, 2015)

1114-13-269 **Casey A Barker***, Mathematics Program, California State University Channel Islands, One University Drive, Camarillo, CA 93012. *On Some Natural Densities that Arise from Integer-Valued Polynomials.*

Given an integral domain D with its field of fractions K, the ring of integer-valued polynomials on D is the sub-ring $\mathrm{Int}(D) = \{f(X) \in K[X] : f(D) \subseteq D\}$ of $K[X]$. There is a family of arithmetic functions that arises in the study of the D-module structure of $\mathrm{Int}(D)$. Let $k > 1$ be an integer, let $n > 0$ be a positive integer, and let $v_k(n)$ be the largest integer a such that k^a divides n. The aforementioned family of functions is $u_k(n) = \sum_{i=1}^{n} \sum_{j=1}^{i} v_k(j)$. We investigate the distribution of values of $u_k(n)$ among the congruence classes, modulo an integer $d > 1$. To quantify this, we calculated the natural densities of $n \in \mathbb{Z}_{\geq 0}$ such that the values of $u_k(n)$ are in the congruence class 0 (mod d) for certain combinations of d, k. (Received August 30, 2015)

1114-13-288 **Branden Stone*** (bstone@adelphi.edu), Post Hall, Room 211 (Math Department), Adelphi University, Garden City, NY 11530-0701. *Classifying graded Cohen-Macaulay rings of graded countable Cohen-Macaulay type.*

In 1988, D. Eisenbud and J. Herzog gave a complete classification of graded rings of graded finite Cohen-Macaulay type. We would like to extend this classification to rings of graded countable Cohen-Macaulay type. This talk will outline the current progress of this task as well as outline the pitfalls. (Received August 31, 2015)

1114-13-293 **Petter Andreas Bergh** and **David A. Jorgensen*** (djorgens@uta.edu). *Complete intersections and equivalences with categories of matrix factorizations.*

Let R be a codimension c complete intersection, and S a codimension $c-1$ intermediate complete intersection, so that $R = S/(x)$ for a nonzerodivisor x of S. In this talk we give an equivalence between the homotopy category of matrix factorizations of x over S and a certain thick subcategory of the singularity category of R determined by a condition on the support varieties of the objects of the singularity category. Our result recovers the well-known result of the case when $c = 1$, that is, of R being a hypersurface. This is joint work with Petter Bergh. (Received August 31, 2015)

1114-13-306 **Gabriel E Sosa*** (gsosa@amherst.edu). *Rees and multi-Rees algebras of principal strongly stable Ideals.*

Strongly stable ideals coincide with Borel fixed monomial ideals (0-Borel) in characteristic 0. A principal strongly stable ideal is a strongly stable ideal whose set of minimal monomial generators can be obtained by applying Borel moves to a distinguished monomial. We prove that the Rees and multi-Rees algebras of certain principal strongly stable ideals are Koszul, Cohen-Macaulay normal domains and we present Grobner basis for their defining ideals

using a combination of a sorting technique due to Sturmfels and an ordering technique. (Received August 31, 2015)

1114-13-319 **Youngsu Kim*** (youngsu.kim@ucr.edu), Department of Mathematics, 900 Univ. Ave., Surge 253, Riverside, CA 92521, and **Vivek Mukundan** (vmukunda@purdue.edu), Department of Mathematics, 150 N Univ. ST, West Lafayette, IN 47907. *Bi-degrees of defining equations of Rees algebras of homogeneous height two perfect ideals.*

Let R be a ring and I an R-ideal. The Rees algebra of I is a graded algebra $R[It] = \oplus_{I\geq 0} I^i$, where $I^0 = R$. If $I = (f_1, \ldots, f_n)$, then there exists a natural homogeneous presentation $\phi : T := R[X_1, \ldots, X_n] \to R[It]$ sending X_i to $f_i t$. The kernel of ϕ is called the defining ideal (equations) of the Rees algebra of I.

When R is graded and I is homogeneous R-ideal, defining ideals are bi-graded, the gradings of R and of X_i, respectively. We investigate the bi-degrees of defining ideals under the following set up: R is a d-dimensional polynomial ring over a field, m the homogeneous maximal ideal, $I = I_d(\varphi)$, and grade $I = 2$, where φ is $d+1$ by d matrix such that the entries of column i have degree d_i for $1 \leq i \leq d$. Here, $I_d(\varphi)$ denotes the ideal generated by d by d minors of φ.

Note that ϕ factors through $\mathrm{Sym}(I)$ the symmetric algebra of I. Under our setup the kernel of the map $T \to \mathrm{Sym}(I)$ is a complete intersection and $(\ker\phi)\mathrm{Sym}(I)$ is equal to $0 :_{Sym(I)} m^\infty$. We study $\ker\phi$ through the Koszul resolution of $\mathrm{Sym}(I)$ as T-module. Such technique was introduced by Kustin-Polini-Ulrich when $\dim R = 2$. (Received August 31, 2015)

1114-13-321 **Roger D. Dellaca*** (rdellaca@uci.edu). *Bounding the Castelnuovo-Mumford regularity of modules.*

In this talk, we will look at bounds for the Castelnuovo-Mumford regularity for modules with a given Hilbert polynomial, generalizing work of Gotzmann. We will also consider the question of sharpness, and some applications. (Received August 31, 2015)

1114-13-345 **Lars Winther Christensen*** (lars.w.christensen@ttu.edu) and **Srikanth B. Iyengar**. *Tests for injectivity of modules over commutative rings.* Preliminary report.

Let R be a commutative ring. In cohomological terms, Baer's criterion says that an R-module M is injective if $\mathrm{Ext}^1_R(R/\mathfrak{a}, M) = 0$ holds for every ideal $\mathfrak{a}$ in R. When R is also noetherian, it suffices to test against prime ideals and locally. Indeed, M is injective if either of the following conditions holds:

- $\mathrm{Ext}^1_R(R/\mathfrak{p}, M) = 0$ for every prime ideal $\mathfrak{p}$ in R;
- $\mathrm{Ext}^1_{R_\mathfrak{p}}(k(\mathfrak{p}), M_\mathfrak{p}) = 0$ for every prime ideal $\mathfrak{p}$ in R.

Here $k(\mathfrak{p})$ denotes the field $(R/\mathfrak{p})_\mathfrak{p}$. The theorem I will discuss says that injectivity can be detected by vanishing of Ext globally against these fields. It leads to the following characterization of injective modules: If F is faithfully flat, then a module M such that $\mathrm{Hom}_R(F, M)$ is injective and $\mathrm{Ext}^i_R(F, M) = 0$ for all $i \geq 1$ is injective. (Received September 01, 2015)

14 ► Algebraic geometry

1114-14-53 **Nathan James Cordner*** (nathancordner91@gmail.com), 910 N 900 E Apt 107, Provo, UT 84604. *Isomorphisms of Landau-Ginzburg $\mathcal{B}$-Models.*

Landau-Ginzburg mirror symmetry predicts isomorphisms between graded Frobenius algebras (denoted $\mathcal{A}$ and $\mathcal{B}$) that are constructed from a nondegenerate quasihomogeneous polynomial W and a related group of symmetries G. In 2013, Tay proved that given two polynomials W_1, W_2 with the same quasihomogeneous weights and same group G, the corresponding $\mathcal{A}$-models built with (W_1,G) and (W_2,G) are isomorphic. An analogous theorem for isomorphisms between orbifolded $\mathcal{B}$-models remains to be found. I will discuss current research towards finding and proving such a theorem for $\mathcal{B}$-models. A result like this will facilitate proving isomorphisms from $\mathcal{A}$ to $\mathcal{B}$ as predicted in mirror symmetry, and will have important theoretical implications for high-energy particle physics. (Received August 03, 2015)

1114-14-163 **Ivona Grzegorczyk*** (ivona.grze@csuci.edu), One University Drive, Camarillo, CA 91320. *Generalized k-ellipses and their algebraic closures.* Preliminary report.

Generalized k-ellipses are defined by fixed sums of distances from k flats (foci) in n-dimensional Euclidean spaces. We provide systematic classification of these objects, discuss their properties, and investigate the algebraic

varieties that are their Zariski closures (generalizing results of Nie, Parrilo, and Sturmfel). (Received August 24, 2015)

1114-14-299 **Alfonso Zamora*** (alfonso.zamorasaiz@csuci.edu), One University Drive, Camarillo, CA 93012. *GIT characterizations of Harder-Narasimhan filtrations.*

We will present constructions of moduli spaces in algebraic geometry by using Geometric Invariant Theory (GIT). When performing such constructions we usually impose a notion of stability for the objects we want to classify and another notion of GIT stability appears, then it is shown that both notions coincide. For an object which is unstable there exists a unique canonical filtration, called the Harder-Narasimhan filtration. On the other hand, GIT stability is checked by 1-parameter subgroups by the classical Hilbert-Mumford criterion, and it turns out that there exists a unique 1-parameter subgroup giving a notion of maximal unstability in the GIT sense. We show that this special 1-parameter subgroup can be converted into a filtration of the object and coincides with the Harder-Narasimhan filtration, hence both notions of maximal unstability are the same. This correspondence can be implemented for the moduli problem of classifying coherent sheaves on a smooth complex projective variety, as well as other moduli problems: holomorphic pairs, Higgs sheaves, rank 2 tensors or quiver representations. (Received August 31, 2015)

1114-14-346 **Derek Hoeft***, dhoeft@csusm.edu, and **Shahed Sharif**. *Possible Matrix Representations of Graph Cycle Spaces.* Preliminary report.

Let Γ be a graph and τ be an automorphism on Γ. The integral representation of τ on the space of cycles of Γ gives rise to a square integer matrix A. We would like to determine what matrices A can arise this way. An obvious necessary condition is that A has finite order. Is this condition sufficient? We show that the answer is no by showing that A cannot have characteristic polynomial $x^4 - x^2 + 1$. (Received September 01, 2015)

15 ► Linear and multilinear algebra; matrix theory

1114-15-178 **Persi Diaconis*** (diaconis@math.stanford.edu). *The Kac-Murdoch-Szegő Theorem and the Heisenberg Group.*

In studying simple random walk on the Heisenberg group (3 x 3 uni-upper triangular matrices with entries in Z) a crop of large matrices needed to be diagonalized. Things like n x n matrices with cos((2pi j)/n) down the main diagonal and ones on the super and sub diagonal. We find sharp bounds for the top (and bottom) eigenvalues and a nice description of the bulk of the spectrum. This is joint work with Dan Bump, Angela Hicks, Laurent Miclo, and Harold Widom. (Received August 25, 2015)

1114-15-199 **Boris Shapiro*** (shapiro@math.su.se), Department of Mathematics, Stockholm Universi, Stockholm University, S-10691 Stockholm, Sweden. *Spectral asymptotic for sequences of matrices originating from quasi-exactly solvable models in quantum mechanics.* Preliminary report.

Title: Spectral asymptotics for sequences of matrices appearing in quantum quasi-exactly solvable models

Boris Shapiro Department of Mathematics, Stockholm University

We present results of theoretical and numerical study of the algebraic part of the spectrum of the classical quasi-exactly solvable quartic and sextic potentials. In mathematical terms, we study the spectral asymptotics of certain intriguing sequences of 3- and 4-diagonal matrices depending on an additional parameter. (Received August 27, 2015)

1114-15-296 **Tyler McMillen*** (tmcmillen@fullerton.edu), CA. *Strong Szegő's limit theorems for non-Toeplitz matrices.*

Szegő's First Limit Theorem gives the limiting statistical distribution of the eigenvalues of large Toeplitz matrices. This theorem was first proved in 1915. Almost 40 years later, Szegő proved what is known as the Strong Theorem, which gives the first order error term in the first theorem. The Strong Theorem also allows one to compute asymptotics of determinants.

In this talk I will describe how the Strong Theorem has been extended to certain classes of non-Toeplitz matrices, and the difficulties of generalizing the result for those cases where the First Theorem has been generalized. (Received August 31, 2015)

1114-15-303 **Alain Bourget*** (abourget@fullerton.edu), Department of Mathematics, California State University at Fullerton, Fullerton, CA 92834, and **Tyler McMillen** (tmcmillen@fullerton.edu), Department of Mathematics, California State University at Fullerton, Fullerton, CA 92834. *The First Szegő Limit Theorem and its generalizations.*

We present some recent results on the limiting statistical distribution of the eigenvalues of matrices whose entries are equidistributed and have small mean variation. Our results extend the classical results on Toeplitz and Kac-Murdoch-Szegő matrices. We conclude with some applications to block matrices and locally Toeplitz matrices. (Received August 31, 2015)

1114-15-309 **Michael T. Vodhanel*** (michael.vodhanel@gmail.com), 9351 Blanche Ave., Garden Grove, CA 92841. *Parallelotope Analysis of Sensor Geometries in GPS Estimation.*

An increasing number of position estimation systems have been under development in recent years and are being used for an ever growing collection of applications. Some of these demand high levels of precision or reliability and some require well defined error bound metrics. There are numerous challenges in meeting these requirements caused by a wide array of physical circumstances. These can include atmospheric conditions, effects of geomagnetic fields, time of day, physical location, signal multipathing, limits to channel availability, and many more. Here, the focus is the problem of sensor (or constellation) geometry, which has an important effect on precision. The quality of a geometry, measured by dilution of precision (DOP), has a proportional effect on the error bound of a position estimate. A method of analyzing DOP as a function of the sensor geometry with respect to a user position is demonstrated. It is shown that behavior of a DOP function can be understood as equivalent to that of a particular parallelotope with useful characteristics which allow for solutions to the geometry optimization problem. Though this method is developed in the context of GPS, it can be applied to many systems such as sound localization, forensic sciences, and virtual reality systems. (Received August 31, 2015)

1114-15-311 **Patrick Cassam-Chenaï*** (cassam@unice.fr), Lab. J. A. Dieudonné, Parc Valrose, UNS, 06100 NICE, France. *Algebraic problems from ab initio computational molecular spectroscopy.*

Computational molecular spectroscopy is gradually taking a larger part in the prediction of molecular spectra. Recent methods to find approximate solutions of the nuclear-motion Schrödinger eq. of molecules, have demonstrated unprecedented abilities to predict high temperature spectra relevant to exoplanet atmospheres, with better reliability than what can be achieved by using spectroscopic databases.

The main accuracy limitation of ab initio quantum calculations lies in the resolution of the Schrödinger eq. for the electrons of the molecule, whose solution provides the potential energy operator (PEO) for the nuclei, in the so-called Born-Oppenheimer approach. The electrons being Fermions their wave function is element of an exterior algebra, which can be endowed with a coproduct to turn into a Hopf algebra. We present a new method making use of Hopf algebra techniques to solve the electronic Schrödinger eq., along with open problems to reduce its computational complexity.

Finally, assuming that the PEO and other observables for the nuclei can be calculated to sufficient accuracy, we explain how to take advantage of integrity basis for modules of polynomial covariants adapted to the molecular symmetry, and state another open problem standing for linear molecules. (Received August 31, 2015)

17 ► Nonassociative rings and algebras

1114-17-234 **Richard M. Green*** (rmg@euclid.colorado.edu), Department of Mathematics, University of Colorado Boulder, Campus Box 395, Boulder, CO 80309-0395. *Invariant forms on minuscule representations.*

A minuscule representation of a simple Lie algebra over the complex numbers is an irreducible representation for which the Weyl group acts transitively on the weights. Minuscule representations are often equipped with invariant multilinear forms that are invariant under the action of the Lie algebra. These include symplectic or orthogonal bilinear forms, as well as an invariant cubic form on a 27-dimensional representation in type E_6, and a symmetric invariant quartic form on the 56-dimensional representation in type E_7. I will discuss how the combinatorial structure of the weights of a minuscule representation can be used to gain insight into these forms. (Received August 28, 2015)

1114-17-305 **Daniel Brice*** (danielbrice@gmail.com). *Upper Triangular Ladder Matrix Algebras.* Preliminary report.

Following a definition of B– and Huang, we examine a class of matrix algebras that extends the class of upper triangular matrix algebras, so called upper triangular ladder matrix algebras (UTLs). It is known that UTLs are zero product determined under standard matrix multiplication. We provide preliminary results towards a proof that UTLs are zero product determined under the Lie bracket. (Received August 31, 2015)

18 ► Category theory; homological algebra

1114-18-19 **Adnan H Abdulwahid*** (adnan-al-khafaji@uiowa.edu), Department of Mathematics 14 MacLean Hall, Iowa City, IA 52242, and **Miodrag C Iovanov** (miodrag-iovanov@uiowa.edu), Department of Mathematics 14 MacLean Hall, Iowa City, IA 52242. *Generators for Comonoids and Universal Constructions.*

Let A be an arbitrary ring with 1. Let V be an (A, A)-bimodule. The question is does V have an A-cofree coring? Agore, A. L. mentioned this question in [1] as an open problem. My advisor and I showed that the A-cofree coring exists over an arbitrary (A, A)-bimodule V. More interestingly, we concretely construct that A-cofree coring, and used that construction to get a transparent picture for certain monoidal categories.

Let H be a bialgebra (or a Hopf algebra), and let M^H and ${}_HM$ be the left H-comodules and the right H-comodules categories, respectively. We used the construction of cofree corings that we got in our work to investigate existence and construction of cofree coalgebras in $Coalg(M^H)$ and $Coalg({}_HM)$, the category of coalgebras in M^H and ${}_HM$, respectively..

References

[1] A.L. Agore. *Limits of Coalgebras, Bialgebras and Hopf Algebras*, Proc. Amer. Math. Soc. 139, 855-863, 2011.

(Received April 20, 2015)

1114-18-125 **Bethany Kubik*** (bakubik@d.umn.edu) and **Sean Sather-Wagstaff** (ssather@clemson.edu). *Path Ideals of Weighted Graphs.*

We explore weighted graphs and their "path ideals" which are ideals in polynomial rings that are defined based on the existing paths of the graphs. We discuss the decomposition of a path ideal and the relation to minimal vertex covers for paths. We examine Cohen-Macaulay weighted graphs in the case of K_3. (Received August 19, 2015)

1114-18-292 **Kosmas Diveris*** (diveris@stolaf.edu), **Marju Purin** and **Peter Webb**. *On the structure of the Auslander-Reiten quiver of a triangulated category.*

We show that if a connected, Hom-finite, Krull-Schmidt triangulated category has an Auslander-Reiten quiver component with Dynkin tree class then the category has Auslander-Reiten triangles and that component is the entire quiver. This is an analogue for triangulated categories of a theorem of Auslander, and extends a previous result of Scherotzke. (Received August 31, 2015)

20 ► Group theory and generalizations

1114-20-85 **Alexander J Hulpke*** (hulpke@math.colostate.edu), Department of Mathematics, Colorado State University, 1874 Campus Delivery, Fort Collins, CO 80526. *Finite Quotients of Arithmetic Groups.* Preliminary report.

A subgroup of $SL_n(\mathbb{Z}$ is called *arithmetic* if it has finite index. For such a group, given by generators, we would like to be able to determine, e.g., the index. We describe an algorithmic approach that uses finite congruence images $SL_n(\mathbb{Z}/m\mathbb{Z})$ to answer such questions. It turns out that the representation theory of $SL_n(p)$ plays a crucial role in making this transition.

This is joint work with Alla Detinko and Dane Flannery (both NUI Galway). (Received August 12, 2015)

1114-20-110 **Stephen P Humphries** (steve@mathematics@byu.edu), 284 TMCB, Department of Mathematics, Brigham Young University, Provo, UT 84601, and **Rebeca A Paulsen*** (lakabecky@gmail.com), 330 TMCB, Department of Mathematics, Brigham Young University, Provo, UT 84601. *Weak Cayley Table Groups of Wallpaper Groups.*

Let G be a group. A Weak Cayley Table mapping $\varphi : G \to G$ is a bijection such that $\varphi(g_1g_2)$ is conjugate to $\varphi(g_1)\varphi(g_2)$ for all g_1, g_2 in G. The set of all such mappings forms a group $\mathcal{W}(G)$ under composition. We study $\mathcal{W}(G)$ for the seventeen wallpaper groups G. (Received August 17, 2015)

1114-20-115 **Jennifer Elder***, arwenu@mail.fresnostate.edu. *The Futurama Theorem.* Preliminary report.

A popular episode of the TV show Futurama features a machine that will swap the brains of two people. The problem is, the machine will only work once for any pair of characters. After a series of swaps that thoroughly mixes up the crew and their friends, they decide that they must resort to using Math to fix their mess. Episode author Ken Keeler created this problem specifically for the show, but when you reduce the problem to functions it becomes a very interesting problem in Abstract Algebra. In this talk, we will cover two methods to solve the problem created in the show, as well as the start of our work to generalize the problem from a two-person machine, to a k-person machine. (Received August 17, 2015)

1114-20-118 **Mark L. Lewis*** (lewis@math.kent.edu), Department of Mathematical Sciences, Kent State University, Kent, OH 44242. *Variations on average character degrees and p-nilpotence.*

We prove that if p is an odd prime, G is a solvable group, and the average value of the irreducible characters of G whose degrees are not divisible by p is strictly less than $2(p+1)/(p+3)$, then G is p-nilpotent. We show that there are examples that are not p-nilpotent where this bound is met for every prime p. We then prove a number of variations of this result. (Received August 18, 2015)

1114-20-205 **Amanda A. Schaeffer Fry** (aschaef6@msudenver.edu), Dept of Mathematical and Computer Sciences, Metropolitan State University of Denver, Denver, CO 80217, and **C. Ryan Vinroot*** (vinroot@math.wm.edu), Department of Mathematics, College of William and Mary, P. O. Box 8795, Williamsburg, VA 23185. *Real classes of finite special unitary groups.*

If G is a group, an element $g \in G$ is said to be real in G if g is G-conjugate to g^{-1}, and is said to be strongly real in G if $hgh^{-1} = g^{-1}$ for some $h \in G$ such that $h^2 = 1$. We classify all conjugacy classes of the finite special unitary groups $SU_n(q)$ which are real and those which are strongly real. It was observed by Gow that there is a natural bijection between the real conjugacy classes of the finite general linear group $GL_n(q)$ and the finite unitary group $GU_n(q)$. Gill and Singh classified the real (and strongly real) conjugacy classes of the finite special linear group $SL_n(q)$, and showed that if n is not 2 mod 4 or q is not 3 mod 4, then a class in $SL_n(q)$ is real if and only if it is real in $GL_n(q)$, and otherwise a class in $SL_n(q)$ is real if and only if it is real in $GL_n(q)$ and has some elementary divisor of the form $f(t)^k$ where k is odd. Given the relationship between $GL_n(q)$ and $GU_n(q)$, one might hope for a parallel description of the real classes of $SU_n(q)$. Somewhat surprisingly, there is not in general. We show that there is a parallel description for real classes of $SU_n(q)$ unless n is divisible by 4 and q is 3 mod 4, in which case the description is somewhat complicated. (Received August 29, 2015)

1114-20-224 **Robert Boltje*** (boltje@ucsc.edu) and **Philipp Perepelitsky**. *Generalizing tensor products of bimodules.*

We introduce a construction due to Serge Bouc that has as input a module for a subgroup $X \leq G \times H$ and a module for a subgroup $Y \leq H \times K$ and as output a module for a naturally defined subgroup $X * Y \leq G \times K$. We present several basic properties of this construction and applications to p-permutation modules and p-permutation equivalences of blocks. (Received August 28, 2015)

1114-20-232 **Alexander Gruber**, **Thomas Michael Keller*** (keller@txstate.edu), **Mark L Lewis**, **Keeley Naughton** and **Benjamin Strasser**. *Finite solvable groups with minimal prime graphs.*

Let G be a finite group. The prime graph of G is the graph with vertex set the set of all prime numbers dividing the order of G and with two vertices p and q being linked by an edge if and only if there exists an element of order pq in G. This graph has been studied intensely particularly for simple groups, but here we look at solvable groups. We define the notion of a minimal prime graph and discuss some properties, such as a bound for the Fitting length, for groups whose prime graph is minimal. (Received August 28, 2015)

1114-20-235 **Jon F. Carlson** and **Peter Webb*** (webb@math.umn.edu). *The graded center of a stable module category.*

The graded center of a triangulated category consists of the natural transformations from the identity functor to powers of the shift functor that commute, modulo a sign, with the shift functor. In the case of the stable module category of a block algebra of a finite group, the graded center is closely related to the Tate cohomology and Hochschild cohomology of the block. We show that elements of the graded center which are non-zero on only a single shift orbit are necessarily of a kind previously constructed by Linckelmann. Under extra conditions, elements which are non-zero on only finitely many shift orbits are sums of Linckelmann's elements. We show

by example that tame block algebras allow a kind of graded center element which cannot arise with wild block algebras. The proofs use Auslander-Reiten theory extensively. (Received August 28, 2015)

1114-20-266 **Alexandre Turull***, Department of Mathematics, University of Florida, Gainesville, FL 32611. *Strengthenings of the Dade Projective Conjecture for p-solvable groups.* Preliminary report.

Dade's Projective Conjecture has been the object of intense study. While it is known to be true for all p-solvable groups by work of Robinson, it remains open in general. Strengthenings of the McKay Conjecture and the Alperin Weight Conjecture proposed by Isaacs and Navarro suggested a natural strengthening of the Dade Projective Conjecture. In a different direction, the Dade Projective Conjecture was also strengthened by Boltje. The resulting strengthened Dade Projective Conjectures were studied for p-solvable groups by Glesser. Turull proposed a different strengthening of the McKay Conjecture. In this talk, we adapt Turull's Conjecture to the point of view of Dade's Projective Conjecture, and to Boltje's Conjecture. We then discuss the proofs of the resulting conjectures (with all the above mentioned strengthenings) for all p-solvable finite groups. As a consequence, we obtain Uno's version of the Dade Projective Conjecture for all p-solvable finite groups. The proof develops a Clifford theory for alternating sums of numbers of characters which respects the rationality of the characters. (Received August 30, 2015)

1114-20-284 **David J Hemmer*** (dhemmer@math.buffalo.edu), 244 Math Building, Buffalo, NY 14260, and **Frederick R Cohen** and **Daniel K Nakano**. *The Complexity of the Lie Module.*

The complexity of a module is an important homological invariant that measures the polynomial rate of growth of its minimal projective resolution. For the symmetric group Σ_n, the Lie module $\mathsf{Lie}(n)$ has attracted a great deal of interest in recent years.

We prove here that the complexity of $\mathsf{Lie}(n)$ in characteristic p is t where p^t is the largest power of p dividing n, thus proving a conjecture of Erdmann, Lim and Tan. The proof uses work of Arone and Kankaanrinta which describes the homology $\mathrm{H}_\bullet(\Sigma_n, \mathsf{Lie}(n))$ and earlier work of Hemmer and Nakano on complexity for modules over Σ_n that involves restriction to Young subgroups. (Received August 31, 2015)

1114-20-291 **Michael A Rosas*** (marosas@buffalo.edu), 125 Glenhaven Drive Unit Right, Amherst, NY 14228. *Specht modules in the principal block of $F\Sigma_{3p}$.*

We discuss the radical structures of Specht modules lying in the principal block of $F\Sigma_{3p}$, where F is a field of characteristic $p \geq 5$. We see that the Loewy length of any Specht module in the block is at most four. Furthermore, we state precisely which Specht modules have Loewy length one, two, three, or four. We also see that the second radical layer of a Specht module in the block is determined by the Ext^1-quiver of the block. Finally, we show that if a Specht module in the block has Loewy length three then its socle and third radical layer coincide. (Received August 31, 2015)

1114-20-294 **Bhama Srinivasan*** (srinivas@uic.edu), Department of Mathematics, m/c 249, 851 S.Morgan Street, Chicago, IL 60607. *Decomposition matrices of finite general linear groups.*

An important and difficult problem in the modular representation theory of finite groups is to determine the decomposition matrices. In the case of the representations of the finite general linear group $GL(n,q)$ in non-defining characteristic, there are connections with Lie theory, in particular with the action of an affine Lie algebra and of a Heisenberg algebra on a Fock space with basis indexed by partitions of all non-negative n. We describe these connections in this talk. (Received August 31, 2015)

1114-20-301 **Mark Greer** and **Lee Raney*** (lraney@una.edu), One Harrison Plaza, UNA Box 5124, University of North Alabama, Florence, AL 35632. *Semidirect Products of Loops with Groups.*

After surveying some recent results, we investigate loops which can be written as a semidirect product of a loop and a group, and we provide necessary and sufficient conditions for such a loop to be Moufang. We also examine closure properties of a class of loop extensions which arise as a result of a finite cyclic group acting as a group of semiautomorphisms of an inverse property loop. (Received August 31, 2015)

1114-20-312 **Stephen J. Trefethen*** (trefethen@math.arizona.edu), 1104 E Halcyon Rd #202, Tucson, AZ 85719. *Quadratic Rational Groups.*

A finite group G is said to be m-rational if $[\mathbb{Q}(\chi) : \mathbb{Q}] \mid m$ for all irreducible characters $\chi \in \mathrm{Irr}(G)$. The structure of rational groups (i.e. $m = 1$) has been studied by R. Gow, W. Feit and G. M. Seitz, and J. G. Thompson. John McKay posed the question of describing the structure of quadratic rational groups (i.e. $m = 2$). In 2013, J. Tent showed that any composition factor of a solvable quadratic rational group is a cyclic group, C_p, with $p \leq 11$.

In this talk, we discuss our findings on the structure of (non-solvable) quadratic rational groups. (Received August 31, 2015)

1114-20-314 **George Glauberman** and **Justin Lynd*** (justin.lynd@mso.umt.edu), Department of Mathematical Sciences, University of Montana, 32 Campus Drive, Missoula, MT 59812.
Centric linking systems and control of fixed points by p-local subgroups.

Andrew Chermak has recently shown that each saturated fusion system has a unique associated centric linking system. I will give an high-level overview of Oliver's version of Chermak's proof, which depends on an ingenious filtration, using the Thompson subgroup and due to Chermak, of the collection of centric subgroups. Both Chermak's and Oliver's proofs use the classification of finite simple groups in an indirect way. I will explain how new applications of a theorem of Glauberman from the early 1970s on control of fixed points by p-local subgroups allow a classification-free proof of Chermak's Theorem. Glauberman's theorem is usually applied with p odd and in the presence of quadratic action, but, perhaps surprisingly, it can be also applied effectively when $p = 2$ in the presence of offenders. Questions arising out of this work, including further directions, will be discussed. (Received August 31, 2015)

1114-20-318 **Catherine Bray Sass*** (cbray2@kent.edu). *Character Degree Graphs of Finite Solvable Groups with Diameter Three.*

Let G be a finite solvable group and $\Delta(G)$ be the character degree graph, a simple undirected graph. The vertices, $\rho(G)$, are the set of primes that divide the character degrees and two primes are adjacent if their product divides a character degree. There are many restrictions on this graph. In particular, Pálfy's Condition tells us that in any subset of $\rho(G)$ that has size three, two of the primes must be adjacent. If follows immediately that if $\Delta(G)$ is connected, the diameter is at most three. We will present the history of these graphs that have diameter three, we will restrict the set of possible graphs, and we will classify the groups that will attain a character degree graph that has diameter three. (Received August 31, 2015)

1114-20-339 **Klaus M Lux*** (klux@math.arizona.edu), 617 N. Santa Rita Rd., Tucson, AZ 85721. *The 3-modular character table of the Fischer group Fi23.* Preliminary report.

We will speak on the computation of the 3-modular character table of the Fischer group Fi23, which is a contribution to the ongoing modular Atlas project. This is joint work with L. Goergen and G. Hiss both at RWTH Aachen University. In the talk, we will give a survey of the main techniques used, which involve methods from computational character and representation theory, most of them implemented in the computer algebra system GAP. The largest module we had to analyze was a reducible module of dimension 186844 over GF(3) and we will discuss how that was done in a reasonable amount of time. (Received September 01, 2015)

1114-20-358 **Amita Malik*** (amalik10@illinois.edu), 1409 W Green Street, Urbana, IL 61801, and **Florin Stan** and **Alexandru Zaharescu**. *Siegel norm and character values of finite groups.*

Define the length of a cyclotomic integer α to be the smallest number of roots of unity which sum up to α. In 1969, Cassels showed that under certain assumptions, an algebraic integer in an abelian field can be represented as a sum of at most two roots of unity. Similar results can be obtained for (irreducible) character values of finite groups. An unpublished theorem of Thompson states that a character takes the value zero or has length one at more than one third of the (finite) group elements. We generalize these results for arbitrary length by establishing a connection between Siegel norm and the length function. In particular, we obtain a result dual to that of Burnside. This is joint work with Florin Stan and Alexandru Zaharescu. (Received September 01, 2015)

22 ► Topological groups, Lie groups

1114-22-128 **Zhiwei Yun***, 450 Serra Mall, Bldg 380, Stanford, CA 94305. *Rigid automorphic forms and applications.*

I will give a survey of the method of rigidity in automorphic forms. The emphasis will not be on the method itself but instead on its applications, which include constructions of rigid local systems with exceptional monodromy groups, certain cases of the inverse Galois problem, and identities of Kloosterman sums. (Received August 20, 2015)

26 ► Real functions

1114-26-45 **Oleg Gleizer*** (prof1140g@gmail.com). *Fractal Dimensions, from a Math Circle Lesson to a Medical Application.* Preliminary report.

In this talk, we will tell a story of how explaining fractal dimensions to a talented high-school student has resulted into a technology capable of early diagnosing Parkinson's disease based on a voice sample, without ever seeing a patient, with an astonishing near 100% accuracy. The mathematical part of the story is based on Darkhovsky dimension of a signal, a novel way of looking at complexity of functions, continuous and discrete, that seems to have a huge industrial potential, from machine-diagnosing various disorders to finance to information security. (Received July 22, 2015)

30 ► Functions of a complex variable

1114-30-78 **Mario Bonk*** (mbonk@math.ucla.edu), Los Angeles, CA 90095-1555. *Dynamics and quasiconformal geometry.*

Questions in geometry group theory or complex dynamics lead to problems of quasiconformal geometry on non-smooth or fractal spaces. For example, there is a close relation of this subject to the problem of characterizing fundamental groups of hyperbolic 3-orbifolds or to Thurston's characterization of rational functions with finite postcritical set. Fractal 2-spheres, Sierpiński carpets, or continuum trees are typical spaces for which a deeper understanding of their quasiconformal geometry is particularly relevant and interesting. In my talk I will give a survey on some recent developments in this area. (Received August 10, 2015)

1114-30-137 **Enrico Le Donne** and **Xiangdong Xie***, xiex@bgsu.edu. *Rigidity of fiber-preserving quasisymmetric maps.*

We study the rigidity property of quasisymmetric maps that preserve a foliation. We show that, under quite general conditions, such quasisymmetric maps are biLipschitz. We then give an application to quasisymmetric maps between Carnot groups.

This is a joint work with Enrico Le Donne. (Received August 20, 2015)

1114-30-138 **Nageswari Shanmugalingam*** (shanmun@uc.edu), Department of Mathematical Sciences, P.O.Box 210025, University of Cincinnati, Cincinnati, OH 45221, and **Panu Lahti**. *Traces of BV functions in metric setting.*

The focus of this talk is to propose a notion of trace of BV functions in the metric setting that does not require extension of the function to the exterior of the domain. (Received August 21, 2015)

1114-30-200 **Shanshuang Yang*** (syang@mathcs.emory.edu), Department of Math and CS, Emory University, Atlanta, GA 30322. *Dilatations and Exponents of Quasisymmetric Homeomorphisms.* Preliminary report.

In this talk, we define several quantities, called dilatations and exponents, associated with a quasisymmetric homeomorphism of the unit circle and study their relations. In particular, we establish a necessary and sufficient condition for the dilatation to be equal to the maximal dilatation for a QS homeoporphism. (Based on a joint work with Tao Cheng) (Received August 27, 2015)

1114-30-213 **Huy V Tran*** (tvhuy@math.ucla.edu) and **Mario Bonk**. *Quasisymmetry between the Julia set of $z^2 + i$ and a continuum self-similar tree.* Preliminary report.

Motivated from a problem in probability, we will show that the Julia set of $z^2 + i$ is quasi-symmetric to a continuum self-similar tree. It is also true for other polynomials. This is joint work with Mario Bonk. (Received August 27, 2015)

1114-30-222 **Swadesh Kumar Sahoo*** (swadesh.sahoo@iiti.ac.in), Discipline of Mathematics, IIT Indore, Simrol, Khandwa Road, Indore, MP 452020, India. *Quasihyperbolic metric and φ-uniform domains.*

We study two hyperbolic-type metrics, namely, the quasihyperbolic metric and the distance ratio metric defined in a proper subdomain of the Euclidean n-space $\mathbb{R}^n$. In connection with these two metrics, we define what is φ-uniform domain and discuss some of its geometric properties. (Received August 28, 2015)

1114-30-236 **Kevin Wildrick*** (kevin.wildrick@montana.edu), P.O. Box 172400, Bozeman, MT 59717.
Quasiconformal mappings of high dimension distortion on foliations. Preliminary report.

Gehring's fundamental result on the higher integrability of the Jacobian of a quasiconformal mapping in space implies that such a mapping is a super-critical Sobolev mapping. More recent work of Balogh, Monti, and Tyson gives quantitative estimates on the frequency with which such mappings can distort the dimension of a fiber of a foliation, greatly generalizing the ACL property. The sharpness of these estimates for Sobolev mappings can be shown using a random construction. We will discuss the sharpness of these estimates for quasiconformal mappings in Euclidean space, as well as recent results in the much more difficult setting of the Heisenberg group. This is joint work with Balogh and Tyson. (Received August 28, 2015)

1114-30-359 **Kourosh Tavakoli*** (ktavakoli@okcu.edu). *The Relationship of Various Conformal-Like Metrics in the Plane.*

In this talk we study different conformal-like metrics in the plane and investigate the relationship of them. We also study the geometric and analytic properties of these metrics. (Received September 01, 2015)

32 ► Several complex variables and analytic spaces

1114-32-91 **Song-Ying Li*** (sli@math.uci.edu), Department of Mathematics, 430 Rowland Hall, University of California at Irvine, Irvine, CA 92697-3875, and **Duong Ngoc Son**.
ddbar-Bochner formulae for maps from pseudo-Hermitian manifolds to Kahler manifolds and applications.

In this talk, I will present some recent work jointly with Duong Ngoc Son. We establish various Bochner formulae for maps from a pseudo-Hermitian CR manifold to a Kahler manifold. As applications, I will introduce Siu's super-Rigidity theorem for harmonic maps between two Kahler manifolds, and I will present our results on the pseudo-Hermitian case. (Received August 13, 2015)

34 ► Ordinary differential equations

1114-34-231 **Ron Buckmire*** (buckmire@oxy.edu), Fowler Hall, Room 313, Department of Mathematics, Occidental College, Los Angeles, CA 90041, and **Jacob Ortega-Gingrich**.
Cinematic Box-Office Dynamics : An Overview Of A Particular Application of Ordinary Differential Equations to the Time Evolution of Theatrical Film Grosses.

Cinematic Box-Office Dynamics is the name given to the study of the way in which theatrically released films earn money over time. This phenomenon is an active area of research in economics and mathematics. We will present an overview of several problems involved in creating effective mathematical descriptions of the evolution over time of a film's earning potential at the box-office. We will also discuss some attempts at developing and testing mathematical models involving ordinary differential equations that can simulate or approximate the box-office dynamics of certain classes of films. (Received August 28, 2015)

1114-34-244 **Kristen Shavlik*** (kshavlik@uwyo.edu). *Numerical Methods for Solving the Zakharov-Shabat Eigenvalue Problem.* Preliminary report.

The Zakharov-Shabat (ZS) eigenvalue problem is one half of the Lax pair for the focusing nonlinear Schrodinger (NLS) equation. In this talk, we present two numerical approaches, the complex shooting method of Bronski and the Evans function root-tracking method of Humpherys and Lytle, for the problem of locating eigenvalues of the ZS problem with real, bell-shaped potentials. In particular, our experiments are designed to explore how perturbations in the potential affect the solution of the NLS equation in the semiclassical (zero-dispersion) limit. (Received August 28, 2015)

35 ► Partial differential equations

1114-35-80 **Nan Lu*** (nal314@lehigh.edu), 14 East Packer Ave, Bethlehem, PA 18015. *Equivariant and Self-similar Standing Waves for a Hamiltonian Spin-Field System.*

n this talk, I will discuss the joint work with Andrea Nahmod and Chongchun Zeng on the existence of equivariant solutions to a Hamiltonian hyperbolic-hyperbolic coupled spin-field system, where the spins are maps from $\mathbb{R}^{2+1}$ into the sphere $\mathbb{S}^2$ or the pseudo-sphere $\mathbb{H}^2$. This model was introduced by Martina *et al.* from the hyperbolic-hyperbolic generalized Ishimori systems. Relying on the hyperbolic coordinates, we prove the existence of

equivariant standing waves both in regular hyperbolic coordinates as well as in similarity variables, and describe their asymptotic behavior. (Received August 10, 2015)

1114-35-95 **Alexis Vasseur** and **Cheng Yu*** (yucheng@math.utexas.edu). *Existence of Global Weak Solutions for 3D Degenerate Compressible Navier-Stokes Equations.*

In this talk, we will talk about the existence of global weak solutions for 3D compressible Navier-Stokes equations with degenerate viscosity. The method is based on the Bresch and Desjardins entropy conservation. The main contribution of this paper is to derive the Mellet-Vasseur type inequality for the weak solutions, even if it is not verified by the first level of approximation. This provides existence of global solutions in time, for the compressible Navier-Stokes equations, for any $\gamma > 1$ in two dimensional space, andd for any $1 < \gamma < 3$ in three dimensional space, with large initial data possibly vanishing on the vacuum. This solves an open problem proposed by Lions. This is a joint work with Alexis Vasseur. (Received August 14, 2015)

1114-35-113 **Janpou Nee*** (jpnee@ctu.edu.tw), General Education Center, ChienKuo Technology University, Changhua, 500, Taiwan. *A counter example of Rauch's conjecture on a symmetry domain.*

The hot spot conjecture was proposed by J. Rauch in 1975. The conjecture suggests that the maximum of the solution of heat equation with Neumann boundary condition should occurs at the boundary. Later in 1999, Burdzy and Werner gave a counter example of this problem on a domain with two holes. The conjecture then revises to symmetry domain. However, a counter example was found on a symmetry domain. To support the conjecture, condition other then the geometry of the domain is needed. (Received August 17, 2015)

1114-35-119 **Phuc Cong Nguyen*** (pcnguyen@math.lsu.edu), Department of Mathematics, Louisiana State University, 303 Lockett Hall, Baton Rouge, LA 70803, and **Cristi Guevara**. *Leray's self-similar solutions to the Navier–Stokes equations with low integrability profiles.*

We rule out the existence of Leray's backward self-similar solutions to the Navier–Stokes equations with profiles in $L^{12/5}(\mathbb{R}^3)$ or in the Marcinkiewicz space $L^{q,\infty}(\mathbb{R}^3)$ for $q \in (12/5, 6)$. This follows from a more general result formulated in terms of Morrey spaces and the first order Riesz's potential. It is also shown that $L_t^\infty(X)$ Leray–Hopf weak solutions to the three-dimensional Navier-Stokes equations are regular for certain spaces X strictly containing $L_x^3(\mathbb{R}^3)$. (Received August 18, 2015)

1114-35-149 **Rupert Frank*** (rlfrank@caltech.edu), Caltech, Mathematics 253-37, Pasadena, CA 91125. *Lieb-Thirring inequalities at positive density.*

Lieb-Thirring inequalities give a lower bound on the kinetic energy of a quantum state with given one-particle density. While the usual Lieb-Thirring inequality concerns the case of a density vanishing at infinity (as is the case in applications in atomic physics), we discuss here the case where the density tends to a positive constant (as encountered in solid state physics). Motivated by this question, we give general conditions under which the difference of a function applied to the Schrödinger operator differs from the same function applied to the Laplacian by a trace class operator.

The talk is based on joint work with M. Lewin, E.H. Lieb and R. Seiringer and with A. Pushnitski. (Received August 23, 2015)

1114-35-155 **Yuanzhen Shao*** (shao92@purdue.edu), 150 N University St., West Lafayette, IN 47907. *Degenerate and singular elliptic operators on manifolds with singularities.*

In this talk, we will introduce the concept of manifolds with singularities and study a class of elliptic differential operators that exhibit degenerate or singular behavior near the singularities. Based on this theory, we investigate the Yamabe flow with "bad" initial metrics. (Received August 23, 2015)

1114-35-167 **Jianfeng Zhang***, USC Mathematics Department, 3620 S. Vermont Ave, KAP 108, Los Angeles, CA. *Viscosity Solutions of Path Dependent PDEs.*

Path Dependent PDEs considers continuous paths as its variable, which is a natural extension of standard PDEs to non-Markovian framework. Due to the path dependence, even a heat equation typically does not have a classical solution, and thus we turn to viscosity solutions. However, the state space of continuous paths is not locally compact, a crucial property required in the standard literature of PDE viscosity theory. To overcome this main difficulty, we propose a new notion of viscosity solution by replacing the pointwise maximum to a maximum in mean. We shall establish the wellposedness of viscosity solutions for fully nonlinear path dependent PDEs, with path dependent HJB equations and path dependent Isaacs equations as the typical examples. (Received August 25, 2015)

1114-35-168 **Treena Basu*** (basu@oxy.edu). *A second order fast method for the one-dimensional space-fractional diffusion equations.* Preliminary report.

Fractional diffusion equations model phenomena exhibiting anomalous diffusion that can not be modeled accurately by the second order diffusion equations. Because of the non-local property of fractional differential operators, the numerical methods have full coefficient matrices which require storage of $O(N^2)$ and computational cost of $O(N^3)$, where N is the number of grid points.

Together we develop a fast finite difference method for the one-dimensional space fractional diffusion equation, which only requires storage of $O(N)$ and computational cost of $O(NlogN)$, while retaining the same accuracy and approximation property as the regular finite difference method. Numerical experiments are presented to show the utility of the method. (Received August 25, 2015)

1114-35-175 **Patrick Guidotti*** (gpatrick@math.uci.edu), 340 Rowland Hall, Department of Mathematics, Irvine, CA 92697. *Nonlinear Diffusions Inspired by Image Processing.*

This talk will focus on the analysis of certain nonlinear diffusions originally inspired by the well-known Perona-Malik equation of Image Processing which have proven useful in providing an understanding of the numerical behavior exhibited by solutions of the mathematically ill-posed Perona-Malik model(a nonlinear forward-backward diffusion) and mathematically well-posed replacements for it which preserve its cherished features and mitigate its known short-comings. (Received August 25, 2015)

1114-35-187 **Tianling Jin*** (tianlingjin@ust.hk), Department of Mathematics, HKUST, Clear Water Bay, Kowloon, Hong Kong, and **Luis Silvestre** (luis@math.uchicago.edu), 5734 S. University Avenue, Department of Mathematics, University of Chicago, Chicago, IL 60637. *Holder gradient estimates for parabolic homogeneous p-Laplacian equations.*

We prove interior Hölder estimates for the spatial gradient of viscosity solutions to the parabolic homogeneous p-Laplacian equation

$$u_t = |\nabla u|^{2-p} \operatorname{div}(|\nabla u|^{p-2}\nabla u),$$

where $1 < p < \infty$. This equation arises from *tug-of-war*-like stochastic games with noise. It can also be considered as the parabolic p-Laplacian equation in non divergence form. (Received August 26, 2015)

1114-35-189 **José Carrillo**, **Sabine Hittmeir**, **Bruno Volzone** and **Yao Yao*** (yaoyao@math.gatech.edu). *Stationary solutions of aggregation equation with degenerate diffusion.* Preliminary report.

In this talk, we consider the aggregation equation with degenerate diffusion in $\mathbb{R}^d$. If the aggregation term is attracting, we prove that every L^1 non-negative stationary solution must be radially decreasing up to a translation. As an application, we show that for the 2D Keller-Segel equation with degenerate diffusion, any initial data with finite second moment must converge to a radially decreasing stationary solution as the time goes to infinity. (Received August 26, 2015)

1114-35-212 **Zhen Lei** and **Qi S. Zhang*** (qizhang@math.ucr.edu), Riverside, CA 92521. *Recent results on axially symmetric Navier-Stokes equations.*

We will describe a recent joint result with Zhen Lei, which shows that the vortex stretching terms of the axially symmetric Navier-Stokes equation are critical instead of super-critical as commonly believed. Regularity conditions which are logarithmic away from regularity by the authors and others will be presented. (Received August 27, 2015)

1114-35-237 **Robert R Jensen*** (rjensen@luc.edu), 1032 W. Sheridan Rd, Chicago, IL 60660. *A Geometric Derivation of the Maximum Principle and Applications.* Preliminary report.

I will describe a geometric derivation of the maximum principle for ellliptic partial differential equations which is particulary applicable to viscosity solutions. By slightly modifying this approach I will recover results previously proved by Yifeng Yu on the gradient of C^2 infinity harmonic functions. (Received August 28, 2015)

1114-35-282 **Agnid Banerjee*** (agnidban@gmail.com) and **Nicola Garofalo**. *A parabolic analogue of the higher-order comparison theorem of De Silva and Savin.*

We show that the quotient of two caloric functions which vanish on a portion of the lateral boundary of a $H^{k+\alpha}$ domain is $H^{k+\alpha}$ up to the boundary for $k \geq 2$. In the case $k = 1$, we show that the quotient is in $H^{1+\alpha}$ if the domain is assumed to be space-time $C^{1,\alpha}$ regular. This can be thought of as a parabolic analogue of a recent important result of De Silva and Savin and we closely follow the ideas in that paper. Analogous results are not true at points on the parabolic boundary which are not on the lateral boundary, i.e., points which are at the corner and base of the parabolic boundary. Besides being an interesting regularity result in its own right,

a direct application of such a result as well as its elliptic counterpart above implies C^∞ smoothness of a priori $C^{1,\alpha}$ free boundaries without the use of the hodograph transformation of Kinderlehrer-Nirenberg-Spruck. This is a joint work with Prof. Nicola Garofalo. (Received August 31, 2015)

1114-35-286 **Nestor Guillen** and **Russell Schwab*** (rschwab@math.msu.edu), Department of Mathematics, Michigan State University, 619 Red Cedar Rd, East Lansing, MI 48824. *Neumann homogenization via integro-differential methods.*

We study the homogenization of fully nonlinear elliptic equations with oscillatory Neumann data in half-space type domains. We employ new methods to prove the averaging, by recasting the original boundary equation as a global interior homogenization problem involving an integro-differential operator on the boundary itself. This is done by using the Dirichlet-to-Neumann mapping for the fully nonlinear equation in the the interior of the domain. This is join work with Nestor Guillen. (Received August 31, 2015)

1114-35-287 **I Kim***, Department of Mathematics, UCLA, LA, CA 90095, and **D Kwon**. *Stability and Long time behavior of normalized mean curvature flow.*

We investigate geometric stability properties and long-time behavior of a normalized mean curvature flow, where the unique smooth stationary solution is a sphere of prescribed volume. Starting from initial data which satisfies a strong version of star-shapedness (ρ-reflection), we prove that the flow preserves the ρ-reflection property. As a consequence it is shown that the evolving set becomes smooth in finite time and uniformly converges to a sphere in Hausdorff topology exponentially fast. (Received August 31, 2015)

1114-35-295 **C V Flores*** (cynthia.flores@csuci.edu), One University Drive, Bell Tower East 2762, Camarillo, CA 93012, and **D L Smith**. *On the controllability and stabilization of the linearized Dispersion Generalized Benjamin-Ono equation on a periodic domain.* Preliminary report.

In this talk, solutions of the linearized Dispersion Generalized Benjamin-Ono equation are studied

$$\partial_t u(x,t) + D^{1+a}u(x,t) = f(x,t) \tag{1}$$

for $0 < a < 1$, $x \in [0, 2\pi]$ and $t \geq 0$ where D^{1+a} denotes the homogeneous derivative. We impose that

$$\frac{\partial^k u}{\partial x^k}(0,t) = \frac{\partial^k u}{\partial x^k}(2\pi,t)$$

for $k = 0, 1$, and 2 so that the process is 2π-periodic in x, and additionally, it is assumed that the distributed control f is generated by a linear feedback law conserving the volume $\int_0^{2\pi} u(x,t)dx$. Included in the discussion are the related controllability and stabilizability preliminary results. (Received August 31, 2015)

1114-35-307 **Lokenath Debnath***, 1201 West University Drive, Edinburg, TX 78539. *Some model equations of nonlinear water waves with applications.*

Some model equations of nonlinear water waves will be presented with examples and applications to oceans dynamics. Some properties of the solutions of these will be discussed. Reference: Nonlinear Partial Differential Equations for Scientists and Engineers (Third Edition) by Lokenath Debnath, Birkhauser- Springer, Boston 2012. (Received August 31, 2015)

1114-35-327 **Derek L Smith*** (dls@math.ucsb.edu) and **Jun-ichi Segata**. *Propagation of regularity and persistence of decay for the fifth order Korteweg-de Vries equation.*

We consider solutions $u = u(x,t)$ to the fifth order Korteweg-de Vries (KdV) equation

$$\partial_t u - \partial_x^5 u - 30u^2\partial_x u + 20\partial_x u\partial_x^2 u + 10u\partial_x^3 u = 0, \quad x,t \in \mathbb{R},$$

corresponding to initial data $u_0(x) \in H^s(\mathbb{R}), s > 5/2$. Suppose that u_0 is additionally contained in $H^k(0,\infty)$, that is, the function possesses k-derivatives when restricted to the half-line $(0,\infty)$ for integer $k > s$. Then for positive times the solution also possesses k-derivatives on any half-line, i.e. $u(\cdot,t) \in H^k(x_0,\infty)$ for all $x_0 \in \mathbb{R}$. In other words, certain singularities travel to the left with infinite speed. This propagation of regularity result was recently established for the k-generalized KdV equation by a modification of a technique used to prove Kato's local smoothing effect. We will also discuss persistence of one-sided polynomial decay, as well as an extension of both results to the KdV hierarchy. (Received September 01, 2015)

1114-35-332 **Marian Bocea***, Loyola University Chicago, Department of Mathematics and Statistics, 1032 W. Sheridan Road, Chicago, IL 60660. *On a family of inhomogeneous torsional creep problems.*

The asymptotic behavior of solutions to a family of inhomogeneous PDEs in divergence form is studied in an Orlicz-Sobolev setting. Solutions are shown to converge uniformly to the distance function to the boundary of the domain. One consequence is that a well-known result in the analysis of problems modeling torsional

creep continues to hold under much more general constitutive assumptions on the stress. Joint work with M. Mihailescu (University of Craiova and "Simion Stoilow" Institute of Mathematics of the Romanian Academy, Bucharest, Romania). (Received September 01, 2015)

1114-35-351 **Nestor D Guillen***, 140 Long Plain Road, Leverett, MA , and **Jun Kitagawa**.
Regularity for surfaces in geometric optics and other Generated Jacobian Equations.

The study of reflector surfaces in geometric optics necessitates the analysis of nonlinear equations of Monge-Ampère type. For many important examples (including the near field reflector problem), the equation no longer falls within the scope of optimal transport, but within the class of "Generated Jacobian equations", recently introduced by Trudinger.

Under natural assumptions, we prove Holder regularity for the gradient of weak solutions. Among the assumptions, there is one analogous to the A3-weak condition introduced by Ma, Trudinger and Wang in optimal transport. The results are new in particular for the near-field reflector problem. (Received September 01, 2015)

1114-35-352 **Hongwei Gao*** (hongweig@uci.edu), Department of Mathematics, UC, Irvine, Irvine, CA 92697. *Strain Induced Slowdown of Front Propagation in Random Shear Flow via Analysis of G-equations.*

It is proved that for the 2-dimensional case with random shear flow of the G-equation model with strain term, the strain term reduces the front propagation. Also an improvement of the main result by Armstrong-Souganidis is provided. (Received September 01, 2015)

37 ► Dynamical systems and ergodic theory

1114-37-92 **Anton Gorodetski*** (asgor@math.uci.edu). *Spectrum of Square Fibonacci Hamiltonian and sums of Cantor sets.*

We will discuss the properties of the spectrum of the Square Fibonacci Hamiltonian. The question reduces to the study of properties of sums of two dynamically defined Cantor sets. We will discuss the current "state of art" of the subject, as well as the results on absolute continuity of convolutions of singular measures (joint with D.Damanik and B.Solomyak) that also provide much better understanding of the density of states measure of Square Fibonacci Hamiltonian. We will also give a definition of "Cantorval" (initially introduced by C.Moreira), and formulate some tempting conjectures on appearance of Cantorval as spectrum of this operator. (Received August 13, 2015)

1114-37-176 **Svetlana Jitomirskaya** (szhitomi@math.uci.edu), Irvine, CA , and **Shiwen Zhang*** (shiwez1@uci.edu), Irvine, CA. *Lower quantum dynamical bounds for minimal potentials and arithmetic criterion of full spectral dimensionality for analytic quasi-periodic Schrödinger operators.*

We will present a purely arithmetic criterion of full spectral dimensionality for discrete analytic quasi-periodic Schrödinger operators in the positive Lyapunov exponent regime. The lower bound estimate for spectral dimension works for general Schrödinger operators with minimal potentials that are exponentially close to periodic ones. This leads to a number of applications to quantum transport and fractal dimensional properties, including arithmetic conditions for quasi-ballistic motion of critical almost Mathieu operators, Sturmian Hamiltonians and results for generic sampling functions over ergodic rotations and skew shifts over higher dimensional tori. (Received August 25, 2015)

1114-37-310 **Svetlana Jitomirskaya** (szhitomi@math.uci.edu), University of California, Irvine, Rowland Hall, Room 540D, Irvine, CA 92697-3875, and **Wencai Liu*** (liuwencai1226@gmail.com), 540V,Rowland Hall, Irvine, CA 92697. *Exact asymptotics of the eigenfunctions and transfer matrices for the almost Mathieu operator.*

Almost Mathieu operator is the central quasiperiodic model in both physics and mathematics. It is given by

$$(H_{\lambda,\alpha,\theta}u)(n) = u(n+1) + u(n-1) + 2\lambda\cos 2\pi(\theta + n\alpha)u(n),$$

where λ is the coupling, α is the frequency, and θ is the phase. For fixed parameters α and λ, $\{H_{\lambda,\alpha,\theta}\}_{\theta\in\mathbb{R}}$ is a family of selfadjoint operators on $\ell^2(\mathbb{Z})$. In this talk, we study the almost Mathieu operator $\{H_{\lambda,\alpha,\theta}\}_{\theta\in\mathbb{R}}$ in localization regime, i.e., $|\lambda| > e^{\beta(\alpha)}$, where

$$\beta(\alpha) = \limsup_{n\to\infty} \frac{\ln q_{n+1}}{q_n},$$

and $\frac{p_n}{q_n}$ are the continued fraction approximants of α.

We determine the exact exponential asymptotics of eigenfunctions and of corresponding transfer matrices of the almost Mathieu operators for all frequencies and almost all phases in this regime. This also gives a constructive proof of the arithmetic version of the second transition conjecture proposed in 1994. (Received August 31, 2015)

1114-37-315 **Rui Han*** (rhan2@uci.edu). *measure of the spectrum of the extended Harper's model.*
In this talk, we will discuss the measure of the spectrum of the extended Harper's model(EHM). The measure of the spectrum of the Harper's model, which in mathematics is better known as the almost Mathieu operator(AMO), is know to be —4-2a— where a is the coupling constant. The way of calculating the measure mainly relies on the analysis of the AMO with rational frequency and the continuity argument. Here we focus on how to calculate the measure of the spectrum of the EHM with rational frequencies, therefore implying the result for irrational frequencies. (Received August 31, 2015)

39 ► Difference and functional equations

1114-39-27 **Muhamed Borogovac*** (muhamed.borogovac@gmail.com), 42 Bexley Rd, Roslindale, MA 02131. *Two Applications of Brouwer's Fixed Point Theorem: in Insurance and in Biology Models.* Preliminary report.
In the first part of the article, a new interesting system of difference equations is introduced. It is developed for re-rating purposes in general insurance. A nonlinear transformation φ of a d-dimensional ($d \geq 2$) Euclidean space is introduced that enables us to express the system in the form $f^{t+1} := \varphi(f^t)$, $t = 0, 1, 2, \ldots$. Under typical actuarial assumptions, existence of solutions of that system is proven by means of Brouwer's fixed point theorem in normed spaces. In addition, conditions that guarantee uniqueness of a solution are given.

The second, smaller part of the article is about Leslie-Gower's system of $d \geq 2$ difference equations. We focus on the system that satisfies conditions consistent with weak inter-specific competition. We prove existence and uniqueness of the equilibrium of the model under surprisingly simple and very general conditions.

Even though the two parts of this article have applications in two different sciences, they are connected with similar mathematics, in particular by our use of Brouwer's Fixed point Theorem. (Received June 02, 2015)

1114-39-217 **Rigoberto Medina*** (rmedina@ulagos.cl), Avenida Fuschlocher 1305, Osorno, 5290000. *Nonlinear Volterra Difference Equations in l_p-Spaces.*
The implicit and explicit Volterra difference equations have motivated an essential interest in investigating the asymptotic properties of its solutions and in developing appropriate methods for the analysis. We present estimates for the $l_\infty-$norms and l_p-norms of solutions of discrete Volterra equations in Banach spaces. The main tool is an estimate for the inverse infinite quasi-nilpotent matrix. To obtain these bounds we will interpret Volterra equations as operator equations in appropiate spaces. (Received August 28, 2015)

1114-39-322 **Maxim Zinchenko***, Department of Mathematics and Statistics, University of New Mexico, Albuquerque, NM , and **Jacob S. Christiansen**. *Lieb–Thirring Inequality for Infinite Gap Jacobi Matrices.* Preliminary report.
This talk is a preliminary report on recent advances in eigenvalue estimates for perturbed almost-periodic tridiagonal matrices. More specifically, we obtain a Lieb–Thirring type estimate for trace class perturbations of a special class of infinite gap Jacobi matrices. (Received August 31, 2015)

40 ► Sequences, series, summability

1114-40-186 **Mehmet Unver** (munver@ankara.edu.tr), Ankara University, Faculty of Science, Department of Mathematics, 06100 Ankara, Turkey, **Seyhmus Yardimci*** (smyardimci@ankara.edu.tr), Ankara University, Faculty of Science, Department of Mathematics, 06100 Ankara, Turkey, and **Murat Olgun** (olgun@ankara.edu.tr), Ankara University, Faculty of Science, Department of Mathematics, 06100 Ankara, Turkey. *Summability of Spliced Sequences in Metric Spaces.*
In this talk we study the summability of spliced sequences in metric spaces and give the Bochner integral representation of A-limits of the spliced sequences for Banach spaces. For this purpose we first introduce a new concept of A-distributional convergence in an arbitrary Hausdorff topological space which is equivalent to A-

statistical convergence for a degenerate distribution function. We also investigate A-distributional convergence as a summability method in an arbitrary Hausdorff topological space. (Received August 26, 2015)

41 ► Approximations and expansions

1114-41-33 **Asuman G. Aksoy*** (aaksoy@cmc.edu), 2841 N. Mountain Ave, Claremont, CA 91711, and **Grzegorz Lewicki**. *Bernstein's Lethargy Theorem in Fréchet Spaces.* Preliminary report.

In this talk, we consider Bernstein's Lethargy Theorem (BLT) in the context of Fréchet spaces. Let X be an infinite-dimensional Fréchet space and let $\mathcal{V} = \{V_n\}$ be a nested sequence of subspaces of X such that $\overline{V_n} \subseteq V_{n+1}$ for any $n \in \mathbb{N}$ and $X = \overline{\bigcup_{n=1}^{\infty} V_n}$. Let e_n be a decreasing sequence of positive numbers tending to 0. Under an additional natural condition on $\sup\{\operatorname{dist}(x, V_n)\}$, we prove that, there exists $x \in X$ and $n_o \in \mathbb{N}$ such that

$$\frac{e_n}{3} \leq \operatorname{dist}(x, V_n) \leq 3e_n$$

for any $n \geq n_o$. By using the above theorem, we prove both Shapiro's and Tyuremskikh's theorems for Fréchet spaces. Considering rapidly decreasing sequences, other versions of the BLT theorem in Fréchet spaces will be discussed. (Received June 17, 2015)

43 ► Abstract harmonic analysis

1114-43-46 **Sergio Albeverio** and **Ambar N Sengupta*** (ambarnsg@gmail.com), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70810. *Representing the Heisenberg group: ideas from Frobenius to von Neumann.*

We explore von Neumann's proof of the equivalence of the Schrödinger and Heisenberg representations in quantum mechanics, and connect with earlier ideas of Frobenius. (Received July 25, 2015)

46 ► Functional analysis

1114-46-13 **Talat Nazir*** (dr.talatnazir@gmail.com), Malardalen University Vasteras, 72123 Vasteras, Sweden. *Fixed and Common Fixed Point Results for Multi-valued Maps Endow with Graph.*

In this talk, we present some fixed and common fixed point results for multi-valued maps endowed with a directed graph. We provide some examples to support our results. These results extend, unify and generalize various comparable results of existing literature. (Received March 17, 2015)

1114-46-15 **Sartaj Ali*** (sartajali2004@yahoo.com), Department of Mathematics, NCBA&E, Lahore, 40-E1, Pakistan. *Best Proximity Point Theorems For Fρ Proximal Contraction In Modular Function Spaces.*

Recently Mohamed Jleli et al. (2013) introduce the class of proximal quasi-contraction of nonself-mappings in modular spaces with the Fatou property. He provide sufficient conditions assuring the existence and uniqueness of best proximity points. M Omidvari et al. (2014) proved the existence of a best proximity point for F-contractive nonself-mappings and state some results in the complete metric spaces. Also they defined two kinds of F-proximal contractions and extended some best proximity point theorems and improved the recent results. In this paper we have made some improvement by unifying and generalizing the results of Mohamed Jleli et al. (2013) and M Omidvari et al. (2014) in modular function spaces. Our results generalized the results of Mohamed Jleli et al. (2013), M Omidvari et al. (2014) and some other results in the literature. Moreover, we discussed some illustrative examples to highlight the realized improvements. (Received March 20, 2015)

1114-46-21 **Sergei Silvestrov*** (sergei.silvestrov@mdh.se), Division of Applied Mathematics, Sch. of Education, Culture and Communication, Malardalen University, 72123 Vasteras, Sweden. *Common Fixed Point Results for Commuting Operators.*

In this talk, I will present common fixed theorems for commuting operators satisfying generalized contractive conditions. Some examples and applications of obtained results will also be presented. These results extend, unify and generalize various recent results in the existing literature. (Received May 06, 2015)

1114-46-25 **Afrah Ahmad Abdou*** (aabdou@kau.edu.sa), J, Meccah 78745, Saudi Arabia. *Fixed Point Theory for Modular Metric Spaces.* Preliminary report.

Contractivity is amongst the sufficient conditions for an operator to have a fixed point in modular metric space. Unlike in metric spaces, the uniqueness is not so instantly obtained. However, if some additional conditions are assumed, then the uniqueness is guaranteed. In this project, we therefore investigate the existence property for several directions of generalized contractive operators in modular metric spaces. (Received May 25, 2015)

1114-46-28 **Mujahid Abbas*** (abbas.mujahid@gmail.com), Department of Mathematics, and Applied Mathematics, University of Pretoria, Lynnwood Road, Pretoria, Gauteng 0002, South Africa. *Soft Fixed Point in Soft Metric Spaces.*

The aim of this talk is to introduce the concept of soft contraction mapping on soft metric spaces and then present among other results, a theorem of Banach contraction principle type called soft contraction theorem in the setup of soft complete metric spaces . We also present a fixed point results when a soft mapping satisfies soft contraction condition on the soft closed balls in complete soft metric spaces. We provide some examples to illustrate the validity of our presented results. We believe that this will open some new avenues of research in soft metric fixed point theory. (Received June 05, 2015)

1114-46-58 **Charles Ejikeme Chidume*** (cchidume@aust.edu.ng), KM 10, Airport Rd. Galadimawa, Abuja, Nigeria, and **Ugo Osisiogu** (uaosisiogu1@yahoo.com), Ebonyi State University, Abakaliki, Abakaliki, Nigeria. *Δ-Convergence Theorems, Application of fixed point technique in developing algorithm for approximating solution of nonlinear equation of Hammerstein-type.* Preliminary report.

Let X be a real normed linear space with dual X^*, $F : X \longrightarrow X^*$ and $K : X^* \longrightarrow X$ be *monotone-type* mappings such that the equation

$$x + KFx = 0 \tag{1}$$

has a solution. It is known that, in general; under this setting, even in a real Hilbert space, KF need not be monotone. Consequently, for arbitrary real normed space E, iterative methods for approximating solutions of

$$u + Au = 0 \tag{2}$$

when $A : E \longrightarrow E$ is of the *accretive-type*, assuming existence, which have been successfully employed for equation (2) are not applicable for equation (1). By defining a new operator A on the Cartesian product $X \times X$ in terms of K and F and using fixed point techniques, a new coupled recursion formula is developed in the original spaces X and X^*. This coupled recursion formula has now proved to be successful for approximating solutions of (1), assuming existence. This recursion formula seems to be the only one now known for approximating solutions of (1). when the operators K and F are either of the accretive-type or of the monotone-type. (Received August 04, 2015)

1114-46-59 **Jake Fillman*** (fillman@vt.edu), **David Damanik** and **Milivoje Lukic**. *Spectra of Limit-Periodic Schrödinger Operators.*

We will discuss the spectral theory of limit-periodic Schrödinger operators on the real line. For an explicit dense set of potentials, the spectrum is a homogeneous set in the sense of Carleson, and the spectral type is purely absolutely continuous. In contrast, a generic limit-periodic potential exhibits purely singular continuous spectrum supported on a Cantor set of zero Lebesgue measure. We also construct a dense set of potentials whose spectra have Hausdorff dimension zero. One can incorporate a coupling constant into the constructions, and then the aforementioned results hold simultaneously for all positive values of the coupling constant. We will discuss the relationship between our work and Deift's conjecture on almost-periodic initial data for the KdV flow. (Received August 04, 2015)

1114-46-64 **Zead Mustafa*** (zead@qu.edu.qa), Department of Mathematics, Stat. and Phy., Doha, Doha 2713, Qatar, **Erdal Karapınar** (ekarapinar@atilim.edu.tr), Dept. of Mathematics, Atılım University, 06836 Incek,, Ankara, Turkey, and **Hassen Aydi** (hassen.aydi@isima.rnu.tn), Université de Sousse, GP1–4011 Hammam Sousse, Tunisia. *A discussion on generalized almost contractions via rational expressions in partially ordered metric spaces.*

The main purpose of this paper is to give some fixed point results for mappings involving generalized (ϕ, ψ)-contractions in partially ordered metric spaces. Our results generalize, extend, and unify several well-known comparable results in the literature (Jaggi in Indian J. Pure Appl. Math. 8(2):223-230, 1977, Harjani et al. in Nonlinear Anal. 71:3403-3410, 2009, Luong and Thuan in Fixed Point Theory Appl.2011:46, 2011). The presented results are supported by three illustrative examples (Received August 06, 2015)

1114-46-106 **Cho-Ho Chu** and **Bernard Russo*** (brusso@uci.edu). *On the Tits-Kantor-Koecher Lie algebra of a von Neumann algebra.*

Every Jordan algebra or triple can be embedded in a Lie algebra according to the well-known Tits-Kantor-Koecher (TKK) construction. For example, the TKK Lie algebras of the full matrix algebras (considered as Jordan algebras) are the classical Lie algebras of type C. Not surprisingly we identify the TKK Lie algebra of a finite von Neumann algebra M as the Lie algebra of finite sums of commutators of 2 by 2 matrices over M. We also show that every structural transformation (a generalization of triple derivation) on an arbitrary von Neumann algebra is inner. These results are by-products of our recent study of the cohomology of Jordan triples via the TKK Lie algebras. (Received August 17, 2015)

1114-46-182 **Michael Hartglass*** (michael.hartglass@ucr.edu), University of California, Riverside, Riverside, CA 92521. *Free product operator algebras associated to weighted graphs.*

I will present a canonical C* -algebra that is formed from a weighted undirected graph. Its K-theory will be computed, and necessary and sufficient conditions will be provided that ensure when this algebra is simple with unique trace. Following work of Shlyakhtenko and Skoufranis, as well as Mai, Speicher, and Weber, I will show that certain self-adjoint elements associated to loops in this algebra have no atoms in their spectral measure. This will be used to give an application to Wishart Matrices. (Received August 26, 2015)

1114-46-183 **Xiaorong Liu*** (xiaorong.liu@colorado.edu). *Existence and uniqueness of solutions of linear sparse matrix equations via a fixed point theorem.*

In this paper we prove several generalizations and applications of the Banach fixed point theorem for the complete metric spaces. This theorem is used to prove the existence and uniqueness of solutions of the linear sparse matrix problem considered. (Received August 26, 2015)

1114-46-197 **Jon P Bannon***, Siena College Department of Mathematics, Loudonville, NY 12211, and **Eli Bashwinger** and **Mohammad Javaheri**. *The correlation numerical range and trace-positive complex polynomials.*

Let $A \in M_n(\mathbb{C})$. We prove that if $W_c(A)$, the correlation numerical range introduced in Hadwin and Han's paper *The Correlation Numerical Range and Connes' Embedding Conjecture*, is a subset of $[0, \infty)$, then $A = P + D$ where P is positive semidefinite and D is a diagonal matrix such that $Tr(D) = 0$. This answers two of three of the problems posed in the above paper. Additionally, we explore a few properties of $W_c(A)$ and $W_{uc}(A)$, another numerical range introduced by Hadwin and Han that is closely related to Connes's Embedding Conjecture. (Received August 26, 2015)

1114-46-206 **Weihua Li*** (wli@colum.edu), Department of Science and Mathematics, 600 S. Michigan Ave., Chicago, IL 60605. *Topological free entropy dimension and MF algebras.*

We obtain upper and lower bounds for topological free entropy dimension, and in many cases we obtain an exact formula for topological free entropy dimension. We also construct some examples of MF algebra. (Received August 27, 2015)

1114-46-344 **Belisario A Ventura*** (bventura@csusb.edu), Department of Mathematics, California State University San Bernardino, 5500 University Parkway, San Bernardino, CA 92407. *Integer Valued Cocycles on Groupoids.* Preliminary report.

We study the correspondence between cocycles on principal r-discrete groupoids and certain non-self-adjoint subalgebras of the groupoid C^*-algebra, called analytic subalgebras. In particular, we consider the problem of constructing a continuous integer valued cocycle that corresponds canonically to a $\mathbb{Z}$-analytic subalgebra of the groupoid C^*-algebra. We will show that such cocycle exists and contrast our cocycle with the canonical cocycle used in the principal measured groupoid analogue of the problem mentioned above. (Received September 01, 2015)

1114-46-350 **Buthinah A. Bin Dehaish*** (bbendehaish@kau.edu.sa), Buthinah A. Bin Dehaish, Department of Mathematics, King Abdulaziz University, Jeddah, 21593, Saudi Arabia. *On new class of Lipichizian mappings in linear spaces and nonlinear spaces.*

Abstract Among this talk we will consider new class of contractive and nonexpansive selfmappings. Furthermore we study the fixed point for these class of mappings in the setting of Banach and metric spaces. (Received September 01, 2015)

47 ► Operator theory

1114-47-17 **Xavier Alexius Udo-utun*** (xvior@yahoo.com), Department of Mathematics and Statistics, Uyo, Nigeria. *On unification of fixed point techniques - Applications of $(\delta, k)-$weak contractions.*

Author (Udo-utun Fixed Point Theory and Applications 2014, 2014:65) derived a novel property in his study of $F-$contractions (Wardowski Fixed Point Theory and Applications 2012:94, 2012). Applications yield asymptotic fixed point theorems for contractive, nonexpansive and all Lipschitzian operators sharing the property. Attempt is made to extend applicability to include certain discontinuous operators in Banach and metric spaces as a unifying significance of the property and the notion of $(\delta, k)-$weak contractions introduced earlier by Berinde (Carpath. J. Math. 19(1):7-22, 2003; Nonlinear Anal. Forum 9(1):43-53, 2004). Interesting examples are illustrated. (Received March 27, 2015)

1114-47-41 **Felicia Obiageli Isiogugu*** (felicia.isiogugu@unn.edu.ng), School of Mathematics, Statistics and, Computer Sciences, University of Kwazulu-, Natal, Durban, 3209, South Africa. *On Approximation of Fixed Points of Multi-valued k-strictly pseudocontractive Mappings in Hilbert Spaces.*

It is proved that if a multi-valued k-strictly pseudocontractive mapping T is of type-one, then $I-T$ is demiclosed at zero. Also, under this condition the Mann (respectively Ishikawa)sequence converges weakly (respectively strongly) to a fixed point of multi-valued k-strictly pseudocontractive(respectively pseudocontractive) mapping T without the condition that the fixed point set of T is strict. The results obtained extend, complement and improve the results on multi-valued and single-valued mappings in the contemporary literature. (Received July 15, 2015)

1114-47-86 **Darren C Ong*** (darrenong@math.ou.edu), Department of Mathematics, University of Oklahoma, Norman, OK 73019-310, and **Christian Remling**, Department of Mathematics, University of Oklahoma, Norman, OK 73019-310. *A characterization of generalized Toda flows using cocycle dynamics.* Preliminary report.

We introduce a method of expressing Toda flows on Jacobi operators through the perspective of cocycle dynamics on transfer matrices. (Received August 12, 2015)

1114-47-116 **Wolfram Bauer**, **Boo Rim Choe** and **Hyungwoon Koo***, Department of Mathematics, Korea University, Seoul, 136-713, South Korea. *Commuting Toeplitz operators with pluriharmonic symbols on the Fock space.*

In the setting of the Bergman space over the disk or the ball, it has been known that two Toeplitz operators with bounded pluriharmonic symbols can (semi-)commute only in the trivial cases. In this talk we present the analogues on the Fock space over the multi-dimensional complex space. As is the case in various other settings, we are naturally led to the problem of characterizing certain type of fixed points of the Berezin transform. For such fixed points, we obtain a complete characterization by means of eigenfunctions of the Laplacian. We also obtain other characterizations. In particular, it turns out that there are many nontrivial cases on the Fock space for (semi-)commuting Toeplitz operators with pluriharmonic symbols. All in all our results reveal that the situation on the Fock space appears to be much more complicated than that on the classical Bergman space setting, which partly is caused by the unboundedness of the operator symbols. (Received August 18, 2015)

1114-47-180 **Stephan Ramon Garcia*** (stephan.garcia@pomona.edu), Department of Mathematics, Pomona College, 610 N College Ave, Claremont, CA 91711. *On a problem of Halmos: unitary equivalence of a matrix to its transpose.*

Halmos asked whether every square complex matrix is unitarily equivalent to its transpose (UET). Ad hoc examples indicate that the answer is no. In this talk, we give a complete characterization of matrices which are UET. Surprisingly, the naïve conjecture that a matrix is UET if and only if it is unitarily equivalent to a complex symmetric (i.e., self- transpose) matrix is true in dimensions $n \leq 7$ but false for $n \geq 8$. In particular, unexpected building blocks appear in dimensions 6 and 8. (Received August 26, 2015)

1114-47-185 **Don Hadwin*** (don@unh.edu) and **Tatiana Shulman**. *Tracially Stable C*-algebras.* Preliminary report.

The notion of weak semiprojectivity and stable relations can be expressed in terms of "partial liftings" of unital *-homomorphisms into ultraproducts of C*-algebas. We define an analogue for separable unital C*-algebras in terms of *-homomorphisms into tracial ultraproducts of C*-algebras. We focus on special cases with the restriction that the algebras in the ultraproduct belong to special classes. We characterize matricial tracial

stability for nuclear C*-algebras. We show that a commutative separable algebra is tracially stable if and only if its maximal ideal space is "approximately path-connected" (perhaps a new topological concept). (Received August 26, 2015)

1114-47-203 **Yuki Takahashi*** (takahasy@uci.edu), 1011, West Peltason Drive, #A, Irvine, CA 92617. *Labyrinth model and products of two Cantor sets.*

We consider the Labyrinth model that was introduced in 80s as a model for two-dimensional quasicrystals. We will show that the spectrum of this model, which is known to be a product of two Cantor sets, is an interval for small values of the coupling constant. We also consider the density of states measure of the Labyrinth model, and show that it is absolutely continuous with respect to the Lebesgue measure for almost all values of coupling constants in small coupling regime. (Received August 27, 2015)

1114-47-204 **Torsten Ehrhardt*** (tehrhard@ucsc.edu), Mathematics Department, University of California, Santa Cruz, CA 95064. *Asymptotics of a determinant of a Hankel-like operator.* Preliminary report.

In the talk, I will explain how to compute the asymptotics of a determinant of identity plus a Hankel-like operator. More precisely, this operator is an integral operator defined on $L^2([-R,\infty))$ with kernel $h(x+y)$ and we are interested in $R\to\infty$. Here h is the Fourier transform of a certain concrete "symbol".

One expects some similarity to the theory of Toeplitz or Wiener-Hopf determinants, but it is not immediately clear how to make a connection. As a "warm-up" we consider the case of nice symbols, where indeed an analogue to the Szegö Limit Theorem can be proved.

However, we are actually interested in symbols which have a zero, so that the symbol is actually of Fisher-Hartwig type. Luckily, in the case at hand, also this much more complicated situation can handled.

The motivation for the problem comes from a recent paper of Rider and Sinclair (*Ann. Appl. Probab.* **24**, 1621-1651, 2015), which investigates the statistics the largest eigenvalue of real Gininbre random matrix ensembles. (Received August 27, 2015)

1114-47-214 **Arkady Kitover** and **Mehmet Orhon*** (mo@unh.edu), Department of Mathematics and Statistics, University of New Hampshire, Durham, NH 03824. *Dual Radon-Nikodym Property in finitely generated Banach $C(K)$-modules.* Preliminary report.

A well known theorem of Lotz states that the dual of a Banach lattice has the Radon-Nikodym Property (RNP) if and only if the Banach lattice does not contain a copy of l^1. Using a result of Lotz and Rosenthal, we extend Lotz's Theorem to the finitely generated Banach $C(K)$-modules. Namely, we show that the dual of a finitely generated Banach $C(K)$-module has the RNP if and only if each cyclic subspace of the module does not contain a copy of l^1.

This complements our previous results about the reflexivity and the weak sequential completeness of finitely generated Banach $C(K)$-modules. (Received August 27, 2015)

1114-47-240 **Marat V. Markin*** (mmarkin@csufresno.edu), Department of Mathematics, California State University, Fresno, 5245 N. Backer Avenue, M/S PB 108, Fresno, CA 93740-8001. *On Generalized Paley-Wiener Theorems for a Scalar Type Spectral Operator.*

Known descriptions of the *Carleman classes of vectors* of a *normal operator* in a complex Hilbert space in terms of its spectral measure are extended to the case of a *scalar type spectral operator* in a complex Banach space.

The results can be considered to be operator analogues of the classic *Paley-Wiener Theorems* relating the smoothness of a square-integrable on the real axis function $f(\cdot)$ to the decay of its *Fourier transform* $\hat{f}(\cdot)$ at $\pm\infty$, which precisely corresponds to the case of the *self-adjoint* differential operator $A = i\dfrac{d}{dx}$ in $L_2(\mathbb{R})$ with the domain $W_2^1(\mathbb{R}) := \{f \in L_2(\mathbb{R}) \big| f(\cdot)$ is *absolutely continuous* on $\mathbb{R}$ and $f' \in L_2(\mathbb{R})\}$.

An immediate implication of the obtained description for the *entire vectors of exponential type* is their *denseness* in the space, a results of interest for approximation and qualitative theories. (Received August 28, 2015)

1114-47-258 **Qi Zhou*** (qizhou628@gmail.com), 22,Hankou Road, Department of Mathematics, Nanjing, JiangSu 210093, Peoples Rep of China. *Non critical dry ten martini problem.*

We show that the Dry Ten Martini Problem, i.e., all possible spectral gaps are open, holds for almost Mathieu operator with noncritical coupling and any irrational frequency. It is joint work with Artur Avila and Jiangong You. (Received August 30, 2015)

1114-47-267 **Hassan Yousefi*** (hyousefi@fullerton.edu), 800 N State College Blvd, Fullerton, CA 92831, and **Don Hadwin**. *Completely Rank-nonincreasing Bilinear Maps.* Preliminary report.

D. Larson and D. Hadwin defined the notion of completely rank-nonincreasing (CRNI) linear maps in an attempt to characterize the linear maps on a subspace of operators on a Hilbert space that are point-strong limits of similarities or point-strong limits of skew-compressions. In this talk we will extend the notion of CRNI linear maps to include the bilinear maps and then we will present some of the preliminary results that we have obtained so far. In particular, we will show that a bilinear map on a finite dimensional Hilbert space is CRNI if and only if it is spatial. (Received August 30, 2015)

1114-47-290 **Yanni Chen**, **Don Hadwin**, **Zhe Liu** and **Eric Nordgren*** (ean@math.unh.edu), Department of Mathematics, Kingsbury Hall, University of New Hampshire, Durham, NH 03824. *A Beurling theorem for generalized Hardy spaces on a multiply connected domain.* Preliminary report.

Beurling's theorem that the closed subspaces of Hardy spaces of the unit disk that are invariant under multiplication by bounded analytic functions all consist of the multiples of an inner function have been generalized in a number of different directions. We establish a version for finitely connected domains and related Hardy and Lebesgue spaces under various norms. (Received August 31, 2015)

1114-47-313 **Yiqian Wang** and **Zhenghe Zhang*** (zzhang@rice.edu), 6100 Main Street, Houston, TX 77005. *Cantor spectrum for 1-frequency quasi-periodic Schrödinger operators with smooth potentials.*

In this talk I will present a recent joint work with Yiqian Wang where we obtained for a class of C^2 potentials and for any fixed *Diophantine* frequency, the spectrum is Cantor. This is perhaps the first rigorous proof of a result of this type, i.e. for quasi-periodic potentials beyond the C^0 and the real analytic categories. Our approach is from dynamical systems which may also be applied to general $\mathrm{SL}(2, R)$ cocycles. (Received August 31, 2015)

49 ► Calculus of variations and optimal control; optimization

1114-49-191 **Hien T Tran*** (tran@math.ncsu.edu), Department of Mathematics, Campus Box 8205, North Carolina State University, Raleigh, NC 27695, and **Lawrence Ives**, **Michael Read**, **Thuc Bui**, **Adam Attarian**, **William Tallis**, **Cynthia Andujar** and **Virginia Forstall**. *Optimal Design a Doubly Convergent Multiple Beam Electron Gun.*

In this talk we discuss the successful interdisciplinary collaboration between North Carolina State University and Calabazas Creek Research, Inc. (CCR). The joint industrial research project focused on the development of computational tools and processes to design a doubly convergent multiple beam electron gun, which was previously considered impractical. All multiple beam devices designed to date use singly convergent electron guns. This means that the electron beam emitted from each cathode converges about the local beam axis. To overcome the limitation on the lifetime of the cathode a large cathode is used to reduce emission current density. This would imply that the diameter of cavity would have to be sufficiently large to accommodate the electron beams rendering it impractical. In this project, we successfully designed a doubly convergent beam gun, where the cathode is moved radially outward and is angled toward the device axis. This effort, spanning approximately 15 months, identified conceptual approaches and implemented computational tools to solve a complex, three-dimensional problem involving charged particle propagation in non-axisymmetric electromagnetic fields. (Received August 26, 2015)

1114-49-324 **Michael J Campbell*** (michaeljcampbell@outlook.com), michaeljcampbell@outlook.com, and **Joseph Hanna**, joeyhanna@berkeley.edu. *The Optimal Can: An Uncanny Approach.*

We examine a novel variation on optimizing cost for a cylindrical can. The standard problem minimizes material costs, which amounts to minimizing the surface area given a fixed volume, yielding a height equal to the diameter of the top circle (square front profile). We add distribution/storage cost to the material cost to get the total production cost. These distribution and storage cost terms are sourced from an actual carrier company that distributes cans, thus the simulation is faithful to real-life shipping and storage costs.

We show numerically that for low distribution/storage costs, the can has the classic square profile, and for distribution/storage costs above a critical value, the symmetry of the square is broken and the can takes on a rectangular profile resulting from the rectangular geometry of the distribution truck or storage cabinet.

Interestingly, the dimensions remain constant above and below the critical ship/store cost, exactly as with a Landau phase transition in statistical mechanics. This Landau-type transition has the same basic phenomenology as a Landau approximation to a magnetic system which is non-magnetic above a critical temperature, but magnetizes below a critical temperature, much like a Curie temperature for a discontinuous phase transition. (Received September 01, 2015)

1114-49-325 **Ke Yin*** (kyin@math.ucla.edu), 520 Portola Plaza, 6363 Math Science Building, Los Angeles, CA 90095, and **Omer Faruk Tekin** and **Farzin Barekat**. *Spectral results for perturbed variational eigenvalue problems and their applications to Compressed PDEs.*

We consider the solutions to a modification of the Courant's minimax characterization of the Dirichlet eigenfunctions of second order linear symmetric elliptic operators in a bounded domain Ω in $\mathbb{R}^d$. In particular, we perturb the objective functional by an arbitrary bounded penalty term. Without perturbation, it is well-known that Courant minimax principle yields the eigenfunctions, which form an orthonormal basis for $L^2(\Omega)$. We prove that the solutions of the perturbed problem still form an orthonormal basis in the case of $d = 1$, and $d = 2$, provided that the perturbation is sufficiently small in the latter case. As an application, we prove completeness results for compressed plane waves and compressed modes, which are the solutions to analogous variational problems with perturbations being an L^1-regularization term. The completeness theory for these functions sets a foundation for finding a computationally efficient basis for the representation of the solution of differential equations. (Received August 31, 2015)

1114-49-340 **Qinglan Xia*** (qlxia@math.ucdavis.edu), Department of Mathematics, University of California, One Shields Ave, Davis, CA 95616. *Analysis and Modeling of Transport Flows.* Preliminary report.

The study of geometric flow has been one of the central fields in differential geometry. Usually, a geometric flow is driven by some extrinsic or intrinsic curvature. In this talk, I will describe a new kind of flow, where the flow is mainly driven by optimal transportation, rather than curvature. As mean curvature flow is modeling the evolution of soap films, the transport flow is modeling the evolution (i.e. the dynamic growth) of a living organ such as a plant leaf, a flower, a lung or a placenta. (Received September 01, 2015)

51 ► Geometry

1114-51-1 **Mina Aganagic*** (aganagic@berkeley.edu), University of California, Berkeley. *Knots and Mirror Symmetry.* Preliminary report.

I will describe a pair of conjectures relating knot theory and mirror symmetry. To every knot K, one can associate a Calabi-Yau manifold Y(K), which is an invariant of the knot. The first conjecture states that every Calabi-Yau that arises in this way is mirror to the conifold, generalizing the Strominger-Yau-Zaslow mirror symmetry. The second conjecture states that one can recover the colored HOMFLY invariants of the knot starting from Y(K), by an appropriate quantization procedure. Knot contact homology plays a key role. The conjectures are based on joint work with Tobias Ekholm, Lenhard Ng and Cumrun Vafa. (Received April 17, 2014)

1114-51-123 **Giuseppe Martone*** (gmartone@usc.edu), Department of Mathematics KAP 415, 3620 South Vermont Avenue, Los Angeles, CA 90089. *Boundaries of Hitchin components.* Preliminary report.

Let S be a closed orientable surface of genus $g \geq 2$. Hitchin representations are higher rank generalizations of hyperbolic metrics on S and form a whole component, called the Hitchin component $\mathrm{Hit}_n(S)$, of the space of homomorphisms from the fundamental group $\pi_1(S)$ to $\mathrm{PSL}(n, \mathbb{R})$. Parreau compactified the Hitchin component by actions of $\pi_1(S)$ on certain affine buildings. I am trying to obtain a better description and understanding of this compactification by using a parametrization of $\mathrm{Hit}_n(S)$ recently developed by Bonahon-Dreyer. (Received August 19, 2015)

1114-51-147 **Craig A. Nolder*** (nolder@math.fsu.edu), Department of Mathematics, Florida State, University, 1017 Academic Way, Tallahassee, FL 32306. *Compactification of Clifford Algebras, Quadratic Spaces and Möbius groups.*

We write $\mathbb{R}^{p,q}$ for the quadratic space $\mathbb{R}^{p+q}$ with quadratic form $x_1^2 + \cdots + x_p^2 - x_{p+1}^2 - \cdots - x_{p+q}^2$. A conformal compactification is topologically a projectivised product of spheres $S^p \times S^q / \sim$. We also write $\mathcal{C}\ell_{r,s}$ for the Clifford algebra generated over the reals with generators $e_j^2 = 1$ for $j = 1, ..., r$ and $e_j^2 = -1$ for $j = r + 1, ..., r + s$. In dimensions two and four, we identify quadratic spaces with Clifford algebras. The product of a generic element with its conjugate is the corresponding quadratic form. In this way we have the identifications : complex

numbers $\mathbb{C} \approx \mathcal{C}\ell_{0,1} \approx \mathbb{R}^{2,0}$, split complex numbers $\mathcal{C}\ell_{1,0} \approx \mathbb{R}^{1,1}$, quaternions $\mathbb{H} \approx \mathcal{C}\ell_{0,2} \approx \mathbb{R}^{4,0}$, split quaternions $\mathcal{C}\ell_{1,1} \approx \mathcal{C}\ell_{2,0} \approx \mathbb{R}^{2,2}$. We discuss the actions of Möbius groups on the compactifications and in particular have the following identifications : $PSL(2, \mathcal{C}\ell_{1,0}) \approx SO_+(2,2)$, $PSL(2, \mathcal{C}\ell_{1,1}) \approx PSL(4, \mathbb{R}) \approx SO_+(3,3)$. (Received August 22, 2015)

1114-51-208 **Oscar Vega*** (ovega@csufresno.edu), 5245 North Backer Avenue M/S PB 108, Fresno, CA 93740-8001, and **Rolando Pomareda** and **Nicolas Abarzua**. *Feet in Buekenhout-Metz Unitals.* Preliminary report.

A unital is a type of block design which when embedded in a (finite) projective plane is an example of a largest possible blocking set. Most of the efforts made to study unitals have been focused on two large families: Classical and Buekenhout-Metz.

Although there exist a considerable amount of literature on Buekenhout-Metz Unitals, not much is known about the substructure formed by the points of tangency on the (tangent) lines through an external point to the unital, which is called the feet of the point. In this presentation we will give a geometric/combinatorial presentation of all feet in Orthogonal-Buekenhout-Metz Unitals. (Received August 27, 2015)

1114-51-246 **Aaron Naber*** (aaronnaber@usa.com), 220 Lunt Hall, 2033 Sheridan Road, Evanston, IL 60208. *Singular Sets of Harmonic Maps and Minimal Surfaces.*

If $f : M -> N$ is a stationary harmonic map, then it is well understood how to stratify M by the singular set of f given by $S^k(f)$. Roughly, $S^k(f)$ is the collection of points in M such that no tangent map of f has $k+1$ degrees of symmetries. It is classical that dim $S^k(f) <= k$, however little else is known in general. In this talk we discuss recent work which proves S^k is k-rectifiable. If f is minimizing, then we prove uniform $n-3$ measure bounds on $S(f)$. More effectively, we show $|\nabla f|$ has uniform estimates in weak L^3, which is sharp, as there are examples which do not live in L^3. The techniques involve an analysis of the recently introduced quantitative stratification, using a new energy covering argument, combined with a new rectifiable-Reifenberg result, and a new L^2-subspace approximation result for stationary harmonic maps. Similar statements are proved for integral currents with bounded mean curvature. This is joint work with Daniele Valtorta. (Received August 29, 2015)

1114-51-347 **Mits Kobayashi*** (mkobayashi@cpp.edu), Department of Mathematics and Statistics, Cal Poly Pomona, Pomona, CA 91768. *The geometric representation of some classical series.* Preliminary report.

Infinite series have been studied at least since the time of Archimedes, and, as was common then, such series had geometric interpretations. However, as mathematicians became more comfortable using algebraic techniques, the geometric connection became unnecessary, leaving behind the question of whether classical series such as Leibniz's series have a geometric interpretation. In the mid-20th century, Viggo Brun answered the question regarding Leibniz's series in the affirmative. Using standard calculus methods, we re-derive Brun's findings and show that these methods apply to other series such as Euler's series for the Euler-Mascheroni constant. (Received September 01, 2015)

52 ► Convex and discrete geometry

1114-52-49 **Hyun Jin Kim*** (hyunjin.sun.kim@gmail.com), Hofstra University, Hempstead, NY 11549-1000, and **Hyun Sun Kim**. *Special Configurations of Triangle Centers.*

For a given triangle, the circumcenter is the unique point in the plane of the triangle at equal distance from all three vertices. Similarly, the orthocenter is the point of intersection of the altitudes of the triangle. Euler proved that for any triangle, the midpoints of the sides, the feet of the altitudes and the midpoints of the segments joining the vertices of the triangle to the orthocenter lie on a circle. The center of this circle is the 9-point center of the triangle. We prove the following: Let A_1, A_2, A_3, A_4 be four points in the plane, no three on a line, all four not on a circle. For all $1 \leq i \leq 4$, let O_i and ω_i be the circumcenters and the 9-point centers of triangle $A_{i+1}A_{i+2}A_{i+3}$, respectively. Then the four-point configurations (O_1, O_2, O_3, O_4) and $(\omega_1, \omega_2, \omega_3, \omega_4)$ are similar. Moreover, the similarity ratio is not constant but depends on the initial points A_i in a way that is made explicit.) There are many triangle centers: these special points can be defined either as the result of some geometric construction (as it is the case with the circumcenter, the orthocenter, and the 9-point center) or may just have a pure algebraic description as explained in the paper. (Received July 31, 2015)

53 ► Differential geometry

1114-53-24 **John Lott*** (lott@berkeley.edu). *3D Ricci flow since Perelman.*

I'll talk about the advances and open questions in three dimensional Ricci flow. Topics include the finiteness of the number of surgeries, the long-time behavior and flowing through singularities. No prior knowledge of Ricci flow will be assumed. (Received May 20, 2015)

1114-53-54 **Robert Haslhofer*** (robert.haslhofer@gmail.com) and **Or Hershkovits** (or.hershkovits@cims.nyu.edu). *Mean convex level set flow in general ambient manifolds.*

We prove two new estimates for the level set flow of mean convex domains in Riemannian manifolds. Our estimates give control - exponential in time - for the infimum of the mean curvature, and the ratio between the norm of the second fundamental form and the mean curvature. In particular, the estimates remove a stumbling block that has been left after the work of White and Haslhofer-Kleiner, and thus allow us to extend the structure theory for mean convex level set flow to general ambient manifolds of arbitrary dimension. (Received August 03, 2015)

1114-53-133 **Ruobing Zhang*** (ruobingz@math.princeton.edu), Fine Hall, Washington Road, Princeton University, Princeton, NJ 08544. *Quantitative nilpotent structure and regularity of collapsed Einstein manifolds.*

In this talk we discuss the regularity of Einstein manifolds and more generally manifolds with just bounded Ricci curvature, in the collapsed setting. A key tool in the regularity theory of non-collapsed Einstein manifolds is the following: If a bigger geodesic ball on an Einstein manifold Mn is sufficiently Gromov-Hausdorff-close to a ball in Rn, then in fact the curvature on a smaller ball is uniformly bounded. No such results are known in the collapsed setting, and in fact it is easy to see without more such results are false. It turns out that the failure of such an estimate is related to topology. Our main theorem is that for the above setting in the collapsed context, there is a correspondence between the uniform curvature estimates and the local nilpotent rank. There are generalizations of this result to bounded Ricci curvature and even just lower Ricci curvature. This is a joint work with Aaron Naber. (Received August 20, 2015)

1114-53-143 **Gang Liu*** (gangliu@berkeley.edu). *On the limit of Kähler manifolds with Ricci curvature lower bound.*

Let X be the Gromov-Hausdorff limit of a sequence of pointed complete Kähler manifolds (M_i^n, p_i) with $Ric(M_i) \geq -(n-1)$ and noncollapsed volume. We prove that, there exists a Lie group isomorphic to R, acting isometrically, on the tangent cone at each point of X. Moreover, the action is locally free on the cross section. This can be regarded as a generalization of Cheeger-Colding's metric cone theorem to the Kähler case. We also discuss some applications to complete Kähler manifolds with nonnegative bisectional curvature. (Received August 22, 2015)

1114-53-228 **Brad Osgood*** (osgopd@stanford.edu), 271 Packard Bldg., Stanford University, Stanford, CA 94305, and **Martin Chuaqui** and **Peter Duren**. *Quasiconformal Extensions to Space of Weierstrass-Enneper Lifts.*

The Ahlfors-Weill extension of a conformal mapping of the disk is generalized to the Weierstrass-Enneper lift of a harmonic mapping of the disk to a minimal surface, producing homeomorphic and quasiconformal extensions to space. The extension is defined through the family of best Möbius approximations to the lift applied to a bundle of Euclidean circles orthogonal to the disk. Extension of the planar harmonic map is also obtained subject to additional assumptions on the dilatation. The hypotheses involve bounds on a generalized Schwarzian derivative for harmonic mappings in terms of the hyperbolic metric of the disk and the Gaussian curvature of the minimal surface. Hyperbolic convexity plays a crucial role. (Received August 28, 2015)

1114-53-242 **Davi Maximo*** (maximo@stanford.edu), **Otis Chodosh** and **Dan Ketover**. *On minimal surfaces with finite index.*

In this talk we will give a precise picture on how a sequence of minimal surfaces with bounded index might degenerate on given closed three-manifold. As an application, we prove several compactness results. (Received August 28, 2015)

1114-53-341 **Daniel M. Kane** and **Joseph Palmer***, j5palmer@ucsd.edu, and **Álvaro Pelayo**. *Understanding semitoric integrable systems by lifting equations from* $\mathrm{SL}(2,\mathbb{Z})$.

A semitoric integrable system is a 4-dimensional integrable system in which one of the integrals generates a Hamiltonian S^1-action. Pelayo-Vũ Ngọc have recently established a classification theorem for such systems

analogous to Delzant's classification of toric systems. I will present a method of defining a natural metric space structure, and thus topology, on the moduli space of semitoric systems (with a fixed number of focus-focus singular points) by exploiting this classification. This space is not connected but we describe its connected components. To show that these components are themselves connected we introduce semitoric fans (in analogy to the fans of toric varieties, which we call toric fans) and a new method related to $\mathrm{SL}(2,\mathbb{Z})$ to understand toric and semitoric fans. (Received September 01, 2015)

54 ► General topology

1114-54-11 **Reza Saadati*** (rsaadati@iust.ac.ir), 14, 6th Fazeli, 4th Fajr, Amol, Iran 46176545, 4617654553 Amol, Iran. *Approximate (α,β,γ)-derivation on random non-Archimedean Lie C^*-algebras via fixed point method.*

In this paper, we define random non-Archimedean Lie C^*-algebras, then we apply a fixed point theorem to investigate some new stability results for (α,β,γ)-derivations on random Lie C^*-algebras associated with a generalized Cauchy—Jensen type additive functional equation via fixed point method. (Received March 15, 2015)

1114-54-36 **Clement Boateng Ampadu*** (drampadu@hotmail.com), 31 Carrolton Road, West Roxbury, MA 02132. *Fixed Point Theorems in Multiplicative Soft Metric Spaces and Multiplicative Quasi-Dislocated Soft Metric Spaces.*

Multiplicative metric was introduced in [A.E. Bashirov, E.M. Kurpınar and A. Ozyapıcı, Multiplicative calculus and its applications, J. Math.Analy. App., 337(2008) 36-48]. On the other hand soft set theory was introduced in [D. Molodtsov, Soft set-theory-first results, Comput. Math. Appl.37(1999) 19-31]. Soft metric spaces have been investigated, see for example [Sujoy Das and S. K. Samanta, Soft metric, Annals of Fuzzy Mathematics and Informatics, 6(1) (2013) 77-94]. In the first part of this talk we introduce a concept of soft multiplicative metric spaces, and prove some fixed point theorems of contractive mappings on soft multiplicative metric spaces.

In [Zeyada et.al, The Arabian Journal of Science and Engineering, 31, 111-114 (2005)] the notion of dislocated quasi-metric space was introduced. On the other hand in [Aage et.al, Applied Mathematical Sciences, 2, 2941-2948 (2008)] dislocated quasi metric version of Kannan mapping theorem was proved. In the second part of this talk a notion of multiplicative dislocated soft quasi metric space is introduced, and some fixed point theorems for contractions and Kannan mappings are derived. (Received July 05, 2015)

1114-54-81 **Jun Kigami*** (kigami@i.kyoto-u.ac.jp), Graduate School of Informatics, Kyoto University, 1-1 Yoshidahonmachi, Sakyo-ku, Kyoto, Kyoto 606-8501, Japan. *Partition of metrizable spaces by trees, volume doubling measures and quasisymmetry.*

In this talk, we will give a definition of partition of metrizable space by infinite trees and study the structures of spaces by means of the partition. We will give necessary and sufficient conditions for a measure to have the volume doubling property and for metrics to be quasisymmetric. This study can be though of as an inverse problem of the construction of Dyadic cubes for spaces of homogeneous type by M. Christ. (Received August 12, 2015)

1114-54-88 **Hyoungjun Kim*** (kimhjun@korea.ac.kr), 102-1202 15-20 Shinbanporo16-gil, Seocho-gu, Seoul, 137800, South Korea. *The bipartite intrinsically knotted graphs with at most 22 edges.*

A graph is intrinsically knotted if every embedding contains a knotted cycle. It is known that intrinsically knotted graphs have at least 21 edges and that the KS graphs, K_7 and the 13 graphs obtained from K_7 by ∇Y moves, are the only minor minimal intrinsically knotted graphs with 21 edges. This set includes exactly one bipartite graph, the Heawood graph. In this talk we classify the intrinsically knotted bipartite graphs with at most 22 edges. (Received August 12, 2015)

1114-54-101 **Alissa S. Crans*** (acrans@lmu.edu), Department of Mathematics, Loyola Marymount University, One LMU Drive, Suite 2700, Los Angeles, CA 90045. *Unital Shelves.*

Preliminary report.

A shelf is a generalization of a rack whose single axiom,

$$(a \lhd b) \lhd c = (a \lhd c) \lhd (b \lhd c)$$

algebraically encodes the Third Reidmeister move. A unital shelf has the additional structure of an element "1" that satisfies:

$$a \lhd 1 = a \quad \text{and} \quad 1 \lhd a = a$$

It turns out that the shelf operation for unital shelves is associative! We will explore properties of unital shelves and their homology in this preliminary work with Mukherjee and Przytycki. (Received August 15, 2015)

1114-54-111 **Robin T. Wilson*** (robinwilson@cpp.edu), 3801 West Temple Ave, Pomona, CA 91768, and **Jesse Johnson** and **Roberto Pelayo**. *The Coarse Geometry of the Kakimizu complex.*

Given a link L in the 3-sphere, one can build simplicial complexes $MS(L)$ and $IS(L)$, called the Kakimizu complexes. These complexes have isotopy classes of minimal genus and incompressible Seifert surfaces for L as their vertex sets and have simplicial structures defined via a disjointness property. We will discuss a recent result that states that the Kakimizu complex of minimal genus Seifert surfaces for a knot in the 3-sphere is quasi-isometric to a Euclidean integer lattice $\mathbb{Z}^n$ for some $n \geq 0$. (Received August 17, 2015)

1114-54-124 **Sungjong No*** (sungjongno84@gmail.com), Seoul, South Korea, **Seungsang Oh**, Seoul, South Korea, and **Minjung Lee**, Seoul, South Korea. *Arc index of spatial graphs.*

In knot theory, the arc index is a very useful invariant. Since knot is a special example of embedded graph, it can extend to graph theory. By using the arc presentation of graphs, we get an upper bound of arc index and stick number of an embedded graph. The arc index $\alpha(G)$ is less than or equal to $c(G) + e(G)$ for the crossing number $c(G)$ and the number of edges $e(G)$ of the embedded graph G. Furthermore the stick number $s(G) \leq \frac{3}{2}c(G) + 2e(G) - \frac{v(G)}{2}$. (Received August 19, 2015)

1114-54-129 **Natsumi Oyamaguchi*** (natsumi.3-29.math@diary.ocn.ne.jp), 1-1 Daigaku-cho, Yachiyo City, Chiba 276-0003, Japan. *Enumeration of Prime Flat Vertex 2-Bouquet Graphs with up to Seven Crossings.* Preliminary report.

We previously enumerated all prime 2-bouquet graphs with six crossings or less up to flat vertex isotopy. We can construct all such graphs from 2-string tangles, and distinguish the resulting graphs by computing their Yamada polynomials. Using the same technique, we will provide an additional enumeration of prime flat vertex 2-bouquet graphs with up to seven crossings. (Received August 24, 2015)

1114-54-271 **Alicia Arrua*** (agarrua@cpp.edu). *On the Additivity of Crossing Numbers.* Preliminary report.

The additivity of crossing numbers over a composition of links has been an open problem for over one hundred years. It has been proved that the crossing number over alternating links is additive independently in 1987 by Louis Kauffman, Kunio Murasugi, and Morwen Thistlethwaite. Further, Yuanan Diao and Hermann Gruber independently proved that the crossing number is additive over a composition of torus links. In order to investigate the additivity of crossing numbers over a composition of a different class of links, we introduce a tool called the deficiency of a link. When the deficiency is equal to 0, we are able to use a powerful result to prove that the crossing number is additive over a composition of links with deficiency 0. Applying this result, we are able to focus on computing the deficiency of a class of links called Montesinos links, specifically alternating pretzel knots and non-alternating pretzel knots. (Received August 30, 2015)

1114-54-289 **Aaron Kaestner*** (akaestne@gmail.com), 3225 West Foster Avenue, Chicago, IL 60618. *Checkerboard coloring and virtual knot invariants.* Preliminary report.

We look at a general method for extending some combinatorial invariants from classical knots to virtual knots via the use of checkerboard colorable surfaces with cross-cuts. (Received August 31, 2015)

55 ► Algebraic topology

1114-55-12 **Robert F. Brown*** (rfb@math.ucla.edu), Department of Mathematics, University of California, Los Angeles, Los Angeles, CA 90095. *Construction of multiply fixed n-valued maps.*

A self-map, either single-valued or multi-valued, is *multiply fixed* if every map homotopic to it has at least two fixed points. Let $p\colon \widetilde{X} \to X$ be a finite covering space, of degree n, of a connected finite polyhedron, and let $f\colon X \to X$ be a map. We lift f to an n-valued map $\phi_{p,f}\colon \widetilde{X} \multimap \widetilde{X}$ and prove that it is multiply fixed if the Nielsen number of f is greater than or equal to two. We obtain a formula for the Nielsen number of $\phi_{p,f}$ in terms of the Nielsen number of f, the induced fundamental group homomorphism of f, and the monodromy action of the covering space. We describe specific constructions of the n-valued maps $\phi_{p,f}$ on graphs, orientable double covers, handlebodies, free G-spaces and nilmanifolds. (Received March 16, 2015)

1114-55-166 **Jamison Blair Barsotti*** (jbarsott@ucsc.edu) and **Thomas W. Mattman** (tmattman@csuchico.edu). *Graphs on 21 edges that are not 2-apex.*

It is known that an intrinsically knotted (IK) graph cannot be 2-apex but to what extent can the effort to catalogue forbidden minors to the 2-apex property be used towards determine the minor minimal IK (MMIK) graphs? We focus on the case of graphs with at most 21 edges and show that the smallest obstruction set to the 2-apex property is exactly the Heawood family of graphs, that is, graphs obtained through ΔY and $Y\Delta$ moves from K_7. As a corollary, we get a new proof that the MMIK graphs with at most 21 edges are those obtained by ΔY moves from K_7.

On our way to this result, we discuss obstructions to apex graphs and show that, for graphs on 16 or fewer edges, this can be characterized by the Petersen family of graphs. (Received August 25, 2015)

1114-55-170 **Jesse T. Prince-Lubawy*** (jprincelubawy@una.edu), One Harrison Plaza, Florence, AL 35632. *Equivalence of cyclic p-squared actions on handlebodies.*

We consider all orientation-preserving $\mathbb{Z}_{p^2}$-actions, where p is prime, on 3-dimensional handlebodies V_g of genus $g \geq 1$. We study the graph of groups $(\Gamma, \mathbf{G})$, which determines a handlebody orbifold $V(\Gamma(\mathrm{v}), \mathbf{G}(\mathbf{v})) \simeq V_g/\mathbb{Z}_{p^2}$. This algebraic characterization is used to enumerate the total number of $\mathbb{Z}_{p^2}$ group actions on such handlebodies, up to equivalence. (Received August 25, 2015)

57 ► Manifolds and cell complexes

1114-57-37 **Heather A Dye*** (heatheranndye@gmail.com). *Checkerboard framings and virtual links.*

I introduce checkerboard framings of virtual links. Then, I show the applications of checkerboard framings. The applications include a virtual link invariant and a bound on the the number of components in a Seifert smoothed state. (Received July 09, 2015)

1114-57-44 **M. Chrisman*** (mchrisma@monmouth.edu), **A. Kaestner** and **R. Todd**. *Some Geometric Applications of Virtual Knot Theory.* Preliminary report.

We present several interrelated geometric applications of virtual knot theory: concordance invariants of knots in fibered 3-manifolds, slice disc and ribbon disc obstructions for links in $\mathbb{S}^3$, and the weak injectivity of satellite operators having nonzero winding number on a large class of smooth knots in fibered 3-manifolds. The main technical tool is the principle of virtual covers, where an oriented virtual knot is associated to an oriented knot in a c.c.o 3-manifold possessing a regular covering by a thickened c.c.o surface. The associated virtual knot, when it exists, is a smooth concordance invariant. The applications follow from this observation. (Received July 16, 2015)

1114-57-48 **Charles Frohman*** (charles-frohman@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242. *Quantum Hyperbolic Invariants of Three-Manifolds that fiber over the circle from the Kauffman bracket skein algebra of the fiber.* Preliminary report.

Let F be a punctured surface. Let $\phi : F \to F$ be an orientation preserving homeomorphism and let $M = F \times [0,1]/\phi$ be the mapping cylinder of ϕ. That is the quotient space from setting $(x,0) \sim (\phi(x),1)$. The map $\phi_\# : \pi_1(F) \to \pi_1(F)$ is only defined up to conjugacy as we aren't fixing a basepoint, however that induces a mapping from the $SL_2\mathbb{C}$-character variety of $\pi_1(F)$. If $\rho : \pi_1(F) \to SL_2\mathbb{C}$ is a representation that is fixed up to conjugacy by the action of ϕ it gives rise to a representation of the fundamental group of M and vice versa.

We will use this to construct invariants of the underlying manifold from the Kauffman bracket skein algebra of F. (Received July 31, 2015)

1114-57-52 **Akio Kawauchi*** (kawauchi@sci.osaka-cu.ac.jp), 3-3-138, Sugimoto, Sumiyoshiku, Osaka, Osaka 558-8585, Japan. *A chord graph constructed from a ribbon surface-link.*

A chord graph in the 3-space is constructed from a ribbon surface-link in the 4-space. In this talk, several moves on diagrams of chord graphs corresponding to the faithful equivalence of a ribbon surface-link are described. Links, virtual links and welded virtual links can be described naturally in terms of the diagrams with the corresponding moves, respectively. (Received August 03, 2015)

1114-57-56 **Louis H Kauffman*** (kauffman@uic.edu), Louis H Kauffman, Math UIC, 851 South Morgan Street, Chicago, IL 60607-7045, and **Allison Henrich** (henricha@seattleu.edu), Allison Henrich, Department of Mathematics, Seattle University, Seattle, WA 98122. *Rigid Vertex Graph Embeddings and Pseudo-Knots.*

This talk will discuss how the formulation of 4-valent rigid vertex graph embeddings in three-dimensional space is related to the concept of pseudo-knots. A pseudo-knot diagram is a knot diagram where certain crossings are marked as 'ambiguous', that is, without a decision about whether the crossing is an over-crossing or an under-crossing. The naturally motivated set of moves (analogous to the Reidemeister moves) for pseudo-knots is formally the same as adding one move to the set of moves for rigid-vertex graphs. (One allows the addition or removal of a trivial loop at a 4-valent vertex.) Thus we have a mapping from rigid vertex link diagrams to pseudo link diagrams by replacing 4-valent vertices by pseudo-crossings. This mapping respects the moves in these categories and is many to one on the equivalence classes. By using this correspondence we discuss methods for obtaining invariants of both rigid-vertex graph embeddings and invariants of pseudo-knots. (Received August 03, 2015)

1114-57-57 **Louis H Kauffman*** (kauffman@uic.edu), Louis H Kauffman, Math UIC, 851 South Morgan Street, Chicago, IL 60607-7045. *Rotational Virtual Links and Quantum Link Invariants.* Preliminary report.

Rotational virtual knot theory is virtual knot theory without the first virtual move (thus one does not allow the addition or deletion of a virtual curl.) Another way to put this is to say that rotational virtual links use the Reidemeister moves plus detour moves that are restricted to be regular homotopies in the plane or in the two-sphere. Diagrams are usually represented in the surface of plane so that we can distinguish clockwise from counterclockwise rotations. The rotational version of virtual knot theory is significant because all quantum link invariants originally defined for classical links extend to rotational virtual knot theory. In this talk we give a number of examples of phenomena in the generalization of the bracket polynomial to rotational virtuals, and we discuss a number of other quantum link invariants in this context. (Received August 03, 2015)

1114-57-62 **Carmen L Caprau*** (ccaprau@csufresno.edu). *Movie moves for singular link cobordisms in 4-dimensional space.*

Two singular links are cobordant if one can be obtained from the other by singular link isotopy together with a combination of births or deaths of simple unknotted curves, and saddle point transformations. A movie description of a singular link cobordism in 4-space is a sequence of singular link diagrams obtained from a projection of the cobordism into 3-space by taking 2-dimensional cross sections perpendicular to a fixed direction. This talk will be focused on a set of movie moves that are sufficient to connect any two movies of isotopic singular link cobordisms. (Received August 05, 2015)

1114-57-63 **Kelsey Renee Friesen*** (kelseyfriesen@mail.fresnostate.edu). *A Quantum Invariant for Virtual Singular Links.*

A singular link is an immersion of a disjoint union of circles into three-dimensional space that admits only finitely many singularities that are all transverse double points. A singular link diagram is a projection of a singular link into a plane, and contains classical and singular crossings.

Virtual knot theory can be regarded as a "projection" of classical knot theory in thickened surfaces. We take one step further by studying virtual singular links, which can be thought as immersions of disjoint unions of circles into thickened surfaces. A virtual singular link diagram contains classical, singular, and virtual crossings. When studying virtual singular links, we seek for ways to tell them apart. An invariant for a virtual singular link is a quantity associated to it, which is independent on the link diagram, and may provide a powerful tool at distinguishing virtual singular links.

In this research, we employ a certain model for the sl(n) polynomial of classical links and extend it to a polynomial invariant for virtual singular links, which is defined as a state-sum formula. After this extension, we investigate how the resulting polynomial behaves with respect to mirror images, disjoint unions, and connected sums of virtual singular links. (Received August 05, 2015)

1114-57-72 **Seungsang Oh*** (seungsang@korea.ac.kr), Department of Mathematics, Korea University, Seoul, 02841, South Korea, and **Kyungpyo Hong** (kphong@nims.re.kr), National Institute for Mathematical Sciences, Daejeon, 305-811, South Korea. *Lattice Model Enumeration by the State Matrix Recursion Algorithm.* Preliminary report.

In this talk, we introduce the state matrix recursion algorithm. This algorithm proceeds with recurrence relations of state matrices, which turn out to be remarkably efficient for the enumeration of two-dimensional regular lattice

models such as polymers (especially dimers and trimers), independent vertex and edge sets, trominoes, squares with various sizes, multiple self-avoiding walks and polygons, and quantum knot mosaics in a rectangular region. These enumerations are deep and difficult combinatorial problems in lattice statistics and have long been studied by probabilists, physicists and computer scientists alike. This new algorithm is demonstrated by an application to the general monomer–dimer problem in an $m \times n$ square lattice, on providing a recursive formula for the partition function with respect to the monomer activity (or the matching polynomial). From this partition function, we extract the enumeration of close-packed dimer configurations and single boundary monomer configurations, and generalize to the weighted monomer–dimer partition function. (Received August 08, 2015)

1114-57-73 **Erica Flapan** and **Kenji Kozai*** (kozai@math.berkeley.edu). *Linking number and writhe in random linear embeddings of graphs.*

We study random embeddings of graphs where the vertices are chosen uniformly in the unit cube, and edges realized by straight line segments. In particular, we show that for K_n, the growth rate of the sum of squared linking numbers and sum of squared writhe are on the order of $\theta(n(n!))$. The methods are also extended to random graphs on n vertices, where each pair of vertices is connected by an edge with probability p. The growth rates of the sum of squared linking numbers and writhe in this case are $\theta(p^n n(n!))$. As a corollary, we show that random linear embeddings of K_6 and $K_{3,3,1}$ have exactly one non-trivial link – which is a Hopf link – with high probability. (Received August 08, 2015)

1114-57-76 **Carmen L Caprau*** (ccaprau@csufresno.edu). *The Khovanov homology and spatial graphs.* Preliminary report.

The Khovanov homology is an invariant of classical knots and links that arises as the homology of a chain complex and which categorifies the Jones polynomial. In this talk, I will discuss an extension of the Khovanov homology to 4-valent spatial graphs. (Received August 10, 2015)

1114-57-77 **Atsushi Ishii**, **Ryo Nikkuni*** (nick@lab.twcu.ac.jp) and **Kanako Oshiro**. *On calculations of the twisted Alexander ideals for spatial graphs, handlebody-knots and surface-links.*

We calculate the twisted Alexander ideals for spatial graphs, handlebody-knots, and surface-links. For spatial graphs, we calculate the invariants of Suzuki's theta-curves and show that the invariants are nontrivial for Suzuki's theta-curves whose Alexander ideals are trivial. For handlebody-knots, we give a remark on abelianizations and calculate the invariant of the handlebody-knots up to six crossings. For surface-links, we correct Yoshikawa's table and calculate the invariants of the surface-links in the table. (Received August 10, 2015)

1114-57-79 **Charles Frohman*** (charles-frohman@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242. *Representations of the Skein Algebra at roots of Unity.* Preliminary report.

Let F be a finite type oriented surface. We denote the Kauffman bracket skein algebra of F with at primitive $2N$th root of unity by $K_N(F)$. If $\chi(F)$ is the $SL_2\mathbb{C}$-characters of the fundamental group of F then $K_N(F)$ is a finite rank central extension of $\chi(F)$. Let P be a maximal collection of disjoint simple closed curves on F so that no curve bounds a disk, and no two curves cobound and annulus. Let $A(P)$ be the $\chi(F)$-subalgebra of $K_N(F)$ generated by P. It is a commutative algebra, so all of its irreducible representations are one dimensional. Choose $\phi : A(P) \to \mathbb{C}$ a homomorphism. Such a homomorphism is specified by a homomorphism $f : \chi(F) \to \mathbb{C}$ along with a choice of Nth roots of the values f assigns to the curves in P.

You can view $K_N(F)$ as right module over $A(P)$. Let $Lin_{A(P)}(K_N(F), \mathbb{C})$ be the space of right $A(P)$-linear maps from $K_N(F)$ to $\mathbb{C}$ where we are using $\phi : A(P) \to \mathbb{C}$ to make $\mathbb{C}$ into a right module over $A(P)$.

The space $Lin_{A(P)}(K_N(F), \mathbb{C})$ is a left module over $K_N(F)$, which defines an irreducible representation of $K_N(F)$. (Received August 10, 2015)

1114-57-83 **Shelly Harvey*** (shelly@rice.edu) and **Danielle O'Donnol**. *Heegaard Floer homology of spatial graphs.*

We extend the theory of combinatorial link Floer homology to a class of oriented spatial graphs called transverse spatial graphs. To do this, we define the notion of a grid diagram representing a transverse spatial graph, which we call a graph grid diagram. We prove that two graph grid diagrams representing the same transverse spatial graph are related by a sequence of graph grid moves, generalizing the work of Cromwell for links. For a graph grid diagram representing a transverse spatial graph $f : G \to S^3$, we define a relatively bigraded chain complex (which is a module over a multivariable polynomial ring) and show that its homology is preserved under the graph grid moves; hence it is an invariant of the transverse spatial graph. In fact, we define both a minus and hat version. Taking the graded Euler characteristic of the homology of the hat version gives an Alexander type

polynomial for the transverse spatial graph. Specifically, for each transverse spatial graph f, we define a balanced sutured manifold $(S^3 \setminus f(G), \gamma(f))$. We show that the graded Euler characteristic is the same as the torsion of $(S^3 \setminus f(G), \gamma(f))$ defined by S. Friedl, A. Juhász, and J. Rasmussen. (Received August 12, 2015)

1114-57-90 **Elizabeth Denne***, Mathematics Department, Washington & Lee University, Lexington, VA 24450. *Folded Ribbon Knots in the Plane.*

Knots and links are modeled as folded ribbons lying in the plane. The ribbonlength of a knot is the the length of a knot divided by the width of the ribbon around it. This problem is related to the ribbonlength of immersed ribbons in the plane, as well as to the ropelength of thick knots. In this talk we'll discuss the construction of folded ribbon knots, and give examples of folded ribbon knots and their ribbonlength. We'll also discuss the topology of folded ribbon knots, and the problem of minimizing ribbonlength for a given knot type - it turns out there are several good candidates for this notion. This is joint work with undergraduate students from Smith College and Washington & Lee University. (Received August 13, 2015)

1114-57-94 **Atsushi Ishii*** (aishii@math.tsukuba.ac.jp). *The Markov theorem for spatial graphs and handlebody-knots.*

We introduce a relationship between spatial graphs and handlebody-knots. A spatial graph (resp. handlebody-knot) is a graph (resp. handlebody) embedded in the 3-sphere. The Markov theorem for handlebody-knots is established. The Markov theorem for spatial graphs is also established as an application of the theorem for handlebody-knots. (Received August 13, 2015)

1114-57-96 **Kenneth C Millett*** (millett@math.ucsb.edu), Department of Mathematics, UCSB, Santa Barbara, CA 93106. *Models of Knotting in Polymeric System.*

Polymeric systems are modeled by collections of mathematical curves that are entangled due to the effects of knotting or linking, both local and global. This mutual interference is implicated in large-scale effects making their characterization and quantification an objective of substantial interest. I will bring together several mathematical streams: (1) classical knot theory; (2) knotting of open chains to characterize protein structures; (3) methods to create open and closed ideal chains and, more recently, with chains with specified thickness (results of Laura Plunkett and Kyle Chapman). In conclusion, I will present a early analysis of the new data. (Received August 14, 2015)

1114-57-102 **Ryan Blair**, **Marion Campisi**, **Jesse Johnson**, **Scott Taylor** and **Maggy Tomova***, maggy-tomova@uiowa.edu. *Neighbors of knots in the Gordian graph.*

We will show that every knot is one crossing change away from a knot of arbitrarily high bridge number and arbitrarily high bridge distance. (Received August 15, 2015)

1114-57-108 **Eric J Rawdon*** (ericrawdon@gmail.com), Department of Mathematics, University of St. Thomas, 2115 Summit Ave, Saint Paul, MN 55105. *Subknots in Tight Knots, KnotPlot Knots, and Random Knots.*

For a fixed knot configuration, the subknots are the knot types seen in the open subarcs of the configuration. For nice knot configurations (like ones minimized with respect to some knot energy), the subknots are typically simpler knot types than the host knot type. We compare and contrast the set of subknots coming from KnotPlot configurations, tight knot configurations, and random configurations. This is joint work with Ken Millett and Andrzej Stasiak. (Received August 17, 2015)

1114-57-112 **Jason Cantarella*** (jason.cantarella@gmail.com), UGA Math Department, 102 D.W. Brooks Drive, Athens, GA 30602, and **Harrison Chapman** and **Matt Mastin**. *Random Knot Diagrams.*

In this talk, we present results from an enumeration of all knot and link diagrams through 10 crossings. The enumeration allows us to define a model of a random knot as the knot obtained from a uniform probability distribution on the finite set of immersions of the circle into the sphere, together with randomly assigned crossing signs and orientation. In this range of crossing numbers, most knots are unknots, and the enumeration reveals some interesting reasons why this is the case. Results by the second author (presented in his talk) prove that unknots are rare among more complicated random knots. (Received August 17, 2015)

1114-57-122 **Nafaa Chbili*** (nafaachbili@uaeu.ac.ae), Department of Mathematical Sciences, College Of Science, United Arab Emirates University, Al Ain, Abu Dhabi 15551, United Arab Emirates. *Graph Skein Modules and Symmetries of Spatial Graphs.*

In this talk, we briefly review the theory of graph-skein modules of three-manifolds and give examples of graph-skein algebras of surfaces. Then, we describe how to use this theory to study the symmetries of spatial graphs.

Moe precisely, we use the topological invariant of spatial graphs, known as the Yamada polynomial, to introduce obstruction criteria for a spatial graph to have a prime period. (Received August 19, 2015)

1114-57-126 **Elaina K Aceves*** (ekaceves@mail.fresnostate.edu). *From Knot Theory to Pseudographs.* Preliminary report.

A new field of research has emerged in knot theory that considers knot diagrams with missing information at the crossings. That is, the observer does not know which strand lies over or under the other at a crossing, and this new type of crossing is known as a precrossing. Pseudodiagrams are knot diagrams with precrossings and we look at pseudodiagrams to distinguish between pseudoknots. The trivializing and knotting number of a pseudodiagram can be used to distinguish between pseudoknots. The trivializing number (and knotting number respectively) of a pseudodiagram is the number of precrossings that need to be changed to a crossing to represent the unknot (a nontrivial knot) regardless of how the remaining precrossings are resolved. Spatial graph theory is a subfield of knot theory that deals with embeddings of graphs in three-dimensional space. This talk will be focused on the trivializing and knotting number for certain spatial pseudograph diagrams, beginning with bouquet pseudographs, based on the number of precrossings and the placement of the precrossings in the spatial pseudograph diagram. (Received August 19, 2015)

1114-57-131 **Ryan Blair**, **Marion Campisi*** (marion.campisi@sjsu.edu), **Jesse Johnson**, **Scott A. Taylor** and **Maggy Tomova**. *Neighbors of knots in the Gordian graph.*

The Gordian graph is the graph with vertex set the set of knot types and edge set consisting of pairs of knots which have a diagram wherein they differ at a single crossing. Bridge number is a classical knot invariant which is a measure of the complexity of a knot. It can be refined by another, recently discovered knot invariant known as "bridge distance". We show that each vertex of the Gordian graph is adjacent to a vertex having arbitrarily high bridge number and bridge distance. (Received August 20, 2015)

1114-57-135 **Masahico Saito*** (saito@usf.edu). *Rack relations and homology.*

Quandle homology was defined from rack homology as the quotient by a subcomplex corresponding to the idempotency, and Reidemeister type I move. Similar subcomplexes have been considered for various relations of racks and moves on diagrams, such as symmetric quandles and the rack rank. We observe common aspects of these subcomplexes; rack relations yield 2-cycles, leading to generating terms of subcomplexes, and the corresponding 2-cocycle extensions inherit the relations. We examine these aspects for Burnside relations. (Received August 20, 2015)

1114-57-169 **Makoto Ozawa*** (w3c@komazawa-u.ac.jp), 1-23-1 Komazawa, Setagaya-ku, Tokyo 154-8525, Japan, and **Shosaku Matsuzaki** (shosaku@aoni.waseda.jp), 1-6-1 Nishiwaseda, Shinjuku-ku, Tokyo 169-8050, Japan. *Embeddings of multibranched surfaces.*

A second countable Hausdorff space X is called a multibranched surface if for any point x of X, there exist an open neighborhood U and a natural number i such that U is homeomorphic to S_i, where S_n denotes a quotient space which is obtained from a disjoint union of n R^2_+ by identifying their boundaries.

In this talk, we consider embeddings of multibranched surfaces into 4-dimensional Euclidian space, 3-manifolds, and in particular, the 3-sphere S^3.

We define a genus of a multibranched surface as the minimal Heegaard genus of 3-manifolds in which it can be embedded, and show that for each non-negative integer n, there exists a multibranched surface of genus n.

We also define a minor of a multibranched surface and consider the obstruction set for a minor-closed property.

We give some examples of multibranched surfaces which are contained in the obstruction set for embeddability into S^3, not intrinsically essential (knotted/linked).

This is a joint work with Shosaku Matsuzaki. (Received August 25, 2015)

1114-57-174 **J. Scott Carter*** (carter@southalalabama.edu), Department of Mathematics and Statistics, ILB 325, Mobile, AL 36688. *Fractal Simplices.*

This work is based upon some notes I made a number of years ago. There are higher dimensional analogues of the Sierpinski triangle that are created by removing a central portion of the n-simplex. These can be simulated via the chaos game, and by coloring the multinomial coefficients mod 2. I am hoping to produce some animations for the talk that illustrates these structures. I imagine that they can be useful point sets to study persistent homology. (Received August 25, 2015)

1114-57-202 **Elena Pavelescu*** (elenapavelescu@southalabama.edu), University of South Alabama, Department of Mathematics and Statistics, Mobile, AL 36608, and **Danielle O'Donnol**, Indiana University, Department of Mathematics, Bloomington, IN 47405. *The total Thurston-Bennequin number of complete and complete bipartite Legendrian graphs.* Preliminary report.

We introduce the basics of Legendrian graphs, with a focus on the Thurston-Bennequin number. We define a new invariant called the total Thurston-Bennequin number of the graph. We show that this invariant is determined by the Thurston-Bennequin numbers of 3−cycles for complete graphs and by the Thurston-Bennequin numbers of 4−cycles for complete bipartite graphs. We discuss the consequences of these results for K_4, K_5 and $K_{3,3}$. (Received August 27, 2015)

1114-57-230 **Danielle O'Donnol*** (odonnol@indiana.edu), Department of Mathematics (RH 229), Indiana University, 831 East 3rd St, Bloomington, IN 47405. *Intrinsic 3-linkedness is Not Preserved by Y-triangle moves.*

A graph, G, is *intrinsically knotted* if every embedding of G in $\mathbb{R}^3$ contains a nontrivial knot. A graph G is *intrinsically n-linked* if every embedding of G in $\mathbb{R}^3$ contains a non-split n-component link. A $Y\nabla$ *move* on an abstract graph is where a valance 3 vertex, v, together with its adjacent edges are deleted, and three edges are added, one between each pair of vertices that had been adjacent to v. The reverse move is called a ∇Y *move*. The combined work of Motwani, Raghunathan, and Saran, and Robertson, Seymour, and Thomas shows that intrinsic 2-linkedness is preserved by both ∇Y and Y∇ moves. Once it was known that intrinsic linkedness is preserved by both ∇Y and Y∇ moves, the natural question arose, which other properties are preserved by both moves. In 2008, Flapan and Naimi showed that Y∇ moves do not preserve intrinsic knottedness. In this talk we will show that 3-linkedness is not preserved by Y∇ moves.

I will present some new constructions of intrinsically 3-linked graphs. Then using one of the new graphs we will see that intrinsic 3-linkedness is not preserved by Y∇ moves. (Received August 28, 2015)

1114-57-233 **Nathan Druivenga*** (nathan-druivenga@uiowa.edu), Department of Mathematics, University of Iowa, 14 MLH, Iowa City, IA 52242, and **Charles Frohman** and **Sanjay Kumar**. *Tangle Functors at Roots of Unity.*

We prove that there is a tangle functor underlying certain semicyclic representations of $U_q sl_2$ when $q = e^{i\pi/N}$ where N is odd. Specifically, when $U_q sl_2$ is presented in the standard way with generators E, F and K these representations have $E^N = a$, where a is a nonzero scalar, $F^N = 0$ and $K^N = 1$.

After proving the existence of the tangle functor we compare the answer to the colored Jones polynomial of level $N-1$ at $q = e^{i2\pi/N}$, for the figure eight knot. (Received August 28, 2015)

1114-57-239 **Joel Hass**, **Abigail Thompson** and **Anastasiia Tsvietkova***, tsvietkova@math.ucdavis.edu. *The number of surfaces of fixed genus in an alternating link complement.*

Let L be a prime alternating link with n crossings. We show that for each fixed g, the number of genus-g incompressible surfaces in the complement of L is bounded by a polynomial in n. Previous bounds were exponential in n. (Received August 28, 2015)

1114-57-245 **Sangbum Cho** and **Yuya Koda*** (ykoda@hiroshima-u.ac.jp). *The tree of tunnels for knots in $S^2 \times S^1$.*

We provide a certain tree $\mathcal{T}$ such that there exists a one-to-one correspondence between the set of equivalence classes of all unknotting tunnels of all tunnel number 1 knots in $S^2 \times S^1$ and a subset of the vertices of $\mathcal{T}$. In fact, this subset is exactly one of the two classes of vertices, once we regard $\mathcal{T}$ as a bipartite graph. The tree $\mathcal{T}$ is obtained by considering the action of the Goeritz group of the genus-2 Heegaard splitting of $S^2 \times S^1$ on the disk complex of the genus-2 handlebody, where the Goeritz group of a Heegaard splitting is defined to be the subgroup of the mapping class group of the Heegaard surface consisting of mapping classes that extend to both handlebodies. (Received August 28, 2015)

1114-57-250 **Allison N. Miller*** (amiller@math.utexas.edu), University of Texas, Austin, Department of Mathematics, RLM 8.100, 2515 Speedway Stop C1200, Austin, TX 78712. *Distinguishing mutant pretzel knots in concordance.*

The metabelian twisted Alexander polynomials developed by Kirk and Livingston provide powerful and computationally accessible obstructions to the topological sliceness of knots. In particular, they are among the few invariants known to be capable of distinguishing mutant knots in concordance. Lecuona and Long independently classified the smoothly slice 4-strand pretzel knots up to mutation. They showed that if $K = P(a, b, c, d)$

is smoothly slice then $\{a,b,c,d\} = \{2n, -2n \pm 1, m, -m\}$; that is, K is a mutant of a ribbon knot. However, there is no reason to believe that $K_{n,m} = P(2n, m, -2n \pm 1, -m)$ should be smoothly slice. We show via explicit computation of twisted Alexander polynomials that a large infinite family of these $K_{m,n}$ are not even topologically slice, providing further evidence for the slice-ribbon conjecture for 4-strand pretzel knots. (Received August 29, 2015)

1114-57-257 **Toru Ikeda*** (ikeda@math.kindai.ac.jp), 3-4-1 Kowakae, Higashi-Osaka, Osaka, Osaka 577-8502, Japan. *Symmetries of spatial graphs in closed onrientable 3-manifolds.*

In this talk, we consider symmetries of spatial graphs in closed orientable 3-manifolds described by smooth finite group actions. We first show that there is an infinite family of hyperbolic spatial graphs with given symmetry. Next, we apply this method to the study of links in 3-manifolds which can be regarded as systems of rotation axes in closed hyperbolic 3-manifolds obtained by Dehn surgeries. (Received August 30, 2015)

1114-57-264 **Erica Flapan** and **Emille Davie Lawrence*** (edlawrence@usfca.edu). *Topological Symmetry Groups of Möbius Ladders.*

Chemists have been trying for decades to to synthesize molecules with topologically interesting structures. This served as motivation for the study of symmetries of graphs embedded in S^3. Furthermore, the questions arising from chemists have led to answers that are topologically fascinating in their own right. We will define the topological symmetry group of a graph embedded in S^3, and discuss recent work on exactly what groups are realizable as topological symmetry groups for a certain class of graphs known as Möbius ladders. (Received August 30, 2015)

1114-57-270 **Jozef H. Przytycki*** (przytyck@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *Cocycle multipliers of Yang-Baxter operators.*

Let $R, R' : V \otimes V \to V \otimes V$ be two (pre) Yang-Baxter operators, with $V = kX$. In the basis X^2 we have $R = (R^{a,b}_{c,d})$ and $R' = ((R')^{a,b}_{c,d})$. We assume that there is a 2-cochain $f : V \otimes V \to k$ with $R^{a,b}_{c,d} = f(a,b)(R')^{a,b}_{c,d}$. (We put $f(a,b) = 0$ if $(R')^{a,b}_{c,d} = 0$ for every (c,d).) We discuss a co-cycle character of f motivated by the case when R' is yielded by wrack or biwrack magmas. Of special interest is the case when R' is a column unital matrix (e.g. column stochastic matrix) that is $\sum_{b,c}(R')^{a,b}_{c,d} = 1$ for any $(a,b) \in X^2$. The definition of homology of such R' is well understood via simple graphical visualization. (Received August 30, 2015)

1114-57-273 **Reiko Shinjo*** (reiko@kokushikan.ac.jp), 4-28-1, Setagaya, setagaya-ku, Tokyo 154-8515, Japan. *On complementary regions of a spatial-graph diagram.*

We can obtain a planar graph embedded on the 2-sphere from a spatial-graph diagram by regarding each crossings as a vertex. This graph divides the sphere into polygons, which we call complementary regions. In this talk, we extend our previous results concerning complementary regions of a spatial-graph diagram. (Received August 30, 2015)

1114-57-283 **Kouki Taniyama*** (taniyama@waseda.jp), Shimouma 6-9-14-201, Setagaya-ku, Tokyo, 154-0002, Japan. *Totally close spatial embeddings of a graph.*

Two spatial embeddings of a finite graph are said to be totally close if they are not ambient isotopic and for any type of crossing change there exists a crossing change of that type from one to another. Here a type of crossing change is a triple (edge, edge, crossing-sign) that specifies the edges involved in a crossing change and the crossing-sign of that crossing. We show that a finite graph without free vertices has two totally close spatial embeddings if and only if the graph is abstractly planar and contains no pair of disjoint cycles. (Received August 31, 2015)

1114-57-297 **Mohamed Elhamdadi*** (emohamed@math.usf.edu), Math Dept USF, 4202 E. Fowler Ave., Tampa, FL 33620. *Sheaves on topological quandles.* Preliminary report.

We will introduce the notion of "sharp" trunk which generalizes the notion of a trunk defined by Fenn-Rourke-Sanderson. This will be used to define the notion of sheaves for topological racks and quandles. This is a joint work with Moutuou. (Received August 31, 2015)

1114-57-298 **Liang Chang*** (changliang996@gmail.com), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77840. *Representations of loop braid groups.*

The loop braid group is defined as the motion group of unknotted and unlinked oriented circles in $\mathbb{R}^3$, which is a generalization of braid groups. In this talk, we will report the recent work on their representations and the resulting invariants of welded links. (Received August 31, 2015)

1114-57-304 **Carson S. Rogers***, One Shields Avenue, Davis, CA 95618. *Bridge position for Seifert surfaces.* Preliminary report.

We define and examine a notion of bridge position for Seifert surfaces, motivated in part by recent work of others on a bridge index/knot genus relationship for high-distance knots and in part by questions surrounding the free genus of a knot. By relating these decompositions to the fundamental group of the surface exterior, we show that the corresponding analogue of the bridge index provides an interesting invariant of the surface: it can be arbitrarily larger than the natural lower bound determined by the Euler characteristic of the surface and the bridge index of the boundary link. In a different direction, we also show that bridge surfaces of links which yield such decompositions of Seifert surfaces typically have low distance. We conclude by discussing the possibility of using this result to establish a bridge index/free genus relationship for high-distance knots. This is work in progress. (Received August 31, 2015)

58 ► Global analysis, analysis on manifolds

1114-58-67 **Casey Lynn Kelleher*** (clkelleh@uci.edu), 4133 Mayfield Street, Newbury Park, CA 91320. *Higher order Yang-Mills flow.*

We define a family of functionals generalizing the Yang-Mills functional. We study the corresponding gradient flows and prove long-time existence and convergence results for subcritical dimensions as well as a bubbling criterion for the critical dimensions. Consequently, we have an alternate proof of the convergence of Yang-Mills flow in dimensions 2 and 3 given by Rade and the bubbling criterion in dimension 4 of Struwe in the case where the initial flow data is smooth. (Received August 06, 2015)

1114-58-130 **Mihail Cocos*** (mike_cocos@yahoo.com), Weber State University, 1702 University Circle, Ogden, UT 84408. *On a possible proof of Chern conjecture for affine manifolds.*

It has been conjectured by Chern that a closed affine manifold has zero Euler characteristic.Using the local Riemannian character of such a manifold we propose a possible way of proving the conjecture. (Received August 20, 2015)

1114-58-152 **Richard H Bamler*** (rbamler@berkeley.edu), University of California, Berkeley, 970 Evans Hall #3840, Berkeley, CA 94720. *On the scalar curvature blow up conjecture in Ricci flow.*

In this talk, I will survey recent results on Ricci flows with bounded scalar curvature.

It is a basic fact that the Riemannian curvature becomes unbounded at every finite-time singularity of the Ricci flow. Sesum showed that, more precisely, even the Ricci curvature becomes unbounded at every such singularity. Whether the same can be said about the scalar curvature has since remained a conjecture. (Received August 23, 2015)

60 ► Probability theory and stochastic processes

1114-60-3 **Eyal Lubetzky*** (eyal@courant.nyu.edu), Courant Institute(NYU). *Random walks on the random graph.* Preliminary report.

We will discuss the behavior of the random walk on two random graph models: on one hand the giant component of the supercritical Erdős-Rényi random graph with constant average degreee. In the former case it is known that the walk mixes in logarithmic time and exhibits the cutoff phenomennon. In the latter case, while starting from the worst trap delays mixing and precludes cutoff, it turns out that starting from a fixed vertex induces the rapid mixing behavior of the regular case.

Joint work with N. Berestycki, Y. Peres and A. Sly. (Received April 17, 2014)

1114-60-22 **Ambar Niel Sengupta*** (ambarnsg@gmail.co), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70810. *The Gaussian Radon Transform.*

The Gaussian Radon transform is an infinite dimensional counterpart for the traditional Radon transform. This talk will describe results and potential applications concerning this transform. (Received May 13, 2015)

1114-60-29 **Sixian Jin*** (sixian.jin@cgu.edu), 710 N. College Ave., Claremont, CA 91711. *Series Representations of Fractional Conditional expectations under Malliavin Calculus.*

Fractional Brownian motion nowadays is considered as one of the most natural extensions of the classical Brownian motion. Based on its Malliavin calculus, we introduce the fractional conditional expectations under which

fractional Brownian motion has the similarly "martingale" property as Brownian motion under general conditional expectations. Then according to fractional Clark-Hausmann-Ocone formula, we represent fractional conditional expectations of a functional of fractional Brownian motion as a convergent series in L^2 space. When the target random variable is some function of a discrete trajectory of fractional Brownian motion, we obtain a backward Taylor series representation; when the target functional is generated by a continuous fractional filtration, the series representation is obtained by applying a "frozen path" operator and an exponential operator to the functional. (Received June 08, 2015)

1114-60-35 **Ivan Nourdin*** (ivan.nourdin@uni.lu). *The Malliavin-Stein approach.*
Since its original development six years ago culminating in my joint book "Normal approximations with Malliavin calculus: from Stein's method to universality" (with Giovanni Peccati), the Malliavin-Stein approach has grown into a mature and widely applicable mathematical theory. In this talk, I will survey some recent results related to this new line of research, with a special emphasis on problems arising from stochastic modeling and statistical inference. (Received June 30, 2015)

1114-60-47 **Khoi N Vo*** (duykhoi1402@gmail.com), Fountain Valley, CA. *Weak Laws of Large Numbers and two interesting applications.*
Recent studies in Mathematical Analysis have developed a new powerful tool called Measure Theory. Since then, many other branches of science, in particular, probability and statistics, have adopted this tool to solve many problems. This project considers, in particular, the Law of Large Numbers. We will start by establishing the critical background measure theory that we will be using. After that, we will consider applications of probability in real world, including the famous St Petersberg's Paradox and unfair fair games. The first application are the study of what happen with a very large data sample ,which we considered to be infinite, comes from a simply predictable outcomes. The result of this seemingly simple experiment turned out to be extremely paradoxical, even through rigorous mathematical reasoning and examination. The second application was a study of same type of large data sample but performed on an unpredictable outcome. And yet, the second application gave another surprising result. In conclusion, it was a great discover of the nature of universe (infinity), that is, full of uncertainty and paradox, and that even through rigorous mathematical reasoning, we will still all be surprised. (Received July 26, 2015)

1114-60-71 **Sergey V Lototsky*** (lototsky@usc.edu), Department of Mathematics, USC, 3620 S Vermont Ave, KAP 104, Los Angeles, CA 90089. *Can you feel the size of a lake?*
Is it possible to estimate the area of a lake by measuring its water temperature? Setting up the question as a statistical estimation problem for a stochastic heat equation leads to a positive answer — and lots of interesting math. (Received August 08, 2015)

1114-60-82 **Maria C Mariani** (mcmariani@utep.edu), 500 W University Ave, Dept of Math Sci, El Paso, TX 79968, and **Osei Kofi Tweneboah*** (oktweneboah@miners.utep.edu), 500 W University Ave, Dept of Math Sci, El Paso, TX 79902. *Stochastic differential equations applied to the study of geophysical and financial time series.* Preliminary report.
This work is devoted to the study of modeling geophysical and financial time series. We propose a stochastic differential equation arising on the superposition of independent Ornstein-Uhlenbeck processes driven by a $\Gamma(a, b)$ process. The stochastic differential equation is applied to the study of earthquakes sequences and financial time series. We obtained very good fitting of the observed magnitudes of the earthquakes and the financial indices with the stochastic differential equations, which supports the use of this methodology for the study of earthquakes sequences and financial time series. (Received August 12, 2015)

1114-60-132 **Alexander Kerss** (kerssad@cardiff.ac.uk), School of Mathematics, Cardiff University, Senghennydd Road, Cardiff, CF24 4 YH, United Kingdom, **Nikolai N Leonenko** (leonenkon@cardiff.ac.uk), School of Mathematics, Cardiff University, Senghennydd Road, Cardiff, CF24 4 YH, United Kingdom, and **Alla Sikorskii*** (sikorska@stt.msu.edu), Department of Statistics and Probability, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48824. *Fractional Skellam processes in modeling of high frequency financial data.*
Recent literature on high frequency financial data includes models that use the difference of two Poisson processes and incorporate a Skellam distribution for forward prices. The exponential distribution of inter-arrival times in these models is not always supported by the data. Fractional generalization of the Poisson process, or fractional Poisson process, overcomes this limitation and has Mittag-Leffler distribution of inter-arrival times. This paper defines fractional Skellam processes via the time changes in Poisson and Skellam processes by an inverse of a

standard stable subordinator. An application to high frequency financial data set is provided to illustrate the advantages of models based on the fractional Skellam processes. (Received August 20, 2015)

1114-60-140 **Pietro Poggi-Corradini***, pietro@math.ksu.edu, **Nathan Albin**, albin@math.ksu.edu, **Max Goering**, mlgoering@gmail.com, and **Faryad Sahneh**, faryad@ksu.edu. *A theoretical reason why modulus of families of walks can be useful to study epidemics.* Preliminary report.

Real life epidemics can be simulated in many different ways. Often a contact network is constructed and then a spreading process is defined on this network. A goal is then to determine how the nature of the network can affect the behavior of the spreading process.

In recent numerical experiments it was noted that vaccination strategies based on modulus centralities are very effective. Modulus of families of walks is a way (originated in function theory) to measure the richness of a family of walks, and so it is plausible that modulus would be useful in studying epidemics.

Here we define the concept of Epidemic Hitting Time (EHT). Then we relate the SI epidemic model to a variable-lengths model, and deduce from this that EHT is a metric. Moreover, we use a result of Lyons, Pemantle and Peres to show that one can give theoretical bounds for EHT in terms of modulus. (Received August 21, 2015)

1114-60-181 **Jianfeng Zhang*** (jianfenz@usc.edu), USC Mathematics Department, 3620 S. Vermont Ave, KAP 108, Los Angeles, CA 90089. *Dynamic Approaches of Some Time Inconsistent Problems.*

We study precommitted strategy of time inconsistent problems, and we note that many such problems in the literature can be transformed into an optimization of a multiple dimensional controlled Backward SDE. We shall introduce a type of "forward utility" so that the problem, which is time inconsistent under the original fixed utility, becomes time consistent under our forward utility. We next characterize our forward utility as a solution to certain master equation. (Received August 26, 2015)

1114-60-192 **Henry O Schellhorn*** (henry.schellhorn@cgu.edu), 710 N. College, Claremont, CA 91711, and **Qidi Peng** and **Sixian Jin**. *A new representation theorem for smooth Lévy martingales.*

We show that, under certain smoothness conditions, a Lévy martingale, when evaluated at a fixed time, can be represented as an exponential of its value at a later time. The time-dependent generator of this exponential operator is equal to one half times the second order Malliavin derivative, when the underlying Lévy process is Brownian motion, and equal to the integral of the Malliavin derivative with respect to the Lévy measure when the underlying process is a Lévy jump process. The exponential operator can be calculated explicitly in a series expansion, which resembles the Dyson series of quantum field theory. For Brownian motion, this result can be seen as a generalization of the semi-group theory of parabolic partial differential equations to the parabolic path-dependent partial differential equations introduced by Dupire (2009) and Cont and Fournié (2011). We suggest open problems that might be solved by using our result: regularity of the solution of backward stochastic differential equations, and representation of the solution of some types of Schrodinger equations. The talk is based on joint work with Qidi Peng, Sixian Jin, and Josep Vives. (Received August 26, 2015)

1114-60-195 **Mark L Huber*** (autotomic@gmail.com), 850 Columbia Avenue, Claremont, CA 91711. *Approximation algorithms for the normalizing constant of Gibbs distributions.*

Consider a family of distributions $\{\pi_\beta\}$ where $X \sim \pi_\beta$ means that $\mathbf{P}(X = x) = \exp(-\beta H(x))/Z(\beta)$. Here $Z(\beta)$ is the normalizing constant for the density. Then $\{\pi_\beta\}$ is known as a Gibbs distribution, and $Z(\beta)$ is the partition function. This work presents new method called the paired product estimator (PPE) for approximating $Z(\beta)$. The PPE approximates the function to a specified level of relative accuracy using a number of samples that grows as $O(\ln(Z(\beta)) \ln(\ln(Z(\beta))))$ when $Z(0) \geq 1$. This is a sharp improvement for previous, similar approaches that used a much more complicated algorithm, yet used $O(\ln(Z(\beta)) \ln(\ln(Z(\beta)))^5)$ samples. (Received August 26, 2015)

1114-60-210 **Rod A Freed***, 4265 marina city drive,#211, marina del rey, CA 90292. *A New Alternative to Regression.*

We present a new Empirical Conditional Distribution (ECD), and prove that it converges to the underlying true conditional distribution.We illustrate the way in which this ECD can be used as an alternative to linear, nonlinear,and/or nonparametric regression (Received August 27, 2015)

1114-60-255 **Chen Liu*** (chen.liu@cgu.edu), **Qidi Peng** and **Henry Schellhorn**. *A Monte Carlo Algorithm for Path-Dependent Bermudan Option Pricing Combining Regression and a Backward Control Variate.*

We consider the problem of pricing Bermudan options by Monte Carlo using a regression approach, in the spirit of Tsistsiklis and Van Roy (1999) and Longstaff and Schwartz (2001).We decompose the option value into a backward control variate, which conditional expectation is easy to calculate, and a remainder, which we handle like in the regression approach. We show that, under some mild conditions, our new estimator has a smaller variance than the traditional regression-based estimator. We then generalize our approach to price path-dependent Bermudan options. We first show that the curse of dimensionality exhibited by Glasserman and Yu (2004) for path-independent options is even worse in the case of path-dependent options. We consider the numerically challenging case where the time lag between two successive exercise dates is significant, and thus where the time step in the simulation of the state variable has to be smaller than that time lag. In that case, we resort to a new technique to calculate conditional expectations, based on Malliavin calculus. (Received August 29, 2015)

1114-60-259 **Asuman Guven Aksoy** (asuman.aksoy@claremontmckenna.edu), 850 Columbia Avenue, Claremont, CA 91711-6420, **Qidi Peng** (qidi.peng@cgu.edu), 710 N.College Ave, Claremont, CA 91711, and **Monairah O Alansari*** (monairah.alansari@cgu.edu), 710 N. College Ave, Claremont, CA 91711. *Graphical Representation Theorems of Metric Trees.*

Abstract In this talk, after defining what a metric tree is, we will discuss Brownian motion indexed by metric trees. We will then introduce a new approach that characterizes metric trees through the indexing of Brownian motion. We will present examples. (Received August 30, 2015)

1114-60-336 **Fengzhu Sun***, Molecular and Computational Biology, University of Southern California, 1050 Childs Way, RRI201, Los Anegeles, CA 90089. *Inference of Markovian properties of molecular sequences from NGS data and applications to comparative genomics.*

Markov chains (MC) have been widely used to model molecular sequences. We develop approximation theory for two widely used statistics related to MCs based on next generation sequence (NGS) reads. Surprisingly the traditional chi-square statistic does not follow chi-square distribution anymore, instead it has an approximate gamma distribution. We develop methods to estimate the order of the MC based on NGS reads. These results are used for alignment-free genome comparison and interesting results are obtained. (Received September 01, 2015)

62 ► Statistics

1114-62-75 **Chad Hazlett*** (chazlett@ucla.edu), UCLA Department of Statistics, 8125 Math Sciences, CA 90095. *Kernel Balancing: A flexible non-parametric weighting procedure for estimating causal effects.*

Matching, weighting, and propensity score methods are widely used to estimate treatment effects. One shortcoming of these methods is that they require the user to know what functions of the covariates are important to ensure balance on, and failure to do so leads to biased estimates. More fundamentally, these methods all seek to solve a more difficult estimation problem than required: unbiased estimation of the average treatment effect on the treated requires only that non-treatment potential outcomes have equal means for the control and treated groups. Kernel balancing achieves this as long as the conditional expectation function for the outcomes is smooth in the covariates, by obtaining equal means for the treated and control groups on a kernel expansion of the covariates. While focusing on this minimal requirement for unbiasedness, these weights are also interpretable as (1) those that ensure a smooth estimate of the multivariate distribution of the covariates is the same for the treated and controls, and (2) an inverse propensity score weight that does not require a model of the treatment. The approach thus has close connections to matching, weighting, and propensity score methods, while overcoming limitations of these methods for reliably estimating treatment effects. (Received August 09, 2015)

1114-62-158 **Xinping Cui*** (xinping.cui@ucr.edu), 1337 Olmsted Hall, University of California, Riverside, Riverside, CA 92521, and **Zhen Xiao**, **Nicolas Brunel** and **Zhenbiao Yang**. *A Constrained Mixed Effects Model Based on Semilinear Differential Equation for Cell Polarity Signaling in Tip Growth of Pollen Tubes.*

The key of tip growth in eukaryotes is the polarized distribution on plasma membrane of a particle named ROP1. This distribution is the result of a positive feedback loop, whose mechanism can be described by a

Differential Equation parametrized by two meaningful parameters kpf and knf. In this paper, we introduce a mechanistic Integro-Differential Equation (IDE) derived from a spatiotemporal model of cell polarity and we show how this model can be fitted to real data i.e ROP1 intensities measured on pollen tubes. At first, we provide an existence and uniqueness result for the solution of our IDE model under certain conditions. Quite interestingly, this analysis gives a tractable expression for the likelihood, and our approach can be seen as the estimation of a constrained nonlinear model. Moreover, we introduce a population variability by introducing a constrained nonlinear mixed model. We then proposed a constrained Least Squares method to fit the model under single pollen tube case, and two methods, constrained Methods of Moments and constrained Restricted Maximum Likelihood (REML) to fit the model under the multiple pollen tubes case. The performances of all the three methods are studied in a simulation example and are used on a real multiple pollen tubes dataset. (Received August 24, 2015)

1114-62-171 **Gulhan Bourget*** (galpargu@fullerton.edu), Fullerton, CA 92831. *Modified F-test in Microarray Experiments.* Preliminary report.

Microarray data has a high dimensional data structure that makes statistical inference drawn from this type of data challenging. Since current statistical methods are generally for "small p (number of variables) and large n (number of sample size)", these methods can be insufficient to draw valid conclusions for microarray data. Nevertheless, some of these methods, such as ANOVA (F-test), are still widely used. Beside having high dimensional data, microarray data also have correlation structure. Most of the current methods either ignore high dimensional data structure or fail to efficiently take correlations among genes into account. In this paper, we propose using an effective column size idea to handle these situations by modifying the classical F-test. We consider various magnitudes of correlation among genes in Monte Carlo simulation studies. We demonstrate the proposed test with real type 2 diabetes mellitus gene expression data, which was obtained from the Gene Expression Omnibus (GEO) database with accession number GSE25724. (Received August 25, 2015)

1114-62-198 **Jun Li*** (jun.li@ucr.edu), Department of Statistics, University of California, Riverside, Riverside, CA 92521, and **Peihua Qiu**. *Nonparametric Dynamic Screening System for Monitoring Correlated Longitudinal Data.*

In many applications, including disease early detection and prevention, and performance evaluation of airplanes and other durable products, we need to sequentially monitor the longitudinal pattern of certain performance variables of a subject. A signal should be given as soon as possible once the pattern becomes abnormal. Recently, a new statistical method called dynamic screening system (DySS) has been proposed to solve this problem. It is a combination of longitudinal data analysis and statistical process control. However, the current DySS method can only handle cases when observations are normally distributed and within-subject observations are independent or follow a specific time series model (e.g., AR(1) model). In this paper, we propose a new nonparametric DySS method which can handle cases when the observation distribution and the correlation among within-subject observations are arbitrary. Therefore, it broadens the application of the DySS method greatly. Numerical studies show that the new method works well in practice. (Received August 27, 2015)

1114-62-201 **Kar-Ming Cheung*** (kar-ming.cheung@jpl.nasa.gov), MS 238-420, 4800 Oak Grove Drive, Pasadena, CA 91745. *Improve Telecommunication System Engineering with (Conceptually) Simple Mathematical Techniques.*

This talk was first given in IEEE Aerospace Conference in March 2015 titled "The Role of Margin in Link Analysis and Planning."

Simple link budgeting approach that assumes link parameters to be deterministic values typically adopted a rule-of-thumb policy of 3 dB link margin. This has been the de facto standard in the aerospace industry in the past few decades.

JPL uses statistical link analysis that adopts the 2-sigma or 3-sigma link margin policy, which takes into account the link uncertainties. However it is still a rule-of-thumb policy that bears no direct relationship with the error rate requirements of the communication link.

In this talk, we use simple statistical techniques to explore the relationship between error rate requirement, operating SNR, and coding performance curve. We compute the "true" SNR design point that would meet the BER/FER requirement by taking into account the random nature of signal power and noise power at the receiver, and the shape of the coding performance curve. This analysis yields a number of valuable insights on the design choice of coding scheme and, "redefines" link margin as the additional SNR to compensate for the "known unknown" of a link to meet the error rate requirement. (Received August 27, 2015)

1114-62-317 **Guangliang Chen*** (guangliang.chen@sjsu.edu), San Jose, CA 95192. *On subspace clustering: An algorithm and its probabilistic analysis.*

Subspace clustering refers to the problem of segmenting a given data set into a union of subspaces. This has been a hot topic during the past decade, with lots of algorithms developed in the literature and many successful applications in computer vision, pattern recognition, and image processing. In this talk, we introduce our algorithm and present some results (theoretical and experimental) about its stochastic performance. (Received August 31, 2015)

1114-62-326 **Nikhyl Bryon Aragam*** (bryon@stat.ucla.edu), **Arash Amini** and **Qing Zhou**. *Concave penalized estimation of sparse Gaussian Bayesian networks: Algorithms and theory.*

Research into graphical models is a rapidly developing enterprise, garnering significant interest from both the statistics and machine learning communities. A parallel thread in both communities has been the study of low-dimensional structures in high-dimensional models with $p \gg n$. Recently, there has been a surge of interest in connecting these threads in order to understand the behaviour of graphical models in high-dimensions. We propose a framework for estimating Gaussian Bayesian networks which is motivated by problems from the regression literature. We show how to adapt recent work in sparse learning and nonconvex optimization to the structure learning problem for Bayesian networks in order to estimate DAGs with several thousand nodes. This framework applies to a general class of regularizers, including the MCP, SCAD, ℓ_1 and ℓ_0 penalties. (Received September 01, 2015)

1114-62-342 **Angel R Pineda***, Mathematics Department, Manhattan College, Riverdale, NY. *Task-Based Optimization of Image Reconstruction in Magnetic Resonance Imaging (MRI).* Preliminary report.

Current approaches to accelerate magnetic resonance imaging (MRI) use prior information about the objects being imaged to acquire less data. This leads to image reconstruction methods with regularization. The associated reconstructions generate images which have the potential to provide the same clinical information at shorter acquisition times than standard methods. The degree to which the images from these accelerated methods are useful depends on how the acceleration affects the performance on clinical tasks. In this work, we study the effect of the regularization parameter on detection of lesions and compare it with standard metrics of image fidelity (mean squared error and structural similarity). (Received September 01, 2015)

1114-62-353 **Reza Ramezan*** (rramezan@fullerton.edu). *A Point Process Manifestation of the Integrate-and-Fire Model.*

Within the nervous system, each neuron carries "information" via sequences of consecutive electrochemical waves (a.k.a. spike trains). These signals are caused by changes in ion concentrations across the membrane potential of the nerve cells. The Integrate-and-Fire (IF) model is a popular and biologically justified mathematical framework for modeling the spike generation process, which focuses on the neural integration law. In this talk, I discuss the newly developed Skellam process with resetting (SPR) model, which is a point process analogous to the IF model. Although SPR is a point process model for spike trains, it does not suffer from the same shortcomings as the Poisson process, and it has a similar biological justification (neural integration) as the IF model. Within this SPR framework, I discuss the inter-spike interval (ISI) distribution, which is closely related to the interesting problem of temporal code in the analysis of neural spike trains. Depending on parameter values, SPR allows for different ISI distributions ranging from Exponential to Inverse Gaussian. The performance of this new model is demonstrated through simulations and real data analyses. To accommodate the analysis of neural ensembles, a multivariate extension of SPR will also be discussed. (Received September 01, 2015)

65 ► Numerical analysis

1114-65-5 **Eka Oche Ogbaji*** (ogbajieka@yahoo.com), Mathematics and Statistics Department,Federal, University Wukari P.M.B1020 Wukari, Wukari, Taraba 9600001, Nigeria, and **E. S. Onah** (ogbajieka@yahoo.com), University of Agriculture Makurdi, Makurdi, Benue 9600001, Nigeria. *Using Heston Model to Empirically verified Stock Prices Return.* Preliminary report.

Volatility is a great concern to investors. Investors like to know how much volatility or risk that they are exposed to before they can invest in a stock. Potential investors are advised to invest in companies that exhibit relative calm or high stability. In Abdelmoula and Dobber(2006)where they used geometric Brownian motion model to

study the behaviour of stock market prices. In their study, volatility was considered over a very long of time in such case, it is difficult for investors to predict the behaviour of stock price for a short period. AlsoYuan(2013) used Heston model, where volatility was considered over a short period.We used selected companies from Nigerian Stock Exchange to empirically verified Heston model. A Pascal programming language was used to code the Euler's –maruyama method of the solution of the Heston model. We conclude that Stock price is random distributed, positive rate of return and low volatility of stock price imply viable and growing company at a particular period, negative rate of return and high volatility of stock price imply non-viable and collapsing company at that particular period,volatility and rate of return are also random distributed. (Received January 30, 2015)

1114-65-10 **E O Adeyefa*** (emmanuel.adeyefa@fuoye.edu.ng), Mathematics Department, Federal University Oye-Ekiti, P.M.B 373, Oye-Ekiti, Nigeria, Ekiti , Nigeria. *Orthogonal-Based Fifth Order Initial Value Solvers for the Solution of Third Order Ordinary Differential Equations.*

The paper presents development of a block algorithm for the numerical solution of ordinary differential equations with application to third order initial value problems. Collocation and interpolation techniques were adopted and a set of orthogonal polynomials valid in interval [-1, 1] with respect to weight function w(x) = x + 1 was constructed and employed as basis function for the development of continuous hybrid schemes. To make the continuous implicit schemes self-starting, a block method of discrete hybrid form was derived. Findings from the analysis of the basic properties of the method using appropriate existing theorems show that the developed schemes are consistent, zero-stable and hence convergent. On implementation, the schemes compared favourably well with the existing methods owing to the fact that they are accurate and efficient (Received March 05, 2015)

1114-65-70 **Ibraheem Alolyan*** (ialolyan@ksu.edu.sa). *A global Optimization Technique for finding the minimum of a Vector Function.*

In this paper we find the minimum of a vector function defined in a box using discarding algorithm. The algorithm splits the domain to smaller cells and each cell is checked by a minimization test. If the cell satisfied the condition it will be kept and it might have the optimal solution. If it does not satisfy the condition it will be omitted. Our goal of this paper is to find such a test then study the convergence of the method and give numerical examples. (Received August 08, 2015)

68 ► Computer science

1114-68-281 **Zhenqiu Liu*** (liuzx@cshs.org), Los Angeles, CA. *Sparse inverse covariance estimation with L0 penalty for network construction with omics data.*

Constructing co-expression and association networks with omics data is crucial for study- ing gene-gene interactions and underlying biological mechanisms. In recently years, learning the structure of a Gaussian graphical model from high dimensional data using L1 penalty has been well-studied and found many applications in bioinformatics and computational biology. However, besides the problem of biased estimators with LASSO, L1 does not always choose the true model consistently.

Based on our previous work with L0 regularized regression, we propose an L0 Regularized sparse Inverse Covariance Estimation (L0RICE) for structure learning with the efficient Alternating Direction (AD) method. The proposed method is robust and has the Oracle property. The proposed method is applied to omics data including data from next- generation sequencing technologies. Novel procedures for network construction and high- order gene-gene interaction detection with omics data are developed. Results from simulation and real omics data analysis indicate that L0 regularized structure learning can identify high- order correlation structure with lower false positive rate and outperform graphical lasso by a large margin. (Received August 31, 2015)

70 ► Mechanics of particles and systems

1114-70-74 **Connor Fox Jackman*** (cfjackma@ucsc.edu), 100 Calvin Place, Santa Cruz, CA 95060. *Fitting pants to N-body problems.*

The Jacobi-Maupertuis principle formulates mechanics at a fixed energy level as finding geodesics of a certain metric. The sign of curvature associated to this metric can then have dynamical consequences. This talk is about the signs of these curvatures for the 3 and 4 body problem with a strong force and some consequences. (Received August 09, 2015)

78 ► Optics, electromagnetic theory

1114-78-26 **Alexey Sukhinin*** (asukhinin@smu.edu), Southern Methodist University, Dallas, TX 75243. *Modeling of laser filamentation based on co-propagation of high intensity optical pulses with different wavelengths.* Preliminary report.

Laser filamentation is an area of research that provides a unique challenges in applied mathematics, physics, computer science and engineering. In this talk I will describe the (3+1)D model of co-propagating nanosecond and femtosecond pulses in air and present the resolution technique that allows to capture all important effects on different time scales. (Received May 31, 2015)

81 ► Quantum theory

1114-81-51 **Mike Dombroski*** (dombroskistm11@verizon.net), CA. *Extending the Preons of Harari, Shupe and Seiberg using Transpose(\ ) with Cispose(/).* Preliminary report.

Dr. Don Lincoln, a senior physicist at Fermilab, wrote an article in the November 2012 issue of Scientific American. In it he referred to "a theory of sublime simplicity". He was talking about a straight-forward model of "preons" proposed independently in 1979 by Haim Harari, Michael A. Shupe, and Nathan Seiberg. In this paper we empirically extend the work of HSS by using two sets (a,m) of nine 3x3 matrices (whose elements are 3x3 real integer matrices). The "averages" of the integers of each set are 0 or +1/3. This is analogous to the electric charges of HSS. The well-known Transpose (\ ) with the important new Cispose (/) transformations, are necessary to generate the newly discovered Fermion Matrices and Boson Matrices. Many different forms are presented. http://dombroskiSTM.org (Received August 08, 2015)

1114-81-156 **David Damanik***, Department of Mathematics, MS-136, Rice University, Houston, TX 77251. *Spectral properties of quasi-periodic Schrödinger operators and applications.* Preliminary report.

We discuss spectral properties of quasi-periodic Schrödinger operators and applications. (Received August 24, 2015)

1114-81-207 **Amanda Young*** (amyoung@math.ucdavis.edu) and **Bruno Nachtergaele**. *Applications of a Modified Martingale Method for Estimating Spectral Gaps.* Preliminary report.

We introduce a form of the martingale method for estimating the spectral gap of a quantum spin system that relies on an increasing sequence of frustration free Hamiltonians rather than an increasing sequence of finite volumes. In particular, this new form is more easily applied to systems with periodic boundary conditions and we use it to prove a non-vanishing spectral gap for finitely correlated state models with periodic boundary conditions and a unique ground state. Further applications to AKLT type models in one and two dimensions with both open and periodic boundary conditions are in progress. This research is supported in part by the National Science Foundation under Grant DMS-1515850. (Received August 27, 2015)

1114-81-223 **David Carfi*** (davidcarfi@gmail.com), 98121 Messina, Italy. *Schwartz Linear Algebra: foundations and some applications.*

We propose here a pretty orthodox development of Laurent Schwartz Distribution Theory, conducted by following the way of Weak Duality on topological vector spaces, aiming at the construction of a feasible and manageable framework for Quantum Mechanics. It turns out that distribution spaces reveal themselves an environment more capable to work in Quantum Mechanics than previously thought. The goal of the research introduced in this book consists in showing that the most natural state spaces of a quantum system, in the infinite dimensional case, are just the distribution spaces. Moreover, we show new, but natural and straightforward, orthodox mathematical structures that reproduce very well some required physical structures and operational procedures of Quantum Mechanics, systematizing the algorithms and notations of Dirac Calculus in such a way that it becomes a more versatile and more powerful tool without struggling with complicated and substantially contradictory arguments. (Received August 28, 2015)

1114-81-226 **David Carfi** (davidcarfi@gmail.com) and **Alessia Donato*** (donatoalessia@hotmail.it). *Dirac Calculus and Schwartz Linear Algebra.*

It was in 1930 that Paul Dirac published his *Principles of Quantum Mechanics*, in this famous treatise Dirac introduced several "manipulation rules" for vectors and operators in a linear space, which, in their complex, constitute the so called "Dirac Calculus". The operation of continuous-superposition is the right tool which allows us to build - in a mathematically rigorous way - the extended Linear Algebra of Dirac in the spaces of

distributions, via their natural topological-linear structures. More precisely, the goal we reach is in the following direction: we shall see that the natural algebraic-topological structure of those spaces allows us to define a generalization of the finite linear combinations, when the sets indexing the families of vectors are continuous sets, even in the case in which the systems of coefficients has a continuous-infinity of terms different from zero. Moreover, besides the reconstruction of the Dirac Calculus, we reread some classic theorems of Functional Analysis, in terms of the new extended linear algebra and we provide a new interpretation of several classic deep concepts of Linear Functional Analysis extremely feasible for applications to Physics, Engineering, Economics and Finance. (Received August 28, 2015)

1114-81-229 **David Carfi** (davidcarfi@gmail.con) and **Dania Panuccio*** (dania.panuccio@gmail.com). *Spectral expansion of Schwartz linear operators.*

In this paper, we prove and apply a theorem of spectral expansion for Schwartz linear operators which have a Schwartz linearly independent eigenfamily. This type of spectral expansion is the analogous of the spectral expansion for self-adjoint operators of separable Hilbert spaces, but in the case of eigenfamilies of vectors indexed by the real Euclidean spaces. The theorem appears formally identical to the spectral expansion in the finite dimensional case, but for the presence of continuous superpositions instead of finite sums. The Schwartz expansion we present is one possible rigorous and simply manageable mathematical model for the spectral expansions used frequently in Quantum Mechanics, since it appears in a form extremely similar to the current formulations in Physics. (Received August 28, 2015)

1114-81-247 **Francesco Strati*** (francesco.strati@unisi.it). *On defining $\mathcal{S}$-spaces.*

The present work is intended to be an introduction to the Superposition Theory of David Carfi. In particular I shall depict the meaning of his brand new theory: on the one hand by an informal discussion, and on the other hand by giving a formal approach of the algebraic structure of the theory: the $\mathcal{S}$-linear algebra. This kind of framework underpins the notion of *$\mathcal{S}$-spaces* by defining both its properties and its nature. Thus I shall define the $\mathcal{S}$-triple as the fundamental *principle* upon which the $\mathcal{S}$-linear algebra is built up, as a generalization of the famous Gel'fand triple. (Received August 29, 2015)

1114-81-268 **Michael Bishop*** (mbishop@math.ucdavis.edu), **Bruno Nachtergaele** and **Amanda Young**. *Gap Dependency on Half Spaces in the Product Vacua and Boundary State Models.* Preliminary report.

We consider for a family of quantum spin 1/2 systems called the Product Vacua and Boundary State (PVBS) models defined on half-spaces of the d dimensional lattice $\mathbb{Z}^d$ with Hamiltonians composed of sums of non-commuting local projections. For any set of parameters for the PVBS model, we prove a simple geometric condition on the half-space which determines the existence or non-existence of a spectral gap. As a corollary, we prove the existence or non-existence of a spectral gap for the model defined on the entire lattice $\mathbb{Z}^d$. This research was supported in part by the National Science Foundation under Grant DMS-1515850. (Received August 30, 2015)

1114-81-279 **David Carfi** (davidcarfi@gmail.com) and **Gabriele Orlando*** (gabrieleorlando15@gmail.com). *Transposable Schwartz families and Dirac Calculus.*

We construct some basic tools of Dirac Calculus, in the context of Schwartz Linear Algebra. Specifically, we see Heisenberg continuous matrices as Schwartz families. We distinguish the subclass of transposable continuous matrices and give some examples in Quantum Mechanics. We define transposable Schwartz families and their transpose families, we prove the transposability of Dirac families and Fourier families. We find the transpose of regular-distribution families in a quite general case. We define symmetric families, the analogous of symmetric matrices in the continuous case. We prove the symmetry of Dirac families and of Fourier families. We define Hermitian families, the analogous of Hermitian matrices in the continuous case. We prove the Hermitianity of Dirac families and of Fourier families. We define unitary families, the analogous of unitary matrices in the continuous case. We prove the unitarity of Dirac families and of the normalized de Broglie family. Then, we use the transpose of a family to find the components of superpositions of transposable families, we give a general result and we apply this result to the Dirac families and the eigenfamilies of the Vector-wave operator. We shall use the transposable families to define the Dirac product in distribution spaces. (Received August 31, 2015)

1114-81-285 **Mircea I Voda*** (mvoda@uchicago.edu). *On non-perturbative localization for continuous Schrödinger operators.*

I will discuss the issue of localization for continuous multifrequency quasiperiodic Schrödinger operators in the regime of positive Lyapunov exponent. The talk is based on joint work with Ilia Binder and Damir Kinzebulatov. (Received August 31, 2015)

1114-81-316 **Chi Shing Sidney Tsang*** (tsangcs@uci.edu) and **Abel Klein** (aklein@uci.edu). *Bootstrap Eigensystem Multiscale Analysis for the Anderson Model.* Preliminary report.

We use a bootstrap argument to enhance the eigensystem multiscale analysis, introduced by Elgart and Klein for proving localization for the Anderson model at high disorder. The eigensystem multiscale analysis studies finite volume eigensystems, not finite volume Green's functions, obtaining exponential localization of finite volume eigenfunctions with high probability, with the eigenvalues and eigenfunctions labeled by the sites of the box. The bootstrap eigensystem multiscale analysis requires only the verification of polynomial decay of the finite volume eigenfunctions, at some sufficiently large scale, with some minimal probability independent of the scale. It yields exponential localization of finite volume eigenfunctions in boxes of side L, with the eigenvalues and eigenfunctions labeled by the sites of the box, with probability higher than $1 - \mathrm{e}^{-L^\zeta}$, for any desired $0 < \zeta < 1$. (Received August 31, 2015)

82 ► Statistical mechanics, structure of matter

1114-82-60 **Alexander Elgart** (aelgart@vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061, and **Abel Klein*** (aklein@uci.edu), University of California, Irvine, Department of Mathematics, Irvine, CA 92697-3875. *An eigensystem approach to Anderson localization.* Preliminary report.

We introduce a new approach for proving localization (pure point spectrum with exponentially decaying eigenfunctions, dynamical localization) for the Anderson model at high disorder. In contrast to the usual strategy, we do not study finite volume Green's functions. Instead, we perform a multiscale analysis based on finite volume eigensystems. We establish localization of finite volume eigenfunctions with high probability, with the eigenvalues and eigenfunctions labeled by the sites of the box. (Received August 04, 2015)

1114-82-104 **Marius Christopher Lemm*** (mlemm@caltech.edu), 1200 E California Blvd, Department of Mathematics, MC 253-37, Pasadena, CA 91125. *Anomalous Lieb-Robinson bounds in an XY spin chain.*

The well-known Lieb-Robinson bounds provide control over the speed of propagation in quantum spin systems. In analogy to relativistic systems, they establish a "light cone" $x \leq vt$ in spacetime outside of which commutators of initially localized observables are exponentially small. We consider an XY spin chain in a quasiperiodic magnetic field and prove an *anomalous* Lieb-Robinson bound which features the modified light cone $x \leq vt^\alpha$ for some $0 < \alpha < 1$. In fact, we can characterize α exactly as the upper transport exponent of a one-body Schrödinger operator. This may be interpreted as a rigorous proof of anomalous quantum many-body transport. Joint work with David Damanik, Milivoje Lukic and William Yessen. (Received August 16, 2015)

1114-82-109 **Eleni Panagiotou*** (panagiotou@math.ucsb.edu), South Hall, Room 6523, Department of Mathematics, University of California Santa Barbara, Santa Barbara, CA 93106-3080, and **Martin Kroeger**. *Pulling-force-induced elongation and alignment effects on entanglement and knotting characteristics of linear polymers in a melt.*

We employ a primitive path (PP) algorithm and the Gauss linking integral to study the degree of entanglement and knotting characteristics of linear polymer model chains in a melt under the action of a constant pulling force applied to selected chain ends. Our results for the amount of entanglement, the linking number, the average crossing number, the writhe of the chains and their PPs and the writhe of the entanglement strands all suggest a different response at the length scale of entanglement strands than that of the chains themselves and of the corresponding PPs. (Received August 17, 2015)

1114-82-241 **Ilya Kachkovskiy*** (ikachkov@uci.edu), 340 Rowland Hall, Department of Mathematics, University of California, Irvine, Irvine, CA 92697. *On transport properties of isotropic quasiperiodic XY spin chains.* Preliminary report.

We consider isotropic XY spin chains whose magnetic potentials are quasiperiodic and the effective one-particle Hamiltonians have absolutely continuous spectra. For a wide class of such XY spin chains, we obtain lower

bounds on their Lieb–Robinson velocities $\mathfrak{v}$ in terms of group velocities of their effective Hamiltonians:

$$\mathfrak{v} \geq \operatorname*{ess\,sup}_{[0,1]} \frac{2}{\pi} \frac{dE}{dN},$$

where E is considered as a function of the integrated density of states. (Received August 28, 2015)

1114-82-249 **Houssam Abdul-Rahman** and **Bruno Nachtergaele*** (bxn@math.ucdavis.edu), Department of Mathematics, University of California, Davis, 1 Shields Ave, Davis, CA 95616, and **Robert Sims** and **Günter Stolz**. *Entanglement Dynamics of Disordered Quantum XY Chains.*

One of the expected signatures of Many-Body Localization is logarithmic (as opposed to ballistic) growth of bipartite entanglement starting from a product initial condition. For a class of disordered quantum XY chains, and a large class of product initial states, we prove that the entanglement satisfies a constant bound, independent of time and system size. Therefore, although disordered XY chains display many of the expected generic features of Many-Body Localization, the dynamics of entanglement appears to be even more localized than is generically expected and observed numerically in other model systems. This research was partially supported by the National Science Foundation under Grants DMS-1069320 (G.S.) and DMS-1515850 (B.N.), and by a grant from the Simons Foundation (#301127 to R.S.). (Received August 29, 2015)

86 ► Geophysics

1114-86-320 **John D. Grace*** (john@earthsci.com), Earth Science Associates, 4300 Long Beach Blvd., Ste. 310, Long Beach, CA 90807, **Tony Dupont** (tony@earthsci.com), Earth Science Associates, 4300 Long Beach Blvd., Ste. 310, Long Beach, CA 90807, and **Scott Morris** (scott@earthsci.com), Earth Science Associates, 4300 Long Beach Blvd, Ste. 310, Long Beach, CA 90807. *Joint Cooperative Research Programs between Earth Science Associates and the Graduate Program in Applied Mathematics at California State University Fullerton.* Preliminary report.

In 2013 and 2015, Earth Science Associates (ESA) and the Masters in Applied Mathematics Program at California State University Fullerton (CSUF) completed two projects on the safety and environmental impacts of oil and gas exploration and production in the Gulf of Mexico (GOM). The 2010 accidental explosion of the BP's Macondo well motivated the 2013 project. Six students stochastically characterized the natural pore pressure field within the sedimentary rocks across approximately 385,000 square kilometers of the GOM from the seafloor to 5,336 meters below it. Ordinary kriging was applied to reservoir and well pressure data to estimate mean pressures and confidence intervals. Co-kriging and hot spot analysis further refined the regional analysis. In 2015, seven students exploited new analyses by the National Hurricane Center (NHC) of "disturbed air" systems, the precursors to tropical storms and hurricanes, to forecast the track of a possible storm up to 2-3 days before it forms. When storms do form and receive an official NHC track forecast, these estimates are disaggregated to the locations of 2,500 individual production platforms across the GOM. The system automatically retrieves NHC data, analyzes it and serves results to users over the web. (Received August 31, 2015)

90 ► Operations research, mathematical programming

1114-90-55 **Mohammed K A Kaabar*** (mkaabar@math.wsu.edu), 750 SE Derby Street, Pullman, WA 99163. *The Three Different Data Analysis Methods for finding the Best Classification Rates for Arabic Sign Language Data.* Preliminary report.

In this talk, we identify several types of methods for finding the classification rates for Arabic sign language data, and these data are extracted from a paper: (*Recognition of Arabic Sign Language Alphabet using Polynomial Classifiers,* Khaled Assaleh and M. AlRousan, EURASIP JASP 2005:13 (2005) 2136-2145). These data represent images that were collected from 30 deaf participants who had to wear colored gloves and then perform their own Arabic sign gestures. We are only using 10 letters (classes) out of the 30 alphabets in Arabic sign language that can be performed in 42 gestures. Firstly, we visualize the three classes of data in 2-D plot using the Principle Component Analysis (PCA). Secondly, we use linear classifier to generate linear discriminant functions by using the pseudo inverse method to find the classification rates for training and testing data. Thirdly, we classify data using neural networks model, and we implement the k-means algorithm to find the classification rates for our data. Finally, we compare the different types of methods with each other to find the best method for achieving excellent classification rates. (Received August 03, 2015)

1114-90-215 **Toru Ohira*** (ohira@math.nagoya-u.ac.jp), Furocho, Nagoya, Aichi 4648602, Japan.
Application of Chase and Escape to Combinatorial Optimization Problems.

Chasing and evading is a mathematical problem which have attracted many mathematical minds in history. For example, one of the earliest problems is to find the path of the chaser who is chasing an evader moving in a circle with a constant speed. The chaser also moves with a constant speed with its velocity vector pointing to the position of the evader. Interests in these problems have grown in various directions, such as "differential game theory" and "discrete search games" . Recently, we have proposed and extended model of chases and escapes in groups, called "Group Chase and Escape".

The main theme of this paper is to propose an idea of applying this chase and escape problem to optimization problems, such as combinatorial optimizations. There are various ways by which we can seek such applications. We here present an approach to identify the states of evaders and chasers with configuration states of the optimization problems. Thus, both evaders and chasers are given associated cost function, which we try to optimize. We perform a chase-and-escape game on the "landscape" of the cost function trying to find the optimized state with the lowest cost.

This research has been supported by The Kayamori Foundation of Informational Science Advancement K25-XVII422. (Received August 28, 2015)

91 ► Game theory, economics, social and behavioral sciences

1114-91-172 **Tien M Nguyen*** (tien.m.nguyen@aero.org), 2310 E. El Segundo Blvd., Mail: P.O. Box 92957, Los Angeles, CA 90009-2957, El Segundo, CA 90245-4609, **Andy T Guillen**, Same as above., and **Sumner S Matsunaga**, Same as above. *Development of Technical Baselines for Future Space Systems Using Advanced Game-Based Mathematical Modeling Approach.* Preliminary report.

The U.S.DoD recently focused on the development of future space systems using Congressional Initiatives (CIs), Defense Innovation Initiative (DII), and BBP 3.0 to improve acquisition efficiency. CIs/BPP/DII impose requirements on innovative, affordability, increasing competition, and decreasing acquisition time. As indicated in the Space Modernization Initiative (SMI) Strategy, the future systems shall meet the design for low Life Cycle Cost (LCC)/Total Ownership Cost (TOC), provide desired system capability to meet warfighter needs and achieve resiliency to operate in contested environments. These objectives have posed conflicting requirements and a real challenge for the DOD Acquisition Authority (DAA).

The components characterized the technical baseline for the future space systems are key requirements, system architecture design and key open subsystem solutions. We propose an Advanced Game-based Mathematical Framework (AGMF) using Bayesian games for acquiring future space systems with complete and incomplete information cases. AGMF provides a recipe for DAA and Space and Missile Systems Center to achieve optimum acquisition. Optimum in the sense of compromising the objectives to achieve low LCC/TOC, innovative, decreasing acquisition time, and meeting warfighter needs. (Received August 25, 2015)

1114-91-277 **Michael J Campbell***, michaeljcampbell@outlook.com. *Phase Transitions in Bounded Rational Potential Games with Applications to Cournot Models and a Speculative and Hedging Model.*

Frequently, real economic agents do not follow purely rational strategies. These individual non-rational behaviors (due to errors in judgment, partial information, emotional bias, etc.) can result in some fascinating organized large-scale structures, which depend on the degree of non-rational behavior.

We look at two such models for Potential Games [Shapley and Monderer]: a dynamical drift-diffusion model, and a static large deviation theory model based on Shannon information entropy and arbitrage. The equilibrium measure in both cases is the Gibbs measure found in statistical mechanics. We show that the variable that gauges non-rational behavior in both models is related to a "temperature" parameter as in statistical mechanics.

A type of localized discrete Cournot oligopoly has a rich phase diagram with an "antiferromagnetic" checkerboard state, striped states and maze-like states with varying widths, and finally a "paramagnetic" unordered state. Such phases have economic implications as to how agents compete given various restrictions on how goods are distributed. The theory is also applied to a Speculative and Hedging Model in Oil and U.S. Dollar Markets [Carfi and Musolino] for many "bank" players, and we speculate on a phase transition in this model. (Received August 30, 2015)

92 ► Biology and other natural sciences

1114-92-89 **Hsuan-Wei Lee** (waynelee1217@gmail.com), **Anzhelika Lyubenko*** (anzhelika.lyubenko@ucdenver.edu), **Yuhang Ma** (ym367@cornell.edu), **Emily Meissen** (emilymeissen@gmail.com), **Daniela Velez-Rendon** (dvelez3@uic.edu), **Nara Yoon** (nxy47@case.edu), **John Peach** (jpeach@ll.mit.edu), **Cammey Cole Manning** (manningc@meredith.edu) and **Christian Gunning** (cegunnin@ncsu.edu). *Modeling Ebola: Three Distinct Models with Similar Predictions.*

We present and compare three models of the Ebola outbreak in Liberia during 2014-2015 and examine the effect of international intervention. We utilize both system dynamics and agent-based approaches. We show that the basic reproduction number of the disease is greater than one before intervention and decreases to less than one after intervention, implying eventual eradication of the disease. We demonstrate that the probability of an outbreak varies depending on the population size and that even for large populations there is a 70% chance of an outbreak if only one person gets exposed to the disease. In addition, if an outbreak is not contained in the early stages and the individuals do not change their behavior as the virus prevails, over 90% of population contracts the disease and about 50% of the population dies because of it. Effective intervention may decrease both figures to be less than 1%. When including spatial movement in the agent-based setting, we conclude that outbreaks can be less severe due to the population not being well-mixed. (Received August 12, 2015)

1114-92-173 **Anael Verdugo*** (averdugo@fullerton.edu). *Analysis of a Dynamic Model of Iron Metabolism.* Preliminary report.

Computational and mathematical modeling has become an important tool for modern life-sciences research in academia and industry. Understanding the molecular interactions and metabolism of iron in healthy and cancer cells is the main goal of this work. We approach this problem by building a mathematical model using dynamical systems theory and experimental data. Our preliminary findings on healthy cells have started to elucidate some of the main pathways associated to a healthy iron regulation. In this talk, I will give a brief overview of iron metabolism and explain some of our experimental and computational findings in this new area of computational cancer biology. (Received August 25, 2015)

1114-92-221 **Phuong Hoang*** (phoang@ncsu.edu), Department of Mathematics, Campus Box 8205, North Carolina State University, Raleigh, NC 27695, and **Hien T Tran** (tran@ncsu.edu), Department of Mathematics, Campus Box 8205, North Carolina State University, Raleigh, NC 27695. *Supervised learning for medical diagnostic decision support system: Hepatitis C and breast cancer diagnosis application.*

Many decision support applications in healthcare depend heavily on early detection and accurate diagnosis. Physician diagnostic performance can be improved with a reliable decision support system. In this talk, we will discuss the machine learning approach to improve the accuracy of these diagnostic systems. Machine learning techniques from classification to model evaluation will be introduced including Support Vector Machine (SVM), Receiver Operating Characteristic (ROC) curve and k-fold Cross Validation. In our initial effort, we test our approach using hepatitis C and breast cancer datasets from the UCI Machine Learning database. It is noted that most datasets in disease diagnostic are imbalanced, i.e., one class heavily outnumbers the others (for example, detecting credit card fraud or email spam). By using a modified SVM with weighted cost, we were able to obtain over 80% accuracy in both sensitivity and specificity.

Similar machine learning approach was previously employed in domain beyond health care. In particular, in collaboration with the MIT Lincoln Laboratory, we built a pitch type prediction model using a database created by Sportvision's PITCHf/x pitch tracking system and obtained 78% overall prediction accuracy. (Received August 28, 2015)

1114-92-227 **Jack L Feldman*** (feldman@g.ucla.edu). *Can mathematics help us understand behavior.*

Mathematical models profoundly inform our understanding of neuron function, yet we lack similar breakthroughs in understanding how neurons generate behavior. A misunderstood aspect of most behaviors is their complexity. We study a relatively simple yet vital and robust behavior in mammals, i.e., breathing. How we generate respiratory rhythm seems like a problem we should have solved. Why not? One component of this failure is oversimplifying the biology, with the result that we have been looking in the wrong places. Several paradigms for understanding breathing rhythmogenesis are simply wrong, as it does not require [1]: pacemaker neurons; postsynaptic inhibition; large amplitude bursting. Unfortunately, attempts to produce a model of neural control of breathing have been built on the foundation of these assumptions. What mechanisms are left? An essential one, which has been ignored largely because it has been experimentally refractory, is the neural microcircuit;

we discovered some basic properties that are indicative of its critical role in rhythm generation [1]. Models that realistically incorporate the network propertiesare essential. I will discuss some experimental data that is in desperate need of clever modeling. [1] Feldman JL and Kam K (2015) J. Physiol 593 (Received August 28, 2015)

1114-92-252 **Qihua Huang** and **Hao Wang*** (hao8@ualberta.ca), CAB 539, University of Alberta, Edmonton, Alberta T6G 2G1, Canada, and **Mark A. Lewis**. *The impact of environmental toxins on predator–prey dynamics.*

To study the impact of environmental toxins on food web, we construct a toxin-mediated predator-prey model that combines both direct and indirect toxic effects on two trophic levels. This work investigates how the balance of the classical predator-prey dynamics changes as a function of environmental toxin levels. While high toxin concentrations are shown to be harmful to both species, possibly leading to extirpation of both species, intermediate toxin concentrations may affect predators disproportionately through biomagnification, leading to reduced abundance of predators and increased abundance of the prey. This counterintuitive effect significantly increases biomass at the lower trophic level. Environmental toxins may also reduce population variability by preventing populations from fluctuating around a coexistence equilibrium. Finally, environmental toxins may induce bistability. Since our toxin-mediated predator–prey model is general, the theory developed here not only provides a foundation for population or community effects of toxicity, but also could help develop management policies to preserve and restore the integrity of contaminated habitats. (Received August 29, 2015)

1114-92-262 **Hugh T Blair*** (blairlab@gmail.com), UCLA Dept. of Psychology, 1285 Franz Hall, 502 Portola Plaza, Los Angeles, CA 90095. *Rate and phase codes for space in the mammalian brain.*

There is one thing no navigator ever wants to be, and that is lost. To prevent this catastrophe from occurring, autonomously navigating organisms possess specialized brain systems for mapping and self-localization. Self-localization is the problem of sensing one's own position in space, which can be reduced to a process known as Kalman filtering, whereby the navigator simultaneously tracks its own position on two different maps—an allothetic map and an ideothetic map—that provide complementary information to the navigator about its own location. The challenge for the navigator is to maintain two different estimates of its own position at the same time, one on each map, resolving any conflicts that arise between them so that both estimates remain as accurate and consistent with one another as possible. Based upon theory and evidence, I will argue that the mammalian nervous system has evolved two distinct neural codes—a firing rate code and a spike phase code—for performing allothetic versus ideothetic mapping, respectively. Understanding how these two codes are generated, and how they interact with one another, can inform our understanding of neural mechanisms not only for navigation, but for perception, memory, and decision-making as well. (Received August 30, 2015)

1114-92-278 **Weitao Chen*** (weitaoc1@uci.edu), **Qing Nie** (qnie@math.uci.edu) and **Arthur Lander** (adlander@uci.edu). *Robust dynamics in tissue growth and development patterning.*

Robustness is observed widely in biological systems and the related study is essential in mathematical modeling. In particular, size control and pattern formation, both displaying strong robustness, can serve as good models to investigate the related mechanisms. Tissue and organ size is genetically specified with remarkable precision, independent of growth rate, cell size, only weakly sensitive to initial conditions and relatively resistant to a variety of external perturbations. The patterning of many developing tissues is organized by morphogens and its formation is often quite resistant to embryonic difference, intrinsic or extrinsic noises. The robustness of different systems can be enhanced by particular mechanisms. In this talk, I will use a multi-stage cell lineage model to discuss general strategies that may contribute in achieving large tissue size robustly. I will also present two particular systems, the papillae formation on a mouse tongue or the scaling behavior during the growth of a wing disc in drosophila, to reveal the mechanisms for obtaining specific patterns with robustness regarding to noise. (Received August 31, 2015)

1114-92-280 **Melisa Hendrata***, Department of Mathematics, California State University, Los Angeles, Los Angeles, CA 90032. *An agent-based bioenergetic model for simulating bacteria life cycle.*

Bacteria colonies undergo several stages during their life cycle. We introduce a bioenergetic agent-based model to simulate their life cycle. The bioenergetic is based on the Dynamic Energy Budget (DEB) theory that focuses on the mechanisms of acquisition and use of energy by individuals, which has consequences in physiological organization and dynamics of the populations. We show that the interplay between the bioenergetic, cell motility

algorithm and cell signaling controls the phase transitions during the colony development. (Received August 31, 2015)

1114-92-349 **Leonila Lagunes*** (leo.lagunes13@gmail.com) and **Charles H. Lee** (charleshlee@fullerton.edu). *Cancer Screening using Biomimetic Pattern Recognition with Hyper-Dimensional Structures.*

Cancer treatments have been shown to be more effective if the cancer is detected at an early stage. Current detection methods include imaging and tissue/blood-sample testing; these are expensive and invasive, thus scientists have been driven to develop alternatives to detect cancer. Biomimetic Pattern Recognition (BPR) is a technique that constructs a hyper-dimensional (HD) geometric body by mimicking a biological system and uses it for classification. BPR is derived from the Principle of Homology-Continuity, which assumes elements of the same class are biologically evolved and continuously connected. That is, between elements of the same class, there is a gradual connection. These connecting branches form HD surfaces. The resulting topological structure mimics a biological class. Recently, BPR has been successfully used in voice, facial, and iris recognition software. We developed new BPR algorithms and classification schemes to detect specific cancers using DNA microarray data. We investigated the performance of the proposed BPR methods based on bladder, colon, leukemia, liver, and prostate cancers. Results indicate that BPR has an increased recognition rate compared to previous techniques. BPR has shown to be a promising approach for cancer detection using DNA microarray data. (Received September 01, 2015)

1114-92-355 **Eric A Eager*** (eeager@uwlax.edu), 1725 State St., La Crosse, WI 54601. *Modeling, Analysis and Simulation of the Stochastic Population Dynamics of a Disturbance Specialist Plant and its Seed Bank.*

In this talk I discuss how stochastic models can be used to understand the population dynamics of species for which an underlying deterministic signature is difficult to detect from census data. I use wild sunflower (*Helianthus annuus*) as a case study. *H. annuus* is a disturbance specialist plant - its seeds do not germinate in the absence of soil disturbance. I model these disturbances as a stochastic process, which gives rise to a stochastic integral projection model for the population density of *H. annuus* and its seed bank. I show that this model predicts population dynamics that converge to invariant probability measure either completely concentrated on the extinction state or completely excluding the extinction state. I use simulation studies to determine how sensitive characteristics of this long-term measure change with respect to characteristics of soil disturbances. (Received September 01, 2015)

93 ► Systems theory; control

1114-93-165 **Vlad Oles*** (voles@math.wsu.edu). *On modeling biological cell with boolean network.* Preliminary report.

This article uses a particular implementation of a boolean network intended to model a biological cell to study boolean networks in general along with their properties. Nodes correspond to certain chemical compounds or genes and the entire representation of a living cell is seen as a unity of overlapping feedback loops, attached to control nodes. Amongst the notions under questions are steady states and limit cycles of either circuits or the entire system and their relations between one another. Theoretical conclusions in this part are reinforced with the applied part, where Procambium cell demonstrates following the predicted patterns on the meta-level. (Received August 24, 2015)

1114-93-354 **Jason M. Erbele*** (erbele@math.ucr.edu). *A PROP model for controllability and observability in linear time-invariant signal-flow diagrams with feedback.* Preliminary report.

Given a free PROP on a set of generating morphisms, we can construct new PROPs by adding relations between morphisms called 'rewrite rules', with a naturally defined functor from the free PROP to the new PROP. The free PROP SigFlow, generated by seven special morphisms plus an infinite family of endomorphisms of 1 indexed by the field $\mathbb{R}$, models the signal-flow diagrams that can be drawn of any control process or plant. Adding rewrite rules familiar to control engineers (and quantum physicists), we get the PROP Stateful, which carries some information about the state of a process. Any control system modelled by a system of linear differential equations $\dot{x} = Ax + Bu$, $y = Cx + Du$ can equivalently be modelled diagramatically in Stateful. Controllability and observability are key concepts associated with the differential equation model, and observability was originally defined as dual to controllability. With Stateful we can see this duality in a categorical sense, with controllability

corresponding to a morphism being epic and observability corresponding to a morphism being monic. (Received September 01, 2015)

94 ► Information and communication, circuits

1114-94-209 **Charles D. Edwards, Jr.*** (chad.edwards@sbcglobal.net). *How an International Martian Telecommunications Relay Network Is Enabling the Robotic Exploration of The Red Planet.*

The mass and power constraints of Mars rovers significantly constrain the quantity of science and engineering telemetry that can be returned on Direct-To-Earth (DTE) communications links over the large Earth-Mars distances of up to 400 million kilometers. To greatly increase our communications capabilities to support Mars exploration, the National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) have deployed a series of Mars science orbiters equipped with telecommunication relay payloads. Today, NASA's Odyssey and Mars Reconnaissance Orbiters support the return of over 500 megabits per sol from the Curiosity Rover. ESA's Mars Express Orbiter is also on orbit and has demonstrated interoperable relay capabilities with NASA landers. Augmenting this current network, NASA's Mars Atmosphere and Volatile EvolutioN Mission (MAVEN) arrived at the Red Planet in September 2014, and ESA plans to launch the ExoMars/Trace Gas Orbiter mission in January 2016, carrying NASA-supplied Electra relay payloads. With the infusion of new error-correcting codes, this network stands ready to provide Gigabits per sol of data return for future Mars landers and rovers. (Received August 27, 2015)

1114-94-274 **Maaaki Harada**, Sendai, Japan, **Ethan Novak**, Houghton, MI 49931, and **Vladimir D Tonchev*** (tonchev@mtu.edu), Houghton, MI 49931. *The weight distribution of the self-dual [128,64] polarity design code.* Preliminary report.

The weight distribution of the binary self-dual [128,64] code being the extended code of the code spanned by the incidence vectors of the blocks of the polarity design in P G(6, 2) is computed. The extended code has the same weight distribution as the 3rd order Reed-Muller code of length 128. (Received August 30, 2015)

97 ► Mathematics education

1114-97-32 **Asuman G Aksoy*** (aaksoy@cmc.edu), 850 Columbia Avenue, Claremont, CA 91711. *Al-Khwarizmi and the Hermeneutic Circle.* Preliminary report.

In this talk we discuss al-Khwarizm's life and aspects of his works and suggest a possible hermeneutic avenue into his contribution to mathematics. (Received June 17, 2015)

1114-97-39 **Melissa A. Riddle*** (melissariddle@csu.fullerton.edu), 800 N State College Blvd, 154 McCarthy Hall, Fullerton, CA 92620-0290. *Which inequalities are important for gifted high school students?*

The theory of analytic inequalities in advanced mathematics is of crucial importance. It's known that the triangle inequality in the n-dimensional Euclidean space reduces to Cauchy-Schwarz inequality. The idea to present elements of the more advanced theory of inequalities to Math Circle students is not new, since inequalities have been asked for several decades in various mathematical competitions all around the world. While working for the Fullerton Mathematical Circle, I reflected on the question: which inequalities are important? I will present a way of generating new inequalities based on a common pattern, and show how they are all related to the triangle inequality. We also illustrate how our Fullerton Mathematical Circle high-school students respond to such techniques. (Received July 11, 2015)

1114-97-40 **Sarah E. Eichhorn*** (s.eichhorn@uci.edu), 110 Theory Dr., Suite 250, Irvine, CA 92617. *Mathematical Outreach: Programs reaching 50 to 50,000 students.*

We will present three unique mathematical outreach programs at UC Irvine. For each program, we will share the target audience, program goals, implementation logistics and program evaluation.

1) Irvine Area Mathematical Modelers program (IAMM) - After school training program for local high school students to train to compete in the HiMCM High School Mathematical Modeling competition.

2) Pre-Calculus Coursera Massive Open Online Course (MOOC) - Open course to enable pre-calculus learning opportunities for populations of students around the world.

3) Society, Science, Survival: Lessons from AMC's "The Walking Dead" MOOC - Open course to utilize pop culture TV show to generate interest for general audiences to learn about outreach mathematics and science topics. (Received July 14, 2015)

1114-97-42 **Davida Fischman*** (fischman@csusb.edu), Mathematics Department, 5500 University Parkway, San Bernardino, CA 92407, and **Laura Wallace** (wallace@csusb.edu), Mathematics Department, 5500 University Parkway, San Bernardino, CA 92407. *Noticing Mathematical Connections and Making Use of Them for Teaching.* Preliminary report.

Mathematical concepts are often taught in isolation, with few opportunities provided for students to make explicit connections between concepts or content areas. However, seeking and making connections is an effective way to deepen conceptual understanding and prepare for advanced mathematics study. Additionally, many high-level careers require critical thinking skills and the inclination and ability to understand how ideas and concepts are intertwined. Teachers are expected to prepare students for mathematics-intensive careers and study, so they need to be able to do these things for themselves, as well as nurture these abilities in their students. How can we support pre-service teachers in learning to make connections? What kinds of problems naturally lead to an intrinsic need to discover and utilize connections and to deepen conceptual understanding? In this talk we describe some ways we have found effective in supporting future teachers of mathematics in being able to make connections themselves, utilizing them for problem-solving, and supporting students' ability and desire to discover and use mathematical connections. (Received July 15, 2015)

1114-97-43 **David L Pagni*** (dpagni@fullerton.edu), dept of mathematics, 800 N. State College Blvd., Fullerton, CA 92834. *Mathematics Intensive Summer Session (MISS), an outreach program for high school females in Algebra 2 and Precalculus.*

MISS is a month-long summer program serving high school female students who are often the first in their family to aspire to attend college. A supportive environment prepares students to be successful in the mathematics course they will take in the fall, including Algebra 2 or Precalculus. Since it began in 1990, over 1500 students have completed the program with 98% entering college; 33% coming to Cal State Fullerton. In November 1992 MISS was featured as a founding member of the SUMMA Consortium (SUMMAC), a project of the Mathematical Association of America's Strengthening Underrepresented Minority Mathematics Achievement Program. MISS continues to be part of SUMMA, and is listed in its Directory of Intervention Projects. In addition, MISS was recognized by Excelencia in Education in the organization's 2007-2014 editions of "What Works for Latino Students: Examples of Excelencia Compendium." In Spring 2011, MISS was featured in an article entitled "Programs have a clear STEM-phasis", published in the Lumina Foundation Focus. MISS is a program that can be replicated on other college campuses. (Received July 16, 2015)

1114-97-50 **Milos Savic*** (savic@ou.edu), **Gulden Karakok**, **Gail Tang**, **Houssein El Turkey** and **Emilie Naccarato**. *Understanding the Proving Process with the Lens of Mathematical Creativity.*

Proof is central to the development of mathematics. More importantly, the process of proving reveals many aspects of a human endeavor such as making connections, creation, taking risks, and evaluation. Undergraduate students have had difficulty with developing proofs and persevering through proving processes (e.g., Moore, 1994; Selden and Selden, 1995). There are many suggestions to guide students through their difficulties, however such guidance should also encourage and value each student's creative potentials. In this talk, we share the studies we have conducted to alleviate students' difficulties, but also nurture students' creativity, during the proving process. Through interviews with mathematicians and students, analyzing students' proving processes via Livescribe pens, and focusing on past K-12 mathematical creativity literature, our research group have created a rubric, the Creativity-in-Progress Rubric (CPR) on Proving. This rubric, coupled with well-chosen (or crafted) tasks, and an environment that allows for the sharing of the proving process, may help undergraduate students improve their proving process. In our talk, we will share some experiences of using the rubric in teaching and research. (Received July 31, 2015)

1114-97-93 **Pavel Sikorskii*** (sikorsk4@msu.edu), 4980 Chipping Camden, Okemos, MI 48864. *Hybrid Bridge Mathematics Programs for Underprepared Incoming Freshmen and Professional Development of Pre-Service Teachers.* Preliminary report.

In this talk we discuss recently developed and implemented hybrid bridge mathematics programs for underprepared incoming freshmen at MSU and the role of future pre-service teachers in making these programs work. The programs have been funded by NSF and DOW Foundation. The two overarching goals of the programs are recruiting and retaining students from underrepresented groups into STEM fields and providing real in-classroom

professional development opportunities for future pre-service teachers. We will present an overview of current challenges, approaches, best practices, as well as preliminary results. (Received August 13, 2015)

1114-97-97 **Todd D CadwalladerOlsker*** (tcadwall@fullerton.edu), Mathematics, MH-154, 800 N. State College Blvd, Fullerton, CA 92831. *Order of Operations in the Interpretations of Conjunction and Disjunction.* Preliminary report.

In the English language, complex sentences involving multiple conjunctive ("and") and disjunctive ("or") statements can be interpreted in multiple ways. When one hears such a sentence, the hearer uses an implicit *order of operations* to process the conjunctions and disjunctions, which may not be the same as that intended by the speaker.

This has implications for the teaching and learning of mathematics. When teaching logical operations, we often use parentheses to make clear the intended order of the operations $\wedge$ and $\vee$. However, parentheses are not used this way in English; we must use other cues when writing English statements that are to be interpreted as logical statements, and make sure that our students are interpreting these cues they way we intend them to. In particular, we must be sensitive to the fact that non-native English speakers may interpret such cues differently than native speakers.

The words "and" and "or" are used in combinatorics problems, and the interpretation of these words is necessary to arrive at the intended answer. In this talk, I will discuss preliminary results from a study of the interpretation of complex sentences with advanced mathematics students in a combinatorics class, and discuss implications for teaching. (Received August 14, 2015)

1114-97-98 **Mihaela B Vajiac*** (mbvajiac@chapman.edu), Schmid College of Science, Chapman University, One University Dr, Orange, CA 92866. *Geometric Loci, a primer for understanding proofs.*

In this talk I will describe the importance of geometric loci as gateway to deeper understanding of proof methods. In this context, geometric loci constitute perfect examples of the danger of tautologies in proof-writing. I have been using these methods in several summer camps dedicated to problem solving techniques in a mathematical competition setting, as well as at the program organized by the mathematics department at California Sate University at Fullerton.
(Received August 14, 2015)

1114-97-139 **Joshua H Park*** (jpark1050@gmail.com), 13342 Portal, Tustin, CA 92782. *Selected Problems from the Fullerton Mathematical Circle.* Preliminary report.

This presentation includes a few solutions given to interesting problems posed during the Fullerton Mathematical Circle's sessions. One of the questions explores a best constant double inequality inspired from the study of the ladder of means and of the Engel's Lemma. The other solutions reflect the author's interest in various problem solving strategies in algebra. (Received August 21, 2015)

1114-97-145 **Scott Baldridge*** (sbaldrid@math.lsu.edu), 380 Lockett Hall, Department of Mathematics, Baton Rouge, LA 70803. *Elementary Mathematics for Teachers: Using K-8 Math Curricula to Teach Teachers.*

This talk describes a mathematics course, designed by mathematicians, for prospective elementary teachers. We will describe three unique features of the course: the extensive use of a K-8 mathematics curriculum, the idea of a "Teaching Sequence," and the use of "Teacher's Solutions" in class and in homework. The goal of the course and its two textbooks (by T. Parker and S. Baldridge) is to present elementary mathematics clearly and coherently while keeping the focus directly on the material that teachers address, grade by grade, in their classrooms.

This approach overcomes many of the practical challenges that university mathe- matics departments face in teaching such courses. (Received August 22, 2015)

1114-97-151 **Phillip Ramirez*** (philramirez3@csu.fullerton.edu), 800 N State College Blvd, 154 McCarthy Hall, Department of Mathematics CSUF, Fullerton, CA 92620-0290, and **Bogdan D Suceavă** (bsuceava@fullerton.edu), 800 N. State College Road, 154 McCarthy Hall, Department of Mathematics CSUF, Fullerton, CA 92620-0290. *The Mathematical Circle as a Training Ground for Pre-Service Teachers.*

The concept of the Fullerton Mathematical Circle is inspired from similar activities done in Central Europe over the last century with Universities offering enrichment programs to interested young gifted mathematicians. The project consists of offering mathematical sessions for gifted middle school and high school students. Most of the events are facilitated by the pre-service teachers studying in our program at Cal State Fullerton. We will illustrate the content of these sessions and describe how beneficial this model is for our pre-service teachers'

development. We will show how our sessions inspired published works (e.g. Kelly A. Hartmann's book review to {*Mathematics Circle Diaries, Year 1: Complete Curriculum for Grade 5 to 7 By Anna Burago,*} *The Mathematical Intelligencer, September 2014) and how this model could be replicated in other academic programs.* *(Received August 23, 2015)*

1114-97-153 **Jennifer E Clinkenbeard***, jclinkenbeard@fullerton.edu. *Attitudes and Experiences in Liberal Arts Mathematics.*

For many university students, the last formal experience in a mathematics classroom is a single semester "general education" math class. Traditionally, students in this type of class often hold negative attitudes towards mathematics. We study a sample of students from this population to research whether a positive experience in a freshman-level general education mathematics course correlates with a positive change in the student's attitude towards math in general. We also explore what specific aspects of such a course contribute most to a positive student experience. The results show that while a positive experience in a freshman-level general education mathematics course correlates with positive responses in the student's attitude about several key variable components of attitude (including motivation to do math, perceived usefulness of math, and confidence while doing math), it does not correlate with positive change. We then investigate the implications of this finding with respect to math identity among liberal arts majors. (Received August 23, 2015)

1114-97-154 **Ami Radunskaya*** (aer04747@pomona.edu), Mathematics Department, Pomona College, Claremont, CA 91711. *Math classes with strings attached.*

Many mathematical constructs can be manifested as sounds. As teachers, we are familiar with visual representations of mathematical ideas. The visual palette is three or dimensional, or four if you include color; in some ways, the sonic palette is richer. Our ears can perceive along many axes, including pitch, loudness, timbre, harmonic complexity and time. I have found it effective to use sonic demonstrations in many of my undergraduate classes. In this talk, I will show how a 'cello can be used to demonstrate ideas from calculus, differential equations, and dynamical systems. For example, why is the "harmonic" series called by this name? Can we hear that the harmonic series diverges? More to the point of this talk: can we hear it with only four strings?

For other examples of "mathematical ideas with strings attached", please come to the talk. (Received August 23, 2015)

1114-97-159 **Alison S. Marzocchi*** (amarzocchi@fullerton.edu). *Pushing Mathematics Content Courses for Elementary Pre-Service Teachers beyond Elementary Mathematics Content.*

The presenter will share strategies for teaching elementary mathematics content courses for pre-service teachers (PSTs) so that the course is not simply re-delivery of elementary mathematics content. Under this course model, the PSTs are supported in reviewing the content on their own so that they are arriving to the class session with (at least) a procedural understanding of the week's materials. This allows valuable class time to be spent on developing the PSTs' conceptual understanding of the material through strategies such as predicting multiple student solutions, assessing the validity of student responses, problem posing, etc. Essentially, the classroom norms establish that it is not sufficient for the PSTs to simply be able to solve the problems for themselves, but to instead understand it more deeply so that they are able to explain it to others. This model aligns with many of the Common Core Standards for Mathematical Practice such as "making sense of problems and persevering in solving them" and "constructing viable arguments and critiquing the reasoning of others." (Received August 24, 2015)

1114-97-179 **Gizem Karaali*** (gizem.karaali@pomona.edu), Claremont, CA 91711. *Can Zombies Write Mathematical Poetry? Mathematical Poetry as a Model for Humanistic Mathematics.*

Mathematics is a creative endeavor, but mathematicians and mathematics instructors often have difficulty convincing others of this fact. In fact most people who are not already oriented toward mathematics fail to notice that mathematics is a perfect model for what makes an activity human, as it involves the three main ingredients of what makes our species special: Cognition, consciousness, and creativity. In this note I share some thoughts on the creative component of mathematics and propose that mathematical poetry is a perfect model and ambassador for a more humanistic understanding of mathematics. (Received August 25, 2015)

1114-97-211 **Olga Radko*** (radko@math.ucla.edu). *Los Angeles Math Circle: My Favorite Topic(s).*

Los Angeles Math Circle is a free weekly enrichment program for over 220 students in grades 1-12 hosted by UCLA. A special feature of the program is that it surves as a training ground for a significant number UCLA's graduate and undergraduate students actively involved in all aspects of its operation.

After giving a short overview of our math circle, I will present some of my favorite topics for different grade levels and discuss how to come up with other engaging and mathematically stimulating subjects that go beyond (and somewhat perpendicular to!) the usual school curriculum. (Received August 27, 2015)

1114-97-248 **Darryl H Yong*** (dyong@hmc.edu), 301 Platt Blvd, Claremont, CA 91711. *Radical Inclusivity in the Mathematics Classroom.*

Mathematicians are a less diverse group of people than they should be and want to be. Outreach programs are vital to broadening participation in the mathematical sciences, but we also need pay more attention to the thing we higher education mathematicians all do: teach mathematics. Perhaps focusing on universal design for learning and attending to basic human needs (safety, belonging, and affirmation) might be the keys to creating a radically inclusive classroom environment. That welcoming classroom environment might in turn lead to the diversity that we desperately need. (Received August 29, 2015)

1114-97-251 **Todd CadwalladerOlsker*** (tcadwall@fullerton.edu). *If Mathematical Induction is Aspirin, How Do You Create the Headache?* Preliminary report.

In the summer of 2015, math education blogger Dan Meyer wrote a series of posts with titles of the form, "If [A Mathematical Topic] is Aspirin, How Do You Create the Headache?" These posts examined ways to create *intellectual need* (a term coined by Guershon Harel) in students learning high school mathematics topics. In this talk, I will present some of the current literature on intellectual need, and my efforts to train preservice teachers to think about intellectual need when teaching proof by mathematical induction. (Received August 29, 2015)

1114-97-253 **Martin V. Bonsangue*** (mbonsangue@fullerton.edu), 800 N. State College Blvd., Fullerton, CA 92831, and **Thomas Duarte** (duarte_t@auhsd.us) and **Susanna Meza** (szmsuez@gmail.com). *Co-teaching as an Alternative Model for Mathematics Teacher Preparation.*

Co-teaching is emerging as an alternative to the traditional student teaching experience. In the co-teaching model, teacher candidates work in equal classroom partnership with the cooperating (master) teacher from the beginning of the semester using several different classroom structures. While reports on co-teaching models based generally on K-5 and special education classes have indicated positive results, there has been limited research of co-teaching models at the secondary level, particularly in mathematics classes. This session discusses the implementation of a co-teaching model at a high-need high school in southern California in foundational level mathematics courses. The session concludes with implications for teacher training and directions for further research. (Received August 29, 2015)

1114-97-300 **Milé Krajcevski*** (mile@mail.usf.edu), Department of Mathematics and Statistics, University of South Florida, CMC 342, 4202 East Fowler Av., Tampa, FL 33620, and **Ruthmae Sears** (ruthmaesears@usf.edu). *Pre-Service Teachers' Misconceptions About Visual Representations of Altitude, Median and Angle Bisector of a Triangle.* Preliminary report.

Visual representations of mathematical notions are prevalent in geometry written and enacted curriculum and has been an integral part of the process of learning geometry. The representations help to make connections between concrete and abstract ideas and often guide our intuition in solving a given problem. In this talk we describe misconceptions pre-service middle school mathematics teachers exhibited when analyzing the relations between altitude, median and angle bisector in a triangle. Subsequently, we will provide instructional recommendations that can address misconceptions identified, and reflect on other incorrect interpretations of images when teaching geometry. (Received August 31, 2015)

1114-97-328 **Zvezdelina E Stankova*** (stankova@mills.edu), 5000 MacArhur Blvd, Oakland, CA 94613. *From the US School Reality to the Successful Math Circle: Is There Something in between?* Preliminary report.

What stands between a successful math circle and the school reality of the surrounding neighborhood? The Berkeley Math Circle, for example, one of the oldest math circles in the US, has grown to 500 students in 12 sessions every week on UCB campus, hosted by three departments of the university. What makes the circle so successful also makes it hard to sustain. Can the circle continue in its present form, or should it change? Can the circle help revamp the school curriculum to bring it to the level required for successful participation in the circle sessions? We shall examine these questions in the context of the ever evolving, sometimes aspiring, and often contradicting movements in the math curriculum in the K-12 public and private schools throughout the Bay Area. (Received September 01, 2015)

1114-97-329 **Kyle Kishimoto*** (kylemoto@yahoo.com), Department of Mathematics, CSUF, 154 McCarthy Hall, Fullerton, CA 92620-0290. *Applications of Differential Calculus Techniques to Fundamental Questions in Algebra.*

Many algebra problems can be approached from an advanced viewpoint. In our presentation we explore various solutions that are incorporating real analysis ideas and techniques, with the goal of reaching a more profound understanding of the mathematical phenomena behind each of the questions under investigation. Some of the applications use the First Derivative Test, others use Second Derivative Test and the study of convexity, while others are applications of multivariable calculus techniques in investigating extrema. Some of the problems we discuss in our talk are recently published by Gazeta matematica, a journal established in 1895. (Received September 01, 2015)

1114-97-333 **Jolene Fleming*** (jofleming@fullerton.edu). *Supporting Pre-Service Teachers: From Tutor to Teacher.*

In order to foster the mathematical, professional, and personal growth of our pre-service teachers at California State University, Fullerton, we offer a sequence of employment opportunities within our department. After completing the first semester of calculus, pre-service teachers begin as tutors in the math department tutoring center. Next, they serve as Supplemental Instruction (SI) leaders. Lastly, we are beginning to offer the additional resource of completing a mentorship with an experienced teacher. This sequence allows pre-service teachers to develop mathematical communication skills early, collaborate with peers throughout, experience first-hand teaching strategies of a mentor teacher, and participate in the mathematics department and overall community. The impact on teachers will be shared, both from first-hand experience and participant comments. (Received September 01, 2015)

1114-97-334 **Adrian I Vajiac*** (avajiac@chapman.edu), One University Drive, Orange, CA 92866. *Discovering Geometry: An Axiomatic Approach.*

In this talk I am analyzing the methods and the implementation of the geometry book with the same title, written in collaboration with W. G. Boskoff, into a General Education curriculum.

The main idea that motivated us to write this work is the important educational content lying within Hilbert's axiomatic system. In this spirit, we wrote a focused presentation, relying on this approach, whose aim is to address the topic to the contemporary students. Our material is designed primarily as an introduction to the subject of axiomatic geometry. The originality of this approach consists in inviting the reader to self-discover and build Geometry from scratch, without the need for defining sophisticated mathematical prerequisites.

In the end I am including a brief assessment of the implementation of this method into GE, major and Honors courses for over a decade. (Received September 01, 2015)

1114-97-356 **Diana White*** (diana.white@ucdenver.edu), 1201 Larimer St., Suite 4118, Denver, CO 80204. *Math Circles - Mathematicians Fostering Habits of Mind in K12 Teachers and Students.*

Part of a growing trend of mathematical outreach programs by mathematics departments and mathematics professionals, Math Circles are a unique form of outreach in which mathematics professionals share their passion for mathematics with K-12 teachers and students in contexts that emphasize the problem solving and discovery aspects of mathematics. Ideal Math Circle problems are low-threshold, high-ceiling; they offer a variety of entry points and can be approached with minimal mathematical background, but lead to deep mathematical concepts and can be connected to advanced mathematics. This talk will provide an overview of Math Circles and their rapid growth, using specific examples to focus on the attributes of particularly effective problems. Through an interactive discussion, we address why Math Circles are an ideal form of informal mathematics education, and why they are a particularly suitable entry point for mathematicians interested in working with K-12 students or teachers. We conclude by sharing resources available to those interested in getting involved with Math Circles or K12 outreach more broadly. (Received September 01, 2015)

1114-97-357 **David L Pagni** (dpagni@fullerton.edu), California State University, Fullerton, Department of Mathematics, 800 No. State College Blvd, Fullerton, CA 92834, and **Cherie Ichinose*** (cichinose@fullerton.edu), California State University, Fullerton, Dept. of Mathematics, 800 No. State College Blvd., Fullerton, CA 92834. *Preparing High School Mathematics Teachers in a University Mathematics Department.*

Cal State Fullerton offer a major in mathematics with a Teaching Concentration. We will share how the pre-service teachers are advised, mentored, and prepared to become high school mathematics teachers prior to and after entering the teaching credential program. (Received September 01, 2015)

00 ► General

1115-00-215 **Xiaoju Xie*** (sophia.xie@okstate.edu). *Expected number of real zeros of random orthogonal polynomials.*

We study the expected number of real zeros for random linear combinations of orthogonal polynomials. It is well known that Kac polynomials, spanned by monomials with i.i.d. Gaussian coefficients, have only $(2/\pi+o(1))\log n$ expected real zeros in terms of the degree n. On the other hand, if the basis is given by Legendre (or more generally by Jacobi) polynomials, then random linear combinations have $n/\sqrt{3}+o(n)$ expected real zeros. We prove that the latter asymptotic relation holds universally for a large class of random orthogonal polynomials on the real line, and also give more general local results on the expected number of real zeros. This is a joint work with Doron S. Lubinsky and Igor E. Pritsker. (Received September 18, 2015)

03 ► Mathematical logic and foundations

1115-03-198 **Allen Gehret*** (agehret2@illinois.edu), 1409 W. Green Street, Urbana, IL 61801. *Towards a Model Theory for Logarithmic Transseries.*

The ordered valued differential field $\mathbb{T}$ of *logarithmic-exponential transseries* has recently been shown (by the authors of [1]) to have a good model theory, completing much of the program described in [1]. There it was also conjectured that the subfield $\mathbb{T}_{\log}$ of $\mathbb{T}$ of *purely logarithmic transseries* would also have a good model theory (model-completeness, NIP, etc.). In this talk I will report on my work on the model theory of $\mathbb{T}_{\log}$.

References

[1] Matthias Aschenbrenner, Lou van den Dries, and Joris van der Hoeven, *Towards a model theory for transseries*, ***Notre Dame Journal of Formal Logic***, vol. 54 (2013), no. 3-4, pp. 279–310.

(Received September 17, 2015)

1115-03-258 **Sylvy Anscombe*** (sanscombe@uclan.ac.uk), Jeremiah Horrocks Institute, Leighton Building, Le7, University of Central Lancashire, Preston, PR1 2HE, United Kingdom, and **Arno Fehm** (arno.fehm@uni-konstanz.de), Universität Konstanz, Fachbereich Mathematik und Statistik, Fach 203, 78457 Konstanz, Germany. *Characterizing diophantine henselian valuation rings and valuation ideals.*

In this talk, I will report on joint work with Arno Fehm in which we give a characterization, in terms of the residue field, of those henselian valuation rings and those henselian valuation ideals that are diophantine. This characterization gives a common generalization of all the positive and negative results on diophantine henselian valuation rings and diophantine valuation ideals in the literature. We also treat questions of uniformity.

This may be seen as an application of our other work (on the existential theory of equicharacteristic henselian valued fields), which is the subject of a separate talk by Arno Fehm. (Received September 20, 2015)

05 ► Combinatorics

1115-05-37 **Jaewoo Lee*** (jalee@bmcc.cuny.edu), Department of Mathematics, Borough of Manhattan Community College, 199 Chambers Street, New York, NY 10007. *A Proof of Khovanskii's Theorem on Geometry of a Sumset and Its Convex Hull.*

Khovanskii wrote a paper on how a sumset grows geometrically. In particular, he showed how iterated sumsets grow within their convex hulls, although his proof contained a gap. We will present a new proof of his theorem. This theorem will tell us how we can approximate integral points within a polytope using sumsets. (Received August 20, 2015)

1115-05-40 **Grady Weyenberg**, City of Bristol, United Kingdom, **Ruriko Yoshida***, 725 Rose Street, Lexington, KY , and **Daniel Howe**, Lexington. *Normalizing kernels in the Billera-Holmes-Vogtmann treespace.*

As costs of genome sequencing have dropped precipitously, development of efficient bioinformatic methods to analyze genome structure and evolution have become ever more urgent. For example, most published phylogenomic studies involve either massive concatenation of sequences, or informal comparisons of phylogenies inferred on a small subset of orthologous genes, neither of which provides a comprehensive overview of evolution or systematic identification of genes with unusual and interesting evolution. We are interested in identifying such "outlying" gene trees from the set of gene trees and estimating the distribution of the tree over the "tree space". This talk describes an improvement to the kdetrees algorithm, an adaptation of classical kernel density estimation to the metric space of phylogenetic trees (Billera-Holmes-Vogtman treespace), whereby the kernel normalizing constants, are estimated through the use of the novel holonomic gradient methods. As the original kdetrees paper, we have applied kdetrees to a set of Apicomplexa genes and it identified several unreliable sequence alignments which had escaped previous detection, as well as a gene independently reported as a possible case of horizontal gene transfer. (Received August 24, 2015)

1115-05-43 **Rebecca Patrias*** (patri080@umn.edu) and **Pavlo Pylyavskyy**. *Dual filtered graphs.*

Using the Hecke insertion algorithm of Buch-Kresh-Shimozono Tamvakis-Yong, we define a K-theoretic analogue of Fomin's dual graded graphs called dual filtered graphs. The key formula in the definition is $DU - UD = D + I$. We discuss two main constructions of dual filtered graphs: the Mobius construction, which corresponds to natural insertion algorithms, and the Pieri construction, which is an algebraic construction. This is work with Pavlo Pylyavskyy. (Received August 24, 2015)

1115-05-57 **Gabe Cunningham*** (gabriel.cunningham@gmail.com). *Tight chiral polyhedra.*

A chiral polyhedron with Schläfli symbol $\{p, q\}$ is called *tight* if it has $2pq$ flags, which is the minimum possible. In this paper, we fully characterize the Schläfli symbols of tight chiral polyhedra. We also provide presentations for the automorphism groups of several families of tight chiral polyhedra. (Received September 02, 2015)

1115-05-68 **William Gasarch** and **Naveen J Raman*** (nav.j.raman@gmail.com), 15510 Villisca Terrace, Derwood, MD 20855. *Three Results on making change (An Exposition).*

Let $a_1 < \cdots < a_L$ where $a_1, \ldots, a_L$ be relatively prime. Let $M = LCM(a_1, \ldots, a_L)$ and $M' = LCM(GCD(a_1, a_2), GCD(a_1, a_3), \ldots, GCD(a_{L-1}, a_L))$. Assume that $a_1, \ldots, a_L$ are denominations of coins. Let $CH(n)$ be the number of ways to make change of n cents. We give a unified exposition of the following three known results: (1) For all $0 \leq b \leq M-1$ if $CH(n)$ is restricted to $n \equiv b \pmod{M}$ then $CH(n)$ is a polynomial; (2) For all $0 \leq b \leq M'-1$ if $CH(n)$ is restricted to $n \equiv b \pmod{M}'$ then $CH(n)$ is a polynomial except for the constant term; (3) $CH(n) = \frac{n^{L-1}}{(L-1)!a_1 a_2 \cdots a_L} + O(n^{L-2})$. (Received September 04, 2015)

1115-05-69 **Hao Wu***, Department of Mathematics, George Washington University, Monroe Hall, Room 240, 2115 G Street, NW, Washington, DC 20052. *Incidence relations and directed cycles.*

Incidence relations have been used extensively in knot theory to study directed graphs arisen from resolving oriented links. We generalize these relations to arbitrary directed links and use them to define a projective algebraic set for each directed graph. As an application, we show that a directed graph contains a directed cycle if and only if its projective algebraic set is non-empty. Moreover, the dimension of this projective algebraic set provides an upper bound for the number of edge-disjoint directed cycles. (Received September 04, 2015)

1115-05-76 **Mark Goresky***, School of Math, Institute for Advanced Study, 1 Einstein Drive, Princeton, NJ 08540. *Topological approaches to complexity of Boolean functions.* Preliminary report.

This is a preliminary report on joint work with Anders Björner and Robert MacPherson. The complexity of a Boolean function $F : \{0,1\}^n \to \{0,1\}$ can be measured by the size of a binary circuit (with n inputs) that produces the function. There are 2^{2^n} different Boolean functions which implies that most functions have exponential circuit complexity. And yet, no explicit sequence of functions is known with circuit complexity greater than n^3. In an effort to study this phenomenon we suggest several ways to associate a topological space $X(F)$ to each Boolean function, with the hopes that the size of the homology $H_*(X(F))$ may provide a handle on the complexity of F. (Received September 05, 2015)

1115-05-87 **Michael Robert Yatauro*** (mry3@psu.edu), 25 Yearsley Mill Rd., Media, PA 19063. *The Unreliability of Paths in the Neighbor Component Order Edge Connectivity Network Model.*

Let G be a finite simple graph. Consider a model in which edges of G fail independently, and when an edge fails we remove it from G along with the incident vertices. We say that a set of edges F is a *failure set* of G if after all edges of F fail, each component of the induced subgraph contains at most $k-1$ vertices, for some prescribed $k > 0$. We define the *neighbor component order edge connectivity* to be the cardinality of a smallest failure set. If the edges fail with probability ρ, then the *unreliability* of G, denoted $u_k(G, \rho)$, is the probability that a randomly selected set of edges is a failure set. Let P_n be the path on n vertices. We will prove a general recursive formula on n for $u_k(P_n, \rho)$ that holds for any fixed k and ρ. (Received September 07, 2015)

1115-05-91 **Wayne Goddard***, goddard@clemson.edu. *Colorings of Graphs without Rainbow or Monochromatic Subgraphs.*

For a coloring of the vertices of a graph, we say that a subgraph is rainbow if all its vertices receive different colors and that it is monochromatic if all its vertices receive the same color. For example, a coloring is proper if and only if every K_2 is rainbow. In this talk we consider colorings that forbid some rainbow subgraph and/or some monochromatic subgraph. For example, we show that for any maximal outerplanar graph on n vertices, the maximum number of colors in a coloring without a rainbow K_3 is always $\lfloor n/2 \rfloor + 1$. Includes joint work with Kirsti Wash and Honghai Xu. (Received September 08, 2015)

1115-05-121 **Siddhartha Sahi*** (sahi@scarletmail.rutgers.edu). *Higher binomial coefficients: some results and conjectures.*

Ordinary binomial coefficients $\binom{l}{m}$ are Taylor coefficients of the monomial x^l at $x = 1$. They are special values of the following degree m polynomial, which is characterized by the conditions $p_m(i) = \delta_{im}$ for $i \leq m$:

$$p_m(s) = s(s-1)...(s-m+1)/m!.$$

Finally, if B and A are the $\mathbb{Z}_{\geq 0} \times \mathbb{Z}_{\geq 0}$ matrices of binomial coefficients and "adjacent" binomial coefficients

$$b_{lm} = \binom{l}{m}, \quad a_{lm} = \begin{cases} l & \text{if } l = m+1 \\ 0 & \text{otherwise} \end{cases};$$

then we have the remarkable identity $\exp(A) = B$.

It turns out that all three approaches can be generalized to several variables, with the monomials x^l replaced by Jack polynomials and Macdonald polynomials P_λ, and they lead to the *same* notion of higher binomial coefficient $\binom{\lambda}{\mu}$. We will describe the main results and formulate some conjectures and open problems. (Received September 12, 2015)

1115-05-139 **Peter A Brooksbank*** (pbrooksb@bucknell.edu), Department of Mathematics, Bucknell University, 1 Dent Drive, Lewisburg, PA 17837. *Polytopes of high rank for linear groups.*

In a 2011 paper, Fernandes and Leemans showed that for each $n \geq 4$ and each integer $r \in \{3, \ldots, n-1\}$ there is an abstract regular r-polytope with automorphism group S_n. In particular, given $r \geq 3$, for each $n > r$ there is an abstract regular r-polytope, $\mathcal{P}_r(n)$ with $\mathrm{Aut}(\mathcal{P}_r(n)) \cong S_n$. It is reasonable to ask whether an analogous result holds for families of linear groups (or their projective variants). As these groups come in 2-parameter families, one can formulate the question in different ways. For instance: *given $r \geq 4$, is there an infinite family of almost simple linear groups, $G(\mathbb{F}_q)$, of fixed Lie rank, and associated family $\mathcal{P}_r(\mathbb{F}_q)$ of abstract regular r-polytopes, such that* $\mathrm{Aut}(\mathcal{P}_r(\mathbb{F}_q)) \cong G(\mathbb{F}_q)$*?*

In this talk I will survey known results and constructions for linear groups in dimensions 2 and 3. I will also present a new construction of a family of 4-polytopes for $\mathrm{PSL}(4, \mathbb{F}_q)$ (whenever the field $\mathbb{F}_q$ has odd order). The latter is joint work with D. Leemans. (Received September 13, 2015)

1115-05-152 **Oliver Pechenik**, Math Dept., 1409 W. Green Street, Urbana, IL 61801, and **Alexander Yong***, Math Dept., 1409 W. Green Street, Urbana, IL 61801. *Genomic tableaux and Equivariant K-theory of Grassmannians.*

I will discuss a tableau rule for equivariant K-theory of Grassmannians. The proof is based on a generalization of Schützenberger's jeu de taquin. This rule is used to resolve the puzzle conjecture of A. Knutson–R. Vakil and a different tableau conjecture of H. Thomas–A. Yong. While this is a continuation of Oliver Pechenik's talk, it will be largely self-contained. (Received September 14, 2015)

1115-05-155 **Oliver Pechenik*** (pecheni2@illinois.edu) and **Alexander Yong** (ayong@uiuc.edu). *Knutson-Vakil puzzles compute equivariant K-theory of Grassmannians.*

Puzzles are combinatorial objects introduced by A. Knutson and T. Tao in their solution of the Horn problem on eigenvalues of Hermitian matrices. By work of A. Knutson and R. Vakil, puzzles are known to encode

certain geometric degenerations relevant to the Schubert calculus of Grassmannians. In 2005, A. Knutson and R. Vakil used puzzles to conjecture the first combinatorial rule for the Schubert structure coefficients in the torus-equivariant K-theory of Grassmannians. We resolve this conjecture by relating it to our recent tableau rule for the same coefficients. (Received September 14, 2015)

1115-05-156 **Burcu Canakci**, **Hannah Christenson**, **Robert Fleischman**, **William Gasarch**, **Nicole McNabb*** (nmcnabb1@swarthmore.edu) and **Daniel Smolyak**. *Using SAT Solvers to find Ramsey-type Numbers.* Preliminary report.

We created and parallelized two SAT solvers to find new bounds on some Ramsey-type numbers.

For $c > 0$, let $L(c)$ be the least n such that for all c-colorings of the $n \times n$ lattice grid there will exist a monochromatic right isosceles triangle forming an L. It is known that $L(2) = 5$. Using a known proof that $L(c)$ exists we obtained $L(3) \leq 2593$. We formulate the $L(c)$ problem as finding a satisfying assignment of a boolean formula. Our parallelized probabilistic SAT solver run on an 8-core virtual machine cluster found a 3-coloring of 20×20 with no monochromatic L's, giving $L(3) \geq 21$.

We also searched for new computational bounds on two polynomial van der Waerden numbers, which we denote to be the "van der Square" number ($VDS(c)$) and the "van der Cube" number ($VDC(c)$). $VDS(c)$ is the smallest positive integer n such that for a given $c > 0$, for all c-colorings of $\{1, \ldots, n\}$ there exist two integers of the same color that are a square apart. $VDC(c)$ is defined analogously with cubes. For $c \leq 3$, $VDS(c)$ was previously known. Our parallelized deterministic SAT found the $VDS(4) = 58$. Our parallelized probabilistic SAT found $VDS(5) > 180$, $VDS(6) > 333$, and $VDC(3) > 521$. All of these results are new. (Received September 14, 2015)

1115-05-158 **Margaret A. Readdy*** (readdy@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506, and **Yue Cai** (yue.cai@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *q-Stirling numbers: A new view.*

We show the classical q-Stirling numbers of the second kind can be expressed more compactly as a pair of statistics on a subset of restricted growth words. The resulting expressions are polynomials in q and $1 + q$. We then extend this enumerative result via a decomposition of a new poset whose rank generating function is the q-Stirling number $S_q[n, k]$. We call this poset the Stirling poset of the second kind. This poset supports an algebraic complex and a basis for integer homology is determined. A parallel enumerative, poset theoretic and homological study for the q-Stirling numbers of the first kind will also be presented. Time permitting, we will indicate a bijective argument showing orthogonality of the (q, t)-Stirling numbers of the first and second kind, as well as some new work involving the major index. (Received September 14, 2015)

1115-05-174 **James Lepowsky*** (lepowsky@math.rutgers.edu). *Some current developments on "motivated proofs" of generalized Rogers-Ramanujan identities.*

I will survey a number of recent developments on "motivated proofs" of families of partition identities of Rogers-Ramanujan type, including work of B. Coulson, S. Kanade, R. McRae, F. Qi, M. Russell, S. Sadowski, A. Sills and myself. These proofs extend, in surprising ways, the "motivated proof" of the original Rogers-Ramanujan identities by G. Andrews and R. Baxter and its generalization by M. Zhu and myself. Such proofs play an interesting role in the long-term interaction between the representation theory of vertex operator algebras and the theory of partition identities. (Received September 15, 2015)

1115-05-179 **Matthew J Willis***, mwillis1@conncoll.edu. *Connecting type A Demazure character formulas.*

In type A Lie theory, a Demazure character is determined by a partition (dominant weight) and a permutation (Weyl group element). There are several methods to compute Demazure characters. Of particular interest here are a semistandard tableaux description attributed to Lascoux and Schützenberger, and a formula derived from the alcove path model of Lenart and Postnikov. The former is based off a "right key" tableau computation, while the latter computes saturated chains in the Bruhat order. We show that the outputs of these methods are equivalent via an intermediate equality with the "scanning tableau" introduced by this author. (Received September 16, 2015)

1115-05-211 **Mark Shattuck*** (shattuck@math.utk.edu), Knoxville, TN 37919. *Pattern Avoiding Set Partitions and Sequence A005773.*

Let L_n, $n \geq 1$, denote the sequence which counts the paths from the origin to the line $x = n - 1$ using $(1, 1)$, $(1, -1)$, and $(1, 0)$ steps that never go below the x-axis (sometimes called *extended Motzkin paths* or *Motzkin left factors*). The L_n count, among other things, certain restricted subsets of permutations and Catalan paths and

occur as entry A005773 in OEIS. Here, we provide new combinatorial interpretations for these numbers in terms of partitions of finite sets by identifying four classes of partitions, each avoiding two classical patterns of length four, that are enumerated by the sequence L_n. Our proof in a couple of cases is combinatorial and identifies bijections between the class of partitions in question and extended Motzkin paths. In the two other cases, our proof is analytic and makes use of the kernel method to solve functional equations which are satisfied by the generating functions. We also give some further results concerning the avoidance of multiple patterns by finite set partitions. (Received September 18, 2015)

1115-05-216 **Jennifer Morse*** (morsej@math.drexel.edu), 3141 Chestnut Street, Philadelphia, PA 19104. *Colorful combinatorics of equivariant K-theory and Macdonald polynomials.*

We introduce a combinatorial family of colored gears and two associated statistics, one of which extends the Lascoux-Schützenberger charge. We prove that the weight generating functions with respect to these statistics are symmetric Macdonald polynomials, and that the gears naturally align with a framework for K-theoretic, equivariant Schubert calculus.

Joint work with Ryan Kaliszewski (Received September 18, 2015)

1115-05-230 **Greta Panova*** (panova@math.upenn.edu). *Lozenge tilings with symmetries.*

We will discuss the limiting behavior of various classes of lozenge tilings (also known as: dimer model on the hexagonal lattice/ rhombus tilings of a triangular grid / plane partitions in some cases): lozenge tilings of a hexagon symmetric about a main diagonal (corresponding to symmetric plane partitions) , and centrally symmetric lozenge tilings of a hexagon (self-complementary plane partitions). As the grid size goes to 0, we prove the existence of a limit surface and show Gaussian Unitary Ensemble eigenvalue distribution for the position of the lozenges near a flat boundary. The proofs involve asymptotic analysis of certain moment generating functions, which happen to be Lie group characters. (Received September 19, 2015)

1115-05-232 **alexander berkovich*** (alexb@ufl.edu), Mathematics Department, 358 Little Hall, Gainesville. *On some partitions with restrictions on even/odd indexed odd parts.*

In this talk I discuss some partitions with restrictions on even/odd indexed odd parts.

In particular, I will show that

A(n) = B(n).

Here A(n) is number of partitions of n into distinct parts with all even indexed parts being even, and B(n) is number of partitions of n into distinct parts not congruent to 3 mod 4.

This talk is based on my recent joint work with Ali Uncu. (Received September 19, 2015)

1115-05-237 **Miklos Bona*** (bona@ufl.edu), Department of Mathematics, University of Florida, Gainesville, FL 32611-8105. *Biologically motivated sorting algorithms and log-concavity.*

We survey numerous permutation sorting algorithms that can be motivated by notions of evolutionary distance. Interestingly, all these sorting algorithms seem to lead to logarithmically concave sequences. Some of them are classic sequences, like that of Stirling numbers, some are not, but are known to be log concave, and some are only conjectured to be log concave. A large part of the results were obtained in various collaborative efforts, with Ryan Flynn, Bruce Sagan, Marie-Louise Bruner and Percy Deift. (Received September 20, 2015)

1115-05-238 **Alexander K Woo*** (awoo@uidaho.edu), 875 Perimeter Dr MS 1103, Moscow, ID 83844-1103. *Hultman elements in type B.* Preliminary report.

Given an element w of a Coxeter group W, the inversion arrangement of w is the set of hyperplanes in the reflection representation corresponding to reflections t such that $tw < w$. Hultman-Linusson-Shareshian-Sjöstrand, verifying a conjecture of Postnikov, showed for S_n that the number of regions in the complement of this arrangement is less than or equal to the size of the interval $[id, w]$ in Bruhat order and showed that equality holds when w avoids certain patterns. Hultman generalized this result to an arbitrary Coxeter group, giving a condition for equality in terms of the directed Bruhat graph for w.

The set of permutations giving equality in S_n had previously shown up in work of Gasharov-Reiner and Sjöstrand as the permutations satisfying certain other conditions. We describe ongoing work finding analogues of the Gasharov-Reiner and Sjöstrand conditions, as well as Billey-Postnikov pattern avoidance conditions, for the elements of the hyperoctahedral group (i.e. type B/C) satisfying the Hultman condition. (Received September 20, 2015)

1115-05-241 **Kağan Kurşungöz*** (kursungoz@sabanciuniv.edu), Orta Mh Universite Cd No 27, Orhanli, 34956 İstanbul, Tuzla, Turkey. *Regular Partition - Overpartition identities via Rogers-Ramanujan dissections.* Preliminary report.

We will present partition identities involving regular partitions on one side, and overpartitions on the opposite side. Their short and elementary proofs via series dissections will be given. Then, deeper proofs involving construction of generating functions will be discussed. Open problems will be listed as time allows. (Received September 20, 2015)

1115-05-256 **Michael J Schlosser*** (michael.schlosser@univie.ac.at), University of Vienna, Faculty of Mathematics, 1090 Vienna, Austria, and **Meesue Yoo**. *Elliptic rook and file numbers.*

The theory of rook numbers was introduced by Kaplansky and Riordan in 1946, and since then it has been further studied and developed by many other people. In 1986 Garsia and Remmel introduced a q-analogue of rook numbers on Ferrers boards for which they considered a statistic involving rook cancellation. By utilizing different elliptic weights attached to the cells of a board, together with an elliptic version of rook cancellation, we construct elliptic analogues of rook numbers for any Ferrers board. Our elliptic rook numbers generalize Garsia and Remmel's q-rook numbers by two additional independent parameters a, b, and a nome p, and are shown to satisfy a factorization theorem. Special cases include an elliptic analogue of Stirling numbers of the second kind and an elliptic analogue of Lah numbers. We also provide an elliptic extension of the file numbers on skyline boards, for which we similarly have a factorization theorem. Here, special cases include an elliptic extension of the unsigned Stirling numbers of the first kind, and an elliptic enumeration of labelled forests of rooted trees. We finally give analogous results for perfect matchings, hereby providing an elliptic extension of work by Haglund and Remmel of 2001. This is joint work with Meesue Yoo. (Received September 20, 2015)

1115-05-291 **John Shareshian*** (shareshi@math.wustl.edu) and **Michelle L Wachs** (wachs@math.miami.edu). *Eulerian quasisymetric functions, stellohedra and Eulerian numbers.*

Beautiful identities involving binomial coefficients and Eulerian numbers were proved by Chung-Graham-Knuth and Chung-Graham. These identities have q-analogues involving the major index, as shown by Chung-Graham and Han-Lin-Zeng. We exhibit symmetric function identities, which upon stable principal specialization become the q-analogues mentioned above, thereby generalizing all of the previous results. Of particular interest is a proof of one of these identities, using the Frobenius characteristic to recast the identity as a statement about actions of symmetric groups on the cohomology of toric varieties associated to polytopes known as (dual) stellohedra. (Received September 21, 2015)

1115-05-294 **Anna Weigandt*** (weigndt2@illinois.edu), 1409 W. Green St, Urbana, IL 61801, and **Alexander Yong** (ayong@uiuc.edu), 1409 W. Green St, Urbana, IL 61801. *The Prism tableau model for Schubert polynomials.*

The Schubert polynomials lift the Schur basis of symmetric polynomials into a basis for $\mathbb{Z}[x_1, x_2, ...]$. We suggest the "prism tableau model" for these polynomials. This alternative to earlier results directly invokes semistandard tableaux; it does so as part of a colored tableau amalgam. In the Grassmannian case, a prism tableau with colors ignored is a semistandard Young tableau. Our arguments are developed from the Groebner geometry of matrix Schubert varieties. (Received September 21, 2015)

1115-05-310 **J. Haglund***, 209 S. 33rd. St., Math Dept., University of Pennsylvania, Philadelphia, PA 19104-6395, and **A. Wilson** and **J. Remmel**. *The Combinatorics of the Delta Conjecture.* Preliminary report.

We introduce an extension of the shuffle conjecture, which gives a combinatorial prediction for the character of diagonal harmonics. Our extension involves the Delta operator from Macdonald polynomial theory. We discuss several interesting combinatorial implications of our conjecture, from multi-paramater Catalan sequences to ordered set partitions. (Received September 21, 2015)

1115-05-314 **Emily Sergel Leven*** (esergel@ucsd.edu). *Parking Functions and the Square Paths Conjecture.* Preliminary report.

In 2005, Halgund, Haiman, Loehr, Remmel and Ulyanov conjectured a relation between parking functions and the image of the elementary symmetric function e_n under a certain modified Macdonald polynomial eigenoperator, ∇. This conjecture was refined by Haglund, Morse and Zabrocki in 2012 and proven by Carlsson and Mellit in 2015. A similar (open) conjecture from 2007 by Loehr and Warrington relates $\nabla(p_n)$ to preference functions. Here we connect this conjecture to parking functions using tools from symmetric function theory and enumerative combinatorics. (Received September 21, 2015)

1115-05-321 **Katherine St. John*** (stjohn@lehman.cuny.edu), Department of Mathematics & Computer Science, Lehman College– City University of New York, Bronx, NY 10468. *Spaces of Trees.*

Phylogenies, or evolutionary histories, play a central role in modern biology, illustrating the interrelationships between species, and also aiding the prediction of structural, physiological, and biochemical properties. The reconstruction of the underlying evolutionary history from a set of morphological characters or biomolecular sequences is difficult since the optimality criteria favored by biologists are NP-hard, and the space of possible answers is huge. Phylogenies are often modeled by trees with n leaves, and the number of possible phylogenetic trees is (2n-5)!!. Due to the hardness and the large number of possible answers, clever searching techniques and heuristics are used to estimate the underlying tree. We explore the combinatorial structure of the underlying space of phylogenetic trees, under different metrics, in particular the interplay between tree rearrangement metrics and the Billera-Holmes-Vogtmann (BHV) metric. The former yield discrete metrics while the later results in a space that is CAT(0). (Received September 21, 2015)

1115-05-343 **Jason Behrstock*** (jason.behrstock@lehman.cuny.edu). *Random graphs and applications to Coxeter groups.*

We will present new results on random graphs which are motivated by ideas in geometric group theory. These result, in turn, have applications to Coxeter groups which will also be discussed. Some of this talk will be on joint work with Hagen and Sisto; other parts are joint work with Falgas-Ravry, Hagen, and Susse. (Received September 22, 2015)

1115-05-347 **Federico Ardila***, 1600 Holloway Ave., San Francisco, CA 94132. *Moving robots efficiently using the combinatorics of CAT(0) cubical complexes.*

Given a reconfigurable system X, such as a robot moving on a grid or a set of particles traversing a graph without colliding, the possible positions of X naturally form a cubical complex S(X). When S(X) is CAT(0), we can explicitly construct the shortest path between any two points, for any of the four most natural metrics: distance, time, number of moves, and number of steps of simultaneous moves. In earlier work we showed that CAT(0) cubical complexes are in correspondence with posets with inconsistent pairs (PIPs), so we can prove that a state complex S(X) is CAT(0) by identifying the corresponding PIP. We illustrate this very general strategy with one known and one new example: Abrams and Ghrist's positive robotic arm on a square grid, and the robotic arm in a strip. We then use the PIP as a combinatorial "remote control" to move these robots efficiently from one position to another. This talk is based on joint work with Tia Baker, Hanner Bastidas, César Ceballos, John Guo, and Rika Yatchak. It will assume no previous knowledge of the subject. (Received September 22, 2015)

1115-05-349 **Marston Conder**, **Isabel Hubard** and **Eugenia O'Reilly-Regueiro***, eugenia@im.unam.mx, and **Daniel Pellicer**. *Chiral polytopes with alternating and symmetric automorphism groups.*

Chiral abstract polytopes are those whose automorphism groups have two orbits on flags, with adjacent flags in different orbits. They were first studied by Schulte and Weiss, and for some time the only finite known examples had ranks 3 and 4. Conder, Hubard, and Pisanski constructed examples of rank 5, and later Conder and Devillers constructed finite examples of ranks 6, 7, and 8. At the same time, Pellicer proved the existence of finite chiral polytopes of any rank at least 3.

Some progress has now been made in the construction of finite abstract chiral polytopes with known automorphism groups. We have proved that for all but finitely many n, both A_n and S_n are automorphism groups of chiral 4-polytopes with tetrahedral facets, and are extending this result to larger ranks. (Received September 22, 2015)

1115-05-357 **Hasan Coskun*** (hasan.coskun@tamuc.edu), 2600 S Neal St, Commerce, TX 75429. *Combinatorial Formulas for Certain Multiple Number Sequences.*

Multiple analogues of several families of combinatorial numbers are recently constructed by the author including the bracket function, binomial coefficients, Stirling, Lah, Bell, Bernoulli, Catalan, and Fibonacci numbers in terms of well poised Macdonald functions. In this talk, we present combinatorial formulas for some of these multiple number sequences. (Received September 22, 2015)

1115-05-401 **Lauren L Rose*** (rose@bard.edu), 30 Campus Road, Annandale, NY 12504, and **Ester Gjoni**. *Basis Criteria for Integer Splines on Cycles.* Preliminary report.

We consider splines on a graph G with positive integer edge labels, called generalized splines. For a fixed labeling of G, the set of all such splines forms a module over the integers, with rank the number of vertices of G. Handschy,

Melnick and Reinders have shown that when G is an n-cycle, a triangular basis always exists. We show that any triangular basis has determinant equal to the product of the edge labels divided by their greatest common divisor. More generally, we show that this determinantal criterion is a necessary and sufficient condition for any set of n-cycle splines to form a basis. We conjecture that this criterion is true for arbitrary graphs. (Received September 22, 2015)

1115-05-403 **Quang T Bach** (qtbach@ucsd.edu), **Roshil Paudyal*** (roshil.paudyal@bison.howard.edu) and **Jeffrey Remmel** (remmel@math.ucsd.edu). *A Fibonacci analogue of Stirling numbers.*

In this work, we present a Fibonacci analogue of the Stirling numbers of the first and second kind. If we let $(x)_{\downarrow_0} = (x)_{\uparrow_0} = 1$ and for $k \geq 1$, $(x)_{\downarrow_k} = x(x-1)\cdots(x-k+1)$ and $(x)_{\uparrow_k} = x(x+1)\cdots(x+k-1)$, then the Stirling numbers of the first and second kind are the connections coefficients between the usual power basis $\{x^n : n \geq 0\}$ and the falling factorial basis $\{(x)_{\downarrow_n} : n \geq 0\}$ in the polynomial ring $\mathbb{Q}[x]$. We study the combinatorial properties of Fibonacci analogues, $\mathbf{Sf}_{n,k}$ and $\mathbf{cf}_{n,k}$, of the Stirling numbers which are defined by the equations

$$x^n = \sum_{k=1}^{n} \mathbf{Sf}_{n,k}\ (x)_{\downarrow_{F,k}} \text{ and } (x)_{\uparrow_{F,n}} = \sum_{k=1}^{n} \mathbf{cf}_{n,k}\ x^k$$

where $(x)_{\downarrow_{F,n}} = x(x-F_1)\cdots(x-F_{k-1})$ and $(x)_{\uparrow_{F,n}} = x(x+F_1)\cdots(x+F_{k-1})$ are the Fibonacci analogues of the falling factorial and rising factorial bases. In particular, we develop a new rook theory model to give combinatorial interpretations to the numbers $\mathbf{Sf}_{n,k}$ and $\mathbf{cf}_{n,k}$. (Received September 22, 2015)

11 ► Number theory

1115-11-12 **Tian An Wong*** (twong@gradcenter.cuny.edu). *Sums of zeroes in the Arthur-Selberg Trace Formula.* Preliminary report.

The 'spectral side' of the Arthur-Selberg trace formula for a noncompact reductive group involves certain distributions arising from Eisenstein series. These distributions can be expressed as logarithmic derivatives of automorphic L-functions, which may be rewritten as sums of zeroes of L-functions. This suggests studying the distribution of zeroes of L-functions as distributions occurring in the trace formula. I will describe this method and its applications in the simplest case, which is GL(2). (Received July 01, 2015)

1115-11-59 **Lior Fishman*** (lfishman@unt.edu), 1155 Union Circle, Denton, TX 76203, and **Keith Merrill** and **David Simmons**. *Intrinsic approximation on the Cantor ternary set and De Bruijn sequences.*

Intrinsic approximation on a subset $K \subset \mathbb{R}^d$ refers to approximating irrational points on K by rational points lying on K. In this talk I will introduce some results obtained on intrinsic approximation on the Cantor ternary set related to a question asked by K. Mahler in the 80's. We shall also discuss an interesting connection between this project and De Bruijn sequences. (Received September 02, 2015)

1115-11-67 **Vanessa Reams*** (vanessareams@my.unt.edu), 1155 Union Circle, Denton, TX 76203, and **Lior Fishman** and **David Simmons**. *The Banach-Mazur-Schmidt game.*

We introduce a new mathematical game; the Banach - Mazur - Schmidt game, merging two well known games. We investigate the properties of the game, as well as providing an application to Diophantine approximation theory. (Received September 03, 2015)

1115-11-85 **Manfred Einsiedler**, **Gregory Margulis**, **Amir Mohammadi*** (amir@math.utexas.edu) and **Akshay Venkatesh**. *Effective equidistribution of certain adelic periods.*

We will discuss a quantitative equidistribution statement for adelic homogeneous subsets whose stabilizer is maximal and semisimple. An application to certain equidistribution theorems will also be given. This is a joint work with Einsiedler, Margulis and Venkatesh. (Received September 07, 2015)

1115-11-86 **George E Andrews*** (gea1@psu.edu), Department of Mathematics, Pennsylvania State University, University Park, FL 16802. *Congruences for m-ary partition functions.*

This is a report on joint work with J. Sellers and A. Fraenkel. We denote by b(m,n) the number of partitions of n into powers of m. We denote by c(m,n) the number of partitions of n into powers of m without gaps. We shall completely determine b(m,n) and c(m,n) modulo m. The evaluations will depend only on the m-ary representation of n. (Received September 07, 2015)

1115-11-166 **Katherine E Stange*** (kstange@math.colorado.edu). *Bianchi groups and Apollonian circle packings.*

Let K be an imaginary quadratic field with ring of integers $\mathcal{O}_K$. The Schmidt arrangement of K is the orbit of the extended real line in the extended complex plane under the Mobius transformation action of the Bianchi group $\mathrm{PSL}(2, \mathcal{O}_K)$. The arrangement takes the form of a dense collection of intricately nested circles. Aspects of the number theory of $\mathcal{O}_K$ can be characterised by properties of this picture: for example, the arrangement is connected if and only if $\mathcal{O}_K$ is Euclidean. I'll explore this structure and its connection to Apollonian circle packings. Specifically, the Schmidt arrangement for the Gaussian integers is a disjoint union of all primitive integral Apollonian circle packings. Generalizing this relationship to all imaginary quadratic K, the geometry naturally defines some new circle packings and thin groups of arithmetic interest. (Received September 15, 2015)

1115-11-167 **Ling Long**, **Robert Osburn** and **Holly Swisher*** (swisherh@math.oregonstate.edu), Oregon State University, 368 Kidder Hall, Corvallis, OR 97331. *Proof of a conjecture of Kimoto and Wakayama.*

We prove a congruence conjecture of Kimoto and Wakayama concerning Apéry-like numbers associated to special values of a spectral zeta function. Our proof uses hypergeometric series and p-adic analysis. (Received September 15, 2015)

1115-11-182 **Howard Garland**, **Stephen D. Miller*** (miller@math.rutgers.edu) and **Manish Patnaik**. *Langlands L-functions from Kac-Moody groups?*

I'll give a status update on attempts to generalize the Langlands-Shahidi method (which is one of the primary methods of constructing L-functions and deriving their analytic properties) to the setting of affine Loop groups, and (more generally) to Kac-Moody groups. (Received September 16, 2015)

1115-11-185 **Michael Magee***, michael.magee@yale.edu. *Lattice point count and continued fractions.*

In this talk I'll discuss a lattice point count for a thin semigroup inside $\mathrm{SL}_2(\mathbf{Z})$. It is important for applications that one can perform this count uniformly throughout congruence classes and for arbitrary moduli. The approach to counting is dynamical - with input from both the real and finite places. At the real place one brings ideas of Dolgopyat concerning oscillatory functions into play. At finite places, a rapid mixing property is supplied by expansion of Cayley graphs and injected into the thermodynamical formalism. The expansion of the relevant Cayley graphs was first established by Bourgain and Gamburd (for prime places) and extended to arbitrary moduli by Bourgain and Varjú. Until recently it was only known how to apply these expansion results in the thermodynamical setting for squarefree moduli. Recently (with Bourgain and Kontorovich) a new decoupling method was developed that allowed arbitrary moduli to be treated. As result of all this work, a power saving in the size of the exceptional set in Zaremba's conjecture is now available. This talk is based on joint works with Oh and Winter, and with Bourgain and Kontorovich. (Received September 16, 2015)

1115-11-190 **Baiying Liu***, School of Mathematics, Institute for Advanced Study, Einstein Drive Simonyi Hall, Princeton, NJ 08540. *On cuspidality of global Arthur packets of quasi-split classical groups.*

Based on the theory of endoscopy, Arthur classified the automorphic discrete spectrum of quasi-split classical groups up to global Arthur packets parametrized by Arthur parameters. Towards studying representations in each Arthur packet, a natural question one may ask is that whether a given Arthur packet has cuspidal representations or not. In this talk, I will introduce some recent progress on this aspect, which is based on relations between the structure of Fourier coefficients of automorphic forms in an Arthur packet and the structure of the corresponding Arthur parameter. This work is joint with Dihua Jiang. (Received September 17, 2015)

1115-11-204 **Nelson Carella***, Department of Mathematics, 2155 University Avenue, Bronx, NY 10453. *Primes And Primitive roots.*

Let $u \neq \pm 1, v^2$ be a fixed integer, let $p \geqslant 2$ be a prime, and let $\mathrm{ord}(u) = d|p-1$ be the order of $(u \bmod p)$. This note provides an effective lower bound $\#\{p \leqslant x : \mathrm{ord}(u) = p-1\} \gg x(\log x)^{-1}$ for the number of primes $p \leqslant x$ with a fixed primitive root $(u \bmod p)$ for all large numbers $x \geqslant 1$. The current results in the literature have the lower bound $\#\{p \leqslant x : \mathrm{ord}(u) = p-1\} \gg x(\log x)^{-2}$, and restrictions on the fixed primitive root to a subset of at least three or more integers. (Received September 18, 2015)

1115-11-245 **Krishnaswami Alladi*** (alladik@ufl.edu), Department of Mathematics, 358 Little Hall, University of Florida, Gainesville, FL 32611. *Combinatorial interpretation and proofs of certain partial theta identities.*

Recently, in studies of Hecke-Rogers series and mock theta functions, Frank Garvan found some partial theta identities. We view these identities in terms of a variant of the Rogers-Fine identity, and a generalized Lebesgue identity in Ramanujan's Lost Notebook, and provide both combinatorial interpretations and proofs. (Received September 20, 2015)

1115-11-250 **Xin Zhang*** (xz87@illinois.edu) and **Zeev Rudnick**. *Gap Distribution in Circle Packings.*

Given a configuration of finitely many tangent circles, one can form a packing of infinitely many circles by Möbius inversions. Fixing one circle from such a packing, we study the distribution of tangencies on this circle via the spectral theory of automorphic forms. Specifically, we will use Anton Good's theorem to show that these tangencies are uniformly distributed when naturally ordered by a growing parameter, and the limiting gap distribution exists, which is conformally invariant. This is a joint work with Zeev Rudnick. (Received September 20, 2015)

1115-11-281 **Jonathan Sondow*** (jsondow@alumni.princeton.edu) and **Kieren MacMillan**. *Primary Pseudoperfect Numbers, Arithmetic Progressions, and the Erdős-Moser Equation.*

A *primary pseudoperfect number* (PPN for short) is an integer $K > 1$ that satisfies the equation

$$\frac{1}{K} + \sum_{p|K} \frac{1}{p} = 1,$$

where p denotes a prime. PPNs arise in studying perfectly weighted graphs and singularities of algebraic surfaces, and are related to Sylvester's sequence and Curtiss's bound on solutions to a unit fraction equation.

For *any* PPN K we show that $K \equiv 6 \pmod{6^2}$ if $6 \mid K$, and we uncover a remarkable 7-term arithmetic progression of residues modulo $6^2 \cdot 8$ in the sequence $6, 42, 1806, 47058, 2214502422, 52495396602,$ 84904215835596884107067712610 86 of known PPNs $K > 2$. On that basis, we pose a conjecture which leads to a conditional proof of the new record lower bound $k > 10^{3.99\times 10^{20}}$ on any non-trivial solution to the Erdős-Moser Diophantine equation $1^n + 2^n + \cdots + k^n = (k+1)^n$. Assuming the Riemann Hypothesis, we obtain the slightly better, but doubly conditional, bound $k > 10^{4\times 10^{20}}$.

Our paper is to appear in the *Monthly* in late 2015. A preprint is available at https://db.tt/sJgFqiwF. (Received September 21, 2015)

1115-11-313 **Hamza Yesilyurt*** (hamza@fen.bilkent.edu.tr), Bilkent University, Department of Mathematics, Ankara, Turkey. *Ramanujan's circular summation, t-cores and twisted partition identities.* Preliminary report.

In this talk, we give new evaluations for Ramanujan's circular summation function. We provide simpler proofs for known evaluations and give some generalizations. We will use a theta function related to Ramanujan's circular summation function and give a uniform proof of Ramanujan's partition congruences for the moduli 5, 7 and 11. We also provide simpler proofs for some twisted partition identities found by Rademacher. This is a joint work with Alexander Berkovich and Frank Garvan. (Received September 21, 2015)

1115-11-322 **WEI ZHANG*** (wzhang@math.columbia.edu), 2990 Broadway MC4423, NEW YORK, NY 10027. *The Euler product and the Taylor expansion of an L-function.*

An L-function (from geometry or automorphic form) is a meromorphic function with two expansions: an Euler product expansion and a Taylor expansion (at a suitable point). We will try to give evidence (some elementary, some less obvious) that both should have interesting geometric meaning. (Received September 21, 2015)

1115-11-331 **Tim Huber*** (timothy.huber@utrgv.edu), **Daniel Schultz** and **Dongxi Ye**. *Higher level Ramanujan-Sato series for* $1/\pi$. Preliminary report.

A systematic construction for Ramanujan-Sato expansions from McKay-Thompson series is given. Expansions for large divisors of the order of the Monster are derived, and a uniform interpretation is given for series parameters as generators of invariant function fields for subgroups of $\Gamma_0(n)$. Relations between the generators extend reciprocal identities satisfied by eta quotients and the continued fractions of Rogers-Ramanujan and Göllnitz-Gordon. (Received September 21, 2015)

1115-11-338 **Keith Merrill*** (merrill2@brandeis.edu), Keith Merrill, Brandeis University, Goldsmith Building, Mailstop 050, Waltham, MA 02453, and **Lior Fishman**, **Tue Ly** and **David Simmons**. *A Dirichlet Theorem for Rank 1 Elliptic Curves.*

In this talk we will sketch some recent work about the distribution of rational points on rank 1 elliptic curves, proving a Dirichlet theorem in this setting. We will then discuss future directions, and connections with a conjecture of Waldschmidt. (Received September 21, 2015)

1115-11-342 **Dmitry Kleinbock** and **Tue Ly*** (ltue@brandeis.edu), Brandeis University, MS050, 415 South Street, Waltham, MA 02453. *Badly approximable S-numbers and Schmidt games.*

Let K be a number field, S be the set of all non-conjugate archimedean valuations of K, and $K_S = \prod_{v\in S} K_v$ be the Minkowski space associated with K. Our main interest is the study of Diophantine approximation on K_S, or more specifically, the set BA of badly approximable elements. We will discuss about its connection to dynamics on homogeneous spaces and a variation of Schmidt game that were used to prove the abundance of BA. (Received September 21, 2015)

1115-11-351 **Min Lee*** (min.lee@bristol.ac.uk), Howard House, University of Bristol, Queen's Avenue, Bristol, BS8 1SD, United Kingdom, and **Andrew R Booker** (andrew.booker@bristol.ac.uk), Howard House, University of Bristol, Queen's Avenue, Bristol, BS8 1SD, United Kingdom. *The Selberg trace formula as a Dirichlet series.*

In this talk we explore the idea of Conrey and Li of presenting the Selberg trace formula for Hecke operators, as a Dirichlet series. We present two applications of our formula. First, we derive a statement equivalent to Selberg's eigenvalue conjecture for prime level, in terms of the analytic properties of twists by the quadratic character of the family of Dirichlet series arising from our formula for level 1. Second, we give a formula for an arithmetically weighted sum of the complete symmetric square L-functions associated to cuspidal Maass newforms of square-free level. (Received September 22, 2015)

1115-11-386 **Kei Nakamura*** (kei.nakamura@rutgers.edu). *Apollonian circle packings from Archimedean polyhedra.*

For any convexly realizable combinatorial polyhedron P, we introduce the notion of an Apollonian packing modeled on the polyhedron P. These circle packings should be regarded as natural generalization of the classical Apollonian packing, which arises when P is taken to be a tetrahedron. In this talk, we consider Apollonian packings that are modeled on Archimedean polyhedra. Remarkably, for some of these polyhedra, one can construct Apollonian packings with all constituent circles having integer bends. We examine the arithmetic properties of the set of bends, and discuss the local-global conjecture for these packings. This talk is partly based on joint work with Alex Kontorovich. (Received September 22, 2015)

1115-11-388 **Joseph A Hundley*** (jahundle@buffalo.edu), Department of Mathematics, 244 Mathematics Building, University at Buffalo, Buffalo, NY 14260. *Combinatorics in the constant term.*

We discuss the problem of showing that the initial Laurent coefficient of a Borel Eisenstein series is square integrable. By Langlands square integrability criterion, this translates to a more combinatorial problem about the various intertwining operators which make up the constant term. We describe some analytic and combinatorial results which, in certain special cases relevant to Arthur's unitarity conjecture for real groups, reduce the problem to finite number of checks, readily amenable to computer verification. (Received September 22, 2015)

12 ► Field theory and polynomials

1115-12-73 **Jan Minac*** (minac@uwo.ca), Western University, Department of Mathematics, Middlesex College, London, Ontario N6A 5B7, Canada. *Why I am excited about the use of Massey products in Galois theory (Joint work with Nguyen Duy Tan).* Preliminary report.

I am excited about the use of Massey products in Galois theory because Massey products seem to be efficient tour guides in "Galoisland". They point out explicit, elegant constructions of Galois p-extensions over all fields. They also point out further exciting connections with the Bloch-Kato conjecture and its possible refinements, as well as connections with various techniques from both classical and modern arithmetic, geometry, and topology. I hope to share some of my excitement about these topics with the audience. This is joint work with Nguyen Duy Tan. (Received September 04, 2015)

1115-12-162 **Sylvy Anscombe** and **Arno Fehm*** (arno.fehm@uni-konstanz), University of Konstanz, Fachbereich Mathematik und Statistik, Fach 203, 78457 Konstanz, Germany. *On the existential theory of equicharacteristic henselian valued fields.*

The first order theory of a henselian valued field of residue characteristic zero is well-understood through the celebrated Ax-Kochen-Ershov principle, which states that it is completely determined by the theory of the residue field and the theory of the value group. For henselian valued fields of positive residue characteristic, no such general principle is known. I will report on joint work with Sylvy Anscombe in which we study (parts of) the theory of equicharacteristic henselian valued fields and prove an Ax-Kochen-Ershov principle for existential (and slightly more general) sentences. I will also discuss applications to the existential decidability (Hilbert's tenth problem) of the local field $\mathbb{F}_q((t))$, which was proven by Denef and Schoutens assuming resolution of singularities. Further applications, on definability of henselian valuation rings, are reported on in a separate talk by Sylvy Anscombe. (Received September 15, 2015)

1115-12-177 **Anna Blaszczok*** (anna.blaszczok@us.edu.pl), Institute of Mathematics, University of Silesa, Bankowa 14, 40-007 Katowice, Poland. *On immediate extensions of valued fields.*

A valued field extension is called immediate if the corresponding value group and residue field extensions are trivial. A better understanding of such extensions turned out to be important for questions in algebraic geometry, real algebra and the model theory of valued fields.

We present results which describe the structure of maximal immediate extensions of valued fields. We give conditions for a valued field to admit maximal immediate extensions of infinite transcendence degree. We further answer the question when an infinite algebraic extension (L, v) of a maximal field (K, v) can be again maximal.

We also investigate the problem of uniqueness of maximal immediate extensions. Kaplansky proved that under a certain condition, called "hypothesis A", a valued field admits maximal immediate extensions which are unique up to isomorphism. We study a more general case, omitting one of the conditions of hypothesis A. We describe the structure of maximal immediate extensions of valued fields under such weaker assumptions. We consider also an opposite case and show that there is a class of valued fields which admit an algebraic maximal immediate extension as well as one of infinite transcendence degree. (Received September 16, 2015)

1115-12-202 **Franz-Viktor Kuhlmann*** (fvk@math.usask.ca), Institute of Mathematics, University of Silesia, Bankova 14, 40-007 Katowice, Poland. *Extremal fields and tame fields.*

We call a valued field (K, v) extremal if for all natural numbers n and all polynomials f in $K[X_1, ..., X_n]$, the set of values $\{v(f(a_1, ..., a_n)) \mid a_1, ..., a_n$ in the valuation ring$\}$ has a maximum (allowed to be infinity, which is the case if f has a zero in the valuation ring). This is an important property since all Laurent Series Fields over finite fields are extremal. As it is a deep open problem whether they have a decidable elementary theory and as we are therefore looking for complete recursive axiomatizations, it is important to know the elementary properties of them well. That these fields are extremal could be an important ingredient in the determination of their structure theory, which in turn is an essential tool in the proof of model theoretic properties.

The notion of "tame valued field" and their model theoretic properties play a crucial role in the characterization of extremal fields. A valued field K with algebraic closure K^{ac} is tame if it is henselian and the ramification field of the extension K^{ac}/K coincides with the algebraic closure. Open problems in the classification of extremal fields have recently led to new insights about elementary equivalence of tame fields in the unequal characteristic case. (Received September 18, 2015)

1115-12-261 **Olga Kashcheyeva*** (kolga@uic.edu), 851 S Morgan St, Chicago, IL 60607. *Semigroups of valuations.*

We discuss an algorithm for defining rational rank 1 valuations on $k(x, y, z)$ and an algorithm for constructing generating sequences of valuations. We also provide examples of semigroups of valuations centered in $k[x, y, z]_{(x,y,z)}$. (Received September 20, 2015)

1115-12-345 **Aaron Michael Silberstein*** (asilbers@math.uchicago.edu), 5734 S. University Avenue, Room 209C, Department of Mathematics, Chicago, IL 60622. *Birational Anabelian Geometry over Algebraically Closed Fields.*

We will discuss the modern theory of birational anabelian geometry over algebraically closed fields. (Received September 22, 2015)

1115-12-383 **Ron Brown** (ron@math.hawaii.edu) and **Jonathan L Merzel*** (jmerzel@soka.edu). *The Space of Real Places of R(x,y).*

The space M of places from the rational function field R(x,y) to the real numbers R is shown to be path connected. (In general these spaces of real places play an important role in studies of the real holomorphy ring

and the reduced Witt ring of a field.) The possible value groups of elements of M are listed, and for each of these it is shown that the set of real places in M with any given value group (up to order isomorphism) is dense in M. Large collections of subsets of M are constructed such that any two elements of one of these collections are homeomorphic. A key tool is a homeomorphism between the space of real places of R((x))(y) and a space of certain sequences called "signatures"; these signatures are related to MacLane's construction of valuations on rational function fields. These signatures are also shown to determine "strict systems of polynomial extensions" (which in turn have been shown to be closely connected with the "complete distinguished chains" of Popescu, et. al.). (Received September 22, 2015)

13 ► Commutative rings and algebras

1115-13-55 **Gabriel E Sosa*** (gsosa@amherst.edu). *Toric Rings Satisfying Sorting and Ordering conditions.*

We present necessary conditions for sets of monomials to satisfy sorting and ordering conditions.

Sorting conditions were introduced by Sturmfels when describing the toric ideal for subrings of Veronese type.

We prove that Rees and multi-Rees algebras of certain principal strongly stable ideals, which correspond to toric rings, satisfy sorting and ordering conditions are Koszul, Cohen-Macaulay, normal domains. We also provide an explicit Grobner basis for the defining ideals of these algebras. (Received August 31, 2015)

1115-13-58 **Rafael H Villarreal*** (vila@math.cinvestav.mx), Apartado Postal 14-740, 07000 Mexico City, Mexico. *Hilbert Functions in Evaluation Codes.* Preliminary report.

Using the theory of Hilbert functions we study the basic parameters of evaluation codes over finite fields, and show a method to estimate the minimum distance using the notion of degree and Groebner basis. The method will apply to vanishing ideals of sets parameterized by Laurent monomials or rational functions. (Received September 02, 2015)

1115-13-60 **Claudia Polini***, 255 Hurley Building, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Rees algebras of codimension three Gorenstein ideals.*

The Rees ring and the special fiber ring of an ideal arise in the process of blowing up a variety along a subvariety. Rees rings and special fiber rings also describe, respectively, the graph and the images of rational maps between projective spaces. A classical open problem in commutative algebra, algebraic geometry, elimination theory, and geometric modeling is to compute explicitly the equations defining the images of rational maps and therefore of such rings. In this talk we describe the solution to this problem for linearly presented grade three Gorenstein ideals. This is joint work with Andrew Kustin and Bernd Ulrich. (Received September 02, 2015)

1115-13-93 **Sara Faridi*** (faridi@mathstat.dal.ca). *Higher dimensional chordality and monomial ideals with linear resolution.*

In 1990 Froeberg gave a criterion for when a degree two monomial ideal would have a linear resolution. This criterion was given in terms of chordality of graphs. Since then there have been many attempts to generalize Froeberg's criterion to all monomial ideals, resulting in various overlapping definitions of chordality in higher dimensions. This talk gives an overview of these constructions, how they relate and where they come from. We will also state some of the latest questions in the subject. (Received September 08, 2015)

1115-13-94 **Susan Marie Cooper*** (susan.marie.cooper@ndsu.edu), Department of Mathematics, NDSU Dept #2750, PO Box 6050, Fargo, ND 58108-6050. *The Alpha Invariant and Symbolic Powers of Monomial Ideals.*

Finding invariants (such as alpha) of symbolic powers of homogeneous ideals is quite challenging, even for monomial ideals. Motivated by conjectures of Harbourne and Huneke, we compare regular and symbolic powers of monomial ideals. In particular, we investigate the alpha invariant using the symbolic polyhedron first introduced by Cooper-Embree-Hà-Hoefel. We also look at recent progress for the related Waldschmidt constant for square-free monomial ideals. (Received September 08, 2015)

1115-13-111 **Mengyao Sun***, Department of Mathematics, Tulane University, 6823 St. Charles Ave, New Orleans, LA 70118. *Regularity of edge ideals of vertex decomposable graphs.* Preliminary report.

The edge ideal construction gives one-to-one correspondence between squarefree monomial ideals and simple hypergraphs. This allows us to study the regularity of squarefree monomial ideals in terms of combinatorial data from associated hypergraphs. In this talk, our focus will be on finding bounds for the regularity of the edge

ideal of a vertex decomposable graph. We provide two upper bounds for the regularity in terms of the induced matching number and the number of cycles and show that they are incomparable. (Received September 10, 2015)

1115-13-113 **Yu Xie*** (yzx1@psu.edu), Department of Mathematics and Statistics, Altoona, PA 16601.
Conjectures of symbolic powers. Preliminary report.

I am going to talk about the recent progress on some conjectures of symbolic powers, including Chudnovsky's conjecture and Huneke's conjecture. (Received September 10, 2015)

1115-13-136 **Neil Epstein*** (nepstei2@gmu.edu), Fairfax, VA 22030, and **Jay Shapiro**. *Perinormality in pullbacks.*

Recently, the authors introduced the notion of perinormality in integral domains. This is a local property that fits between the concepts of Krull domain and weakly normal (R_1) domain. In the current work, we explore ways in which perinormal domains may be constructed, both in Noetherian and non-Noetherian contexts, via pullback diagrams. In the former case, we introduce a very flexible method of construction by "gluing" the primary decomposition of any ideal of height at least two in a reasonable normal domain. In the latter, we show how perinormality arises from hypersurface contraction and the classical $D + M$ construction. One of the tools we use is a new concept of relative perinormality associated to an arbitrary ring inclusion. (Received September 13, 2015)

1115-13-146 **Adam Boocher**, **Alessio D'Alì**, **Eloisa Grifo**, **Jonathan Montaño** and **Alessio Sammartano*** (asammart@purdue.edu). *Deviations of graded algebras.*

The deviations of a standard graded k-algebra are a sequence of numbers that determine its Poincaré series and arise as the number of generators of certain DG algebra resolutions. We study extremal deviations among those of algebras with a fixed Hilbert series. We prove that deviations, like the Betti numbers, do not decrease when passing to initial ideals and lexsegment ideals. We also prove that deviations grow exponentially for Golod rings and for algebras presented by certain edge ideals. (Received September 13, 2015)

1115-13-147 **Sabine El Khoury***, Department of Mathematics, Bliss 316, American University of Beirut, Riad El Solh 11-0236, Beirut, 1107-2020, Lebanon, and **Manoj Kummini** and **Hema Srinivasan**. *Bounds for the Multiplicity of Gorenstein algebras.*

We prove upper bounds for the Hilbert-Samuel multiplicity of standard graded Gorenstein algebras. The main tool that we use is Boij-Söderberg theory to obtain a decomposition of the Betti table of a Gorenstein algebra as the sum of rational multiples of symmetrized pure tables. Our bound agrees with the one in the quasi-pure case obtained by Srinivasan [J. Algebra, vol. 208, no. 2, (1998)]. (Received September 14, 2015)

1115-13-148 **Jorge Neves**, **Maria Vaz Pinto*** (vazpinto@math.tecnico.ulisboa.pt) and **Rafael Villarreal**. *Regularity of vanishing ideals associated to bipartite graphs.* Preliminary report.

Let X be an algebraic toric set in a projective space, parameterized by the s edges of a simple graph over a finite field K, and let I(X) be the vanishing ideal of X, which is a lattice ideal of S = K[t1,...,ts]. For certain families of graphs, we find explicit sets of binomial generators for I(X), obtained combinatorially from the respective graphs, and use those generators to compute the Castelnuovo-Mumford regularity of S/I(X). (Received September 14, 2015)

1115-13-164 **Alessandro De Stefani*** (ad9fa@virginia.edu), University of Virginia, Charlottesville, VA 22904. *Products of ideals may not be Golod.*

We give an example of two monomial ideals I, J in a polynomial ring S over a field such that the quotient S/IJ is not Golod. We discuss some notions related to Golodness, and some recent developments in the area. (Received September 15, 2015)

1115-13-175 **Hema Srinivasan*** (srinivasanh@missouri.edu), Dept. Of Mathematics, University of Missouri, Columbia, MO 65211. *On Subadditivity of Maximal shifts in Minimal Resolutions.*

Let $R = S/I$ be a standard graded algebra, with S, polynomial ring over a field k. Denote by $(\mathbb{F}, \partial)$ be a graded free resolution of R over S where $\mathbb{F}_a = \oplus_{j=t_a}^{T_a} S(-j)^{\beta_{aj}}$. For each a, T_a denotes the maximal shifts in the resolution $\mathbb{F}$. We say $\mathbb{F}$ satisfes subadditivity for maximal shifts if $T_{a+b} \leq T_a + T_b$ for all a and b. In general, minimal resolutions of graded algebra may not always satisfy subadditivity of maximal shifts. Some additional hypothesis is needed. In joint work with J. Herzog, we prove that $T_p \leq T_1 + T_{p-1}$ where $p =$ projective dimension of S/I and further more, if I is a monomial ideal then $T_a \leq T_1 + T_{a-1}$ for all a. In a joint work with S. El Khoury,

we strengthen this for Gorenstein algebras to prove that $T_{a+b} \leq T_a + T_b$, for $a+b \geq p-1$. We further establish some inequalities for the minimal and maximal shifts for special types of resolutions. (Received September 16, 2015)

1115-13-186 **Ian Aberbach**, **Aline Hosry** and **Janet Striuli*** (jstriuli@fairfield.edu), Fairfield, CT 06824. *Uniform Bounds of Artin-Rees type for free resolutions.*

Let (R, m) be a local noetherian ring of dimension d. Given a finitely generated R-module M we study a free resolution of M, which we denote by $(F_\bullet^M, \partial_i^M)$. We show that there exists a positive integer h such that $I^n F_i^M \cap Im(\partial_{i+1}^M) \subseteq I^{n-h} Im(\partial_{i+1}^M)$ for all $i \geq 0$, for all $n > h$, for all the ideals $I \subseteq R$ and for all modules that are d-th syzygies. The proof of this statement involves the definition of Koszul annihilator sequence which we will introduce for the talk. (Received September 16, 2015)

1115-13-192 **Adela Vraciu*** (vraciu@math.sc.edu). *Rings that do not have non-free totally reflexive modules.* Preliminary report.

We present a new class of Artinian rings for which it can be shown that every totally reflexive module is free. (Received September 17, 2015)

1115-13-196 **Hannah Altmann**, **Eloísa Grifo**, **Srikanth Iyengar**, **Jonathan Montaño*** (jmontano@ku.edu), **William Sanders** and **Thanh Vu**. *Level of perfect complexes.* Preliminary report.

Let R be a commutative ring. A complex of R-modules F is perfect if it is quasi-isomorphic to a bounded complex of finitely generated projective modules, or equivalently, if it belongs to the smallest thick subcategory of $\mathsf{D}(R)$ that contains R. The later implies that every perfect complex can be built from R using a finite sequence of mapping cones, shifts, and direct summands. The level of F, denoted by $\operatorname{level}^R(F)$, measures the number of steps it takes to build F. In this talk, we will present a lower bound for $\operatorname{level}^R(F)$ in terms of the gaps in the homology of F. This result allows us to give estimates for levels of Koszul complexes and of complexes whose homology has finite length. This is joint work with Hannah Altmann, Eloísa Grifo, Srikanth Iyengar, William Sanders, and Thanh Vu. (Received September 17, 2015)

1115-13-218 **Charles Li*** (cli2@mercy.edu), Department of Mathematics, Mercy College, 555 Broadway, Dobbs Ferry, NY 10522. *Dual Graphs of Divisorial Valuations and Information Theory.* Preliminary report.

We consider the problem of how to optimally represent in binary the dual graphs of divisorial valuations on function fields of dimension two. The dual graphs are thought of as sequences of three types of blowups, which are then encoded into binary. The information theoretic notion of entropy gives a measure of the efficiency of such binary encodings of the dual graphs. (Received September 19, 2015)

1115-13-228 **Peder Thompson*** (pthompson4@math.unl.edu). *Stable local cohomology.*

Let R be a Gorenstein local ring, I an ideal in R, and M an R-module. The local cohomology of M supported at I can be computed by applying the I-torsion functor to an injective resolution of M. Since R is Gorenstein, M has a complete injective resolution, so it is natural to ask what one gets by applying the I-torsion functor to it. Following this lead, we define stable local cohomology for modules with complete injective resolutions. This gives a functor to the stable category of Gorenstein injective modules. We show that in many ways this behaves like the usual local cohomology functor. Our main result is that when there is only one non-zero local cohomology module, there is strong connection between that and stable local cohomology; in fact, the latter gives a Gorenstein injective approximation of the former. (Received September 19, 2015)

1115-13-260 **K Alan Loper*** (loper.4@osu.edu), Department of Mathematics, Ohio State University, Columbus, OH 43210, and **Nick Werner**. *Totally irrational valuation domains as unions of quadratic transforms.* Preliminary report.

Let D be a three-dimensional regular local ring with maximal ideal M generated by x,y, and z. Assign x,y, and z positive real number values which are independent over the rational numbers. We examine when the corresponding valuation domain can be realized as a union of a chain of quadratic transforms of D. (Received September 21, 2015)

1115-13-262 **Bruce Olberding*** (olberdin@nmsu.edu), Department of Mathematical Sciences, Las Cruces, NM 88011. *Intersecting valuation rings in the Zariski-Riemann space of a field.*

The Zariski-Riemann space of a field F is the collection of all valuation rings having quotient field F endowed with the Zariski topology. This topology is spectral and hence the collection of valuation rings admits the patch

as well as inverse topologies. We discuss some recent applications of the topological point of view to the study of intersections of valuation rings. We also discuss limitations of a strictly topological approach, some of which can be overcome by viewing the Zariski-Riemann space X as a locally ringed space and considering morphisms into projective schemes. Issues of interest then include whether a subspace of X lies in an affine scheme. We discuss a number of situations in which this is the case. We also relate this topic to rings of classical interest in Noetherian and non-Noetherian commutative ring theory. (Received September 20, 2015)

1115-13-284 **Branden Stone*** (bstone@adelphi.edu). *Classifying graded Cohen-Macaulay rings of graded countable Cohen-Macaulay type.*

In 1988, D. Eisenbud and J. Herzog gave a complete classification of graded rings of graded finite Cohen-Macaulay type. We would like to extend this classification to rings of graded countable Cohen-Macaulay type. This talk will outline the current progress of this task as well as outline the pitfalls. (Received September 21, 2015)

1115-13-289 **Olgur Celikbas**, **Lars Winther Christensen*** (lars.w.christensen@ttu.edu), **Li Liang** and **Greg Piepmeyer**. *Stable homology.* Preliminary report.

Tate homology and cohomology originated in the realm of group algebras, and through a series of generalizations it evolved to the setting of Gorenstein rings. The cohomological theory has a more far-reaching generalization to the setting of associative rings; it is now called stable cohomology. On the homological side, the picture is not quite this clear. In the talk I will discuss recent work on that topic. (Received September 21, 2015)

1115-13-305 **Emilie Dufresne** and **Jack Jeffries*** (jackjeff@umich.edu). *Separating sets for actions of tori.*

One modern notion in invariant theory is that of a separating set. A separating set for a group action G on a variety X is a set of invariants S such that if there is some $f \in k[X]^G$ such that $f(v) \neq f(w)$, then there is an $h \in S$ such that $h(v) \neq h(w)$. This notion has attracted interest because it may be much easier to compute a separating set than to compute the whole ring of invariants, but separating sets still reflect much of the geometry of the group action like invariant rings do. In this talk, I will discuss some new results on separating sets for actions of tori, focusing on connections with local cohomology and secant varieties. This is based on joint work with Emilie Dufresne. (Received September 22, 2015)

1115-13-340 **Liana M Sega*** (segal@umkc.edu) and **Melissa Menning**. *Cohomology of finite modules over short Gorenstein rings.*

Let R be a Gorenstein local ring with maximal ideal $\mathfrak{m}$ satisfying $\mathfrak{m}^3 = 0$. Set $k = R/\mathfrak{m}$ and $e = \operatorname{rank}_k(\mathfrak{m}/\mathfrak{m}^2)$. If $e > 2$ and M, N are finitely generated R-modules, we show that the formal power series

$$\sum_{i=0}^{\infty} \operatorname{rank}_k \left(\operatorname{Ext}^i_R(M,N) \otimes_R k\right) t^i \quad \text{and} \quad \sum_{i=0}^{\infty} \operatorname{rank}_k \left(\operatorname{Tor}^R_i(M,N) \otimes_R k\right) t^i$$

are rational, with denominator $1 - et + t^2$. (Received September 21, 2015)

1115-13-360 **Basanti Poudyal*** (basanti.poudyal@mavs.uta.edu). *Existence of Exact Zero Divisors in Artinian Gorenstein Rings.*

Let A be a local ring with maximal ideal m. We say that (a, b) is an exact pair of zero divisors if there exists a pair of elements a, b in m such that $(0 : a) = (b)$ and $(0 : b) = (a)$. It is known that a generic Artinian Gorenstein ring of socle degree 3 contains exact pairs of zero divisors. We are interested in the existence of exact zero divisors in the case of socle degree $d > 3$. In this talk, I will discuss the conditions when an Artinian Gorenstein ring of socle degree $d > 3$ contains linear pairs of exact zero divisors. (Received September 22, 2015)

1115-13-367 **Petter Andreas Bergh** and **David A. Jorgensen*** (djorgens@uta.edu). *Support varieties over complete intersections made easy.*

We exploit an alternate definition of support variety for pairs of finitely generated modules over a commutative local complete intersection ring. The alternate definition allows for short proofs of known results as well as new applications. We will see a few of these. (Received September 22, 2015)

1115-13-372 **Joseph P. Brennan*** (joseph.brennan@ucf.edu), Department of Mathematics, University of Central Florida, 4393 Andromeda Loop N, Orlando, FL 32816-1364, **Zixia Song**, Department of Mathematics, University of Central Florida, 4393 Andromeda Loop N, Orlando, FL 32816-1364, and **Alexander York**, Department of Mathematics, University of Central Florida, 4393 Andromeda Loop N, Orlando, FL 32816-1364. *Workings in the Sandpile.* Preliminary report.

This report considers the behavior of the sandpile group of a graph (also known as the Picard group of a graph) under edge contraction. This leads to questions concerning duality over Gorenstein rings and the generalization of a theorem of Frobenius and Stickelberger. (Received September 22, 2015)

1115-13-390 **Jason Hardin*** (jhardin@worcester.edu). *Bounding the Degrees of Ext-Modules over Complete Intersections.*

Given a module M over a complete intersection R of codimension c, $\operatorname{Ext}^*_R(M,k)$ can be viewed as a graded module over the polynomial ring in c variables with an action given by the Eisenbud operators. We provide an upper bound on the degrees of the generators of this graded module in terms of the regularities of two associated coherent sheaves. In the codimension two case, this bound recovers a bound of Avramov and Buchweitz in terms of the Betti numbers of M. (Received September 22, 2015)

14 ► Algebraic geometry

1115-14-21 **Sieu K Tran*** (tsieu95@vt.edu), 11 Ravenscroft lane, Hampton, VA 23669, and **Markus Rosenkranz** (m.rosenkranz@kent.ac.uk). *Discrete Boundary Problems via Integro-Differential Algebra.* Preliminary report.

We build up an algorithmic structure to specify discrete boundary problems and their boundary conditions, and to solve them via discrete operators $\Delta\colon f_k \to f_{k+1} - f_k$ and $\Sigma\colon f_k \to \sum_{i=0}^{k-1} f_i$. To do so, we write the relations between these operators in the form of *rewrite rules*, which we then show to be a Noetherian and confluent rewrite system. In other words, the system corresponds to a noncommutative Gröbner basis and constitutes a convergent reduction system on the corresponding free K-algebra. Let F be a commutative K-algebra with $f, g \in F$ and Φ be the set of all characters with $\varphi, \psi \in \Phi$. We show that every discrete operator in $F_\Phi[\Delta, \Sigma]$ can be reduced to a linear combination of monomials $f\varphi\Sigma g\psi\Delta^i$, where $i \geq 0$ and each of f, φ, Σ, g, and ψ may also be absent. Additionally, every boundary condition of $|\Phi)$, denoting the right ideal of Φ, has the normal form $\sum_{\varphi\in\Phi}\left(\sum_{i\in\mathbb{N}} a_{\varphi,i}\varphi\Delta^i + \varphi\Sigma f_\varphi\right)$ with $a_{\varphi,i} \in K$ and $f_\varphi \in F$ almost all zero. (Received July 22, 2015)

1115-14-36 **Changjian Su*** (changjiansu@gmail.com). *Stable basis for $T^*(G/B)$ and its applications.*

In this talk, I will first introduce the definition of stable basis for $T^*(G/B)$, which is defined by Maulik and Okounkov for general symplectic resolution. Then I will talk about the restriction formula for the stable basis, from which we can deduce the restriction formula for Schubert varieties by a limiting process. Time permitting, I will also talk about quantum multiplication by divisors in $T^*(G/B)$ in terms of stable basis, which gives a combinatorial proof of the main result of Braverman-Maulik-Okounkov(2009). (Received August 17, 2015)

1115-14-41 **Paolo Aluffi** and **Leonardo C Mihalcea*** (lmihalce@vt.edu), 460 McBryde Hall, Dept. of Mathematics, Blacksburg, VA 24060. *Chern-Schwartz-MacPherson classes for Schubert cells in flag manifolds.*

The Chern-Schwartz-MacPherson (CSM) class of a variety X is a class in the homology of X, which is a substitute for the total Chern class of the tangent bundle of X. Its existence was conjectured by Deligne and Grothendieck, and it was first constructed by MacPherson. One can associate a CSM class to any constructible subset of X. In joint work with Paolo Aluffi we used Bott-Samelson resolutions to give an algorithm calculating CSM classes of Schubert cells in any generalized flag manifold G/P. The algorithm is based on certain Demazure-Lusztig type operators, which send the CSM class of a cell to the class of a cell of dimension larger by 1. These CSM classes are also conjectured to be Schubert positive - we observed this in a significant set of examples, and proved it in some particular cases. (Received August 24, 2015)

1115-14-42 **Gavril Farkas** and **Nicola Tarasca*** (tarasca@math.utah.edu). *Pointed Castelnuovo numbers.*

The classical Castelnuovo numbers count linear series of minimal degree and fixed dimension on a general curve, in the case when this number is finite. Castelnuovo's work dates back to the 1880's and uses a subtle degeneration argument and Schubert calculus. In this talk, I will present a formula for the number of linear series on a general

curve with prescribed ramification at an arbitrary point, when the expected number is finite. As an application, I will show how to solve certain enumerative problems on moduli spaces of curves, and how to obtain improved bounds for the slope of the cone of effective divisor classes on symmetric products of a general curve. (Received August 24, 2015)

1115-14-44 **June Huh*** (huh@princeton.edu), Princeton, NJ 08540. *Positivity of Chern classes of Schubert cells and varieties.*

Chern-Schwartz-MacPherson class is a fuctorial Chern class defined for any algebraic variety. I will explain a proof of the positivity conjecture of Aluffi and Mihalcea that Chern classes of Schubert cells and varieties are positive in the case of Grassmannians, and pose a few questions concerning the general case of the conjecture. (Received August 25, 2015)

1115-14-77 **Cristian Lenart*** (clenart@albany.edu), Department of Mathematics and Statistics, State University of New York at Albany, 1400 Washington Avenue, Albany, NY 12222, and **Kirill Zainoulline** (kirill@uottawa.ca), Department of Mathematics and Statistics, University of Ottawa, 585 King Edward Street, Ottawa, Ontario K1N 6N5, Canada. *Combinatorial aspects of Schubert calculus in elliptic cohomology.*

Modern Schubert calculus has been mostly concerned with the study of the cohomology and K-theory (including their equivariant and quantum generalizations) of flag manifolds. The basic results for other cohomology theories have only been obtained recently; additional complexity is due to the dependence of the geometrically defined classes on a reduced word for the corresponding Weyl group elements. After this main theory was developed, the next step is to derive explicit combinatorial formulas. I will describe my work with K. Zainoulline in this direction, which focuses on (torus equivariant) elliptic cohomology. We generalize the formulas of Billey (in ordinary cohomology) and Graham-Willems (in K-theory) for the equivariant Schubert classes. Another result is concerned with defining a Schubert basis (i.e., classes independent of a reduced word), using the Kazhdan-Lusztig basis of a certain Hecke algebra. (Received September 05, 2015)

1115-14-96 **Eduardo González*** (eduardo@math.umb.edu), Mathematics Department, UMASS Boston, Boston, MA 02125, Boston, MA 02125, and **Christopher Woodward**. *Quantum Kirwan for quantum K-theory.* Preliminary report.

We extend, under certain assumptions, the definition of Kirwan map to quantum K-theory: a map from the equivariant quantum K-theory of a polarised variety to the quantum K-theory of the geometric invariant theory quotient. As an application we give a presentation of the quantum K-theory of projective spaces and Grassmannians originally due to A. Buch and L. Mihalcea. This is joint work with C. Woodward. (Received September 09, 2015)

1115-14-126 **Maria Elisa Fernandes*** (maria.elisa@ua.pt) and **Dimitri Leemans**. *Hypertopes of high rank for the symmetric group.*

We classify C-groups of ranks $n-1$ and $n-2$ for the symmetric group S_n. We also show that all these C-groups correspond to hypertopes, that is, thin, residually connected flag-transitive geometries. Therefore we generalise some similar results obtained in the framework of string C-groups that are in one-to-one correspondence with abstract regular polytopes. (Received September 11, 2015)

1115-14-165 **Oliver Pechenik*** (pecheni2@illinois.edu) and **Dominic Searles**. *The Belkale-Kumar product on generalized flag manifolds.*

For generalized flag manifolds, P. Belkale–S. Kumar introduced a deformation of cohomology with applications to generalizations of Horn's problem on eigenvalues of Hermitian matrices. They proved their product was well-defined through geometric invariant theory. Another proof was supplied by W. Graham–S. Evens using relative Lie algebra cohomology. We give an essentially elementary proof, applicable to a more general family of products that we introduce. (Received September 15, 2015)

1115-14-181 **William Fulton*** (wfulton@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Symplectic Degeneracy Loci.*

This talk will sketch joint work with Dave Anderson that gives a simple and unified approach to finding formulas for degeneracy loci in types A and C. (Received September 16, 2015)

1115-14-200 **Steven Dale Cutkosky*** (cutkoskys@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *A generalization of Abhyankar's theorem to extensions of associated graded rings along a valuation.*

We consider finite separable extensions of affine domains along a valuation and the corresponding extension of associated graded rings along the valuation. We show that good properties of the valued field extension tend to also hold asymptotically in the extension of associated graded rings, after enough blowing up. Things are much better in defectless extensions. We show that a generalization of Abhyankar's theorem on ramification holds asymptotically in characteristic zero. (Received September 18, 2015)

1115-14-231 **Brian Harbourne*** (bharbourne1@unl.edu), **David Cook II**, **Juan Migliore** and **Uwe Nagel**. *Line arrangements, fat points, and syzygies.* Preliminary report.

For which finite reduced sets Z of points in the plane does a general fat point mP not impose the expected number of conditions on forms of some degree t vanishing on Z? Recent work of D. Faenzi and J. Vallès, and of R. Di Gennaro, G. Ilardi and J. Vallès, give interesting connections between this problem and syzygies of the Jacobian ideal of the form defining the line arrangement in the plane dual to Z. We refine and extend these results. (Received September 19, 2015)

1115-14-233 **Kiumars Kaveh*** (kaveh@pitt.edu). *Genus of complete intersections in spherical varieties.*

I will start with discussing theory of virtual polytopes and Ehrhart-Macdonald reciprocity as well as classical results of Khovanskii on genus of complete intersections in algebraic torus $(\mathbb{C}^*)^n$. I will then discuss our recent work generalizing these results to complete intersections in a spherical homogeneous space G/H. We give formula for the genus in terms of number of lattice points in associated convex polytopes (namely moment and Newton-Okounkov polytopes). Important classes of examples are complete intersections in flag varieties G/P as well as the group G itself. This is a joint work with Askold Khovanskii. (Received September 19, 2015)

1115-14-235 **Ryan Kinser**, **Allen Knutson** and **Jenna Rajchgot*** (rajchgot@umich.edu). *Three combinatorial formulas for type A quiver polynomials and K-polynomials.*

I'll describe a closed immersion from each representation space of a type A quiver with bipartite (i.e., alternating) orientation to a certain opposite Schubert cell of a partial flag variety. This "bipartite Zelevinsky map" restricts to an isomorphism from each orbit closure to a Schubert variety intersected with the above-mentioned opposite Schubert cell. For type A quivers of arbitrary orientation, I'll discuss a similar result up to some factors of general linear groups.

Using these identifications, I'll explain how one can obtain various combinatorial formulas for the quiver polynomial and K-polynomial of an arbitrarily oriented type A quiver locus embedded inside of its representation space. These formulas are generalizations of three of Knutson-Miller-Shimozono's formulas from the equioriented type A setting.

This is joint work with Ryan Kinser and Allen Knutson. (Received September 19, 2015)

1115-14-239 **Bernard Teissier*** (bernard.teissier@imj-prg.fr), 73 Rue Claude Bernard, 75005 Paris, France. *Extensions of valuations from an excellent local domain to its completion.*

I will present some of the motivations for the following conjecture: Given a zero dimensional valuation ν of an excellent equicharacteristic local domain (R, m), there exist prime ideals H of the m-adic completion $\hat{R}$ such that $H \cap R = (0)$ and the valuation ν extends to a valuation $\hat{\nu}$ of $\hat{R}/H$ *with the same value group.* Moreover, after a birational ν-modification of R, one can even obtain that the natural inclusion of graded rings $\mathrm{gr}_\nu R \subset \mathrm{gr}_{\hat{\nu}} \hat{R}/H$ is an equality. (Received September 20, 2015)

1115-14-249 **Andrew S Obus*** (andrewobus@gmail.com), 745 WALKER SQ, APT 3B, CHARLOTTESVILLE, VA 22903, and **Stefan Wewers**. *Wild Ramification Kinks.*

Given a branched cover $f : Y \to X$ between smooth projective curves over a non-archimedean mixed-characteristic local field and an open rigid disk $D \subseteq X$, we study the question under which conditions the inverse image $f^{-1}(D)$ is again an open disk. More generally, if the cover f varies in an analytic family, is this true at least for some member of the family? Our main result gives a valuation-theoretic criterion for this to happen. The criterion is related to kinks in the "Berkovich different" introduced by Cohen-Temkin-Trushin. (Received September 20, 2015)

1115-14-251 **Mattias Jonsson***, Mathematics, University of Michigan, 530 Church St, Ann Arbor, MI 48109-1043. *Valuations and the study of complex degenerations.*

I will show how valuations can be used to study various questions on degenerations in complex analysis and geometry. A main protagonist in this story is a kind of Berkovich analytic space that combines Archimedean and non-Archimedean information. (Received September 20, 2015)

1115-14-255 **Allen Knutson*** (allenk@math.cornell.edu) and **Paul Zinn-Justin**. *Chern-Schwartz-MacPherson classes on flag manifolds.* Preliminary report.

We observe that the Maulik-Okounkov "stable envelopes" give classes in $H_*^{\mathbb{C}^\times}(T^*G/P) \cong H_*(G/P)[\hbar]$ that specialize at $\hbar \mapsto -1$ to the Chern-Schwarz-MacPherson classes studied by Aluffi-Mihalcea. With this, we prove the Schubert-positivity of the CSM classes. In the type A case, we give a formula for a "CSM double Schubert polynomial" in alphabets x, y. (Received September 20, 2015)

1115-14-266 **Martha Precup*** (meprecup@math.northwestern.edu), Mathematics Department, Evanston, IL 60208, and **Julianna Tymoczko** (jtymoczko@smith.edu). *The Betti numbers of parabolic Hessenberg varieties.*

Recent results of Tymoczko show that the Betti numbers of a given Springer fiber are equal to the Betti numbers of a certain union of Schubert varieties. This characterization combinatorially connects two very well-studied subvarieties of the flag variety, and is especially notable since their geometric descriptions differ greatly. In this talk, we extend these results to parabolic Hessenberg varieties and analyze their geometric structure. (Received September 20, 2015)

1115-14-282 **Linda Chen*** (lchen@swarthmore.edu), **Mario Sanchez** and **Jorin Schug**. *Equivariant Pieri formulas, tableaux, and Kostka coefficients.*

We give a formulation of the Pieri rule for the equivariant cohomology ring of the Grassmannian in terms of tableaux. In particular, the structure constants can be read directly from hooks of particular associated tableaux, manifestly exhibiting Graham positivity. We also define equivariant Kostka coefficients and give explicit formulas in special cases in terms of classical Kostka numbers. This is joint work with Mario Sanchez and Jorin Schug. (Received September 21, 2015)

1115-14-292 **Richard Rimanyi*** (rimanyi@email.unc.edu), Department of Mathematics, CB#3250 Phillips Hall, UNC Chapel Hill, Chapel Hill, NC 27599. *Equivariant Chern-Schwartz-MacPherson classes by interpolation.* Preliminary report.

The Chern-Schwartz-MacPherson class of a possibly singular variety is a remarkable deformation of the notion of fundamental class of the variety. We will study equivariant CSM classes of Schubert cells in partial flag manifolds. We show a set of interpolation properties that uniquely determine CSM classes of Schubert cells, as well as a formula, of 'localization type'. The formula coincides with the formula for so called weight functions introduced by V. Tarasov and A. Varchenko in the context of q-hypergeometric solutions of qKZ equations. Connections with quantum group actions on cohomology algebras (recent works of the author with V. Gorbounov, V. Tarasov, A. Varchenko) will be reviewed. Also, 'dynamic' generalizations, as well as generalizations for representations with finitely many orbits will be presented. (Received September 21, 2015)

1115-14-298 **David C Lax*** (dclax@live.unc.edu), Phillips Hall CB#3250, Chapel Hill, NC 27599. *Explicit Standard Monomial Basis for Coordinatization of Schubert Varieties.*

The Plucker embedding of the flag manifold is a concrete projective coordinatization using products of minors of a matrix as coordinates. These products are nicely indexed by tableaux on a Young diagram. Lakshmibai, Musili, and Seshadri gave a standard monomial basis for the projective coordinates when restricted to a Schubert subvariety. Reiner and Shimozono made this theory more explicit by giving a straightening algorithm for the products of the minors in terms of the right key of a semistandard Young tableau. Since then, Willis introduced scanning tableaux as a more direct way to obtain right keys. We use scanning tableaux to give more-direct proofs of the spanning and the linear independence of the standard monomials. This basis is a weight basis for the dual of a Demazure module for a Borel subgroup of GL(n). As a result, we independently obtain an expression for these Demazure characters as sums of weights over the tableaux used to index the standard monomial basis. (Received September 21, 2015)

1115-14-299 **Nealy Ann Bowden*** (nealy.bowden@gmail.com). *A Survey of Recent Work on Generalized Splines.*

Let R be a ring and G a connected, finite, graph such that the edges of G are labeled with ideals in R. A generalized spline on G over R is a set of vertex labels on G satisfying the condition that the labels of any two

adjacent vertices are chosen such that their difference is an element of the ideal generated by the label of the edge that joins them. The collection of splines over a given graph G and for a fixed ring R forms a module, the structure of which is dependent upon R. Recent investigations into generalized splines will be discussed, with a special focus on the cases when $R = \mathbb{Z}/m\mathbb{Z}$ and when $R = \mathbb{Z}$. (Received September 21, 2015)

1115-14-315 **Rebecca Goldin*** (rgoldin@gmu.edu), 4400 University Drive, MS 3F2, Fairfax, VA 22039. *Equivariant Schubert calculus using Bott-Samelson manifolds.*

In the 1950s, Raoul Bott and Hans Samelson introduced a manifold that maps to G/B in a generically one-to-one fashion, and whose cohomology ring contains an isomorphic copy of the cohomology ring of G/B. The construction of each of these manifolds, now called Bott-Samelson manifolds, depends on a choice of reduced word expression for the long word in the associated Weyl group. The original construction works equally well for equivariant cohomology, considering the left torus action on a Bott-Samelson and on G/B. The multiplicative structure of the equivariant cohomology of a Bott-Samelson manifold can be "pushed forward" to obtain formulas for the structure constants downstairs; in some cases one can derive positive formulas. I will describe several of the positive formulas obtained in Schubert calculus using these methods. Part of this work is joint with Allen Knutson. (Received September 22, 2015)

1115-14-337 **Paolo Bravi** and **Bart Van Steirteghem***, Medgar Evers College - CUNY, 1650 Bedford Ave, Brooklyn, NY 11225. *The moduli scheme of affine spherical varieties with a free weight monoid.*

Spherical varieties form a remarkable class of algebraic varieties equipped with an action of a complex reductive group G. They include toric, flag and symmetric varieties. A natural invariant of an affine spherical variety X is its weight monoid $\Gamma(X)$: it is the set of irreducible representations of G that occur in the coordinate ring of X.

Thanks to highest weight theory, we can view $\Gamma(X)$ as a submonoid of the weight lattice of G. In this talk, we will consider Alexeev and Brion's moduli scheme M_Γ of affine spherical varieties with a given weight monoid Γ, under the assumption that Γ is free. We will describe the tangent space to M_Γ at its most degenerate point in terms of the combinatorial invariants of spherical varieties and deduce that the irreducible components of M_Γ are affine spaces. (Received September 21, 2015)

1115-14-353 **Frank Sottile*** (sottile@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843-3368, and **Andrew Morrison**, Department of Mathematics, ETH, Zürich, Switzerland. *Murnaghan-Nakayama Rules in Schubert Calculus.*

The Murnaghan-Nakayama rule expresses the product of a Schur function with a Newton power sum in the basis of Schur functions. As the power sums generate the algebra of symmetric functions, the Murnaghan-Nakayama rule is as fundamental as the Pieri rule. Interesting, the resulting formulas from the Murnaghan-Nakayama rule are significantly more compact than those from the Pieri formula. In geometry, a Murnaghan-Nakayama formula computes the intersection of Schubert cycles with tautological classes coming from the Chern character.

In this talk, I will discuss some background, and then some recent work with Andrew Morrison establishing Murnaghan-Nakayama rules for Schubert polynomials and for the quantum cohomology of the Grassmannian. The results I discuss are contained in the preprint arXiv:1507.06569. (Received September 22, 2015)

1115-14-399 **Julianna Tymoczko*** (jtymoczko@smith.edu), Department of Mathematics and Statistics, Smith College, 44 College Lane, Northampton, MA 01060. *Splines and GKM theory.*

GKM theory is a combinatorial method of computing equivariant cohomology, named after Goresky-Kottwitz-MacPherson. Their work rediscovered a well-known construction in analysis and applied mathematics: splines. We describe a general characterization of splines as well as some new results, including progress towards a longstanding conjecture of Alfeld and Schumaker. (Received September 22, 2015)

15 ► Linear and multilinear algebra; matrix theory

1115-15-62 **Birhanu Mulat Addis*** (gezy7271@gmail.com), University of Gondar, Gondar, Ethiopia. *One side invertible matrices.*

This paper provides the characterization of the class of all left (respectively right) inverses of a rectangular matrix. (Received September 03, 2015)

1115-15-123 **Anthony Iarrobino**, **Leila Khatami*** (khatamil@union.edu), **Bart Van Steirteghem** and **Rui Zhao**. *Nilpotent commutator of a nilpotent matrix.*

Let B be an $n \times n$ nilpotent matrix and let partition P of n denote the Jordan type of B. It is well-known that the nilpotent commutator of B, consisting of all nilpotent matrices that commute with B, is an irreducible variety. In particular, there is a unique partition of n, denoted by $Q(P)$, that is the Jordan type of a generic matrix in the nilpotent commutator of B. In this talk we report the results of joint work with Anthony Iarrobino, Bart Van Steirteghem and Rui Zhao in which we study the set of all nilpotent matrices that have the same generic commuting Jordan type. In other words, we study the inverse map Q^{-1}. The paper provides a complete description of $Q^{-1}(Q)$ when Q has 2 parts, confirming a conjecture of P. Oblak from 2012. We also suggest a generalization of Oblak's conjecture to the cases where Q has an arbitrary number of parts. (Received September 11, 2015)

16 ► Associative rings and algebras

1115-16-71 **Baptiste Calmes**, **Cristian Lenart**, **Kirill Zainoulline** and **Changlong Zhong*** (czhong@albany.edu). *Schubert classes in the oriented cohomology of flag varieties.*

I will talk about algebraic construction of generalized cohomology groups of flag varieties and of the Schubert classes in these groups. The push-pull operators between cohomology groups of flag varieties will also be explained. (Received September 04, 2015)

1115-16-247 **Corina Calinescu**, **Antun Milas** and **Michael Penn*** (michael.penn@coloradocollege.edu), Department of Mathematics & Computer Science, Colorado College, 14 East Cache La Poudre St., Colorado Springs, CO 80903. *Vertex Algebraic Structure of Principal Subspaces of Basic $A_{2n}^{(2)}$-Modules.*

We derive presentation of principal subspaces of basic $A_{2n}^{(2)}$–modules. By using certain difference equations, we prove that their characters are given by certain Nahm sums coming from the tadpole Dynkin diagram $T_n = A_{2n}/\mathbb{Z}_2$. An evidence for modularity of these Nahm sums is also presented. (Received September 20, 2015)

1115-16-379 **Alex S. Dugas** and **Graham J. Leuschke*** (gjleusch@syr.edu). *A generalization of Knörrer periodicity, with applications to noncommutative hypersurfaces.* Preliminary report.

We prove a generalization of Knörrer periodicity, relating matrix factorizations of an element f in a regular ring S and matrix factorizations of $f + z^n$ in $S[z]$. For each $k = 1, \ldots, n$, we obtain a covariantly finite subcategory of matrix factorizations of $f + z^n$. The case of $k = 1$ and an ADE singularity f leads to a class of noncommutative rings over which every minimal projective resolution is eventually periodic of period 2, suggesting that they might be called noncommutative hypersurfaces. We also provide an application to the dimension of the derived category of certain hypersurface rings. (Received September 22, 2015)

1115-16-398 **Zajj B Daugherty*** (zdaugherty@ccny.cuny.edu), Department of Mathematics, The City College of New York, NAC 8/133, New York, NY 10031, and **Arun Ram**. *Representations of the two boundary Temperley-Lieb algebra.* Preliminary report.

The classical Temperley-Lieb algebra arises both in statistical mechanics and in representation theory, in Schur-Weyl duality with sl(2). The two-boundary Temperley-Lieb algebra arises as a generalization of the classical case in both the physical context and the Schur-Weyl duality context. In this way, it presents as a diagram algebra in multiple ways, each giving different approaches to studying its representations. (Received September 22, 2015)

17 ► Nonassociative rings and algebras

1115-17-50 **Kailash C. Misra*** (misra@ncsu.edu), 2311 Stinson Drive, Raleigh, NC 27695. *Multiplicities of some maximal dominant weights of the affine Lie algebra $\widehat{sl}(n)$ and avoiding permutations.*

We consider a family of maximal dominant weights of the affine Lie algebra $\widehat{sl}(n)$. Using the theory of crystal bases we show that the multiplicities of these weights are given by the number of certain lattice paths on a colored square. Then we relate the counting of these lattice paths with the number of certain standard tableaux. Finally we show that these multiplicities are given by the number of certain avoiding permutations. This talk is based on some joint work with Rebecca Jayne. (Received August 28, 2015)

1115-17-81 **Shashank Kanade*** (kanade@ualberta.ca). *On a Koszul complex related to the principal subspace of the level 1 vacuum module of $A_1^{(1)}$.*

Stimulated by an idea of J. Lepowsky, we introduce and analyze a certain a Koszul complex related to the principal subspace of the level 1 vacuum module of $A_1^{(1)}$. The aim of this program is finding a systematic approach towards "bosonic" character formulas for the principal subspaces of standard modules of affine Lie algebras. We explain how the construction and the results we obtain are related to the Garland-Lepowsky resolution and also to certain conjectures of Gorsky-Oblomkov-Rasmussen on the stable Khovanov homology of torus knots. (Received September 06, 2015)

1115-17-173 **James Lepowsky*** (lepowsky@math.rutgers.edu) and **Jinwei Yang** (jyang7@nd.edu). *Twisted generating functions incorporating singular vectors in Verma modules and their localizations.*

We give what turns out to be a surprising recasting of the well-known classical singular vectors in the Verma modules for the classical simple Lie algebra sl(2), using certain new "twisted generating functions" incorporating the singular vectors. The familiar singular vectors then arise from a certain simple partial differential equation. We also extend this to a localized setting for singular vectors, where the twisted generating functions are now based on a certain divergent formal series which, as it turns out, appeared in Euler's study of the Euler-Gompertz constant. Our twisted-generating-function methods generalize. (Received September 15, 2015)

1115-17-217 **Yi-Zhi Huang***, Department of Mathematics, Rutgers University, Piscataway, NJ 08854, and **Fei Qi**, Department of Mathematics, Rutgers University, Piscataway, NJ 08854. *The first cohomology, derivations and the reductivity of a grading-restriced vertex algebra.* Preliminary report.

Determining whether modules for a vertex (operator) algebra in a suitable class are completely reducible is a difficult problem. The existing results are mostly for special examples of vertex operator algebras.

In this work, we obtain a criterion for the complete reducibility of an important class of modules for a grading-restricted vertex algebra V using the first author's cohomology theory. We consider V-bimodules whose left and right actions by V do not have to be related by skew-symmetry. Let $\hat{H}^1(V, M)$ be the first cohomology without the restrictions on shuffles introduced by the first author. If $\hat{H}^1(V, M) = 0$ for every grading-restricted $\mathbb{Z}$-graded V-bimodule M, or equivalently, if every derivation from V to every grading-restricted $\mathbb{Z}$-graded V-bimodule M is inner, then every grading-restricted generalized V-module is completely reducible. In fact, our result is proved for a much more general class of algebra called meromorphic open-string vertex algebra. We conjecture that the converse of this theorem is also true. (Received September 19, 2015)

1115-17-263 **Marco Aldi*** (maldi2@vcu.edu) and **Andrija Peruničić**. *p-adic Berglund Hübsch Duality.*

We introduce a D-module theoretic interpretation of Borisov's vertex-algebra-theoretic proof of Berglund-Hübsch duality. An advantage of our approach is that in the p-adic case one obtains a non-trivial Frobenius map acting on the chiral ring. We discuss how the Frobenius map behaves under Berglund-Hübsch and some applications to the arithmetic of invertible hypersurfaces. (Received September 20, 2015)

1115-17-274 **Antun Milas*** (antun.milas@gmail.com). *Unrolled quantum groups and narrow vertex W-algebras.* Preliminary report.

We introduce (higher rank) unrolled quantum groups at root of unity, discuss their representation theory and conjectural correspondence with certain vertex W-algebras. (Received September 21, 2015)

1115-17-312 **Robert McRae** (robertmcrae77@gmail.com), South Bend, IN 46637, and **Jinwei Yang*** (jyang7@nd.edu), South Bend, IN 46637. *Vertex algebraic intertwining operators among generalized Verma modules for $sl(2)^\wedge$.*

We construct vertex algebraic intertwining operators among certain generalized Verma modules for $sl(2)^\wedge$ and calculate the corresponding fusion rules. Our construction relies on the irreducibility of the maximal proper submodules of generalized Verma modules appearing in the Garland-Lepowsky resolutions of standard $sl(2)^\wedge$-modules. (Received September 21, 2015)

1115-17-335 **Christopher M. Sadowski*** (csadowski@ursinus.edu) and **Michael Penn** (michael.penn@coloradocollege.edu). *Vertex-algebraic structure of principal subspaces of $D_4^{(3)}$-modules.*

Principal subspaces of standard modules for untwisted affine Lie algebras were introduced by Feigin and Stoyanovsky, and have been further studied by many other authors. In this talk, we introduce and discuss principal

subspaces of certain standard modules for the twisted affine Lie algebra $D_4^{(3)}$. We extend earlier results and vertex-algebraic techniques of Calinescu, Lepowsky, and Milas on principal subspaces of standard $A_2^{(2)}$-modules. (Received September 21, 2015)

1115-17-339 **Katrina Barron*** (kbarron@nd.edu), 255 Hurley Hall, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556, and **Nathan Vander Werf** (nvanderw@nd.edu), 255 Hurley Hall, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Constructions and classifications of twisted modules for vertex operator superalgebras.* Preliminary report.

We will discuss certain twisted constructions for vertex operator superalgebras and implications for the classification of twisted module categories in terms of other "simpler" twisted module categories. (Received September 21, 2015)

1115-17-385 **Nathan P Vander Werf*** (nvanderw@nd.edu), 1225 Bissell, South Bend, IN 46615. *Special pairs of screening operators and certain subalgebras of a rank d lattice vertex operator algebra.*

We discuss the notion of special pairs of screening operators for a rank d lattice vertex operator superalgebra. Such screening pairs $(\tilde{Q}, Q)$ in the rank 1 case proved to be useful machinery in studying the internal structure of the $\mathcal{W}$-algebra $\mathcal{W}(p) = \ker \tilde{Q}$ and proving the C_2-cofinite property. From an analysis of screening pairs that can arise, one can construct a large number of subalgebras of V_L by considering the intersection of the kernels of certain screening operators that share a common Virasoro element. Some subalgebras that emerge share features similar to the $\mathcal{W}(p)$-algebra in the rank 1 setting while others do not as much. If time permits, we will show in the rank 2 setting how the kernel of a long screening operator $\ker \tilde{Q}$ (and in some cases the intersection of the kernels of two screening operators) can be computed. With such decompositions, the problem of studying the internal structure of $\ker \tilde{Q}$, such as finding a strongly generating set for $\ker \tilde{Q}$ and proving the C_2-cofinite property, as well as determining the representation theory, all become tractable. (Received September 22, 2015)

1115-17-393 **Bud B Coulson*** (bud@math.rutgers.edu). *A new interpretation of motivated proofs for identities of the Rogers-Ramanujan type.*

A "motivated proof" of the Rogers-Ramanujan identities was given by G. E. Andrews and R. J. Baxter, and was subsequently generalized to motivated proofs of other identities of the Rogers-Ramanujan type, including some new identities, by J. Lepowksy and his students.

In this talk, I will demonstrate a new approach to the motivated proof for the Rogers-Ramanujan identities, which comes naturally from considering the structure of the affine Lie algebra $A_1^{(1)}$. I anticipate that this viewpoint will provide insight into the ongoing program of vertex-algebraic categorification of the various motivated proofs. (Received September 22, 2015)

18 ► Category theory; homological algebra

1115-18-297 **Nathan Steele***, nathan.steele@mavs.uta.edu. *Realizability of Support Varieties of Totally Acyclic Complexes.* Preliminary report.

Support varieties of pairs of modules over a complete intersection ring have been well studied. In particular, it is well known that every algebraic variety is realizable as the support of some pair of modules. We will present two equivalent definitions of the support variety of a pair of totally acyclic complexes and prove that every algebraic variety is the support of some pair of complexes. (Received September 21, 2015)

20 ► Group theory and generalizations

1115-20-65 **David Vogan*** (dav@math.mit.edu), Room E17-442, MIT, 77 Massachusetts Avenue, Cambridge, MA 02139. *Matrices almost of order two.* Preliminary report.

Langlands' conjectures about automorphic forms suggest that infinite-dimensional irreducible representations of $GL(n, \mathbb{R})$ (something quite subtle) correspond more or less to conjugacy classes of elements of order 2 in $GL(n, \mathbb{C})$ (something extremely simple).

I'll explain where this statement comes from, and how Langlands made precise the "more or less" so that the statement is actually true. I'll explain further how to use the same point of view to address other interesting problems, like Cartan's classification of real semisimple Lie groups. (Received September 03, 2015)

1115-20-98 **Kristen Pueschel** and **Timothy Riley*** (tim.riley@math.cornell.edu), Malott Hall, Cornell University, Ithaca, NY 14853. *Dehn functions of mapping tori of right-angled Artin groups.* Preliminary report.

The algebraic mapping torus M of a group G with an automorphism ϕ is the HNN extension of G in which conjugation by the stable letter performs ϕ. Dehn functions are invariants concerning both the isoperimetry of a group and the complexity of its word problem.

When G is a finitely generated free or free-abelian group, how the Dehn function of M depends on ϕ is fully understood. As right angled Artin groups (RAAGs) are a family of groups interpolating between free and free-abelian groups, it is natural to ask to understand the Dehn function of M when G is a RAAG. We answer this for rank-3 RAAGs. (Received September 09, 2015)

1115-20-125 **George Lusztig*** (gyuri@math.mit.edu). *Involutions in Coxeter groups.*

Let I be the set of involutions in a Weyl group W with Hecke algebra H. In a 2012 paper, Vogan and the author defined an H-module structure M on a vector space with basis indexed by I. In this talk, I will present two results related to M. 1) I will show how M can be used to compute a "Poincare series based on involutions" in W. 2) I will show that M can be realized as the left ideal in H generated by a single, rather simple element of H. Both results can be extended to arbitrary Coxeter groups. (Received September 11, 2015)

1115-20-134 **Bogdan Ion** and **Siddhartha Sahi*** (sahi@scarletmail.rutgers.edu). *Double affine Hecke algebras and congruence groups.*

The most general construction of double affine Artin groups (DAAG) and Hecke algebras (DAHA) associates such objects to pairs of compatible reductive group data. We show that DAAG/DAHA *always* admit a faithful action by automorphisms of a finite index subgroup of the braid group on three strands, which descends to a faithful outer action of a congruence subgroup of $\mathrm{SL}(2,\mathbb{Z})$ or $\mathrm{PSL}(2,\mathbb{Z})$. This was previously known only in some special cases and, to the best of our knowledge, not even conjectured to hold in full generality.

The DAAG/DAHA of *adjoint* type are naturally associated to affine Kac-Mody Lie algebras, and we have a more precise result in this case. If the affine Lie algebra has twist type $r = 1, 2, 3$, then we obtain a natural action of the braid group of type A_2, B_2, G_2, respectively, which descends to an outer action of congruence subgroup $\Gamma = \Gamma_1(r)$. In particular Γ acts on the dual of the DAAG/DAHA, and any Γ-stable representation inherits a projective representation of Γ. (Received September 13, 2015)

1115-20-207 **Alex J Feingold*** (alex@math.binghamton.edu) and **Daniel Valliéres** (daniel.vallieres@maine.edu). *Lorentzian Weyl Groups.* Preliminary report.

The Weyl groups of some Lorentzian Kac-Moody Lie algebras will be discussed and described as 2x2 matrices with entries from a Clifford algebra (Vahlen groups). This generalizes previous work of Feingold-Frenkel (1983) and of Feingold-Kleinschmidt-Nicolai (2009) on certain hyperbolic Weyl groups. This current work is joint with Daniel Valliéres. (Received September 18, 2015)

1115-20-210 **Enrico Leuzinger** (enrico.leuzinger@kit.edu) and **Robert Young*** (ryoung@cims.nyu.edu). *High-dimensional fillings and distortion in horospheres and Q-rank 1 lattices.*

The distortion of a subgroup measures the difference between lengths in the subgroup and lengths in the group. Higher-order analogues of distortion can be used to measure the difference between areas and volumes in a subgroup and in a group. In this talk, we give new bounds on the higher-order distortion of horospheres in a symmetric space, inspired by ideas from combinatorial Morse theory. These bounds imply that a $\mathbb{Q}$–rank 1 lattice in a symmetric space of rank k has Euclidean filling volume functions up to dimension $k-1$ and resolve a conjecture of Bux and Wortman for such lattices. (Received September 18, 2015)

1115-20-252 **Jeb F. Willenbring*** (jw@uwm.edu), Department of Mathematical Sciences, EMS Building, Room E403, 3200 N Cramer Street, Milwaukee, WI 53211-3029. *Symmetric function identities in the context of Vinberg pairs.* Preliminary report.

The classical theory of spherical harmonics on $\mathbb{R}^3$ was generalized by Kostant in his 1963 paper *Lie group representations on polynomial rings*, which in turn was generalized by Kostant and Rallis in their 1971 paper *Orbits and representations associated with symmetric spaces*. Much of the theory in the latter was generalized by Vinberg's 1976 theory of θ-groups in *The Weyl group of a graded Lie algebra*. A survey of Vinberg's paper appears in Wallach's forthcoming book *Geometric invariant theory over the real and complex numbers*. New to this picture is the analog of the Kostant–Rallis theory of harmonic polynomials.

In this talk we will provide an overview of a family of identities from the theory of symmetric functions that reflect the structure of the harmonics for the Vinberg pair $(GL_{p+q+r}, GL_p \times GL_q \times GL_r)$ as $p, q, r \to \infty$. (Received September 20, 2015)

1115-20-253 **Lee Mosher*** (mosher@rutgers.edu), Dept. of Math. and Comp. Sci., 101 Warren Street, Rutgers University, Newark, NJ 07102. *The geometry of the outer automorphism group of a free group.*

Geometric methods initiated by Dehn, Nielsen, Whitehead and others in the first half of the 20th century remain at the heart of the modern understanding of $\mathrm{Out}(F_n)$, the outer automorphism group of a rank n free group F_n. In this talk we shall show how the modern versions of several geometric tools arise naturally by considering some of the simplest and/or earliest problems in the study of $\mathrm{Out}(F_n)$. For example, a reconsideration of Whitehead's algorithm — which decides whether a given element of F_n is part of a free basis for F_n — leads to Stallings fold paths in the Culler–Vogtmann outer space. (Received September 20, 2015)

1115-20-283 **Mark D Mixer*** (mixerm@wit.edu), MA. *The ranks for which Alt(n) acts as a string C-group.*

In 'Problems on polytopes, their groups, and realizations,' Hartley asks if one can construct polytopes whose automorphism group is an alternating group $Alt(n)$. The answer for regular polytopes in rank 3 can be found in the doctoral thesis of Conder, where it shown that, for each $k > 6$, all but finitely many $Alt(n)$ are the automorphism group of a regular map of type $\{3, k\}$. Recently, it has also been shown that for all $n > 11$, there are string C-groups of rank $\lfloor \frac{n-1}{2} \rfloor$ isomorphic to $Alt(n)$. In this talk, I will explain a construction that fills in the missing ranks, and shows that for all $n > 11$, the alternating group $Alt(n)$ acts as a regular polytope of rank r if $n > 2r$. (Received September 21, 2015)

1115-20-304 **David Futer*** (dfuter@temple.edu) and **Daniel T. Wise**. *The geometry of generic few-relator groups.*

Given a presentation of a group G with many more generators than relations, where the relations are random long words, we construct a 2-dimensional complex with nice geometry whose fundamental group is G. This complex is built out of hyperbolic polygons, glued by isometry along the edges, with a negative curvature condition at the vertices. The entire construction is inspired by the study of ideal triangulations of 3-manifolds. As a consequence of this "geometric realization" of the group, we learn that G is hyperbolic and enjoys several other pleasant group-theoretic properties. For instance, all finitely generated subgroups are undistorted, hyperbolic, and separable. (Received September 21, 2015)

1115-20-320 **Charles E Cunningham*** (ccunning@bowdoin.edu). *The Geometry of Outer Automorphism Groups of Right-angled Coxeter Groups.*

We investigate the combinatorial and geometric properties of automorphism groups of universal right-angled Coxeter groups. McCullough-Miller space is a polyhedral complex which is virtually a geometric model for the outer automorphism group of a universal right-angled Coxeter group, $\mathrm{Out}(W_n)$. As it is currently an open question as to whether or not $\mathrm{Out}(W_n)$ is CAT(0) or not, it would be helpful to know whether McCullough-Miller space can always be equipped with an $\mathrm{Out}(W_n)$-equivariant CAT(0) metric. We show that the answer is in the negative. This is particularly interesting as there are very few non-trivial examples of proving that a space of independent interest is *not* CAT(0). (Received September 21, 2015)

1115-20-324 **James Belk** (belk@bard.edu) and **Bradley Forrest*** (bradley.forrest@stockton.edu). *Rearrangements of Fractals and CAT(0) Cube Complexes.*

The Vicsek box fractal is a plane fractal that can be obtained from a simple geometric construction involving squares. In this talk, we will describe a remarkable group of piecewise-similar homeomorphisms of the Vicsek fractal. This group contains Thompson's group F and shares many of its properties. Following the methods of Farley, we will construct a locally finite CAT(0) cube complex on which this group acts properly by isometries. By analyzing the descending links of the complex, we will show that this group has type F_∞. Finally, we will discuss how this example can be generalized to a large class of Thompson-like groups acting on fractal spaces. (Received September 21, 2015)

1115-20-326 **Daniel Groves** and **Jason F Manning*** (jfmanning@math.cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853. *Dehn filling and elementary splittings.*

An example of a relatively hyperbolic group pair is (G,H) where G is the fundamental group of a hyperbolic knot exterior, and H is the fundamental group of the deleted neighborhood of the knot. Another example is

(A*B, A,B) where the star indicates free product. The first example admits no elementary splittings (splittings over virtually cyclic or parabolic subgroups), whereas the second does admit an elementary splitting.

Thurston's hyperbolic Dehn filling theorem has a group theoretic version which can be generalized to relatively hyperbolic group pairs, giving a way to produce new relatively hyperbolic pairs from old ones. We show that for all "sufficiently long" Dehn fillings of a relatively hyperbolic pair, the property of having no elementary splittings is preserved. (Received September 21, 2015)

1115-20-329 **Priyam Patel*** (patel376@purdue.edu), **Khalid Bou-Rabee** and **Mark F. Hagen**. *Quantifying separability properties of right-angled Artin groups.*

Right-Angled Artin groups (RAAGs) and their separability properties played an important role in the recent resolutions of some outstanding conjectures in 3-manifold theory. We begin this talk by defining two separability properties of groups, residual finiteness and subgroup separability, and provide a topological reformulation of each. We then discuss joint work with K. Bou-Rabee and M.F. Hagen regarding quantifications of these properties for RAAGs and the implications of our results for the class of virtually special groups. (Received September 21, 2015)

1115-20-332 **Corey Bregman*** (cjb5@rice.edu), Department of Mathematics MS-136, Rice University, 6100 Main St., Houston, TX 77005. *Isometries of cube complexes and the Torelli subgroup for a right-angled Artin group.*

Let G be a right-angled Artin group and let Out(G) be its outer automorphism group. The Torelli subgroup of Out(G) is the kernel of the action of Out(G) on the abelianization of G. Recently, Charney-Stambaugh-Vogtmann constructed an outer space for a subgroup of Out(G), whose vertices correspond to certain cube complexes called blow-ups of Salvetti complexes. Using this outer space, we present a geometric proof that the Torelli subgroup of Out(G) is torsion-free. The proof relies on understanding the combinatorial geometry of blow-ups of Salvetti complexes. (Received September 21, 2015)

1115-20-365 **Camelia Karimianpour*** (ckari099@uottawa.ca), Ottawa, K1S2A1, Canada. *On the* K*-types of the Unramified Principal Series Representations of the n-fold Metaplectic Covers of* $\mathrm{SL}_2(\mathbb{F})$. Preliminary report.

Covering groups of $\mathrm{SL}_2(\mathbb{F})$, for a p-adic field $\mathbb{F}$, are topological central extensions of $\mathrm{SL}_2(\mathbb{F})$ by the group of n-th roots of unity. In this talk, we compute the K-types of the principal series representations of these covering groups. Among these representations are the reducible unramified principal series representations for which we investigate the distribution of the K-types into its irreducible constituents. (Received September 22, 2015)

22 ► Topological groups, Lie groups

1115-22-38 **David Vogan*** (dav@math.mit.edu), Room E17-442, MIT, 77 Massachusetts Avenue, Cambridge, MA 02139. *Coherent sheaves on nilpotent cones.* Preliminary report.

Suppose G is a complex reductive algebraic group, and $\mathcal{N} \subset \mathfrak{g}^*$ is the nilpotent cone. A conjecture of Lusztig, proved by Bezrukavnikov, says that there is a natural bijection between irreducible G-equivariant vector bundles on G orbits on $\mathcal{N}$, and dominant weights for G.

I'll explain a definition of this bijection in terms of finite-dimensional representation-theory, and applications to infinite-dimensional representations that would follow from computing it. (Received August 20, 2015)

1115-22-39 **Matthew G. Dawson*** (matthew.dawson@cimat.mx), CIMAT, Col. Valenciana, 36240 Guanajuato, GTO, Mexico, and **Gestur Ólafsson** (olafsson@math.lsu.edu) and **Raúl Quiroga-Barranco** (quiroga@cimat.mx). *Commuting Toeplitz operators and holomorphic discrete series representations.*

Toeplitz operators provide a well-studied example of quantization in the context of weighted Bergman spaces on bounded symmetric domains. One of the traditional problems in Toeplitz-operator theory is to construct and classify commutative C*-algebras generated by Toeplitz operators. We produce several new examples of such algebras and move closer to a classification by using results on multiplicity-free restrictions of holomorphic discrete series representations. Along the way we have proved several multiplicity-free results for various restrictions of scalar-type holomorphic discrete series representations of $\mathrm{SU}(n,1)$ to maximal abelian subgroups. (Received August 20, 2015)

1115-22-132 **Raul Gomez**, **Dmitry Gourevitch** and **Siddhartha Sahi*** (sahi@scarletmail.rutgers.edu). *Generalized and degenerate Whittaker models.*

Let G be a reductive group over a local field of characteristic 0. A *Whittaker pair* is an ordered pair $(h, e) \in \mathfrak{g} \times \mathfrak{g}$ such that $ad(h)$ is rational semi-simple and $[h, e] = 2e$. Following Moeglin-Waldspurger we attach to (h, e) a certain smooth representation of G, called the *degenerate Whittaker model*. If h is a neutral element for e, then the model depends only on the orbit of e and we refer to it as a *generalized Whittaker model*.

Our main result is the construction of an epimorphism from the generalized Whittaker model to any degenerate Whittaker model corresponding to the same orbit, as well as to certain degenerate Whittaker models corresponding to bigger orbits. We also give choice-free definitions of generalized and degenerate Whittaker models. Finally, we explain how our methods imply analogous results for Whittaker-Fourier coefficients of automorphic representations. (Received September 12, 2015)

1115-22-220 **Ju-Lee Kim*** (julee@math.mit.edu), Cambridge, MA 02139. *An asymptotic behavior of supercuspidal characters and orbital integrals.*

We study asymptotic behaviors of supercuspidal characters and orbital integrals as their formal degrees diverge. Similarly, we study orbital integrals at pseudo coefficients of supercuspidal representations. This is a joint work with Sug Woo Shin and Nicolas Templier. (Received September 19, 2015)

1115-22-229 **Benjamin Harris*** (benjamin.harris@simons-rock.edu). *Regular Elliptic Cotangent Vectors and Regular Elliptic Discrete Spectra.*

An element of a Lie group is called elliptic if it is contained in a compact subgroup. When G is a reductive Lie group, Harish-Chandra showed that $L^2(G)$ has a discrete spectrum if, and only if G contains an open subset of elliptic elements.

Let X be a homogeneous space for a real, reductive algebraic group G. In this talk, we explore the relationship between regular elliptic cotangent vectors in T^*X and regular elliptic discrete spectra in $L^2(X)$.

This talk is related to a joint paper with Gestur Olafsson and Hongyu He and a joint paper with Tobias Weich. (Received September 19, 2015)

1115-22-244 **Mark Reeder*** (reederma@bc.edu). *Dyadic Exercises in Exceptional Groups.* Preliminary report.

Let Γ be the absolute Galois group of the field $\mathbb{Q}_2$ of dyadic numbers and let $\mathfrak{g}$ be a simple complex Lie algebra of rank r. We study the Swan conductors $sw(\varphi, \mathfrak{g})$ of continuous representations $\varphi : \Gamma \to G$, where G is the group of inner automorphisms of $\mathfrak{g}$.

Conjecture: *Assume that φ is totally ramified. Then $sw(\varphi, \mathfrak{g}) \geq r$ and if $sw(\varphi, \mathfrak{g}) = r$ then φ is unique up to conjugacy in G.*

There is a variant of this conjecture for more general representations $\varphi : \Gamma \to Aut(\mathfrak{g})$. The conjecture is known for $\mathfrak{g}$ of type A_n and G_2. In general it is implied by the Local Langlands Conjecture.

Let $\mathfrak{h} < \mathfrak{k} < \mathfrak{g}$ be the natural chain of Lie algebras of type D_4, F_4 and E_6. We verify the inequality in the conjecture for $\mathfrak{k}, \mathfrak{g}$ and its variant for the triality group $H \cdot 3 < Aut(\mathfrak{h})$, and we describe a solvable filtered subgroup $D < H \cdot 3$ of order $64 \cdot 21 \cdot 64 \cdot 8 \cdot 4$ such that if the Swan conductor of φ attains its lower bound in any of the three cases then the image of φ is conjugate to D. (Received September 20, 2015)

1115-22-254 **Wilfried Schmid*** (schmid@math.harvard.edu), Department of Mathematics, Harvard University, Cambridge, MA 02138. *On the Orbit Theorems of Hodge Theory.*

Kari Vilonen and I have formulated a conjecture on the irreducible unitary representations of reductive Lie groups. The conjecture rests on a generalization of Saito's theory of Mixed Hodge Modules - in effect, Saito's theory without an underlying rational structure. Logically, this involves an extension of the Nilpotent Orbit theorem of Hodge Theory. I shall describe this extension, and the resulting generalization of Saito's theory. (Received September 20, 2015)

1115-22-257 **Monica Nevins*** (mnevins@uottawa.ca), Department of Mathematics and Statistics, 585 King Edward Ave., Ottawa, ON K1N 6N5, Canada. *Branching to the derived group of some toral supercuspidal representations.*

Let π be a length-one toral supercuspidal representation of a connected reductive group G, such as constructed by Adler (and in greater generality by Yu). Using methods appearing in the work of Hakim and Murnaghan, we give an explicit decomposition of the restriction of π to the derived group G' of G. This restriction is given in terms of the restriction to G' of the G-datum used for the construction of π. In particular we are able to show that the restriction has multiplicity one, affirming a case of a conjecture of Adler and Prasad. (Received September 20, 2015)

1115-22-264 **Nigel Higson*** (higson@math.psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802. *Contractions of tempered irreducible representations.* Preliminary report.

In the 1970's George Mackey suggested that the degeneration of a real reductive group G to its Cartan motion group ought to lead to a "correspondence" between "most" of the irreducible unitary representations of G and those of its motion group. Mackey's suggestion doesn't seem to have received much careful scrutiny until quite recently, when a connection with index theory revived interest in it from within noncommutative geometry. Rather remarkably, Mackey's approach, suitably modified, leads to *exact bijections* at the level of tempered or admissible (but not unitary) irreducible representations. I'll describe how this comes about, but not why; a conceptual explanation is not yet available. (Received September 20, 2015)

1115-22-306 **Annegret Paul*** (annegret.paul@wmich.edu). *Parabolic induction using the* atlas *software.* Preliminary report.

We explain how to use the atlas software to compute the constitutents of representations of reductive Lie groups obtained by both real and cohomological parablic induction. (Received September 21, 2015)

1115-22-334 **Cesar Valverde*** (cvalverde@mec.cuny.edu), 1638 Bedford Ave., Brooklyn, NY 11225. *Irreducible generic representations of the General Linear group distinguished by orthogonal subgroups.*

Let F be a local non-archimedean field of characteristic zero. We prove that an irreducible, generic representation of $GL(n, F)$ is distinguished by an orthogonal group if and only if the corresponding inducing quasi-square integrable representations are distinguished by appropriate orthogonal groups. (Received September 21, 2015)

1115-22-363 **Laura J Rider*** (laurajoy@mit.edu) and **Amber Russell**. *Formality for the nilpotent cone and Lusztig's generalized Springer correspondence.* Preliminary report.

Borho–MacPherson's version of the Springer correspondence associates perverse sheaves on the nilpotent cone with representations of the Weyl group. However, not all perverse sheaves on the nilpotent cone appear in this correspondence. Lusztig extended this to include all perverse sheaves and related them to the representation theory of a so-called relative Weyl group. In my talk, I'll give a gentle introduction to perverse sheaves, discuss the generalized Springer correspondence, an orthogonal decomposition of the derived category associated to cuspidal data, and a description of the derived category of sheaves on the nilpotent cone in terms of differential graded modules. This is joint work with Amber Russell. (Received September 22, 2015)

1115-22-369 **Joseph Hundley** and **Stephen D. Miller*** (sdmiller@gmail.com). *Residual Eisenstein series connected to unipotent unitary representations.*

Arthur's conjectures predict the existence of some very interesting unitary representations occurring in spaces of automorphic forms. We prove the unitarity of the "base element" of unipotent Arthur packets for split real groups using Eisenstein series and the ATLAS software. This involves an analysis of Langlands' constant term formula, using analytic properties of intertwining operators along with some mild arithmetic input from the theory of Dirichlet L-functions.

This is part 1 of a series of two talks; the second talk by Hundley will discuss the combinatorics of the constant term calculation. (Received September 22, 2015)

1115-22-397 **James Keesling*** (kees@ufl.edu), Department of Mathematics, University of Florida, P.O. Box 118105, Gainesville, FL 32611-8105, and **Joanna Furno**. *Profinite groups and generalized covering spaces.* Preliminary report.

Our study of the Hilbert-Smith Conjecture has led us to consider generalized covering spaces together with ways of topologizing fundamental groups in general settings. We have found interesting examples using infinite-dimensional topology. We present these results with with the groups coming from the category of profinite Abelian groups. (Received September 22, 2015)

1115-22-408 **Ran Cui*** (cuiran@math.umd.edu), 4176 Campus Dr., Mathematics Building, College Park, MD 20742. *The Real-Quaternionic Indicator.* Preliminary report.

The Frobenius-Schur indicator, also called the ε indicator, tells if a self-dual representation is orthogonal or symplectic. The real-quaternionic indicator, also called the δ indicator, indicates if a self-conjugate representation is of real or quaternionic type. It is interesting to compute the ε and δ indicators. 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 introduced in "Unitary Representation of Real Reductive Groups" by Adams, van Leeuwen, Trapa and Vogan. (Received September 23, 2015)

1115-22-409 **Jeffrey Adams*** (jda@math.umd.edu), 314, College Park, MD 20742. *Atlas of Lie Groups and Representations.*

The Atlas of Lie Groups and Representations is computational project in the representation theory of real reductive groups. The main goal is the computation of the unitary dual. Secondary goals include many other calculations in Lie theory. I will give an overview of the current status of the project. (Received September 23, 2015)

28 ► Measure and integration

1115-28-199 **Sarah Dumnich*** (src210@lehigh.edu), Christmas Saucon Hall, 14 E. Packer Ave, Bethlehem, PA 18015. *A Solution to the Dilation Equation for Measures.*

A multiresolution analysis is a tool used in the construction of orthogonal wavelets. The dilation equation is an equation that arises naturally when using an MRA to construct a wavelet basis. One way to understand the dilation equation is through a measure theoretic approach. By constructing a solution to the dilation equation for measures, we are able to uniquely determine a corresponding wavelet basis. In this talk, I will define a sequence of discrete measures μ_n, and show that this sequence weakly converges to a solution of the dilation equation for measures. (Received September 17, 2015)

30 ► Functions of a complex variable

1115-30-99 **Jorge A Acosta*** (jaa4@rice.edu), 7777 Greenbriar Apt 1015, Houston, TX 77030. *On the Limits of Certain Opers.* Preliminary report.

Opers are differential operators on certain line bundles on a Riemann Surface. $SL(n,\mathbb{C})$ opers are parameterized by the Hitchin base and have holonomy in the $SL(n,\mathbb{C})$ character variety. The aim of the talk is to understand the limits of the holonomy as you follow a ray in this parameterization in terms of the geometric data of the holomorphic differentials and equivariant maps to the corresponding symmetric space. (Received September 09, 2015)

1115-30-103 **Ara S. Basmajian*** (abasmajian@gc.cuny.edu). *Equations over deformation spaces.*

Let X be a compact hyperbolic surface with either geodesic or horocyclic boundary. The homotopy class (rel the boundary) of a non-trivial arc from the boundary to itself can be realized by an *orthogeodesic*- a geodesic segment perpendicular to the boundary at its initial and terminal points. This talk is about a special subclass of orthogeodesics called *primitive* orthogeodesics. In work with Hugo Parlier and Ser Peow Tan we show that the primitive orthogeodesics arise naturally in the study of maximal immersed pairs of pants in X and are intimately connected to regions of X in the complement of the natural collars. These considerations lead to continuous families of equations (so called *identities*) that remain constant on the deformation space of hyperbolic structures. (Received September 09, 2015)

33 ► Special functions

1115-33-52 **Gaurav Bhatnagar*** (bhatnagarg@gmail.com), Indian Statistical Institute, 7 S. J. S. Sansanwal Marg, Delhi, 110016, India. *A_n to A_m Heine transformation formulas.*

We generalize Heine's transformation formula to multivariable series related to the root system A_n. Heine's transformation formula transforms a ${}_2\phi_1$ series into a multiple of another ${}_2\phi_1$ series. Our formulas transform an A_n series into a multiple of an A_m series, somewhat like the results of Kajihara (2004). Our identities are closely related to multivariable q-binomial identities due to Gustafson and Krattenthaler (1997), Milne (1997), and Milne and Lilly (1995). (Received September 18, 2015)

34 ► Ordinary differential equations

1115-34-14 **Stuart P Hastings***, sph@pitt.edu. *Existence of Traveling Pulses in a Neural Model including Synaptic Depression.*

In 1992 G. B. Ermentrout and J. B. McLeod published a landmark study of traveling wavefronts for a differential-integral equation model of a neural network. Since then a number of authors have extended the model by adding an additional equation for a "recovery variable", thus allowing the possibility of travelling pulse type solutions. In a recent paper G. Faye gave perhaps the first rigorous proof of the existence (and stability) of a traveling pulse solution for such a model. The excitatory weight function used in this work allowed the system to be reduced to a set of four coupled ODEs, and a specific firing rate function, with parameters, was considered. The method of geometric singular perturbation was employed, together with blow-ups. In this paper we extend Faye's results on existence by dropping one of his key hypotheses, proving the existence of pulses at at least two different speeds, and in a sense, allowing a wider range of the small parameter in the problem. The proofs are classical, and self-contained aside from standard ode material. (Received July 13, 2015)

1115-34-23 **Xiao-Biao Lin*** (xblin@ncsu.edu), Department of Mathematics, NC State University, Raleigh, NC 27695-8205. *Multiple homoclinic solutions near a periodically perturbed degenerate homoclinic orbit.*

Using the moving coordinates, existence of traveling waves of a PDE becomes the existence of homoclinic/heteroclinic solutions of an ODE. Waves in periodic media can be modeled by periodically perturbed homoclinic/heteroclinic solutions. In this talk, we study homoclinic bifurcations for a periodically perturbed system. The unperturbed autonomous equation has a degenerate homoclinic orbit asymptotic to a hyperbolic equilibrium. We assume that the linear variational equation around the homoclinic orbit has 3 bounded linearly independent solutions, hence the homoclinic bifurcation is determined by 3 bifurcation equations. To the lowest order, the bifurcation equations become 3 quadratic equations, which can be simplified by the codiagonalization of quadratic forms. We find that, under general conditions, 4 transverse homoclinic orbits can be created near the degenerate homoclinic orbit. In terms of the original PDE, the traveling wave bifurcates into 4 traveling waves. This is joint work with Changrong Zhu, Chongqing University, China (Received July 28, 2015)

1115-34-83 **Amera H. Almusharrf*** (aalmusha@oakland.edu), 2409 Eastern Ave, Rochester Hills, MI 48307, and **Mier Shillor**, **Anna Spagnuolo** and **Nofe Al-asoud**. *On the Logistic Equation with Two Delays.* Preliminary report.

This work studies and numerically simulates three version of the logistic equation with two delays. Each version can be used as a model for population dynamics, however with different underlying assumptions. (Received September 06, 2015)

1115-34-287 **John Jinho Kim*** (jkim40@ncsu.edu). *Numerical computation of heteroclinic orbits based on the Principle of Wazewski.* Preliminary report.

The principle of Wazewski states that if there is a bounding region for the differential equation $\dot{x} = f(x)$ that satisfies certain hypotheses, then there exists a solution inside the region all the time. This has been a major tool to show the existence of traveling waves in many areas of mathematics such as predator-prey models, chemical reactions, and thermodynamics.

The purpose of this research is twofold. The first part is to develop a shooting method based on the principle of Wazewski to numerically compute the heteroclinic solution of the dynamical system, and determine the speed of convergence in terms of eigenvalues and the angles of intersection between stable and unstable manifolds of the equilibria.

The second part is to prove an inverse of the principle of Wazewski for some specific cases. Given the differential equation $\dot{x} = f(x)$ in $\mathbb{R}^3$, if there is a heteroclinic orbit formed by the intersection between the unstable manifold of E^- and the stable manifold of E^+, then the trapping region containing such an orbit can be constructed.

This talk is based on the thesis in North Carolina State University under direction of Professor Xiao-Biao Lin. (Received September 21, 2015)

35 ► Partial differential equations

1115-35-15 **Linghai Zhang*** (liz5@lehigh.edu), 14 East Packer Ave, Bethlehem, PA 18015.
Existence and Stability of Infinitely Many Traveling Pulse Solutions of Nonlinear Singularly Perturbed System of Integral Differential Equations Arising from Synaptically Coupled Neuronal Networks.

Consider the following nonlinear singularly perturbed system of integral differential equations arising from synaptically coupled neuronal networks

$$\begin{aligned} \frac{\partial u}{\partial t} + u + w &= \alpha \int_0^\infty \xi(c) \left[\int_{\mathbb{R}} K(x-y) H\left(u\left(y, t - \frac{1}{c}|x-y| \right) - \theta \right) \mathrm{d}y \right] \mathrm{d}c \\ &+ \beta \int_{\mathbb{R}} W(x-y) H(u(y,t) - \Theta) \mathrm{d}y, \\ \frac{\partial w}{\partial t} &= \varepsilon(u - \gamma w). \end{aligned}$$

In this system, K and W represent synaptic couplings between neurons in synaptically coupled neuronal networks.

The main purpose of this paper is to accomplish the existence and stability of infinitely many fast traveling pulse solutions as well as the existence and instability of infinitely many slow traveling pulse solutions of the nonlinear singularly perturbed system of integral differential equations arising from synaptically coupled neuronal networks. We will introduce speed index functions and stability index functions, establish a global strong maximum principle for the stability index functions, couple together linearized stability criterion and stability index function to accomplish the existence and stability/instability of fast/slow multiple traveling pulse solutions of the system. (Received July 13, 2015)

1115-35-24 **Anna Ghazaryan*** (ghazarar@miamioh.edu), Department of Mathematics, Bachelor Hall, Rm 123, Miami University, Oxford, OH 45056, and **Stephane Lafortune** and **Peter McLarnan**. *Stability of fronts in a model for combustion in hydraulically resistant porous media.*

We study front solutions of a system that models combustion in highly hydraulically resistant porous media. The spectral stability of the fronts is tackled by a combination of energy estimates and numerical Evans function computations. Our results suggest that there is a parameter regime for which there are no unstable eigenvalues. We use recent works about partially parabolic systems to prove that, in the regime when unstable eigenvalues are absent, the fronts are convectively unstable. (Received July 30, 2015)

1115-35-28 **Gro Hovhannisyan*** (ghovhann@kent.edu), 6000 Frank Avenue, NW, North Canton, OH.
Darboux transformations for dynamic systems on a time-space scale.

We describe Darboux transformations for dynamic systems on a time-space scale, that includes discrete and continuous dynamic systems. We prove Darboux's and Crum's theorems, and discuss the possible applications. (Received August 06, 2015)

1115-35-45 **Christine Breiner*** (cbreiner@fordham.edu) and **Tobias Lamm**. *Compactness Results for Biharmonic Maps.*

Critical points for the functional $E(u) = \int |\Delta u|^2$ are called biharmonic maps and are natural fourth order analogues of harmonic maps. Compactness theory for harmonic maps in two dimensions is well understood. In this talk we will discuss recent work with T. Lamm in which we determine energy quantization and the C^0 limit picture for sequence of approximate biharmonic maps from four dimensional manifolds into spheres. In particular, when the approximate map is in $L \log L$ we demonstrate that the energy does not concentrate. Moreover, we determine that if the $L \log L$ norm of the approximate maps does not concentrate, the image of the bubbles are connected without necks. (Received August 25, 2015)

1115-35-47 **Jianzhong Su*** (su@uta.edu), Department of Mathematics, University of Texas at Arlington, Arlington, TX 76019, and **Larrissa Owens** and **Sarah Langford**. *Modeling and Stability Analysis for Foreign Body Fibrotic Reactions.*

The implantation of medical devices often triggers several immune responses, one kind of which is categorized as foreign body reactions. It is well established that macrophages and many other cells participate in the complex processes of foreign body reactions, and cause severe inflammations and fibrotic capsule formation in surrounding tissues.

This talk introduces a kinetics-based model for analyzing reactions of various cells/proteins and biochemical processes as well as their transient behavior during the implant healing in 2-dimensional space. In particular, we provide a detailed modeling study of different roles of macrophages and their effects on fibrotic reactions. The

mathematical result indicates that the stability of the inflamed steady state depends primarily on the reaction dynamics of the system. However, if the said equilibrium is unstable by its reaction-only system, the spatial diffusion and chemotactic effects can help to stabilize when the model is dominated by classical and regulatory macrophages over the inflammatory macrophages. We also find that the simulation results are consistent with the experimental observations. These findings support that the model can reveal quantitative insights for studying foreign body reaction processes. (Received August 26, 2015)

1115-35-61 **Kelly McQuighan*** (kmcquigh@bu.edu), 111 Cummington Mall, Boston, MA 02215, and **Gene Wayne** (cew@bu.edu). *Towards Metastability in the Viscous Burgers Equation with Periodic Boundary Conditions.* Preliminary report.

Roughly speaking, metastable solutions are capture transient behavior which persists for long times. Recent work on Burgers equation on the real line and on Navier-Stokes equation with periodic boundary conditions have provided some insight into various mechanisms for metastability. In this talk we discuss a candidate metastable solution for the viscous Burgers equation with periodic boundary conditions. We construct the "frozen-time" spectrum for this solution using ideas from singular perturbation and Melnikov theory. Finally, we indicate future directions in which this spectrum can be used to understand metastability for the full PDE. (Received September 02, 2015)

1115-35-72 **Charles L. Epstein** and **Camelia A. Pop*** (capop@umn.edu). *Transition probabilities for degenerate diffusions arising in population genetics.* Preliminary report.

Generalized Kimura operators are a class of boundary-degenerate elliptic operators, introduced in the work of Charles Epstein and Rafe Mazzeo, to provide a unified framework for the study of diffusion processes arising in population genetics. They are an extension of the Wright-Fisher model for gene frequencies, and are defined on compact manifolds with corners, of which simplices are particular examples. In the present work, we study the structure and regularity properties of the transition probabilities of generalized Kimura diffusions. (Received September 04, 2015)

1115-35-78 **Jill Pipher*** (jill_pipher@brown.edu), Department of Mathematics, Brown University, 151 Thayer St., Providence, RI 02906. *Harmonic analysis and elliptic boundary value problems.*

The aim of this talk is to describe some of the modern developments in the theory of elliptic boundary value problems. A classical and well-studied example of a second order elliptic problem is the Dirichlet problem for Laplace's equation; the solutions are called harmonic functions. The Laplacian is a constant coefficient elliptic operator: but we shall consider variable coefficient operators as well. We want to understand when a variety of boundary value problems are well-posed in the presence of minimal assumptions on the prescribed boundary data, the geometry or smoothness of the domain, and the regularity of the coefficients. This is a big program, and this lecture will merely explore a small fraction of it, with a few motivating examples. (Received September 05, 2015)

1115-35-84 **Solomon Manukure*** (smanukure@mail.usf.edu), Department of Mathematics & Statistics, University of South Florida, 4202 E Fowler Ave, CMC16, Tampa, FL 33613, and **Wen-Xiu Ma**. *A soliton hierarchy associated with a new spectral problem and its Hamiltonian structure.*

A hierarchy of soliton equations together with its Hamiltonian structure is constructed from a new spectral problem associated with the three-dimensional special orthogonal real Lie algebra, so(3,$\mathbb{R}$). The Liouville integrability of the presented soliton hierarchy is proved, based on the Hamiltonian structure. (Received September 06, 2015)

1115-35-88 **Anna Ghazaryan**, **Stéphane Lafortune** and **Vahagn Manukian*** (manukive@miamioh.edu), Department of Mathematics, Miami University, 1601 University Blvd, Hamilton, OH 45011. *Stability of front solutions in a model for a surfactant driven flow on an inclined plane.*

We consider a model for the flow of a thin liquid film down an inclined plane in the presence of a surfactant. The model is known to possess various families of traveling wave solutions. We use a combination of analytical and numerical methods to study the stability of the traveling waves. We show that for at least some of these waves the spectra of the linearization of the system about them are within the closed left-half complex plane. (Received September 08, 2015)

1115-35-90 **Dipendra Regmi*** (regmid@farmingdale.edu), Farmingdale State College, Farmingdale, NY 11735. *The global regularity of two-and-half dimensional magnetohydrodynamic equations.* Preliminary report.

Whether or not classical solutions of the 2D incompressible MHD equations without full dissipation and magnetic diffusion can develop finite-time singularities is an outstanding open problem in fluid dynamics. We study the global regularity of classical solution to two-and-half dimensional MHD with horizontal dissipation and horizontal magnetic diffusion. In this presentation, we will discuss some recent results related to two and half dimensional MHD equations. (Received September 08, 2015)

1115-35-100 **Alim Sukhtayev*** (alimsukh@iu.edu). *The Morse and Maslov indices for one- and multidimensional Schrödinger operators. The generalized Hadamard's formula.*

We study the spectrum of the Schrödinger operators with matrix valued potentials utilizing tools from infinite dimensional symplectic geometry. Using the spaces of abstract boundary values, we derive relations between the Morse and Maslov indices for a family of operators on a Hilbert space obtained by perturbing a given self-adjoint operator by a smooth family of bounded self-adjoint operators. The abstract results are applied to the Schrödinger operators with theta-periodic, Dirichlet, Neumann and Robin boundary conditions. In particular, we derive an analogue of the Morse-Smale Index Theorem for the multidimensional Schrödinger operators. We also derive the generalized Hadamard's formula via the Maslov form. (Received September 09, 2015)

1115-35-138 **Nam Q. Le*** (nqle@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405, and **Ovidiu Savin** (savin@math.columbia.edu), Department of Mathematics, Columbia University, New York, NY 10027. *Global smoothness of the Monge-Ampere eigenfunctions.*

In this talk, we will discuss global smoothness of the eigenfunctions of the Monge-Ampere operator on smooth, bounded and uniformly convex domains in all dimensions. A key ingredient in our analysis is boundary Schauder estimates for certain degenerate Monge-Ampere equations. This is joint work with Ovidiu Savin. (Received September 13, 2015)

1115-35-143 **Yanyan Li*** (yyli@math.rutgers.edu), Department of Mathematics, 110 Frelinghusen Rd., Piscataway, NJ 08854, and **Jingang Xiong**. *Compactness of conformal metrics with positive constant Q-curvature.*

Let (M, g) be an $n \geq 5$ dimensional smooth compact Riemannian manifold of positive Yamabe type, which is not conformally equivalent to the standard sphere. We prove compactness of conformal metrics of g with positive constant Q-curvature provided that (M, g) is locally conformally flat, or $n = 5, 6, 7$. For $n \geq 8$, we prove the compactness result provided that the Weyl tensor of g does not vanish anywhere. (Received September 13, 2015)

1115-35-144 **Antonella Marini*** (marini@yu.edu), **Vincent Moncrief** (vincent.moncrief@yale.edu) and **Rachel Maitra** (maitrar@wit.edu). *Euclidean signature semi-classical methods for bosonic field theories.*

Elegant 'microlocal' methods have been extensively developed for the analysis of conventional Schrödinger eigenvalue problems. For technical reasons though these have not been applicable to quantum field theories. In this article we initiate a *Euclidean-signature semi-classical*) program to extend the scope of these analytical techniques to encompass the study of self-interacting scalar fields. The basic microlocal approach entails the solution of a single, nonlinear equation of Hamilton-Jacobi type followed by the integration (for both ground and excited states) of a sequence of *linear* 'transport' equations along the 'flow' generated by the 'fundamental solution' to the Hamilton-Jacobi equation. Using a combination of the direct method of the calculus of variations, elliptic regularity theory and the Banach space implicit function theorem we establish the existence, uniqueness and global regularity of the 'fundamental solution' to the relevant, Euclidean-signature Hamilton-Jacobi equation for the systems under study. Our methods are applicable to (massive) scalar fields with polynomial self-interactions as well as to Yang-Mills fields in $2 + 1$ and $3 + 1$ dimensions. (Received September 13, 2015)

1115-35-161 **Tianling Jin*** (tianling@caltech.edu), 1200 E California Blvd. Mail Code 9-94, Pasadena, CA 91125, **YanYan Li** (yyli@math.rutgers.edu), 110 Frelinghuysen Rd., Piscataway, NJ 08854, and **Jingang Xiong** (jx@bnu.edu.cn), Main Building 1307 A, School of Mathematical Sciences, Beijing Normal University, Beijing, Beijing 100875, Peoples Rep of China. *The Nirenberg problem and its generalizations: A unified approach.*

The classical Nirenberg problem asks for which functions on the sphere arise as the scalar curvature of a metric that is conformal to the standard metric. In this talk, we will discuss similar questions for fractional Q-curvatures.

This is equivalent to solving a family of nonlocal nonlinear equations of order less than n, where n is the dimension of the sphere. We will give a unified approach to establish existence and compactness of solutions. The main ingredient is the blow up analysis for nonlinear integral equations with critical Sobolev exponents. (Received September 15, 2015)

1115-35-240 **Antonio G Ache*** (aache@math.princeton.edu), Princeton, NJ 08544. *Sharp Trace-Sobolev inequalities of order four.*

We establish sharp Sobolev inequalities of order four on Euclidean d-balls for $d \geq 4$. When $d = 4$, our inequality generalizes the classical second order Lebedev-Milin inequality on Euclidean 2-balls. Our method relies on the use of scattering theory on hyperbolic d-balls. As an application, we charcaterize the extremals of the main term in the log-determinant formula corresponding to the conformal Laplacian coupled with the boundary Robin operator on Euclidean 4-balls. This is joint work with Alice Chang. (Received September 20, 2015)

1115-35-279 **Wenrui Hao*** (hao.50@osu.edu), 1735 Neil Ave., Columbus, OH 43210. *The LDL-HDL Profile Determines the Risk of Atherosclerosis.*

In this talk, I will describe a recent mathematical model that predicts the formation of a plaque as a function of the combined levels of (LDL, HDL) in the blood. The cholesterol levels in the blood reveal the risk of plaque growth in the artery. The model is given by a system of partial differential equations within the plaque. I will also briefly talk about some ongoing projects about aneurysm and red blood cell aggregation, which would have some potential blood biomarkers for diagnosis of AAA. (Received September 21, 2015)

1115-35-362 **Bo Guan*** (guan.19@osu.edu), Ohio State University, and Xiamen University. *Estimates for fully nonlinear PDEs on Riemannian manifolds.*

In this talk we give a survey on our recent work on fully nonlinear elliptic and parabolic PDEs. We discovered some new methods to derive apriori estimates which are crucial in solving fully nonlinear equations. Our methods give new result for equation in Euclidean spaces, but are powerful enough to work for equations on real on complex manifolds. The talk is based on joint work with my collaborators. (Received September 22, 2015)

37 ► Dynamical systems and ergodic theory

1115-37-20 **Aminur Rahman*** (ar276@njit.edu), Culimore Hall, New Jersey Institute of Technology, Newark, NJ 07103. *Neimark-Sacker bifurcation and evidence of chaos in a discrete dynamical model of walkers.*

Bouncing droplets on a vibrating fluid bath can exhibit wave-particle behavior, such as being propelled by the waves they generate. These droplets seem to walk across the bath, and thus are dubbed *walkers*. These walkers can exhibit exotic dynamical behavior which give strong indications of chaos, but many of the interesting dynamical properties have yet to be proven. In recent years discrete dynamical models have been derived and studied numerically. We prove the existence of a Neimark-Sacker bifurcation for a variety of eigenmode shapes of the waves from one such model. Then we reproduce numerical experiments and produce new numerical experiments and apply our theorem to the test functions used for that model in addition to new test functions. Further evidence of chaos is shown by numerically studying a global bifurcation. (Received July 21, 2015)

1115-37-128 **Dmitry Dolgopyat*** (dmitry@math.umd.edu) and **Omri Sarig**. *Windings of unipotent flows.* Preliminary report.

We discuss windings of unipotent orbits when the length of the orbit is uniformly distributed between zero and a large number T. This extends the results obtained by Joszef Beck for circle rotations. (Received September 11, 2015)

1115-37-223 **Ann Brett*** (ann.brett@jwu.edu) and **Mustafa Kulenovic**. *Two species competitive model with the Allee effect.*

We consider the following system of difference equations: $x_{n+1} = \frac{ax_n^2}{1+x_n^2+cy_n}$, $y_{n+1} = \frac{by_n^2}{1+y_n^2+dx_n}$, $n = 0, 1, \dots$, where a, b, c, d are positive constants and x_0,$y_0 \geq 0$ are initial conditions. This system has interesting dynamics and can have up to nine equilibrium points. The most complex and perhaps most interesting case is the case of nine equilibrium points, four of which are local attractors, four of which are saddle points, and one of which is a repeller. Using recent results of Kulenović and Merino we are able to characterize the basins of attractions of all local attractors and thus to describe the global dynamics of this system. This case can be considered as a two-dimensional version of the Allee effect for competitive systems. (Received September 19, 2015)

1115-37-226 **Yakov Pesin*** (pesin@math.psu.edu), Department of Mathematics, Eberly College of Science, Pennsylvania State University, University Park, PA 16802. *Thermodynamics of the Katok Map.*

I will describe the thermodynamical formalism for the smooth non-uniformly hyperbolic map of the two dimensional torus known as the Katok map. It is a slowdown of a linear Anosov automorphism near the origin and it is a local (but not small) perturbation. I demonstrate existence and uniqueness of equilibrium measures associated with the geometric potential and discuss their ergodic properties including the decay of correlations and the Central Limit Theorem. This is a joint work with S. Senti and K. Zhang. (Received September 19, 2015)

1115-37-227 **Svetlana Katok*** (sxk37@psu.edu), Department of Mathematics, The Pennsylvania State University, University Park, PA 16802. *Reduction theory for Fuchsian groups and coding of geodesics.* Preliminary report.

I will discuss a method of coding of geodesics on quotients of the hyperbolic plane by Fuchsian groups using boundary maps and "reduction theory". These maps are piecewise fractional-linear given by generators of the Fuchsian group, and the orbit of a point under the boundary map defines its boundary expansion. For compact surfaces they are generalizations of the Bowen-Series map, and for the modular surface are related to a family of (a,b)-continued fractions. For the natural extensions of the boundary maps Zagier's Reduction Theory Conjecture (RTC) holds: for the appropriate open sets of parameters they have attractors with finite rectangular structure to which (almost) every point is mapped after finitely many iterations. The RTC is used for representing the geodesic flow as a special flow over a cross-section of "reduced" geodesics parametrized by the attractor.

When a boundary expansion has a so-called "dual", the coding sequences are obtained by juxtaposition of the boundary expansions of the end points of the corresponding geodesic, and the set of coding sequences is a sofic shift. This was proved for the modular group and generalizes for Fuchsian groups that satisfy the RTC. The talk is based on joint works with Ilie Ugarcovici. (Received September 21, 2015)

1115-37-275 **Livio Flaminio**, **Giovanni Forni*** (gforni@math.umd.edu) and **James Tanis**. *Effective equidistribution of twisted horocycle flows and horocycle maps.*

We will discuss recent results, which improve upon earlier work of A. Venkatesh, on bounds on the rate of equidistribution of twisted horocycle flows and horocycle maps for hyperbolic surfaces of finite area. The main motivation is given by applications to sparse equidistribution problems (in particular a question of Shah and Margulis on equidistribution of horocycles at polynomial times) and to bounds on cusp forms, as well as general questions about effective equidistribution of unipotent flows. Our approach is based on harmonic analysis (in particular the classification and description of unitary representations by Gelfand-Naimark, Bargmann and Harish-Chandra), scaling of invariant distributions of the twisted horocycle flow and estimates on close return orbits of the horocycle flow. (Received September 21, 2015)

1115-37-301 **Mike Boyle*** (mmb@math.umd.edu). *Flow equivalence of G-SFTs and PET sofic shifts; complete algebraic invariants and their decidability, with application to Cuntz-Krieger algebras.*

I'll give complete algebraic invariants for flow equivalence of (1) G-SFTs (here G is an arbitrary finite group, and a G-SFT is a shift of finite type with a free shift-commuting G-action) and (2) irreducible PET (Point Expansion Type) sofic shifts ("PET" is a natural subclass of the AFT (almost finite type) class introduced by Marcus.) Then, (3) decidability for these invariants, and for the related "K-web" invariants for flow equivalence and Cuntz-Krieger algebras. (This involves stability bounds, algebraicity of elementary matrix groups and the decidability of simultaneous integral similarity of integral matrices due to Grunwald-Siegal.) I'll give historical background and context, including flow equivalence of Markov shifts with measures.

(1) and (2) are joint work with Toke Carlsen and Soren Eilers. (3) is joint work with Ben Steinberg. (Received September 21, 2015)

1115-37-318 **Hiroshi Kokubu*** (kokubu@math.kyoto-u.ac.jp), Department of Mathematics, Kyoto University, Kyoto, 606-8502, Japan. *Dynamical time-series analysis for Morse decomposition - an application to meteorological data with noise.*

A new time-series analysis method for Morse decomposition, a topological feature of global dynamics, is proposed, which can detect not only attractors but also unstable dynamical objects.

As an application, we study meteorological reanalysis data of pressure patterns in the northern hemisphere over 30 years of winter season (December - February). Direct application of the method to the data shows very noisy behavior without any clear structure, but an attempt to reducing effect of noise in the method shows

a transition among several characteristic patterns which is in good agreement with a common knowledge of meteorologists.

This is a joint work with Hidetoshi Morita (Kyoto), Masaru Inatsu (Sapporo) and Ippei Obayashi (Sendai). (Received September 21, 2015)

1115-37-319 **Anatole Katok*** (axk29@psu.edu), Department of Mathematics, The Pennsylvania State University, University Park, PA 16802. *Flexibility of entropies and Lyapunov exponents for smooth dynamical systems.* Preliminary report.

Entropies and Lyapunov characteristic exponents for "physical" measures are essential numerical measures of exponential complexity of orbit behavior. With few exceptions they cannot be precisely calculated. The flexibility program looks for finding general restrictions for those numbers and their interrelations that are expected to be few, and to showing that within those restrictions all values can be attained. I will discuss non-trivial progress that has been reached in two areas: geodesic flows on surfaces (joint with Alena Erchenko), and area-preserving diffeomorphisms on three-dimensional manifolds (joint with Jaime Bochi and Federico Rodriguez Hertz; in progress). I will outline general conjectures and mention some specific interesting problems. (Received September 21, 2015)

1115-37-323 **Ilya Vinogradov***, ivinogra@math.princeton.edu. *Effective equidistribution of horocycle lifts.*

We give a rate in the problem of equidistribution of lifted horocycles in the space of unimodular two-dimensional lattice translates. The ineffective version is due to Elkies and McMullen and relies on Ratner's Theorem. The approach used here follows recent works of Strömbergsson as well as Browning and the author. (Received September 21, 2015)

1115-37-328 **Hiroe Oka*** (oka@rins.ryukoku.ac.jp), Department of Applied Mathematics, and Informatics, Ryukoku University, Otsu, Shiga 520-2194, Japan. *Morse decomposition of regulatory networks via determining nodes.*

The regulatory network is a coupled ODE system associated with a network representing regulation relations among variables. This is a mathematical formulation of a biological regulatory network, given by Fiedler et al. (JDDE 2013). One of the main theorems of their paper is that the global attractor of a regulatory network can be reconstructed if one monitors all the information of solutions on the negative real line only at a suitable subset of nodes called the feedback vertex set (abbrev. FVS). This means that one can understand the nontrivial global dynamics of regulatory networks only from their FVS variables.

This result is, unfortunately, not very useful for practical applications, as one needs to monitor infinitely long time. In this talk, we shall show that, if one restricts attention to only a coarse information of global dynamics, namely its Morse decomposition, it is sufficient to monitor only on a finite time interval, or even at finitely many sample time points, at the FVS. We shall also show a result of numerical computation for Mirsky's circadian rhythm network as a test example.

This is a joint work with Bernold Fiedler (FU Berlin), Hiroshi Kokubu (Kyoto U), Atsushi Mochizuki (RIKEN), and Gen Kurosawa (RIKEN). (Received September 21, 2015)

1115-37-333 **Tomas Gedeon*** (gedeon@math.montana.edu), Department of Mathematical Sciences, Montana State University, Bozeman, MT 59717-2400, **Bree Cummins**, Montana State University, MT 59717-2400, and **Shaun Harker** and **Konstantin Mischaikow**. *Database for Dynamics: a new platform for qualitative modeling of dynamics.*

Experimental data on gene regulation is mostly qualitative, where the only information available about pairwise interactions is the presence of either up-or down- regulation. Quantitative data is often subject to large uncertainty and is mostly in terms of fold differences. Given these realities, it is very difficult to make reliable predictions using mathematical models. The current approach of choosing reasonable parameter values, a few initial conditions and then making predictions based on resulting solutions is severely subsampling both the parameter and phase space. This approach does not produce provable and reliable predictions.

We present a new approach that uses continuous time Boolean networks as a platform for qualitative studies of gene regulation. We compute a Database for Dynamics, which rigorously approximates global dynamics over entire parameter space. The results obtained by this method provably capture the dynamics at a predetermined spatial scale. (Received September 21, 2015)

1115-37-344 **Alexander Wright*** (alexmurraywright@gmail.com), 204 Durand Way, Palo Alto, CA 94304. *The fascinating and unlikely geometry of billiards in certain polygons.* Preliminary report.

We will give new examples of flat surfaces (including unfoldings of billiard tables) with amazing and unexpected geometry and dynamics. The talk will feature connections to algebraic geometry, but will be mostly self-contained. Joint work with Alex Eskin, Curt McMullen, and Ronen Mukamel. (Received September 22, 2015)

1115-37-359 **Yixin Guo*** (yixin@math.drexel.edu), 3141 Chestnut St, Department of Mathematics, Drexel University, Philadelphia, PA 19104, and **Aijun Zhang**. *Traveling pulses in a neural network with asymmetric coupling and non-saturating gain.*

We consider a neural field coupled by asymmetric off-centered connection. We first compute the traveling pulses using a system of delayed differential equations derived from the neural field model. We then investigate the necessary conditions for traveling pulses to exist in such a neural network. We find that the asymmetry in the coupling function is crucial for traveling pulses to exist. We explore when the traveling pulses cease to exist in terms of the off-center shift presented in the asymmetric coupling. We further study other dynamical properties of the traveling pulses and how the propagating speed depends on the gain and coupling parameters. (Received September 22, 2015)

1115-37-370 **Lucas Backes**, **Aaron W Brown*** (awbrown@math.uchicago.edu) and **Clark Butler**. *Continuity of Lyapunov exponents for 2D fiber-bunched cocycles.*

Consider a Hölder-continuous, 2-dimensional linear cocycle over a subshift of finite type equipped with an ergodic measure with product structure. We moreover assume the cocycle is fiber-bunched so as to admit a continuous family of holonomies. We show that the Lyapunov exponents of the cocycle vary continuously when restricted to the set of fiber-bunched Hölder cocycles. As a corollary, we derive continuity of Lyapunov exponents for some non-linear systems. This extends recent results of Viana-Bocker and Viana-Malheiro for i.i.d. and Markov random products of 2-dimensional matrices. (Received September 22, 2015)

1115-37-376 **Boris Kalinin** and **Victoria Sadovskaya*** (sadovskaya@psu.edu). *Normal forms on contracting foliations: smoothness and homogeneous structure.*

We consider a diffeomorphism f of a compact manifold M which contracts an invariant foliation W with smooth leaves. If the differential of f on TW has narrow band spectrum, there exist coordinates $H_x : W_x \to T_xW$ in which $f|_W$ has polynomial form. We present a modified approach that allows us to construct maps H_x that depend smoothly on x along the leaves of W. Moreover, we show that on each leaf they give a coherent atlas with transition maps in a finite dimensional Lie group. Our results apply, in particular, to C^1-small perturbations of algebraic systems. (Received September 22, 2015)

1115-37-377 **Tanya Firsova***, 138 Cardwell Hall, Manhattan, KS 66506, and **Jeremy Kahn** and **Nikita Selinger**. *Deformation spaces of rational maps.* Preliminary report.

I'll talk about topological properties of deformation spaces. (Received September 22, 2015)

1115-37-392 **Boris Kalinin*** (kalinin@psu.edu) and **Victoria Sadovskaya**. *On smooth classification of hyperbolic higher rank abelian actions.* Preliminary report.

Hyperbolic actions of $\mathbb{Z}^k$ and $\mathbb{R}^k$ extend the classical notion of Anosov diffeomorphisms and flows, which are hyperbolic actions of $\mathbb{Z}$ and $\mathbb{R}$. In contrast to the rank one case, higher rank hyperbolic actions exhibit various rigidity properties. We will focus on the problem of smooth classification, that is finding a smooth conjugacy to an algebraic model, and discuss recent progress for actions on an arbitrary manifold. (Received September 22, 2015)

1115-37-410 **Misha Guysinsky*** (mxg30@psu.edu), Pennsylvania State University. *Livšic Theorem for Diffeomorphisms Group*

We are proving that a Hölder continuous cocycle over a transitive homeomorphism with closing property (for example Anosov map or a transitive shift of finite type) with values in the group of diffeomorphisms of a compact manifold is a coboundary if and only the value of the cocycle over periodic points is the identity map. We do not assume that the cocycle is close to the identity. (Received September 23, 2015)

39 ► Difference and functional equations

1115-39-27 **Evelina G Lapierre*** (elapierre@jwu.edu), 8 Abbott Park Place, Providence, RI 02903, and **Wirot Tikjha** and **Edward Grove**. *On a Family of First-Order Piecewise Linear Systems.*

We will give a detailed analysis, complete with generalizations, open problems and conjectures, of the global character of the solutions of the piecewise linear difference equations

$$\begin{cases} x_{n+1} &= |x_n| + ay_n + b \\ \\ y_{n+1} &= x_n + c|y_n| + d \end{cases}, \quad n = 0, 1, \ldots$$

where the initial condition $(x_0, y_0) \in \mathbf{R}^2$ and the parameters $a, b, c, d \in \{-1, 0, 1\}$. (Received July 31, 2015)

1115-39-70 **William T Jamieson*** (jamieson_william@wheatoncollege.edu), Dept. of Mathematics and Computer Science, Wheaton College, 26 East Main Street, Norton, MA 02766. *On the Local Behavior of Real Analytic Non-hyperbolic Planar Maps.*

A complete classification of the qualitative behavior of real analytic planar maps in a neighborhood of an isolated fixed point with exactly one characteristic value equal to ± 1 will be presented. (Received September 05, 2015)

1115-39-106 **sabina jasarevic hrustic** and **mustafa kulenovic*** (mkulenovic@uri.edu), department of mathematics, university of rhode island, kingsion, RI 02881, and **mehmed nurkanovic**. *Local Dynamics and Global Stability of Certain Second Order Rational Difference Equation with Quadratic Terms.* Preliminary report.

In this talk we present a complete local dynamics and investigate the global dynamics of the following second order difference equation

$$x_{n+1} = \frac{Ax_n^2 + Ex_{n-1} + F}{ax_n^2 + ex_{n-1} + f}, \quad n = 0, 1, 2, ...$$

where the parameters A, E, F, a, e, f are nonnegative numbers with condition $A + E + F > 0$, $a + e + f > 0$ and the initial conditions x_{-1}, x_0 are arbitrary nonnegative numbers such that $ax_n^2 + ex_{n-1} + f > 0, n = 0, 1, 2, ...$ (Received September 10, 2015)

1115-39-107 **toufik khyat*** (toufik17@my.uri.edu), department of mathematics, university of rhode island, kingston, RI 02881, **mustafa r.s. kulenovic** (mkulenovic@uri.edu), department of mathematics, university of rhode island, kingston, RI 02881, and **esmir pilav** (esmirpilav@gmail.com), university of sarajevo, sarajevo, Bosnia-Herzegovina. *Global asymptotic stability and Naimark-Sacker bifurcation of a certain difference equation.* Preliminary report.

In this talk we consider the difference equation

$$x_{n+1} = a + \frac{x_n^2}{x_{n-1}^2}, \quad n = 0, 1, \ldots, \tag{1}$$

where the parameter a is positive number and the initial conditions x_{-1} and x_0 are positive numbers. Clearly equation (1) has the unique equilibrium point $\bar{x} = a + 1$. Linear fractional version of equation (1)

$$x_{n+1} = a + \frac{x_n}{x_{n-1}}, \quad n = 0, 1, \ldots, \tag{2}$$

was considered and we proved that the unique equilibrium $\bar{x} = a + 1$ of equation (2) is globally asymptotically stable. Introduction of quadratic terms into equation (2) changes local stability analysis and consequently the global dynamics as well. In particular, quadratic terms introduces the possibility of Naimark-Sacker bifurcation and the existence of locally stable periodic solution. (Received September 10, 2015)

1115-39-163 **Anatoli F Ivanov*** (aivanov@psu.edu), P.O. Box PSU, Lehman, PA 18627. *Homtervals and sinks in one-dimensional difference equations.*

The problem of existence of homtervals and infinitely many sinks for smooth interval maps is considered. It is shown that both can exist for C^∞ maps, in which case their ω-limit set must contain a flat critical point. Homtervals and/or infinitely many sinks can also exist away from the critical set of a map, in which case its smoothness cannot exceed $C^{2-\varepsilon}$. (Received September 15, 2015)

1115-39-180 **Arzu Bilgin*** (bilgin_a@my.uri.edu), Department of Mathematics, University of Rhode Island, Kingston, RI 02881, and **Ann Brett**, Johnson and Wales University, Providence, RI. *Global Dynamics of Cooperative Discrete System in the Plane.* Preliminary report.

In this paper we consider the cooperative system

$$x_{n+1} = ax_n + \frac{by_n^2}{1+y_n^2} \quad y_{n+1} = \frac{cx_n^2}{1+x_n^2} + dy_n, \quad n = 0, 1, \ldots,$$

where all parameters a, b, c, d are positive numbers and the initial conditions x_0, y_0 are nonnegative numbers. We describe the global dynamics of this system in number of cases. An interesting feature of this system is that exhibits a coexistence of locally stable interior equilibrium and locally stable positive periodic solution as well as the Allee's effect. This system has potential in modeling since all transition functiona are either linear or sigmoid Beverton Holt functions. (Received September 16, 2015)

1115-39-213 **Mark DiPippo***, Department of Mathematics, Rhode Island College, Providence, RI 02881. *Global Dynamics of Some Anti-competitive Systems of Difference Equations in the Plane.*

We investigate the global dynamics of several anti-competitive systems of rational difference equations which are special cases of general linear fractional system of the form

$$x_{n+1} = \frac{\alpha_1 + \beta_1 x_n + \gamma_1 y_n}{A_1 + B_1 x_n + C_1 y_n}, \quad y_{n+1} = \frac{\alpha_2 + \beta_2 x_n + \gamma_2 y_n}{A_2 + B_2 x_n + C_2 y_n}, \quad n = 0, 1, ...,$$

where all parameters and the initial conditions x_0, y_0 are arbitrary nonnegative numbers such that both denominators are positive. We find the basins of attraction of all attractors of these systems. (Received September 18, 2015)

1115-39-225 **Emmanouil Drymonis*** (edrymoni@providence.edu), Department of Mathematics and Computer Sc., Providence College, Providence, RI 02918. *Necessary and Sufficient Conditions for Boundedness of Rational Systems.* Preliminary report.

We present necessary and sufficient conditions for the boundedness character of the rational system:

$$x_{n+1} = \frac{\alpha_1 + \beta_1 x_n + \gamma_1 y_n}{A_1 + B_1 x_n + C_1 y_n} \text{ and } y_{n+1} = \frac{\alpha_2 + \beta_2 x_n + \gamma_2 y_n}{A_2 + B_2 x_n + C_2 y_n}$$

with nonnegative parameters and with arbitrary nonnegative initial conditions such that the denominators are always positive. We have discovered that there exist 15 patterns of boundedness which describe in detail the boundedness characterizations of all special cases of this system. We also present some thought provoking facts, open problems and conjectures on the global character of rational systems. Now that we know the boundedness behavior of this system we believe that rational systems offer a fertile area of research in the global character of solutions of nonlinear difference equations and nonlinear systems of difference equations. (Received September 19, 2015)

1115-39-286 **Daniel Hadley*** (dhadley@uri.edu), Department of Mathematics, University of Rhode Island, Kingston, RI. *Local Dynamics and Global Attractivity of Difference Equation* $x_{n+1} = \frac{Ax_n^2 + Cx_{n-1}^2 + Ex_{n-1}}{ax_n^2 + cx_{n-1}^2 + ex_{n-1}}$. Preliminary report.

We investigate local and global character of the equilibrium and local stability of the period-two solution of the difference equation

$$x_{n+1} = \frac{Ax_n^2 + Cx_{n-1}^2 + Ex_{n-1}}{ax_n^2 + cx_{n-1}^2 + ex_{n-1}}$$

where the parameters a, c, e, A, C, E are nonnegative numbers which satisfy $a+c+e > 0$ and the initial conditions x_{-1} and x_0 are arbitrary nonnegative numbers such that $ax_n^2 + cx_{n-1}^2 + ex_{n-1} > 0$ for all $n \geq 0$. (Received September 21, 2015)

1115-39-288 **David T McArdle*** (dmcardle@my.uri.edu), 257 Mile Rd, Coventry, RI 02816. *On the Dynamics of the Kth-Order Rational Difference Equation* $x_{n+1} = \frac{A_0}{x_n} + \frac{A_1}{x_{n-1}} + \frac{A_2}{x_{n-2}} + \cdots + \frac{A_k}{x_{n-k+1}}$. Preliminary report.

We consider the kth order rational difference equation

$$x_{n+1} = \frac{A_0}{x_n} + \frac{A_1}{x_{n-1}} + \frac{A_2}{x_{n-2}} + \cdots + \frac{A_k}{x_{n-k+1}}, \quad n = 0, 1, \ldots,$$

where $A_0, A_1, \ldots, A_k$ are positive constants and $x_0, y_0 \geq 0$ are the initial conditions. This equation was studied by Ladas and Grove in *Periodicities in Nonlinear Difference Equations* from 2005. An alternative proof of this result is presented here which allows for a considerably shortened proof of the global asymptotic result of Ladas. The proof draws on recent results of Kulenović and Janowski. (Received September 21, 2015)

1115-39-290 **Elliott Bertrand*** (ebertrand@my.uri.edu), Department of Mathematics, University of Rhode Island, Kingston, RI 02881. *Global Dynamics of a Second-Order Quadratic Fractional Difference Equation* $x_{n+1} = \dfrac{Cx_{n-1}^2 + Ex_{n-1} + F}{ax_n^2 + dx_n + f}$. Preliminary report.

In this paper we investigate the second-order difference equation

$$x_{n+1} = \frac{Cx_{n-1}^2 + Ex_{n-1} + F}{ax_n^2 + dx_n + f},$$

where the initial conditions x_{-1} and x_0 are arbitrary nonnegative numbers and the parameters satisfy $C, E, F, a, d, f \geq 0$, $C + E + F > 0$, and $a + d > 0$. Using the theory of monotone systems, we provide some results on the global character of this equation with the basins of attraction of its equilibria and periodic solutions. (Received September 21, 2015)

1115-39-295 **Michael A. Jones*** (maj@ams.org), 406 Fourth Street, Ann Arbor, MI 48103, and **Jennifer M Wilson** (wilsonj@newschool.edu), 65 West 11th Street, New York, NY. *Dynamics and Geometry of Three-Player Bankruptcy Rules.*

We use difference equations to define and analyze a dynamic approach to bankruptcy rules for three players by using the geometry of the 2-simplex. The dynamic process averages the projections of a 3-player allocation to three projection lines. For consistent, resource monotonic rules, we prove that the dynamic process converges to the 3-player solution. We show that the projection lines for these rules partition the simplex into six connected regions and we relate this geometry to the dynamic process. We also consider a random dynamic based on projection lines. Finally, we discuss generalizations to the n-player rule. (Received September 21, 2015)

1115-39-395 **E. Denette*** (edenette@uri.edu), **M.R.S. Kulenovic** (kulenm@math.uri.edu) and **E. Pilav** (esmirpilav@gmail.com). *Birkhoff normal forms, KAM theory and time reversal symmetry for certain rational map.*

By using the KAM theory and time reversal symmetries we investigate the stability of the equilibrium solutions of the system:

$$\begin{cases} x_{n+1} = \frac{1}{y_n} \\ y_{n+1} = \frac{\beta x_n}{1+y_n} \end{cases}, \quad n = 0, 1, 2, \ldots$$

where the parameter $\beta > 0$, 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 neighborhood 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 September 22, 2015)

47 ► Operator theory

1115-47-142 **Seyed Zoalroshd*** (szoalros@mail.usf.edu), 4202 East Fowler Avenue, Tampa, FL 33620. *The Schatten class membership of single layer potentials.*

In this talk, we discuss the Schatten class membership of single layer operators on planar curves. We also give some conditions regarding injectivity of layer potentials. (Received September 13, 2015)

1115-47-170 **Waleed Al-Rawashdeh*** (walrawashdeh@mtech.edu), Montana Tech, 1300 West Park Street, Butte, MT 59701. *Composition Operators on Generalized Weighted Nevanlinna Class.*

Let φ be an analytic self-map of open unit disk $\mathbb{D}$. The operator given by $(C_\varphi f)(z) = f(\varphi(z))$, for $z \in \mathbb{D}$ and f analytic on $\mathbb{D}$ is called a composition operator. Let ω be a weight function such that $\omega \in L^1(\mathbb{D}, dA)$, where dA denotes the normalized area measure on $\mathbb{D}$. The generalized weighted Nevanlinna class $\mathcal{N}_\omega$ consists of all analytic functions f on $\mathbb{D}$ such that $\|f\|_\omega = \int_{\mathbb{D}} \log^+(|f(z)|)\omega(z)dA(z)$ is finite; that is, $\mathcal{N}_\omega$ is the space of all analytic functions belong to $L_{\log^+}(\mathbb{D}, \omega dA)$. In this talk we investigate the boundedness, compactness and the essential norm of these composition operators on the space $\mathcal{N}_\omega$. (Received September 15, 2015)

51 ► Geometry

1115-51-130 **Jerzy Dydak*** (jdydak@utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 37996. *Axiomatization of geometry employing group actions and topology.* Preliminary report.

The aim of the talk is to outline a new axiomatization of planar geometry by reinterpreting the original axioms of Euclid. The basic concept is still that of a line segment but its equivalent notion of betweenness is viewed as a topological, not a metric concept. That leads quickly to the notion of connectedness without any need to dwell on the definition of topology. In our approach line segments must be connected. Lines and planes are unified via the concept of separation: lines are separated into two components by each point, planes contain lines that separate them into two components as well. We add a subgroup of bijections preserving line segments and establishing unique isomorphism of basic geometrical sets, and the axiomatic structure is complete. Of fundamental importance is the Fixed Point Theorem that allows for creation of the concepts of length and congruency of line segments.

Another thread of the talk is the introduction of boundary at infinity, an important concept of modern mathematics, and linking of Pasch Axiom to endowing boundaries at infinity with a natural relation of betweenness. That way spherical geometry can be viewed as geometry of boundaries at infinity. (Received September 12, 2015)

1115-51-188 **Egon Schulte*** (schulte@neu.edu), Northeastern University, Department of Mathematics, Boston, MA 02115. *Hereditary Polytopes.*

Regular polytopes have the remarkable property that they inherit all symmetries of each of their facets. This property distinguishes a natural class of polytopes called hereditary. In this talk we present the basic theory of hereditary abstract polytopes focussing on the analysis and construction of hereditary polytopes with highly symmetric facets. We also discuss the hereditary property for geometric polytopes and polyhedra. (Received September 16, 2015)

1115-51-197 **Dimitri Leemans*** (d.leemans@auckland.ac.nz), Private Bag 92019, Auckland, 1142, New Zealand. *Hypertopes with diagrams of assigned shape.* Preliminary report.

I will present some joint work with Marston Conder and Daniel Pellicer. We studied regular hypertopes with preassigned shape for their diagrams. The hypertopes with a path diagram are the usual polytopes. The smallest regular examples had been found by Conder in 2013. Here we looked at other shapes of diagrams and wanted to find the smallest examples for these diagrams. I will explain some results we obtained and how we obtained them. (Received September 17, 2015)

1115-51-330 **Ren Guo***, Departement of Mathmatics, Oregon State University, Corvallis, OR 97331. *Spaces of polyhedral metrics.*

Let V be a non-empty finite subset of points in a compact surface S. The space of Euclidean/spherical/hyperbolic polyhedral metrics on (S, V), is the set of all equivalence classes of Euclidean/spherical/hyperbolic polyhedral metrics on (S, V). The decorated Teichmüller space is the set of all decorated hyperbolic metric on $S - V$ up to isometry isotopic to the identity map. The Teichmüller space of a surface with boundary is the space of all equivalence classes of hyperbolic metrics with geodesic boundary on $S - V$. The five spaces of metrics are C^1-diffeomorphic to each other. The diffeomorphisms are equivariant under the action of the mapping class group. (Received September 21, 2015)

1115-51-380 **Aaron D Abrams*** (abrams.aaron@gmail.com), Mathematics Department, Washington and Lee University, Lexington, VA 24450. *Turaev's glide complexes.* Preliminary report.

I will discuss work of Turaev on glide complexes. (Received September 22, 2015)

1115-51-413 **Yooseob Jung**, **Seung Yoon Lee** and **Richard Kyung*** (nycrick@gmail.com), Choice Research Group, Cresskill, NJ 07626. *Solving the Square Triangle Picking Problem Using a New Method.*

Given three randomly chosen points inside a unit square, what is the expected area of the triangle formed by connecting the points? This problem is known as square triangle picking. In 1867, Wesley S. B. Woolhouse presented an answer to this problem. However, he left his answer in the form of 6 successive integrals. In this paper, a new solution has been proposed to this problem, which is easily computable by hand. The technique behind this is to first consider a bounding rectangle of the triangle, where the side lengths of the rectangle are parallel to those of the unit square. We can combine the cases based on where the vertices are located on the bounding rectangle. Case (a) represents diagrams where two of the vertices are in opposite corners and one

vertex is in the interior. There are 2 subcases: (i) Two vertices are in the upper-left and lower-right corners. (ii) Two vertices are in the lower-left and upper-right corners. Case (b) represents diagrams where one vertex is in a corner and two vertices each on sides not incident to the corner vertex. There are 4 subcases including one vertex is in the upper-left corner and the other vertex is in the lower-left corner. This paper shows that the mean area of the triangle to be close to the value of 11/144. (Received September 23, 2015)

52 ► Convex and discrete geometry

1115-52-25 **Hyun Jin Kim*** (hyunjin.sun.kim@gmail.com), Hofstra University, Hempstead, NY 11549-1000, and **Hyun Sun Kim**. *Special Configurations of Triangle Centers.*

For a given triangle, the circumcenter is the unique point in the plane of the triangle at equal distance from all three vertices. Similarly, the orthocenter is the point of intersection of the altitudes of the triangle. Euler proved that for any triangle, the midpoints of the sides, the feet of the altitudes and the midpoints of the segments joining the vertices of the triangle to the orthocenter lie on a circle. The center of this circle is the 9-point center of the triangle. We prove the following: Let A_1, A_2, A_3, A_4 be four points in the plane, no three on a line, all four not on a circle. For all $1 \leq i \leq 4$, let O_i and ω_i be the circumcenters and the 9-point centers of triangle $A_{i+1}A_{i+2}A_{i+3}$, respectively. Then the four-point configurations (O_1, O_2, O_3, O_4) and $(\omega_1, \omega_2, \omega_3, \omega_4)$ are similar. Moreover, the similarity ratio is not constant but depends on the initial points A_i in a way that is made explicit.) There are many triangle centers: these special points can be defined either as the result of some geometric construction (as it is the case with the circumcenter, the orthocenter, and the 9-point center) or may just have a pure algebraic description as explained in the paper. (Received July 31, 2015)

1115-52-92 **Dmitry Ryabogin*** (ryabogin@math.kent.edu). *On convex bodies with congruent projections.*

We discuss several results and problems related to the old question of Züss: let K and L be two convex bodies such that their orthogonal projections onto every subspace are congruent. Does it follow that K and L coincide up to translation and reflection at the origin? (Received September 08, 2015)

1115-52-102 **Valeriu Soltan*** (vsoltan@gmu.edu), George Mason University, 4400 University Drive, Fairfax, VA 22030. *Convex surfaces with planar polar sets and point-source shadow-boundaries.* Preliminary report.

Generalizing certain characteristic properties of ellipsoids, we describe all convex hypersurfaces in R^n, possibly unbounded, whose polar sets and point-source shadow-boundaries satisfy planarity conditions. (Received September 09, 2015)

1115-52-124 **T. Bisztriczky*** (tbisztri@ucalgary.ca). *Linked Neighbourly 4-polytopes.* Preliminary report.

Let $\mathcal{N}_n$ denote the family of combinatorially distinct neighbourly 4-polytopes P with n > 5 vertices. For P $\in \mathcal{N}_n$: any two vertices of P determine an edge of P, and an edge E of P is *universal* if the convex hull of E and any vertex of P is a face of P. With $\mathcal{U}$(P) denoting the set of universal edges of P, we say that P=P_n is *linked* if for m=n-1,...,5, there exist P_m in $\mathcal{N}_m$ with the property that $P_{m+1} \supset P_m$ and $\mathcal{U}(P_{m+1}) \setminus \mathcal{U}(P_m)$ is not empty. We note that any P_n is linked for n<10, and there is exactly one non-linked P_n for n=10. We examine some properties of linked P in $\mathcal{N}_n$ for any n>5. (Received September 11, 2015)

1115-52-184 **Daniela Maftuleac*** (dmaftule@uwaterloo.ca), David R. Cheriton School of Computer Science, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada. *Shortest path problem in CAT(0) rectangular complexes.* Preliminary report.

CAT(0) metric spaces constitute a far-reaching common generalization of Euclidean and hyperbolic spaces and simple polygons: any two points x and y of a CAT(0) metric space are connected by a unique shortest path. In this talk, we present an efficient algorithm for answering two-point distance queries in two-dimensional CAT(0) cube complexes (or also called CAT(0) rectangular complexes) and two of theirs subclasses, ramified rectilinear polygons (CAT(0) rectangular complexes in which the links of all vertices are bipartite graphs) and squaregraphs (CAT(0) rectangular complexes arising from plane quadrangulations in which all inner vertices have degrees $\geq$ 4). (Received September 16, 2015)

1115-52-203 **Carl W. Lee** (lee@uky.edu) and **Sarah A. Nelson*** (sarah.nelson@uky.edu). *Convex Polytopes, Toric g-Vectors, and Gale Transforms.* Preliminary report.

If P is a convex d-polytope with n vertices, then the combinatorial structure of P can be represented by a certain set of n points in $\mathbf{R}^e$ (a Gale transform), where $e = n - d - 1$. Associated with P is its flag-f-vector, which enumerates the numbers of chains of faces of the various possible types. The toric g-vector is a certain linear transformation of this vector. Lee proved that in the case of simplicial polytopes, the g_k can be interpreted as winding numbers of certain structures, called k-splitters, around points in the Gale transform, and also showed how this interpretation leads to the construction of special triangulations of P when $e = 2$ and $g_k = 0$. Welzl independently proved this latter triangulation result as well. We will extend these results by showing how to determine g_k of some types of nonsimplicial polytopes. In particular, we show how to determine g_k from two-dimensional Gale transforms, and prove the existence of special triangulations of P when $g_k = 0$ in this case. (Received September 22, 2015)

1115-52-243 **Jim Lawrence*** (lawrence@gmu.edu), Department of Mathematical Sciences, George Mason University, 4400 University Drive, Fairfax, VA 20330-4444. *Sections, Projections, and Shadow Boundaries.* Preliminary report.

We will present an oriented matroid theoretic description of the section by a given affine subspace of the shadow boundary of a simplex with respect to a given projection. A special case concerns the section or the projection of an arbitrary convex polytope. Some results and open problems will be given. (Received September 20, 2015)

1115-52-309 **Eric Ens*** (ericens@me.com), 504-177 Saint George street, Toronto, Ontario M5R 2M5, Canada. *Rank 4 Regular Toroidal Hypertopes.*

A regular toroidal polytope is a quotient of a regular tessellation T of euclidean n-space by a normal subgroup of translational symmetries. We can build these by starting with an infinite irreducible string Coxeter group and taking it's associated tessellation and finding the needed subgroup.

We will look at what we can build if we instead use the same process for any of the Infinite Irreducible Coxeter Groups. In the case of rank 4 there are 3 such groups, all subgroups of the tessellation by cubes. These constructions can be candidates for a regular hypertope, though this remains to be seen. We will also see how there are no rank 4 chiral toroidal hypertopes, much like there are no chiral toroidal rank 4 polytopes. (Received September 21, 2015)

1115-52-346 **Mathieu Dutour Sikirić**, **Alexey Garber*** (alexeygarber@gmail.com), **Achill Schürmann** and **Clara Waldmann**. *Enumeration of five-dimensional Dirichlet-Voronoi parallelohedra.*

In this talk we will report about full classification of combinatorially different five-dimensional Dirichlet-Voronoi parallelohedra for lattices.

The classification of affinely different Delone triangulations (L-type domains) can be done using Voronoi's second reduction theory. It was done completely for small dimensions up to 5. Dimensions 3 and 4 can be done without using the reduction theory, but already in dimension 5 it plays an important for classification. The classification of five-dimensional L-type domains was made by E. Baranovskii and S. Ryshkov in 1973. They found 221 different triangulations, but later P. Engel in 1998 found that they missed one triangulation.

In this talk we will show how one can extend the Voronoi's reduction theory to find all affinely non-equivalent lattice Delone decompositions and combinatorially different Dirichlet-Voronoi parallelohedra in arbitrary dimension and present our computational results in dimension 5.

Our main result is the following. There are 110244 affine types of lattice Delone triangulations and 110244 combinatorial types of Dirichlet-Voronoi parallelohedra in dimension 5. (Received September 22, 2015)

1115-52-371 **Karoly Bezdek*** (bezdek@math.ucalgary.ca). *On spherical Reuleaux polytopes.*

I call a spherical convex polytope a spherical Reuleaux polytope if it is of constant spherical width of $\pi/2$. The talk will discuss a number of basic properties of spherical Reuleaux polytopes. (Received September 22, 2015)

1115-52-387 **Nicholas A Matteo*** (matteo.n@husky.neu.edu). *k-Orbit Convex Polytopes.*

Convex polytopes and tilings of Euclidean space by convex polytopes whose symmetry groups have one orbit on their flags have been classified for a long time. We discuss the classification of convex polytopes and tilings with two, three, four, or five orbits. (Received September 22, 2015)

53 ► Differential geometry

1115-53-8 **Ovidiu Munteanu*** (ovidiu.munteanu@uconn.edu), Department of Mathematics, 196 Auditorium Rd, U-3009, Storrs, Connecticut 06269-3009, Storrs, CT 06268. *Ricci solitons.*

I will survey some recent development in the study of shrinking Ricci solitons. These are some generalizations of Einstein manifolds, and have proved to be very important for the study of the Ricci flow. They are classified in dimension two and three, but much less is understood in higher dimension. We will present some new results in dimension four, which show that the behavior of scalar curvature controls the geometry of the manifold. For example, we show that if the scalar curvature is bounded, then so is the Riemann curvature operator, and furthermore the curvature must be asymptotically non-negative, with an explicit decay rate at infinity. Furthermore, if the scalar curvature converges to zero at infinity, then the soliton must be asymptotically conical. Some extensions to arbitrary dimension can be obtained as well. This is joint with Jiaping Wang. (Received June 24, 2015)

1115-53-13 **Rafael Montezuma*** (rafaelmc@impa.br). *Min-max minimal hypersurfaces in non-compact manifolds.*

In this talk, I will discuss about the existence of embedded closed minimal hypersurfaces in complete non-compact manifolds containing a bounded open subset with smooth and strictly mean-concave boundary and a natural behavior on the geometry at infinity. For doing this, we develop a modified min-max theory for the area functional following Almgren and Pitts' setting, to produce minimal surfaces with intersecting properties. (Received July 10, 2015)

1115-53-19 **Bennett Chow*** (benchow@math.ucsd.edu), Department of Mathematics, University of California, San Diego, La Jolla, CA 92093, and **Peng Lu**. *Some results on the geometry near infinity of shrinking gradient Ricci solitons.* Preliminary report.

Let (M^n, g, f) be a complete noncompact shrinking gradient Ricci soliton (GRS). Then $\mathrm{Rc} + \nabla^2 f = \frac{1}{2} g$, where Rc and ∇^2 denote the Ricci tensor and Hessian, respectively. Assuming that the potential function f is normalized, we have $R + |\nabla f|^2 = f$, where R is the scalar curvature. The work of H.-D. Cao and D.-T. Zhou on a qualitatively sharp lower bound for f as well as at most Euclidean volume growth leads on to believe that shrinking GRS should have some sort of rigidity. Recent results on the geometry near infinity by O. Munteanu and J. Wang, B. Kotschwar and L. Wang, and others strongly support this belief. In this talk we discuss some consequences of these and other works in this area. (Received July 19, 2015)

1115-53-22 **Matthew J Gursky*** (mgursky@nd.edu), Department of Mathematics, 262 Hurley Hall, University of Notre Dame, Notre Dame, IN 46556. *A Riemannian structure on the space of conformal metrics.*

I will describe a Riemannanian structure on the space of conformal metrics satisfying a certain positivity condition. This metric is inspired by the Riemannian of the space of Kahler metrics, and shares many of the same properties. After defining the metric and deriving the geodesic equation, I will specialize to the case of two dimensions and prove some of the basic properties of the space. This is joint work with J. Streets (UC-Irvine). (Received July 25, 2015)

1115-53-30 **Peng Wu*** (wupenguin@math.cornell.edu). *A Weitzenbock formula for canonical metrics on four-manifolds and applications.*

The Weitzenbock formula plays a key role in the classification of Einstein four-manifolds with positive curvature. In this talk we will first discuss a new proof of the Weitzenbock formula for Einstein metrics using Berger curvature decomposition, then establish a unified framework for the Weitzenbock formula for a large class of canonical metrics on four-manifolds, which are called generalized m-quasi-Einstein metrics (or "Einstein metrics" for smooth metric measure spaces, including for example gradient Ricci solitons, quasi-Einstein metrics, and conformally Einstein metrics). As applications we will discuss several rigidity theorems for four-dimensional Einstein manifolds, conformally Einstein manifolds, gradient Ricci solitons, and quasi-Einstein manifolds. (Received August 09, 2015)

1115-53-31 **Robert Haslhofer*** (robert.haslhofer@gmail.com), University of Toronto, and **Or Hershkovits**, Courant Institute of Mathematical Sciences. *Mean convex level set flow in general ambient manifolds.*

We prove two new estimates for the level set flow of mean convex domains in Riemannian manifolds. Our estimates give control - exponential in time - for the infimum of the mean curvature, and the ratio between the norm of the second fundamental form and the mean curvature. In particular, the estimates remove a stumbling

block that has been left after the work of White and Haslhofer-Kleiner, and thus allow us to extend the structure theory for mean convex level set flow to general ambient manifolds of arbitrary dimension. (Received August 10, 2015)

1115-53-32 **Or Hershkovits*** (or.hershkovits@gmail.com), 581 prospect Ave apt 2R, Brooklyn, NY 11215. *Mean curvature flow of Reifenberg sets.*

The mean curvature flow, the gradient flow of the area functional, is one of the most natural geometric flows to consider for embedded hyper-surfaces in $\mathbb{R}^{n+1}$. Classically, given a sufficiently smooth hyper-surface (for which both the area and its gradient are defined), there exists a unique flow starting from it that exists for some positive time. Moreover, the flow smooths the hyper-surface instantaneously. In the early 90s it was shown by Ecker and Huisken that the smoothness assumption can be weakened to the class of uniformly locally Lipschitz hyper-surfaces (for which the area is defined, but its gradient may not be). When $n > 1$, this is the least regular object for which the flow was known to exist.

In this talk, we will show the short time existence and uniqueness of smooth mean curvature flow in arbitrary dimension starting from (sufficiently flat) Reifenberg sets, a class which is general enough to include some fractals sets. When $n > 1$, this provides the first known example of instant smoothing, by mean curvature flow, of sets with Hausdorff dimension larger than n. (Received August 10, 2015)

1115-53-34 **Adam Jacob*** (ajacob@math.ucdavis.edu), **Tristan C Collins** and **Shing-Tung Yau**. *(1,1) forms with specified Lagrangian phase.*

Let (X, α) be a Kähler manifold of dimension n, and let $[\omega] \in H^{1,1}(X, \mathbb{R})$. We study the problem of specifying the Lagrangian phase of ω with respect to α, which is described by the nonlinear elliptic equation

$$\sum_{i=1}^{n} \arctan(\lambda_i) = h(x)$$

where λ_i are the eigenvalues of ω with respect to α. When $h(x)$ is a topological constant, this equation corresponds to the deformed Hermitian-Yang-Mills (dHYM) equation, and is related by Mirror Symmetry to the existence of special Lagrangian submanifolds of the mirror. We introduce a notion of subsolution for this equation, and prove a priori $C^{2,\beta}$ estimates when $|h| > (n-2)\frac{\pi}{2}$ and a subsolution exists. Using the method of continuity we show that the dHYM equation admits a smooth solution in the supercritical phase case, whenever a subsolution exists. Finally, we discover some stability-type cohomological obstructions to the existence of solutions to the dHYM equation and we conjecture that when these obstructions vanish the dHYM equation admits a solution. We confirm this conjecture for complex surfaces. (Received August 13, 2015)

1115-53-46 **Christine Breiner*** (cbreiner@fordham.edu) and **Stephen J. Kleene**. *New examples of embedded minimal disks.*

We discuss recent work, joint with S. J. Kleene, which uses rather elementary gluing methods to produce new laminations of embedded minimal disks. We outline the basic steps of the construction and discuss how one might adapt the problem to produce laminations of surfaces with non-trivial topology. (Received August 25, 2015)

1115-53-51 **Xinliang An*** (anxinliangsky@gmail.com), Hill Center for the Mathematical Sciences, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. *On Gravitational Collapse in General Relativity.*

Abstract: In the process of gravitational collapse, singularities may form, which are either covered by trapped surfaces (black holes) or visible to faraway observers (naked singularities).

In this talk, I will present three results.

The first is a simplified approach to Christodoulou's monumental result which showed that trapped surfaces can form dynamically by the focusing of gravitational radiation from past null infinity. We extend the methods of Klainerman-Rodnianski, who gave a simplified proof of this result in a finite region.

The second result extends the theorem of Christodoulou by allowing for weaker initial data but still guaranteeing that a trapped surface forms in the causal domain. In particular, we show that a trapped surface can form dynamically from initial data which is merely large in a scale-invariant way. The second result is obtained jointly with Luk.

The third result extends Christodoulou's celebrated example on formation of naked singularity for Einstein-scalar field system under spherical symmetry. With numerical and analytic tools, we generalize Christodoulou's result and construct an example of naked singularity formation for Einstein vacuum equation in higher dimension. The third result is obtained jointly with Zhang. (Received August 29, 2015)

1115-53-66 **Biao Wang*** (biwang@qcc.cuny.edu). *Stability of spherical catenoids and helicoids in hyperbolic 3-space.*

For a family of spherical catenoids $\{\mathcal{C}_a\}_{a>0}$ in the hyperbolic 3-space, there exists a constant $a_c > 0$ such that $\mathcal{C}_a$ is an unstable minimal surface with Morse index one if $0 < a < a_c$ and $\mathcal{C}_a$ is a globally stable minimal surface if $a \geq a_c$.

For a family of helicoids $\{\mathcal{H}_{\bar{a}}\}_{\bar{a}>0}$ in the hyperbolic 3-space, there exists a constant $\bar{a}_c = \coth(a_c)$ such that $\mathcal{H}_{\bar{a}}$ is an unstable minimal surface with Morse index infinity if $\bar{a} > \bar{a}_c$ and $\mathcal{H}_{\bar{a}}$ is a globally stable minimal surface if $0 \leq \bar{a} \leq \bar{a}_c$. (Received September 03, 2015)

1115-53-74 **Dami Lee*** (damilee@indiana.edu). *On a triply periodic polyhedral surface whose vertices are Weierstrass points.*

In this talk, we will construct an example of a closed Riemann surface X that can be realized as a quotient of a triply periodic polyhedral surface $\tilde{X}$ where the Weierstrass points of X coincide with the vertices of the polyhedron. First we construct $\tilde{X}$ by attaching Platonic solids in a periodic manner. Due to periodicity we can find a compact quotient of it. Its symmetries allow us to construct hyperbolic structure and various translation structures on X that are compatible with its conformal type. The translation structures are the geometric representations of the holomorphic 1-forms of X and thus they allow us to identify the Weierstrass points. (Received September 05, 2015)

1115-53-75 **Peter McGrath*** (peter_mcgrath@brown.edu), Department of Mathematics, Box 1917, 151 Thayer Street, Providence, RI 02912. *New Examples of Closed Mean Curvature Flow Self-Shrinking Surfaces.*

Self-similar solitons, and in particular self-shrinking surfaces for the Mean Curvature Flow, are models for the formation of singularities in Mean Curvature Flow. Despite their importance, relatively few examples of self-shrinking surfaces have been rigorously shown to exist. I will describe a recent construction of an infinite family of closed, embedded self-shrinking surfaces. (Received September 05, 2015)

1115-53-79 **Goncalo Oliveira*** (oliveira@math.duke.edu). *Gauge Theory on G2 manifolds.* Preliminary report.

Gauge theoretical equations, as the instanton equation, have been used in low dimensions (less or equal than 4) with great success over the last 4 decades. When extra structure on the underlying manifold is available, one can extend some of these equations to higher dimensions and preserve their ellipticity modulo gauge. In this talk I will describe recent results related to one of these gauge theories on a G2 manifold. (Received September 05, 2015)

1115-53-97 **Andy Huang*** (ach3@rice.edu). *On harmonic maps between non-compact surfaces of different genera.* Preliminary report.

Harmonic diffeomorphisms between compact and non-compact surfaces have been very useful in parameterizing minimal surfaces and surface group representations, characterized by their underlying holomorphic data. Looking toward higher Teichmuller theory, harmonic maps between compact surfaces of different genera give rise to certain non-faithful surface group representations to which we can correspond the holomorphic data. In this talk, we'll begin this exploration by presenting a harmonic map from a punctured torus to the hyperbolic plane. Geometric considerations are used to ensure the subconvergence of a sequence of harmonic maps of a compact exhaustion. Along the way, we'll note where the construction can be generalized to higher genus surfaces and what holomorphic data we should expect in those cases. (Received September 09, 2015)

1115-53-141 **Andrew A Cooper*** (andrew.cooper@math.ncsu.edu), Box 8205, North Carolina State University, Raleigh, NC 27695. *Singularities of Lagrangian Mean Curvature Flow Are Mild or Conical.*

We investigate the singularities of compact Lagrangian mean curvature flows in complex Euclidean space by means of smooth singularity models. Singularities of such flows are either mild (type I) or can be modeled by unions of special Lagrangian cones. We will discuss applications of this result to conjectures of Thomas-Yau-Wang and Joyce regarding the structure of special Lagrangians in Calabi-Yau manifolds. (Received September 13, 2015)

1115-53-145 **Ling Xiao*** (lx70@math.rutgers.edu), Department of Mathematics, Rutgers University, 110 Frelinghuysen Rd., New Brunswick, NJ 08854. *A Level Set Approach for Motion by General Curvature.*

In this talk, I will introduce a level set approach to Ben Andrew's non-collapsing result, which provides a new way of understanding Ben Andrew's method. Moreover, this approach enables us to generalize Ben Andrew's result to weak solutions. (Received September 13, 2015)

1115-53-150 **Huai-Dong Cao*** (huc2@lehigh.edu), Department of Mathematics, Lehigh University, Bethlehem, PA 18015, and **Chenxu He** (chenxu.he@ucr.edu), Department of Mathematics, University of California at Riverside, Riverside, CA 92521. *On the Martin compactification of a complete Cartan-Hadamard surface.*

We discuss the Martin compactification of a complete non-compact surface of negative curvature, which is bounded from below but approaches zero along some paths to the infinity (of the surface). In particular, we investigate positive eigenfunctions with eigenvalue one of the Laplace operator and prove a certain uniqueness result. The uniqueness problem arises in our study of deformations of three-dimensional collapsed gradient steady Ricci solitons. (Received September 14, 2015)

1115-53-153 **Zihan Hans Liu***, zhliu@math.mit.edu. *The index of mean curvature flow singularities.*

We will discuss stability for singularities of the mean curvature flow, and introduce a notion of Morse index for these singularities. We will show that in three dimensions, rotationally symmetric, unstable singularities automatically have index at least 3. We will also give a generalization to higher dimensions. (Received September 14, 2015)

1115-53-159 **Mihai Bailesteanu*** (mihaib@ccsu.edu), Central Connecticut State University, 1615 Stanley Street, 120 Marcus White Hall, New Britain, CT 06050. *A Harnack inequality for the parabolic Allen-Cahn equation.* Preliminary report.

We prove a Harnack inequality for the solution of the parabolic Allen-Cahn equation $\frac{\partial f}{\partial t} = \triangle f - (f^3 - f)$ on a closed n-dimensional manifold. As a corollary we find a gradient bound for the standing wave solution, which improves on a result of Modica from the 1980s. (Received September 14, 2015)

1115-53-160 **Brett Lawrence Kotschwar*** (kotschwar@asu.edu), School of Math. and Stat. Sciences, Arizona State University, P.O. Box 871804, Tempe, AZ 85287-1804. *Short-time persistence of bounded curvature under the Ricci flow.*

We use a first-order energy quantity to prove a strengthened statement of uniqueness for the Ricci flow. One consequence of this statement is that if a complete solution on a noncompact manifold has uniformly bounded Ricci curvature, then its sectional curvature will remain bounded for a short time if it is bounded initially. In other words, the Weyl curvature tensor of a complete solution to the Ricci flow cannot become unbounded instantaneously if the Ricci curvature remains bounded. (Received September 14, 2015)

1115-53-168 **Yakov I Berchenko-Kogan*** (yashabk@math.mit.edu). *Yang-Mills Replacement.* Preliminary report.

Harmonic replacement is a technique for reducing the energy of a map $u\colon \Sigma^2 \to M$ by replacing it on a small ball B^2 with a harmonic map $v\colon B^2 \to M$ with the same values on the boundary as u. Harmonic replacement has proven to have a wide range of applications, such as the Perron method for constructing global harmonic functions, and, more recently, Colding and Minicozzi's proof of the finite extinction of Ricci flow on homotopy 3-spheres. We develop an analogous technique for Yang-Mills connections on 4-manifolds, where we replace a connection A on a small 4-ball B^4 with a Yang-Mills connection B that has the same restriction to the boundary as A, thereby decreasing the energy. In both settings, the maps u and connections A are assumed to be L^2_1, not necessarily continuous, leading to subtleties involving borderline Sobolev spaces. It is hoped that this Yang-Mills replacement technique could be used to simplify the proofs in Taubes's work on the stable topology of the moduli spaces of anti-self-dual connections, as well as to provide a simpler alternative to Yang-Mills gradient flow in certain applications. (Received September 15, 2015)

1115-53-176 **Heather Macbeth*** (hmacbeth@mit.edu). *Conformal classes realizing the Yamabe invariant.*

I will present an algebraic characterization of the conformal classes realizing a compact manifold's Yamabe invariant (if any such classes exist). This characterization is a nonlinear analogue of an observation of Nadirashvili for metrics realizing the maximal first eigenvalue, and of an observation of Fraser and Schoen for metrics realizing the maximal first Steklov eigenvalue. (Received September 16, 2015)

1115-53-201 **Xiaodong Wang*** (xwang@math.msu.edu) and **Ye-Kai Wang**. *Heintze-Karcher inequality on static manifolds.*

Static manifolds come from general relativity. Important examples are the de Sitter-Schwarzschild manifolds for which Brendle recently established Heintze-Karcher inequalities for certain warped product manifolds and used them to prove uniqueness results for constant mean curvature hypersurfaces. We generalize Brendle's method to prove a similar inequality for general static manfiolds. As an application we derive a reversed Penrose inequality. (Received September 18, 2015)

1115-53-352 **Ruobing Zhang*** (ruobingz@math.princeton.edu). *Positivity of Non-local Curvature and Topology of Locally Conformally Flat Manifolds.*

In this talk, we focus on the geometry of compact conformally flat manifolds (M^n, g) with positive scalar curvature. It is a classical result by R. Schoen and S. Yau that the universal cover of M^n is conformally embedded in S^n such that M^n is a Kleinian manifold. Moreover, the limit set of the Kleinian group has Hausdorff dimension $< (n-2)/2$. If additionally we assume that the non-local curvature $Q_{2\gamma} > 0$ for some $1 < \gamma < 2$, we prove that the Hausdorff dimension of the limit set is less than $< (n-2\gamma)/2$. In fact, the above upper bound is sharp. As applications, we obtain some topological rigidity and classification theorems for dimensions less than 6. (Received September 22, 2015)

1115-53-384 **Brice Pascal Loustau*** (brice.loustau@gmail.com), 101 Warren Street, Newark, NJ 07102. *Minimal surfaces in hyperbolic 3-manifolds and deformation spaces.*

I will discuss aspects of the theory of minimal surfaces in hyperbolic 3-manifolds and their importance in the study of representations of surface groups into PSL2(C) and related deformation spaces, such as the deformation space of quasi-Fuchsian structures, Taubes' moduli space of minimal hyperbolic germs and the moduli space of Higgs bundles. (Received September 22, 2015)

1115-53-389 **Susan Tolman*** (stolman@math.uiuc.edu), Urbana, IL 61801. *Non-Hamiltonian circle actions.*

Let a circle act on a compact connected symplectic manifold with isolated fixed points. If the action is Hamiltonian, then the moment map determines an important basis for the (equivariant) cohomology, and gives a great deal of information about the original manifold. The leqads to following question is often called the "McDuff conjecture": Are such actions always Hamiltonian. I show that the answer to this question is "no" by producing a non-hamiltonian symplectic circle action with isolated fixed points on an compact, connected symplectic manifold. Based in part on joint work with J. Watts. (Received September 22, 2015)

1115-53-405 **Jaigyoung Choe** and **Ailana Fraser*** (afraser@math.ubc.ca), Vancouver, Canada. *Minimal submanifolds in a manifold of nonnegative Ricci curvature.* Preliminary report.

Let M be a compact orientable Riemannian manifold of nonnegative Ricci curvature and Σ a compact embedded orientable minimal hypersurface in M. It is proved that there is a dichotomy: If Σ does not separate M then Σ is totally geodesic and $M \setminus \Sigma$ is isometric to the Riemannian product $\Sigma \times (a, b)$, and if Σ separates M then the map $i_* : \pi_1(\Sigma) \to \pi_1(M)$ induced by inclusion is surjective. This surjectivity is also proved for a compact hypersurface with mean curvature $H \geq (n-1)\sqrt{k}$ in a manifold of Ricci curvature $Ric_M \geq -(n-1)k, k > 0$, and for a free boundary minimal hypersurface in a manifold of nonnegative Ricci curvature with nonempty strictly convex boundary. (Received September 22, 2015)

54 ► General topology

1115-54-26 **Leonard R Rubin*** (lrubin@ou.edu), Department of Mathematics, University of Oklahoma, 601 Elm Ave., Rm. 423, Norman, OK 73019. *Universal Spaces in Dimension Theory.*

A universal object for a class $\mathcal{C}$ of topological spaces is an element X of $\mathcal{C}$ having the property that each element of $\mathcal{C}$ embeds in X. For covering dimension, dim, the existence of universal objects for the class of metrizable compacta with $\dim \leq n$, $n \geq 0$, the existence of universal spaces has been known since the 1930s. For compact Hausdorff spaces or metrizable spaces of infinite weight $\leq w$, this result is repeated.

For cohomological dimension $\dim_G$, G an abelian group, there is also some theory in this direction. According to a result of W. Olszewski from 1995, for each countable abelian group G and $n \geq 0$, the class of separable metrizable spaces of $\dim_G \leq n$ has a universal element. It is not known if this fact can be established for

arbitrary G or with separable metrizable replaced by metrizable spaces of infinite weight $\leq w$. When it comes to the class of metrizable compacta with $\dim_G \leq n$, the situation is more enigmatic.

In this presentation we will explain to some extent the ideas behind proving the known results and indicate what might be done about the unsolved problems. (Received July 31, 2015)

1115-54-259 **Kyle Istvan*** (kistva1@lsu.edu), **Khaled Qazaqzeh** and **Ayman Abouzaid**. *The Kauffman Polynomial of Periodic Links.*

A periodic link has a diagram that is invariant under a finite-order rotation in the plane. I will define a necessary condition for a link to be p-periodic. It takes the form of a congruence between a specialization of the 2-variable Kauffman polynomial of a link and that of the link's mirror image. The result is derived using a state sum formula for the 2-variable polynomial, and can be used to verify (for example) Traczyk's result that the knot 10_{101} is not 7-periodic. (Received September 20, 2015)

1115-54-396 **Jeffrey Tithof*** (jtithof3@gatech.edu), **Balachandra Suri**, **Miroslav Kramár**, **Rachel Levanger**, **Mu Xu**, **Mark Paul**, **Konstantin Mischaikow** and **Michael F. Schatz**. *Using Persistent Homology to Describe Convection Experiments and Simulations.*

Persistent homology, a branch of algebraic topology, provides a powerful mathematical formalism which can be used to characterize complicated patterns which arise in nature and technology. We explore the application of persistent homology to describe spatiotemporal dynamics in a canonical fluid mechanics problem, Rayleigh-Bénard convection (RBC). RBC refers to the buoyancy-driven flow of a thin layer of fluid which is heated from below and cooled from above, much like Earth's atmosphere. We collect time series of two-dimensional flow field patterns (e.g., the midplane temperature field) for both simulations and experiments as they evolve in a chaotic regime. For each flow field, we compute a persistence diagram (PD), which yields a reduced description of the flow field. By applying different metrics to the space of PDs, we relate characteristic features in PDs to the geometry of the corresponding flow fields. Our results show that persistent homology is a powerful way to gain new physical insights into the complicated dynamics of large spatially extended systems that are driven far-from-equilibrium. (Received September 22, 2015)

55 ► *Algebraic topology*

1115-55-115 **Hiraku Abe*** (hirakuabe@globe.ocn.ne.jp), **Megumi Harada**, **Tatsuya Horiguchi** and **Mikiya Masuda**. *The cohomology of regular Hessenberg varieties and representations of symmetric groups.*

Hessenberg varieties are defined as subvarieties of a flag variety. This class of subvarieties contains, as some special cases, the Peterson variety and the toric variety associated with a root system. In this talk, we will concentrate on the type A case, and we will discuss a relation between cohomology rings of "regular nilpotent" Hessenberg varieties (e.g. the Peterson variety) and "regular semisimple" Hessenberg varieties (e.g. the toric variety associated with the root system of type A) in terms of representations of a symmetric group. This is a joint work with Megumi Harada, Tatsuya Horiguchi, and Mikiya Masuda. (Received September 10, 2015)

1115-55-242 **Mao Li** and **Washington Mio*** (mio@math.fsu.edu), Department of Mathematics, Florida State University, Tallahassee, FL 32306-4510. *Persistent Homology and Barcode Fields.* Preliminary report.

Persistent homology, among other things, lets us construct informative topological summaries of the shape of data. Using a kernel construction, we propose a localized form of homology represented by a continuous barcode field that is stable with respect to the Wasserstein metric and thus robust to noise and outliers. We also discuss applications to shape analysis. (Received September 20, 2015)

1115-55-271 **Brittany Terese Fasy*** (brittany@fasy.us), Montana State University, Computer Science Department, 357 EPS Building, Bozeman, MT 59717. *Statistics in TDA.*

Persistent homology is a widely used tool in Topological Data Analysis that encodes multi-scale topological information as a multi-set of points in the plane, called a persistence diagram. The method involves tracking the birth and death of topological features as one varies a tuning parameter. Features with short lifetimes are informally considered to be "topological noise," and those with a long lifetime are considered to be "topological signal." We bring some statistical ideas to persistent homology in order to derive confidence sets that allow us to separate topological signal from topological noise. We also observe that it is difficult to apply statistical theory directly to a random sample of diagrams. Instead, we summarize the persistent homology with the persistence

landscape and silhouette, which convert diagrams into a well-behaved real-valued functions. We can then apply statistical theory to these functions rather than the original diagrams. (Received September 21, 2015)

1115-55-302 **Ross Geoghegan*** (ross@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902-6000. *Shape theory and aperiodic tilings.* Preliminary report.

Suppose given finitely many "colored" compact convex polyhedral subsets of the plane, called "proto-tiles", where it is assumed that if one of these can be obtained from another by rigid planar translation then their "colors" must be different. A "tile" in the plane is a copy of a proto-tile obtained by rigid planar translation. A "tiling" is a cover of the plane by tiles, where two tiles which meet do so in a full face of both. The tiling is "aperiodic" if it is not preserved by any non-trivial planar translation. There is a well-established equivalence relation on the set of all tilings of the plane, and the equivalence class of a tiling T gets a sensible topology making it a 2-dimensional metric continuum. It is called the "tiling space" of T. For many kinds of aperiodic tilings the Cech cohomology of this space has been studied. I will discuss the shape theory of this space. (Joint work with John Hunton). (Received September 21, 2015)

1115-55-303 **Elizabeth Munch*** (emunch@albany.edu) and **Bei Wang**. *Reeb Space Approximation with Guarantees.*

The Reeb space, which generalizes the notion of a Reeb graph, is one of the few tools in topological data analysis and visualization suitable for the study of multivariate scientific datasets. First introduced by Edelsbrunner et al., the Reeb space of a multivariate mapping $f : \mathbb{X} \to \mathbb{R}^r$ parameterizes the set of components of preimages of points in $\mathbb{R}^r$. Intuitively, it summarizes the data by compressing the components of the level sets of f and captures the relationship among the multiple real-valued functions within subsets of the domain. Two approximations of the Reeb space have been given, the Joint Contour Net (JCN) by Carr and Duke, and the mapper construction given by Singh et al. While it is often assumed that these constructions converge to the Reeb space, to the knowledge of the authors, no formal statement or proof to that effect has been previously given.

In this talk, we give formal results proving the convergence between the Reeb space and its discrete approximations, JCN and mapper, in terms of the interleaving distance. At a fixed resolution of the discretization, this distance allows us to quantify the approximation quality and leads to guarantees for existing Reeb space approximations. (Received September 21, 2015)

1115-55-354 **Gregory Henselman*** (grh@seas.upenn.edu). *A Morse-theoretic algorithm to compute persistent homology, with generators.*

We introduce two Morse-theoretic methods for memory-efficient computation of persistent homology on a filtered clique complex. The first utilizes a notion of 'ghost' simplex to remove top-dimensional cells dynamically during construction of the input space; the second appeals to an algebraic interpretation of the Morse boundary operator to recover, in a memory-efficient fashion, barcode representatives in the unreduced complex via row operations. Experiments with random, geometric, and empirical data suggest that, for complexes with large cliques, the reduction approach may decrease the number of cells stored in memory by several orders of magnitude, while the memory requirement of storing generators remains approximately linear in the rank of the top-dimensional boundary operator. (Received September 22, 2015)

1115-55-381 **Vladimir Itskov*** (vladimir.itskov@math.psu.edu), Department of Mathematics, University Park, PA 16802, **Chad Giusti**, PA , and **William Kronholm**, CA. *Convexity and combinatorial topology of neural codes.*

The brain represents information via patterns of neural activity. These patterns often describe a space of stimuli that possess an intrinsic geometric structure. Deducing this structure from the combinatorics of the neural code alone is a largely unsolved problem.

A combinatorial code (i.e. a subset of $2^{[n]}$) is called convex if it arises from intersection patterns of open (or closed) convex sets in some Euclidean space. Not every combinatorial code is convex. While some topological obstructions to convexity are known, what makes a combinatorial code convex is still poorly understood. I will give a short introduction to this new subject and review the currently known results and open problems. (Received September 22, 2015)

1115-55-382 **Carina Curto*** (ccurto@psu.edu), Department of Mathematics, The Pennsylvania State University, University Park, State College, PA 16802, and **Chad Giusti**, **Vladimir Itskov** and **Eva Pastalkova**. *Clique topology reveals intrinsic geometric structure in neural correlations.*

Detecting meaningful structure in neural activity and connectivity data is challenging in the presence of hidden nonlinearities, where traditional eigenvalue-based methods may be misleading. We introduce a novel, topological approach to matrix analysis that uncovers features of the data that are invariant under arbitrary monotone transformations. These features are encoded in the order complex, a combinatorial object that keeps track of the ordering of matrix entries. We found that topological invariants of the order complex, called Betti curves, can be used to distinguish random from non- random structure, and provide reliable signatures of geometric organization. We then analyzed the pattern of correlations among pyramidal neurons in rat hippocampus, where geometric structure is an expected correlate of position coding. Remarkably, we found that hippocampal activity exhibits geometric signatures not only during spatial navigation, but also during non-spatial behaviors such as wheel running and sleep. (Received September 22, 2015)

57 ► Manifolds and cell complexes

1115-57-10 **Tian Yang***, Building 380, Stanford, CA 94305. *On type-preserving representations of the four-punctured sphere group.*

We give counterexamples to a conjecture of Bowditch that if a non-elementary type-preserving representation $\rho : \pi_1(\Sigma_{g,n}) \to PSL(2;\mathbb{R})$ of a punctured surface group sends every non-peripheral simple closed curve to a hyperbolic element, then ρ must be Fuchsian. The counterexamples come from relative Euler class ± 1 representations of the four-punctured sphere group. As a related result, we show that the mapping class group action on each non-extremal component of the character space of type-preserving representations of the four-punctured sphere group is ergodic. The main tool we use is Penner's lengths coordinates of the decorated character spaces defined by Kashaev. (Received June 29, 2015)

1115-57-53 **BoGwang Jeon*** (bogwang.jeon@gmail.com), 2990 Broadway, New York, NY 10027. *Realization of hyperbolic surfaces.* Preliminary report.

In this talk, we show the following statement:

every real number field arises as the trace field of any hyperbolic surface. (Received August 31, 2015)

1115-57-56 **Mustafa Hajij*** (mhajij@usf.edu), Tampa, FL 33647, and **Mohamed Elhamdadi** (emohamed@mail.usf.edu), Tampa, FL 33647. *Pretzel Links and q-Series.* Preliminary report.

The tail of the colored Jones polynomial is a q-power series alternating knot invariant. It has been shown that the tail of the colored Jones polynomial of (2,p) torus knots give the Andrews Gordon identities for the two variable Ramanujan theta function as well as corresponding identities for the false theta function. In this talk we show some q-series identities that one can obtain from pretzel links. (Received August 31, 2015)

1115-57-89 **Anh T Tran*** (att140830@utdallas.edu), The University of Texas at Dallas, Richardson, TX 75080. *On the AJ conjecture for cable knots.*

We study the AJ conjecture for (r,2)-cables of a knot, where r is an odd integer. Using skein theory, we show that the AJ conjecture holds true for most (r,2)-cables of some classes of two-bridge knots and pretzel knots. (Received September 08, 2015)

1115-57-101 **Steven Frankel*** (steven.frankel@yale.edu). *Coarse hyperbolicity and closed orbits for quasigeodesic flows.*

A flow on a 3-manifold is called quasigeodesic when each flowline is coarsely comparable to a geodesic. In this talk we will show that every quasigeodesic flow on a closed hyperbolic 3-manifold has closed orbits, resolving a question of Calegari's.

A quasigeodesic flow is defined by a tangent condition. In contrast, a pseudo-Anosov flow is defined by a transverse condition; the transverse structure is hyperbolic in the sense that nearby flowlines diverge in some directions and converge in others.

A priori, these transverse and tangent conditions are unrelated. However, when the ambient manifold is hyperbolic, a quasigeodesic flow admits a transverse structure that is remarkably similar to that of a pseudo-Anosov flow, except that it is only *coarsely* hyperbolic. Nevertheless, we can prove a sort of closing lemma for

coarsely hyperbolic flows, allowing us to approximate recurrent orbits by closed orbits. (Received September 09, 2015)

1115-57-104 **Louis H Kauffman*** (kauffman@uic.edu), Math UIC, 851 South Morgan Street, Chicago, IL 60607-7045. *Rotational Virtual Links and Quantum Link Invariants.* Preliminary report.

Rotational virtual links are virtual links where the detour move is restricted to regular homotopy. All quantum link invariants for classical links generalize to rotational virtual links. We show how the theory of such invariants is closely related to the structure of a functor from the virtual tangle category to the category of a quantum algebra and we give examples of links that are not detectable by any quantum link invariants known to us at this time. (Received September 10, 2015)

1115-57-105 **Robert J Daverman***, Deparrtment of Mathematics, University of Tennessee, Knoxville, TN 37996. *Smearing the wildness of crumpled cubes via cell-like maps.*

The setting involves a closed n-cell complement C in S^n and a cell-like map $f : S^n \to S^n$ such that $f(BdC)$ is a sphere and all non-degenerate point preimages under f lie in BdC. We think of f as smearing the wildness of BdC about $f(C)$ and investigate the effects of the smearing process. It can happen that smearing simplifies $f(C)$, yielding an n-cell, but it definitely can complicate the situation. For instance, there is a C such that BdC is locally flat modulo a Cantor set standardly embedded in BdC and $f(BdC$ is everywhere wild. Of primary interest is the extent to which $f(BdC)$ is more complicated than BdC itself. (Received September 10, 2015)

1115-57-108 **Eriko Hironaka*** (ehironaka@gmail.com). *Braid-like Mapping Classes.*

In this talk, we investigate mapping classes that are flow-equivalent to braid monodromies. Given a braid, the associated braid closure is a fibered link, which fibers in an infinite number of ways. We study the properties of the monodromies of these fibrations. (Received September 21, 2015)

1115-57-110 **Allison H Moore*** (allison.h.moore@rice.edu), MS-136, Box 1892, Houston, TX 77251-1892, and **Tye Lidman**, 1 Einstein Drive, Princeton, NJ 08540. *Nugatory crossings and symmetric unions.*

The cosmetic crossing conjecture asserts that the only crossing changes which preserve the isotopy class of a knot are nugatory. Previously, the knots known to satisfy this conjecture included two-bridge and fibered knots. We will show that knots with branched double covers that are L-spaces also satisfy the cosmetic crossing conjecture, provided the first singular homology of the branched double cover decomposes into summands of square-free order. Additionally, we will demonstrate how a symmetric union, a classical construction of Kinoshita-Terasaka, can be used to generate an infinite family of knots satisfying this conjecture. Part of this work is joint with Lidman. (Received September 10, 2015)

1115-57-114 **Robert J Daverman** (daverman@math.utk.edu) and **Shijie Gu*** (shijiegu@uwm.edu). *A hierarchy for closed n-cell-complements.*

The existence of wildly embedded spheres in the n-sphere S^n has been recognized since the 1920's, with the publication of the famous Alexander Horned Sphere and a related 2-sphere wildly embedded in S^3 presented by Antoine. Later in the 20th century, there was an extensive study of conditions under which an $(n-1)$-sphere in S^n is locally flat and, hence, standardly embedded. Little has been done, however, to classify or organize the rich variety of wildly embedded objects. In this talk, we will strive to initiate that organizational effort via studying the features of the wildness comparisons. As the basic comparison, we say that a crumpled n-cube C is "at least as wild as" a crumpled n-cube D if there exists a map $f_h : C \to D$ such that $f_h^{-1}(BdD) = BdC$, where f_h is the extension of a homeomorphism $h : BdC \to BdD$. (Received September 10, 2015)

1115-57-116 **Sergey A. Antonyan*** (antonyan@unam.mx), Departamento de Matematicas, Facultad de Ciencias, UNAM, 04510 Mexico City, Mexico. *The Gromov-Hausdorff hyperspace of a Euclidean space.* Preliminary report.

The Gromov-Hausdorff distance d_{GH} is a useful tool for studying topological properties of families of metric spaces. It was introduced by M. Gromov in 1979. For two compact metric spaces X and Y the number $d_{GH}(X, Y)$ is defined to be the infimum of all Hausdorff distances $d_H(i(X), j(Y))$ for all metric spaces M and all isometric embeddings $i : X \to M$ and $j : Y \to M$. It induces a metric on the family GH of isometry classes of compact metric spaces. The metric space $(\mathrm{GH}, \mathrm{d_{GH}})$ is called the Gromov-Hausdorff hyperspace. It is a challenging open problem to understand the topological structure of this metric space. This talk contributes towards this problem.

We are mainly interested in the following subspace of GH denoted by $\mathrm{GH}(\mathbb{R}^n)$, $n \geq 1$, and called the Gromov-Hausdorff hyperspace of $\mathbb{R}^n$. Here $\mathrm{GH}(\mathbb{R}^n)$ is the subspace of GH consisting of the classes $[E] \in$GH whose representative E is a metric subspace of the Euclidean space $\mathbb{R}^n$.

In this talk we shall describe the topological structure of $\mathrm{GH}(\mathbb{R}^n)$ and related spaces. (Received September 11, 2015)

1115-57-120 **Nathan M Dunfield*** (nmd@illinois.edu), Dept of Math, UIUC, MC-382, 1409 W. Green Street, Urbana, IL 61801. *Random knots: their properties and algorithmic challenges.* Preliminary report.

I will discuss various models of random knots in S^3, surveying what is known about them theoretically and what is conjectured about them experimentally. In particular, I will discuss experiments that probe the practical/average case complexity of questions like computing the genus of a knot. The talk will contain many pretty pictures and charts, and is joint work with Malik Obeidin. (Received September 11, 2015)

1115-57-122 **Mark Steinberger***, Department of Math and Stat, University at Albany, Albany, NY 12222. *From fibrations to nonlinear similarity.*

A grateful acknowledgement of a multiyear collaboration with an important mentor in my mathematical life and development. (Received September 11, 2015)

1115-57-135 **Ryan Budney*** (ryan.budney@gmail.com), Mathematics and Statistics, University of Victoria, Victoria, BC V8W 2Y2, Canada. *Exploring the 4-manifold landscape using triangulations.* Preliminary report.

I will describe a long-term project with Ben Burton, where we enumerate the "smallest" smooth 4-manifolds in the sense that they are triangulable with 6 or less 4-dimensional simplices. Homotopy spheres and 2-knot exteriors form a large part of the census. I will describe what we know about this table of 4-manifolds and current obstructions to smooth classification. (Received September 13, 2015)

1115-57-151 **Frank Connolly*** (connolly.1@nd.edu), **James F. Davis** and **Qayum Khan** (khanq@slu.edu). *Classification Of The Set of Co-compact Proper Pseudo-free Group Actions on Contractible Manifolds.*

For a group Γ, let $S(\Gamma)$ denote the set of equivariant homeomorphism classes of contractible manifolds equipped with a proper co-compact action of Γ.

Suppose that Γ is a discrete co-compact group of isometries of a contractible, non-positively curved Riemannian manifold X. Suppose also that

$$X_{sing} := \{x \in X \mid \Gamma_x \neq 1\}$$

is a discrete subset of X, and that $vcd(\Gamma) \geq 5$.

Theorem: If Γ has no element of order 2, then $S(\Gamma)$ consists only of X.

If Γ has elements of order 2, $S(\Gamma)$ is an abelian group, isomorphic to a direct sum of copies of $UNil_{n\pm1}(Z; Z, Z)$ where $n = vcd(G)$. The sum is indexed by the conjugacy classes of maximal infinite dihedral subgroups of Γ. (Received September 14, 2015)

1115-57-169 **Federico Ardila**, **Megan Owen** and **Seth Sullivant*** (smsulli2@ncsu.edu). *Computing geodesics in CAT(0) cube complexes.*

We describe an algorithm to compute the geodesics in an arbitrary CAT(0) cubical complex. A key intermediate tool is the Owen-Provan algorithm for computing geodesics in CAT(0) orthant complexes. We will also discuss issues of algebraic complexity that arise in these computations. (Received September 15, 2015)

1115-57-171 **Christian K Zickert*** (zickert@math.umd.edu). *Coordinates for representations of 3-manifold groups.*

We study the shape and Ptolemy varieties of a triangulated compact 3-manifold M. The varieties give coordinates for representations of $\pi_1(M)$ in the sense that each point determines a representation (up to conjugation). We describe the varieties, how to compute them, and how to compute invariants such as trace fields and complex volume. (Received September 15, 2015)

1115-57-172 **Moira Chas*** (moira.chas@stonybrook.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *Computer Driven Questions and Theorems and in Geometry.*

Three numbers can be associated to a non-based or free homotopy class of closed curves on a surface S with boundary and negative Euler characteristic:

- the self-intersection number (this is the smallest number of times a representative of the curve crosses itself),

- the word length (given a minimal set of generators of the fundamental group, this is the smallest number of generators in a word representing the deformation or conjugacy class) and

- the length of the geodesic in the class (given a hyperbolic metric on S with geodesic boundary)

The interrelations of these three numbers exhibit many patterns when explicitly determined or approximated using nontrivial algorithms and a computer. We will discuss how these computations can lead to counterexamples of existing conjectures, to the discovery of new conjectures and to subsequent theorems in some cases. (Received September 15, 2015)

1115-57-187 **Valentina Disarlo*** (vdisarlo@indiana.edu), Department of mathematics, 831 E 3rd street, Bloomington, IN 47401, and **Hugo Parlier**. *On the geometry of the flip graph.*

The flip graph of an orientable punctured surface is the graph whose vertices are the ideal triangulations of the surface (up to isotopy) and whose edges correspond to flips. In this talk we will explore some geometric properties of this graph, in particular we will see that it provides a coarse model of the mapping class group in which the mapping class groups of some subsurfaces are strongly convex. We will also establish some bounds on the growth of the diameter of the flip graph modulo the mapping class group, extending a result of Sleator-Tarjan-Thurston. This is a joint work with Hugo Parlier. (Received September 16, 2015)

1115-57-189 **Colin Adams*** (cadams@williams.edu), Bronfman Science Center, 18 Hoxsey St., Williamstown, MA 01267, and **Aaron Calderon**, **Xinyi Jiang**, **Alexander Kastner**, **Gregory Kehne**, **Nathaniel Mayer** and **Mia Smith**. *Volumes and volume densities of hyperbolic knots and links.*

Utilizing bipyramids and truncated bipyramids, we obtain a variety of bounds on hyperbolic volume in terms of projections of hyperbolic links. We also consider volume density, given by volume divided by crossing number, and extend known results to various new categories of links. (Received September 17, 2015)

1115-57-206 **John A. Baldwin** (john.baldwin@bc.edu), **Adam Simon Levine*** (asl2@math.princeton.edu) and **Sucharit Sarkar** (sucharit@math.princeton.edu). *Khovanov homology and knot Floer homology for pointed links.*

There are spectral sequences relating reduced Khovanov homology to a variety of other homological link invariants, including the Heegaard Floer homology of the branched double cover and instanton knot homology. However, there is no known relationship between Khovanov homology and knot Floer homology, despite considerable computational evidence and numerous formal similarities. I will describe our ongoing efforts to find a spectral sequence relating these two invariants. The main new development is a variant of Khovanov homology for links with one or more basepoints on each component, which more closely parallels the behavior of knot Floer homology. (Received September 18, 2015)

1115-57-208 **Radmila Sazdanovic*** (rsazdanovic@math.ncsu.edu), Department of Mathematics, North Carolina Sta, SAS Hall PO Box 8205, Raleigh, NC 27695, and **Adam Lowrance**. *Khovanov homology, chromatic homology, and torsion.* Preliminary report.

We show that a suitable version of the chromatic polynomial categorification has no odd torsion. Then we use a partial isomorphism between the categorification of the chromatic polynomial of a graph and Khovanov homology of a related link in order to show that the Khovanov homology of a semi-adequate link has no odd torsion in prescribed gradings. (Received September 18, 2015)

1115-57-212 **Kathleen Finlinson** and **Jessica S Purcell*** (jessica.purcell@monash.edu). *Volumes of Montesinos links.*

We show that the volume of any Montesinos link can be bounded above and below in terms of the combinatorics of its diagram. This was known for Montesinos links with at most two tangles, and those with at least five tangles. We complete the result for the remaining cases. (Received September 18, 2015)

1115-57-214 **Bruce Hughes*** (bruce.hughes@vanderbilt.edu). *Stratified rigidity of quasitoric manifolds.* Preliminary report.

In joint work with Vassilis Metaftsis and Stratos Prossids, we prove that if M is a quasitoric manifold with its natural stratification, then M is stratified rigid relative to low dimensional strata. This means that if X is a manifold stratified space and $f\colon X \to M$ is a stratified homotopy equivalence that restricts to a homeomorphism on a closed union Y of strata of X that includes all strata of dimension less than five, then f is stratified homotopic rel Y to a homeomorphism. (Received September 18, 2015)

1115-57-222 **Micah Chrisman*** (mchrisma@monmouth.edu). *Detecting Non-Invertible Links with Virtual Covers.* Preliminary report.

It is well known that virtual knots have easily computable polynomial invariants that detect non-invertibility. We use this observation to prove that some multi-component links in $\mathbb{S}^3$ are non-invertible. The connection between

multi-component links and one-component virtual knots is made through virtual covers. Briefly, a virtual cover associates a virtual knot v to a knot K in a 3-manifold N that possesses a regular covering by a thickened surface (under certain hypotheses on K). Virtual covers of links in $\mathbb{S}^3$ come from taking K to be a knot in the complement of a fibered link J. It will be shown that if $J \sqcup K$ is invertible, then v satisfies a certain symmetry condition to which some virtual knot polynomials are sensitive. (Received September 19, 2015)

1115-57-224 **Nathan Druivenga*** (nathan-druivenga@uiowa.edu), The University of Iowa, 14 MacLean Hall, Iowa City, IA 52242, and **Charles Frohman** and **Sanjay Kumar**. *Tangle Functors at Roots of Unity.*

We prove that there is a tangle functor underlying certain semicyclic representations of $U_q sl_2$ when $q = e^{i\pi/N}$ where N is odd. Specifically, when $U_q sl_2$ is presented in the standard way with generators E, F and K these representations have $E^N = a$, where a is a nonzero scalar, $F^N = 0$ and $K^N = 1$. (Received September 19, 2015)

1115-57-234 **Adam Giambrone*** (adam.giambrone@uconn.edu). *σ-Adequate Link Diagrams and the Tutte Polynomial.* Preliminary report.

A well-known bijection between checkerboard-colored link diagrams and edge-signed planar graphs has led to a number of connections between link polynomials and graph polynomials. As an example, Thistlethwaite extracted a "boundary term polynomial" from the unnormalized Kauffman polynomial and expressed this polynomial as a product of Tutte polynomials. From this result, Thistlethwaite proved that a link diagram is A-adequate if and only if its boundary term polynomial is nonvanishing. In this talk, we will discuss an extension of this result to σ-adequate link diagrams. We will also show how a relatively recent expansion of the Tutte polynomial can be used to prove that every link diagram is σ-adequate. (Received September 19, 2015)

1115-57-246 **Tao Li*** (taoli@bc.edu), Department of Mathematics, Boston College, Chestnut Hills, MA 02467-3806. *Degree-one maps, surgeries and Heegaard splittings.* Preliminary report.

We study how Heegaard genus changes under a certain surgery on a 3-manifold. This has a close relation with a difficult conjecture concerning degree-one maps. We also study a related question on tunnel number of a satellite knot. (Received September 20, 2015)

1115-57-265 **Oliver Dasbach*** (kasten@math.lsu.edu), Department of Mathematics, LSU, Baton Rouge, LA 70803, and **Adam Lowrance**. *Signatures and Turaev Genera of Knots.* Preliminary report.

We will discuss formulas for the signature of knots with small Turaev genus. (Received September 20, 2015)

1115-57-272 **Safia Chettih*** (safia@uoregon.edu). *Topology of Configurations on Graphs.*

Given a graph Γ, suitably subdivided, we can construct a discretized model for its n-configuration space that is also a cubical complex. This complex is locally CAT(0) or nonpositively curved. Applying a discrete version of Morse theory to this complex simplifies it within its homotopy type, by 'flowing' most of the cells onto a smaller subset of critical cells. I will describe this discrete Morse flow and give explicit presentations for homology and cohomology classes as well as pairings for ordered and unordered configurations of two points on trees, and talk about the geometric and combinatorial structures interrelating configurations on graphs. (Received September 21, 2015)

1115-57-273 **Seungwon Kim*** (math751@gmail.com). *Link diagrams with low Turaev genus.* Preliminary report.

The Turaev genus of a link is a topological measure of how far a given link is from being alternating. We classify the link diagrams with Turaev genus one and two in terms of an alternating tangle structure. In this talk, we will discuss this classification and several applications. (Received September 22, 2015)

1115-57-276 **Laurence R Taylor*** (taylor.2@nd.edu), Department of Mathematics, 255 Hurley Hall, Notre Dame, IN 46556. *Bilinear forms and Wu-like cosets.* Preliminary report.

Wu's definition of the Wu classes of a manifold is straightforward. The surprise is that they are determined by the tangent bundle. We will discuss additional situations in which the tangent bundle constrains the Steenrod algebra structure in a manifold. The Lustzig-Milnor-Peterson treatment of the deRahm invariant of an orientable $4k+1$ dimensional manifold is one example and this talk will discuss others.

An easily stated corollary is that if X is a $2n$-dimensional closed compact manifold for which the middle Wu class is non-zero, then only finitely many finite 2 groups can act freely on X. (Received September 21, 2015)

1115-57-280 **Grigori Avramidi**, **Michael W. Davis**, **Boris Okun*** (okun@uwm.edu) and **Kevin Schreve**. *Action dimension of right-angled Artin groups.*

The action dimension of a group G, $actdim(G)$ is the least dimension of a contractible manifold which admits a proper G-action.

I will explain a partial computation of *actdim* for the right-angled Artin groups and why it is interesting from the point of view of L^2-homology.

This is a joint work with Grigori Avramidi, Mike Davis, and Kevin Schreve. (Received September 21, 2015)

1115-57-316 **Cameron McA. Gordon***, gordon@math.utexas.edu, and **Tye Lidman**. *Taut foliations and cyclic branched covers of satellite knots.* Preliminary report.

For a prime 3-manifold M it is conceivable that the following are equivalent: (1) M supports a co-orientable taut foliation, (2) $\pi_1(M)$ is left-orderable, and (3) M is not a Heegaard Floer L-space. We will present some evidence suggesting that, in most cases, if M is the n-fold cyclic branched cover of a prime satellite knot then M satisfies conditions (1), (2) and (3). (Received September 21, 2015)

1115-57-317 **Peter Feller*** (peter.feller.2@bc.edu). *On the topological slice genus of torus knots.*

We use elementary 3-dimensional topology and Freedman's Disk Theorem to obtain a Seifert matrix criterion that allows to calculate the topological slice genus for many knots. In particular, we show that torus knots with maximal signature are the only torus knots for which the topological slice genus and the three-genus agree. This extends work of Rudolph who first observed that the topological slice genus of most torus knots is strictly smaller than their three-genus. Based on joint work with S. Baader, L. Lewark, and L. Liechti. (Received September 21, 2015)

1115-57-327 **Genevieve S Walsh*** (genevieve.walsh@gmail.com), Mathematics Department, 574 Boston Ave, Medford, MA 02155. *Limit sets and boundaries.* Preliminary report.

We will discuss hyperbolic groups whose boundaries are homeomorphic to the limit sets of certain convex co-compact Kleinian groups. We will also discuss which hyperbolic groups can be quasi-isometric to a certain type of convex co-compact Kleinian group. This is joint work with Peter Haissinsky and Luisa Paoluzzi. (Received September 21, 2015)

1115-57-341 **Craig R Guilbault*** (craigg@uwm.edu), Dept. of Mathematical Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI 53201, and **Ross Geoghegan** (ross@math.binghamton.edu) and **Michael L Mihalik** (michael.l.mihalik@vanderbilt.edu). *End properties of spaces admitting free group actions.* Preliminary report.

In 2012 Geoghegan and Guilbault improved upon a theorem by David Wright which asserted that, when a one-ended, simply connected, locally finite polyhedron X with pro-monomorphic fundamental group at infinity admits a proper $\mathbb{Z}$-action, then the fundamental group at infinity of X is (up to pro-isomorphism) an inverse sequence of finitely generated free groups. Using a rather indirect argument, G-G were able to add π_1-semistability to the conclusions, thereby showing that X must have a *stable* finitely generated free fundamental group at infinity.

In this talk, we will describe further improvements to this theorem. Most notably, the pro-monomorphic hypothesis is weakened to the existence of a 'coaxial' homeomorphism $j : X \to X$ generating the $\mathbb{Z}$-action. Under that hypothesis we still obtain all of the above conclusions, aside from the pro-monomorphic part—which was true only by hypothesis. The new proof, which is direct and geometric, provides additional detail and a clear picture of the fundamental group at infinity of such a space X. (Received September 21, 2015)

1115-57-364 **Abhijit Champanerkar*** (abhijit@math.csi.cuny.edu), Department of Mathematics, College of Staten Island. CUNY, 2800 Victory Blvd, Staten Island, NY 10314, **Ilya Kofman** (ikofman@math.csi.cuny.edu), Department of Mathematics, College of Staten Island. CUNY, 2800 Victory Blvd, Staten Island, NY 10027, and **Jessica Purcell** (jessica.purcell@monash.edu). *Determinant density spectrum and biperiodic alternating links.*

The determinant density of an alternating link K is $2\pi \log(det(K))/c(K)$, where $det(K)$ is the determinant and $c(K)$ is the crossing number of K. The determinant density spectrum is the set of all limit points of determinant densities. We prove that for any sequence of links approaching a fixed biperiodic alternating link, the determinant density is related to the Mahler measure of a 2-variable polynomial, arising from the toroidal dimer model on an associated biperiodic graph. Thus, we explicitly realize points in the determinant density spectrum. (Received September 22, 2015)

1115-57-366 **Ilya Kofman*** (ikofman@math.csi.cuny.edu), Dept. of Mathematics, 2800 Victory Boulevard, 1S, New York, NY 10314, **Abhijit Champanerkar** (abhijit@math.csi.cuny.edu), Dept. of Mathematics, 2800 Victory Boulevard, 1S, New York, NY 10314, and **Jessica Purcell**. *Volume density spectrum and biperiodic alternating links.* Preliminary report.

The volume density is the ratio of volume to crossing number of a hyperbolic knot or link, which is bounded above by the volume of a regular ideal octahedron. The volume density spectrum is the set of all limit points of volume densities of hyperbolic links. We prove that for any sequence of links approaching certain fixed biperiodic alternating links L, the corresponding sequence of volume densities approaches the volume density of the quotient link of L in $T^2 \times I$. Thus, we explicitly realize certain points in the volume density spectrum. (Received September 22, 2015)

1115-57-368 **Mark C Hughes*** (hughes@mathematics.byu.edu). *Braided cobordisms and the braid rank of a knot.*

We describe a new technique to recast geometric problems involving the 4-ball genus of a link in terms of algebraic properties of a braid representative. These techniques make use of braided cobordisms, and require the study of certain shortest word problems in the braid group described by Rudolph. This leads to a new algebraic invariant of the knot. We will present an upper bound to the solution of this shortest word problem. (Received September 22, 2015)

1115-57-373 **Cody W. Armond*** (carmond@southalabama.edu) and **Adam M. Lowrance** (adlowrance@vassar.edu). *Turaev Genus and Alternating decompositions.*

We prove that the genus of the Turaev surface of a link diagram is determined by a graph whose vertices correspond to the boundary components of the maximal alternating regions of the link diagram. Furthermore, we use these graphs to classify link diagrams whose Turaev surface has genus one or two, and we prove that similar classification theorems exist for all genera. (Received September 22, 2015)

1115-57-378 **Joe Quinn*** (jquinn1@gradcenter.cuny.edu), 365 Fifth Avenue, New York, NY 10016. *Macfarlane spaces and arithmetic hyperbolic surfaces and 3-manifolds.*

Quaternion algebras and their arithmetic properties are used to study hyperbolic surfaces and 3-manifolds. Quaternion algebras are generalizations of Hamilton's quaternions, which were geometrically motivated, famously providing an intrinsic multiplicative structure for Euclidean rotations. It is natural to ask whether there is a similar interpretation for hyperbolic space using quaternion algebras. Using ideas of Macfarlane from 1894 together with Dickson's algebraic definition of generalized quaternion algebras, I will extend Hamilton's theorem for certain classes of arithmetic surfaces and 3-manifolds. (Received September 22, 2015)

1115-57-404 **Chris Hruska*** (chruska@uwm.edu), Department of Mathematical Sciences, University of Wisconsin-Milwaukee, PO Box 413, Milwaukee, WI 53201-0413, and **Hoang Thanh Nguyen**, Department of Mathematical Sciences, University of Wisconsin-Milwaukee, PO Box 413, Milwaukee, WI 53201-0413. *Distortion of surfaces in graph manifolds.* Preliminary report.

We examine the large scale geometry of immersed horizontal surfaces in 3-dimensional graph manifolds. An immersed surface in a 3-manifold is *virtually embedded* if the immersion lifts to an embedding into a finite sheeted cover of the manifold. Virtual embedding is equivalent to separability of the surface group in the fundamental group of the 3-manifold.

We prove that the distortion of a horizontal surface is quadratic if the surface is virtually embedded, and is exponential otherwise. The proof depends on a combinatorial characterization of horizontal surfaces that virtually embed, due to Rubinstein-Wang. (Received September 22, 2015)

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1115-58-33 **Tamas Darvas*** (tdarvas@math.umd.edu) and **Yanir A. Rubinstein**. *Tian's properness conjectures and Finsler geometry on the space of Kahler metrics.*

In the 90's, Tian introduced a notion of properness in the space of Kähler metrics in terms of Aubin's J-energy for Mabuchi's K-energy and formulated several conjectures on the relation between properness and Kähler-Einstein metrics. In joint work with Y. Rubinstein we disprove one of these conjectures, and prove the remaining ones. Our results extend to a variety of canonical metrics, in particular Kähler-Einstein edge metrics and Kähler-Ricci

solitons. Lastly, we formulate a corresponding conjecture for constant scalar curvature metrics and reduce it to a regularity question on minimizers of the K-energy. (Received August 12, 2015)

1115-58-35 **Casey Lynn Kelleher*** (clkelleh@uci.edu), **Jess Boling** and **Jeffrey D Streets**. *Entropy, stability, and harmonic map heat flow.*

Inspired by work of Colding-Minicozzi on mean curvature flow, Zhang introduced a notion of entropy stability for harmonic map flow. We build further upon this work in several directions. First we prove the equivalence of entropy stability with a more computationally tractable F-stability. Then, focusing on the case of spherical targets, we prove a general instability result for high-entropy solitons. Finally, we exploit results of Lin-Wang to observe long time existence and convergence results for maps into certain convex domains and how they relate to generic singularities of harmonic map flow. This is joint work with Jess Boling and Jeffrey Streets. (Received August 15, 2015)

1115-58-49 **Dennis Burke**, **Raushan Buzyakova*** (raushan_buzyakova@yahoo.com) and **Alex Chigogidze**. *Coloring of Maps on Euclidean Spaces.*

Given a continuous self-map $f : X \subset \mathbb{R}^n \to X$, a closed subset F of X is a color of f if F misses $f(F)$. The map f is colorable if X can be covered by finitely many colors. A historical overview of the topic rooted back to the famous map coloring problem/theorem will be given. We will then outline new results related to single and multi-valued self-maps on Euclidean spaces and their subspaces. A few open questions that maybe of interest to mathematicians from different areas will be mentioned. (Received September 01, 2015)

1115-58-82 **Thomas G. Leness*** (lenesst@fiu.edu), Department of Mathematics, DM 430, Florida International University, Miami, FL 33199. *Gluing theorems for SO(3) monopoles.* Preliminary report.

The non-compact ends of the moduli space of SO(3) monopoles on smooth four-manifolds are described by the gluing maps. We describe joint work with P. Feehan on the construction of these gluing maps, their role in proofs of Witten's conjecture relating Donaldson and Seiberg-Witten invariants and of the superconformal simple type conjecture, and we describe the particular properties of these maps needed in these proofs. (Received September 06, 2015)

1115-58-117 **Fengbo Hang*** (fengbo@cims.nyu.edu), 251 Mercer Street, New York, NY 10012, and **Paul C Yang**. *Paneitz operator and Q curvature in dimensions other than 4.*

For a Riemannian metric with positive Yamabe invariant, we will describe several conformal invariant conditions which are equivalent to the existence of a conformal metric with positive Q curvature. In particular, we can express the Green's function of Paneitz operator as an infinite sum involving the Green's function of the conformal Laplacian operator. This can be applied to find a conformal metric with constant Q curvature. (Received September 11, 2015)

1115-58-137 **Akos Nagy*** (nagyakos@math.msu.edu). *On the Berry connection of the Ginzburg–Landau vortices.*

The Ginzburg–Landau theory is a gauge theory that models superconductivity close to the critical temperature. In this talk, the critically coupled 2-dimensional Ginzburg–Landau vortices are analyzed. Using results of Taubes and Bradlow, we establish approximate formulas for the tangent vectors of the vortex moduli space. As applications, we compute the curvature and the holonomy of the corresponding Berry connection in the large vortex size limit. (Received September 13, 2015)

1115-58-140 **Matthew McGonagle*** (mmcgona1@math.washington.edu), University of Washington, Department of Mathematics, Box 354350, Seattle, WA 98195, and **Ling Xiao**. *Minimal Graphs and Graphical Mean Curvature Flow in $M \times \mathbb{R}$.*

In this paper, we investigate the problem of finding minimal graphs in $M^n \times \mathbb{R}$ with general boundary conditions using a variational approach. We look at so called generalized solutions of the Dirichlet Problem that minimize a functional adapted from the area functional. We construct barriers to show that for certain conditions on our boundary data, $\phi(x)$, the solutions obtain the boundary data $\phi(x)$. We also consider solutions $u^\epsilon(x,t)$ of a perturbed mean curvature flow for $\epsilon > 0$. We show that there are sub-sequences ϵ_i where $u^{\epsilon_i}(x,t)$ converges to a function $u(x,t)$ satisfying the mean curvature flow, and sub-sequences $u(\cdot,t_i)$ converge to a generalized solution $\overline{u}(x)$ of the Dirichlet problem. Furthermore, $\overline{u}(x)$ depends only on the choice of sequence ϵ_i. (Received September 13, 2015)

1115-58-293 **Alex S Waldron*** (awaldron@scgp.stonybrook.edu), 158 Sheep Pasture Rd, Port Jefferson, NY 11777. *Convergence of Yang-Mills flow with low self-dual energy.*

I will discuss the convergence theorem for 4D Yang-Mills flow with low self-dual energy proved in my thesis. The result relates to the general problem of passing from subsequential convergence to true convergence in time, which is nontrivial in the presence of singularities. (Received September 21, 2015)

1115-58-374 **Paul Feehan** and **Manousos Maridakis*** (mmanos@math.rutgers.edu), Hill Center for mathematical Sciences,Bush, Campus, Piscataway, NJ 08854. *Lojasiewicz-Simon gradient inequalities with applications to Yang-Mills pairs and Harmonic maps.*

Lojasiewicz-Simon gradient inequalities have become increasingly interesting by their wealth of potential applications. In this article we are concerned with an abstract version of a Lojasiewicz-Simon gradient inequality established under very weak assumptions and its applications for coupled Yang-Mills energy functionals and Harmonic map energy functional. (Received September 22, 2015)

60 ► Probability theory and stochastic processes

1115-60-16 **Zachary P Kilpatrick*** (zpkilpat@math.uh.edu), University of Houston, Department of Mathematics, Houston, TX. *Stochastic synchronization of neural activity waves.*

We demonstrate that waves in distinct layers of a neuronal network can become phase-locked by common spatiotemporal noise. This phenomenon is demonstrated for stationary bumps, traveling waves, and breathers. A weak noise expansion is used to derive an effective equation for the position of the wave in each layer, yielding a stochastic differential equation with multiplicative noise. Stability of the synchronous state is characterized by a Lyapunov exponent, which we can compute analytically from the reduced system.

Neural fields are integrodifferential equations whose integral term describes the connectivity of a neuronal network:

$$du_j(x,t) = \left[-u_j(x,t) + \int_{-\pi}^{\pi} w(x-y) f(u(y,t)) dy\right] dt + \varepsilon dW(x,t), \qquad j = 1, 2,$$

where $u_j(x,t)$ is population activity of population, $w(x-y)$ describes synaptic connectivity, and $f(u)$ is a firing rate nonlinearity. Small amplitude ($\varepsilon \ll 1$) spatiotemporal noise $dW(x,t)$ is white in time and has spatial correlations $C(x-y)$. Noise-induced synchronization of bumps, $u_j \approx U_j(x + \Delta_j(t))$, whereby $|\Delta_1 - \Delta_2| \to 0$ occurs in all realizations as $t \to \infty$. (Received July 13, 2015)

1115-60-127 **Michael Damron*** (mdamron6@gatech.edu), Department of Mathematics, Georgia Institute of Technology, 686 Cherry St, Atlanta, GA 30332, and **Jack Hanson** (jack.hanson@math.gatech.edu), Department of Mathematics, Georgia Institute of Technology, 686 Cherry St, Atlanta, GA 30332. *Bigeodesics in first-passage percolation.*

In first-passage percolation, we place i.i.d. continuous weights at the edges of $\mathbb{Z}^2$ and consider the weighted graph metric. A distance minimizing path between points x and y is called a geodesic, and a bigeodesic is a doubly-infinite path whose segments are geodesics. It is a famous conjecture that almost surely, there are no bigeodesics. In the '90s, Licea-Newman showed that, under a curvature assumption on the "asymptotic shape," there are no bigeodesics with one end directed in some deterministic subset D of $[0, 2\pi)$ with countable complement. I will discuss recent work with Jack Hanson in which we show that there are no bigeodesics with one end directed in any deterministic direction, assuming the shape boundary is differentiable. This rules out existence of ground state pairs for the related disordered ferromagnet whose interface has a deterministic direction. (Received September 11, 2015)

1115-60-129 **Jae Kyoung Kim**, **Grzegorz A. Rempala** and **Hye-Won Kang*** (hwkang@umbc.edu). *Title: Reduction for stochastic reaction networks with multi-scale conservation.*

Abstract: Many chemical reaction networks are known to have multi-scale property: reaction rates vary and several time scales exist in which chemical species evolve. A large amount of researches have been done on constructing multi-scale methods for stochastic chemical reaction networks to approximate temporal changes in the abundance of chemical species and to reduce network complexity. Moreover, stochastic simulation algorithms with various approximation strategies have been developed using multi-scale property to increase simulation efficiency. Among different approaches, the multi-scale approximation method developed by Ball et al. (2006) and extended by Kang and Kurtz (2013) will be introduced. When the chemical reaction network conserves linear combinations of some chemical species with quantities in different scales, the multi-scale approximation method suggested may induce some errors. In this talk, a modified multi-scale approximation method for stochastic

chemical reaction networks with conservation will be investigated and will be applied to an example in enzyme kinetics and to one generating oscillations. This is joint work with J. Kim and G.A. Rempala. (Received September 12, 2015)

1115-60-131 **Shannon L Starr*** (slstarr@uab.edu), UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170, and **Meg Walters** (walters@math.rochester.edu), UR Mathematics, 915 Hylan Building, RC Box 270138, Rochester, NY 14627. *Fluctuation bounds for the Mallows measure.*

The Mallows measure on permutations gives a probability for $\pi \in S_n$ proportional to q-to-the-power $I(\pi)$ where $I(\pi)$ is the number of inversions of π: the number of pairs $1 \leq j < k \leq n$ such that $\pi(j) > \pi(k)$. There has been much work on this model in the regime where q is close to 1 (the uniform case), and when q is farther away. I will describe simple, but not very precise, bounds when q is close to 1, so that $1 - q$ is $O(1/n)$. (Received September 12, 2015)

1115-60-178 **Di Liu*** (richardl@math.msu.edu), D217 Wells Hall, East Lansing, MI 48824. *Analysis and simulation of ntracellular bio-chemical reacting networks with multiple time scales.*

Intracellular reacting networks involving gene regulation often exhibits multiscale properties. That includes multiple reacting rates, multiple population magnitudes and multi-stability. Direct Stochastic Simulation Algorithm (SSA) would turn out to be inefficient dealing with such systems. Schemes such as Nested SSA and Tau-leaping method have proved to be effective for certain asymptotic regimes. I will present recent results on the convergence analysis and applications of the algorithms. (Received September 16, 2015)

1115-60-191 **Sevak Mkrtchyan*** (sevak.mkrtchyan@rochester.edu). *Plane partitions with two-periodic weights.*

We will discuss scaling limits of skew plane partitions with two-periodic weights under several boundary conditions. We will discuss the frozen boundary and the correlation kernel of the limiting point processes. Of particular interest is the process at the turning points. The turning points that appear in the homogeneous case split in the two-periodic case into pairs of turning points macroscopically separated by a "semi-frozen" region. As a result the point process at a turning point is not the GUE minor process, but rather a pair of GUE minor processes, non-trivially correlated. We will also discuss an intermediate regime when the weights are periodic but all converge to 1. In this regime the limit shape and correlations in the bulk are the same as in the case of homogeneous weights and periodicity is not visible in the bulk. However, the process at turning points is still not the GUE minor process. (Received September 17, 2015)

1115-60-205 **Peter Roland Kramer*** (kramep@rpi.edu), **Yuzhou Qian** and **Patrick Underhill**. *Fluctuation Models for Suspensions of Swimming Microorganisms.*

The collective dynamics of swimming microorganisms ("microswimmers") such as bacteria and algal cells have been of considerable recent interest, both as paradigms of collective patterns arising from individual autonomous agents and for their relevance to technological issues such as biofilm formation and power sources for microdevices. We will discuss some recent efforts to characterize stochastic fluctuations in a continuum "mean field" partial differential equation framework for the effective microswimmer dynamics in a suspension. (Received September 18, 2015)

1115-60-221 **Elena Kosygina***, elena.kosygina@baruch.cuny.edu, and **Martin P. W. Zerner**. *A zero-one law for recurrence and transience of frog processes.*

We provide sufficient conditions for the validity of a dichotomy, i.e. zero-one law, between recurrence and transience of frog models on a large class of non-random and on some random graphs. In particular, the results cover frog models with i.i.d. numbers of frogs per site where the frog dynamics are given by quasi-transitive Markov chains or by random walks in a common random environment including super-critical percolation clusters on $\mathbb{Z}^d$. We also give a sufficient and almost sharp condition for recurrence of uniformly elliptic frog processes on $\mathbb{Z}^d$. Its proof uses the general zero-one law. (Received September 19, 2015)

1115-60-248 **Arjun Krishnan*** (arjunkc@math.utah.edu) and **Jeremy Quastel** (quastel@math.toronto.edu). *Fluctuations of polymer models in intermediate disorder.* Preliminary report.

Directed polymer models are finite-temperature versions of first- and last-passage percolation on the lattice. In 1+1 dimensions, the free-energy of the directed polymer is conjecturally in the Tracy-Widom universality class at all finite temperatures. Tracy-Widom universality has only been proven for a small class of polymers - the so-called solvable models that include Seppalainen's gamma polymers and the O'Connell-Yor semi-discrete polymer

- with very special shapes and edge-weight distributions. We present some new fluctuation results towards the universality conjecture for polymers in the intermediate disorder scaling regime. (Received September 20, 2015)

1115-60-267 **Harry Crane*** (hcrane@stat.rutgers.edu). *Relatively exchangeable structures.*
Classical theorems of de Finetti, Aldous, Hoover, and Kallenberg give generic representations for exchangeable random sequences, arrays, and more general structures. More recent work on spin-glass models (Austin & Panchenko, 2014) and combinatorial stochastic processes (Crane 2014, 2015) characterizes certain random structures that are partially exchangeable with respect to the symmetries of an underlying structure. We generalize these results, introducing the concept of 'relative exchangeability' and giving an Aldous-Hoover-type representation for random structures that are relatively exchangeable with respect to a suitably nice structure M. We also discuss how the representation varies depending on how 'nice' M is, where 'nice' is described precisely in terms of its model theoretic properties. (Received September 20, 2015)

1115-60-277 **Tom Nye*** (tom.nye@ncl.ac.uk). *Stochastic processes on Billera-Holmes-Vogtmann tree-space.*
Evolutionary trees lie in a geodesic metric space known as Billera-Holmes-Vogtmann tree-space. Several existing methods for analysing data sets of evolutionary trees rely on least-squares procedures. As an alternative to these procedures, probabilistic models are difficult to construct due to the geometry of tree-space. Tree-valued stochastic processes offer a way of building such models. We describe methods for simulating random walks on tree-space, together with various generalizations. We then briefly describe Bayesian methods for fitting simple models based on random walks and discuss possible applications. (Received September 21, 2015)

1115-60-300 **David Belius*** (david.belius@cantab.net), Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York, NY 10012. *Branching in log-correlated random fields.* Preliminary report.
Log-correlated random fields show up in diverse settings, including the study of random walk cover times, random matrix theory and number theory. I will discuss how this can be explained by the presence of an underlying approximate branching structure in each of the models. I will also describe the most basic model of the log-correlated class, namely Branching Random Walk (BRW), where the branching structure is explicit, and explain how to adapt ideas developed in the context of BRW to models where the branching structure is not immediately obvious. (Received September 21, 2015)

1115-60-311 **Julien Dubedat*** (dubedat@math.columbia.edu). *Double dimers and isomonodromic deformations.*
The double-dimer model consists in superimposing two independent, identically distributed perfect matchings on a planar graph, which produces an ensemble of non-intersecting loops. Kenyon established conformal invariance in the small mesh limit by considering topological observables of the model parameterized by SL(2,C) representations of the fundamental group of the punctured domain. The scaling limit is conjectured to be CLE(4), the Conformal Loop Ensemble at $\kappa = 4$. In support of this conjecture, we prove that a large subclass of these topological correlators converge to their putative CLE(4) limit. Both the small mesh limit of the double-dimer correlators and the corresponding CLE(4) correlators are identified in terms of the τ-functions introduced by Jimbo, Miwa and Ueno in the context of isomonodromic deformations. (Received September 21, 2015)

1115-60-336 **Mihai Nica*** (nica@cims.nyu.edu). *Convergence of non-intersecting walkers.*
We will develop a model of discrete family of non-crossing walkers that have a nice combinatorial description. We show that in a certain limit these have nice descriptions in terms of non-intersecting Brownian bridges. (Received September 21, 2015)

1115-60-356 **Jian Ding**, **Allan Sly** and **Nike Sun*** (nsun@mit.edu), MIT Mathematics Department, E18-470, 77 Massachusetts Avenue, Cambridge, MA 02139. *The exact k-SAT threshold for large k.*
We establish the random k-SAT threshold conjecture for all k exceeding an absolute constant k_0. That is, there is a single critical value $\alpha_*(k)$ such that a random k-SAT formula at clause-to-variable ratio α is with high probability satisfiable for $\alpha < \alpha_*(k)$, and unsatisfiable for $\alpha > \alpha_*(k)$. The threshold $\alpha_*(k)$ matches the explicit prediction derived by statistical physicists on the basis of the one-step replica symmetry breaking (1RSB) heuristic. In the talk I will describe the main obstacles in computing the threshold, and explain how they are overcome in our proof. (Received September 22, 2015)

1115-60-358 **Subhro Ghosh*** (sg18@princeton.edu), 46 West Countryside Drive, Princeton, NJ 08540. *Rigidity phenomena in random point sets.*

In several naturally occurring (infinite) point processes, the number the points inside a finite domain can be determined, almost surely, by the point configuration outside the domain. There are also other processes where such "rigidity" extends also to a number of moments of the mass distribution. The talk will focus on point processes with such curious "rigidity" phenomena, and their implications. We will also talk about applications to stochastic geometry and some questions in harmonic analysis. (Received September 22, 2015)

1115-60-361 **Scott A McKinley*** (scott.mckinley@tulane.edu) and **J Darby Smith**. *Intracellular transport: The paradox of codependence among antagonistic motors.*

Transport in neurons is intrinsically bidirectional, with each movement modality carried out by molecular motors in either the kinesin (anterograde) or the dynein (retrograde) families. Because all motors are present at a given time there must be competition and/or cooperation among motors that simultaneously bind a single vesicle to nearby microtubules. The prevailing tug-of-war model captures this dynamic, but fails to account for a recently recognized phenomenon: that in many situations, disabling one family of motors somehow inhibits the performance of motors that are working in the opposite direction. In this talk we will survey a few proposed mechanisms that may account for this behavior and will look at recent work that focuses on a potential role played by the helper protein dynactin. (Received September 22, 2015)

1115-60-375 **Jinho Baik** and **Zhipeng Liu*** (zhipeng@cims.nyu.edu). *Asymptotics in periodic TASEP with step initial condition.*

We consider the periodic TASEP model in the space $\{(x_1, x_2, \cdots, x_N); x_1 < x_2 < \cdots < x_N < x_1 + M\}$. We discuss the limiting distributions of a fixed partile as the parameters N, M, t all go to infinity. For the step initial condition and fixed $M/N = \alpha$, when $t < O(N^{3/2})$, the limiting distribution is either Tracy-Widom distribution a a product of two Tracy-Widom distributions. When $t = O(N^{3/2})$ which is the critical region, we obtain a new distribution. We also discuss some properties of this new distribution. (Received September 22, 2015)

1115-60-402 **Eyal Lubetzky*** (eyal@courant.nyu.edu), Courant Institute, New York University, 251 Mercer Street, New York, NY 10012. *Interacting spin systems: how fast is it to forget the past?*

We survey recent progress and open problems on dynamical aspects of interacting spin systems on lattices, from the Ising model to more general ones (e.g., non-reversible rules, hard constraints, etc.). (Received September 22, 2015)

1115-60-406 **Steven T Morrow*** (morrows@wit.edu), WIT, 550 Huntington Ave, Dept of Applied Mathematics, Boston, MA 02115. *An Extension of a Multiplicative Coboundary Theorem for Some Sequences of Random Matrices.* Preliminary report.

Klaus Schmdit proved the following in 1977: Given a strictly stationary sequence $(X_k, k \in \mathbb{Z})$ of real-valued random variables, such that the family of distributions of the sequence of partial sums is tight, there exists a strictly stationary sequence $(Y_k, k \in \mathbb{Z})$ such that for each k, $X_k = Y_k - Y_{k+1}$. We say that the sequence (X_k) is a "coboundary".

In 1995, Richard Bradley improved this to include non-stationary sequences, while retaining the result of Schmidt as a corollary. Various other results on coboundaries have been proven with tightness being replaced by moment conditions. In 1996, Bradley proved an analog of Schmidt's result for certain sequences of random matrices, with matrix products replacing partial sums, and the coboundary condition becoming $X_k = Y_k Y_{k+1}^{-1}$. That result restricted the entries of the matrices to integers. This talk will discuss a new approach which extends the result for random matrices to those with entries from $\mathbb{R}$. (Received September 22, 2015)

62 ► Statistics

1115-62-80 **Yen-Chi Chen*** (yenchic@andrew.cmu.edu), 4742 Centre Ave, Apt 405, Pittsburgh, PA 15213. *Asymptotic theory for density ridges.*

The large sample theory of estimators for density modes is well-understood. We consider density ridges, which are a higher-dimensional extension of modes. Modes correspond to zero-dimensional, local high-density regions in point clouds. Density ridges correspond to $s-$dimensional, local high-density regions in point clouds. We derive geometric properties for density ridges and study asymptotic behavior for ridge estimators. We propose a valid procedure for constructing a confidence set for density ridges using the bootstrap. We apply our method to a cosmology dataset to show the validity. (Received September 06, 2015)

1115-62-391 **Jisu Kim*** (jisuk1@andrew.cmu.edu), Department of Statistics, CMU, 5000 Forbes Avenue, Baker Hall 132, Pittsburgh, PA 15213-3890, and **Alessandro Rinaldo** and **Larry Wasserman**. *Minimax Rate for Estimating the Dimension of a Manifold.*

Most manifold learning algorithms require as input the intrinsic dimension of the manifold. This parameter is however rarely known and therefore has to be estimated. We derive upper and lower bounds on the probability of false rejection for testing the hypothesis that the support of the data-generating probability distribution is a well-behaved manifold of intrinsic dimension d_1 versus the alternative that it is of dimension d_2. With an i.i.d. sample of size n, we provide an upper bound of order $O\left(n^{-(d_2/d_1-1-\epsilon)n}\right)$ based on the TSP path through the data points. We also demonstrate a lower bound of $\Omega\left(n^{-(2d_2-2d_1+\epsilon)n}\right)$ by applying Le Cam's lemma with a specific set of d_1-dimensional probability distribution. (Received September 22, 2015)

1115-62-400 **Sean Skwerer*** (sean.skwerer@yale.edu). *Regression for Tree Structured Populations.*

Modern imaging techniques have enabled the acquisition of samples from populations of anatomical tree structured objects such as dendrites and parts of the vascular system. Regression of a sample of brain artery trees, represented as points in a CAT(0) space, will be presented. General challenges and existing approaches for treespace based analyses of tree structured data objects will be discussed. (Received September 22, 2015)

65 ► Numerical analysis

1115-65-18 **Blake Barker*** (blake_barker@brown.edu) and **Kevin Zumbrun**. *Rigorous Verification of Stability of Traveling Waves Via Computer Assisted Proof.*

We discuss recent results in rigorous verification of stability of traveling waves via computer assisted proof. In particular, we describe the difficulties that arise when using interval arithmetic, a key component of rigorous verification, and the solutions we use to overcome these challenges. Through a combination of analytic results and rigorous computations, we establish spectral stability, hence nonlinear stability, of some traveling waves in conservation laws. (Received July 16, 2015)

1115-65-269 **Duk-Soon Oh*** (duksoon.oh@rutgers.edu), 110 Frelinghuysen Rd., Piscataway, NJ 08854, and **Olof B. Widlund**, **Clark R. Dohrmann** and **Stefano Zampini**. *Adaptive BDDC methods for problems posed in $H(div)$.*

A BDDC preconditioner is defined by a coarse component, expressed in terms of primal constraints and a weighted average across the interface between the subdomains, and local components given in terms of Schur complements of local subdomain problems. BDDC methods for vector field problems discretized with Raviart-Thomas finite elements are introduced. Our methods are based on an adaptive selection of primal constraints developed to deal with highly oscillating coefficients. Bounds on the condition number of the preconditioned linear system are also provided which are independent of the values and jumps. (Received September 20, 2015)

68 ► Computer science

1115-68-236 **Yu-Min Chung***, Department of Mathematics, College of William and Mary, P.O. Box 8795, Williamsburg, VA 23185, and **Sarah Day**, Department of Mathematics, College of William and Mary, P.O. Box 8795, Williamsburg, VA 23185. *Persistent Homology based thresholding method and applications.*

An automated image thresholding method based on the persistent homology is presented. The primary difference among traditional methods is that the resultant binary image respects underlying topological features. Furthermore, in the presence of noise, the method provides more information to obtain a better estimate of the Betti numbers. Finally, we will show applications to practical datasets—binary alloy from Material Science, and firn from Climatology. (Received September 19, 2015)

1115-68-278 **Michael Kerber**, **Donald R. Sheehy*** (don.r.sheehy@gmaill.com) and **Primoz Skraba**. *Persistent Homology and Nested Dissection.*

Nested dissection is a way of solving systems of linear equations by divide and conquer. For many linear systems that occur naturally in many settings, nested dissection gives a guaranteed improvement over naive Gaussian elimination. These are the so-called beta-separable systems, where beta is a constant that governs how big the improvement will be. In this talk, I will show how separability affects the computation of persistent homology. In particular, I will describe an algorithm for computing the persistent homology that exploits a separator structure

on the underlying simplicial complex to give running times that are faster than matrix multiplication for a large class of inputs.

This talk will be based on joint work with Primoz Skraba and Michael Kerber to appear at SODA 2016. (Received September 21, 2015)

1115-68-296 **Ellen Gasparovic*** (gasparoe@union.edu), **Paul Bendich**, **John Harer** and **Christopher Tralie**. *Multi-scale Data Modeling via Cover Trees, Local PCA, and Persistent Homology.* Preliminary report.

Geometric and topological methods in data analysis are capable of exposing essential shape information that may be hidden in the original data. In this preliminary work, our goal is to introduce an algorithm for producing multi-scale models for data using cover tree methodology, techniques from persistent homology, and multi-scale local principal component analysis. Our method takes in a point cloud and produces a model for the data that is fundamentally based on its local geometric properties, as well as a data scaffolding that captures how the different pieces of the model fit together. We will consider applications of our methods to both synthetic and real data. (Received September 21, 2015)

1115-68-308 **Dan P. Guralnik*** (guraldan@seas.upenn.edu), Dept. of Electrical and Systems Engineering, 200 South 33rd Street, Moore bldg. 203, Philadelphia, PA 19104, and **Daniel E. Koditschek** (kod@seas.upenn.edu), Dept. of Electrical and Systems Engineering, 200 South 33rd Street, Moore bldg. 203, Philadelphia, PA 19104. *Universal Memory Architectures: CAT(0) cubical event representations for learning and control.*

We show how the Sageev-Roller duality between poc-sets and median algebras may be applied to allow the construction of agents capable of autonomously forming an internal representation of their interactions with their environment *from scratch*, given no prior knowledge and based only on observations of binary data streams (or *'sensors'*). This representation takes the form of the CAT(0) cubical envelope of the set of sensory equivalence classes permitted by implications learned from the environment. It is completely encoded in a data structure supported on the dual poc set. As a result, maintenance and reactive planning costs are reduced from exponential to quadratic in the number of sensors. Maintaining this representation *dynamically* required (1) an extension of Sageev-Roller duality to cover a larger class of complemented ordered structures, and (2) the characterization of data structures enabling efficient statistical learning of implications in the environment. Time permitting, we will discuss the topological and geometric obstructions to planning in our representations and how they impact the possible application range of this approach as seen through the lenses provided by Category Theory. (Received September 21, 2015)

70 ► Mechanics of particles and systems

1115-70-325 **Lenka Kovalcinova*** (lk58@njit.edu), 323 Martin Luther King Blvd., Cullimore Hall 208, Newark, NJ 07102, and **Miro Kramar**, **Joshua A Dijksman**, **Jie Ren**, **Robert P Behringer**, **Konstantin Mischaikow** and **Lou Kondic**. *Importance of Topological Measures in Describing Sheared Granular Systems.*

Granular systems are usually analyzed using either experimental techniques or numerical simulations. There is a lack of studies that would directly compare the two approaches. Here, we present such a comparison for a granular system composed of photoelastic disks placed on a plane confined within a rectangular box. In particular, we use the topological techniques on both sets of (experimental and numerical) results. The granular system is linearly sheared up to a maximum strain of 27%. We extract complete information about force networks and use standard measures such as pressure, system anisotropy and inter-particle contact dynamics to characterize their evolution during the shear. For most of the considered measures, we find good agreement between simulations and experiments. However, this is not the case for topological measures - Betti numbers B_0 and B_1. We find that Betti numbers are able to pick up the additional noise in experiments that could not be found using standard measures. Once we artificially add a noise to numerical data, B_0 and B_1 agree for both experiments and simulations, while the standard measures are not qualitatively affected by this change.

Acknowledgement: This research was supported by NSF Grants No. DMS-0835611 and DMS-1521717 (Received September 21, 2015)

1115-70-407 **Joon Hyung Lee** (jhlee@brooksschool.org), 1160 Great Pond Road, North Andover, MA 01845, and **Richard Kyung*** (richardkyung@yahoo.com), Cresskill, NJ 07626. *Application of a Sequence for Cost Effective Building Construction.*

A valence sequence is a mathematical term used for a group of numbers representing the number of lines in a polygon or polyhedral to triangulate the plane or volume. It is created by connecting vertices with lines that do not already meet. A good structural design can result in cost-efficient building. Therefore, finding a pattern in the valence sequence to triangulate structures could help both researchers and workers with current problems, when it comes to designing and building complicated structures. The purpose of this experiment is to find a pattern of the valence sequence for the polygons and pyramids, and to analyze a system using an efficient and cost-effective strategy for optimization. Using the presented theory, this paper shows how one can find a simplified pattern for man-made structures, or a common and visually complex system. Triangulation of the truss structures in order to give stability to structures will also be discussed in this paper. This relates particularly to the truss structures since these types of pinned structures have no resistance to bending moments when a force is applied (Received September 23, 2015)

1115-70-412 **Joo Hyun Kim**, **William Xiao** and **Richard Kyung***, Choice Research Group, Cresskill, NJ 07626. *A Study on the Optimization of Wheelchair Geometry Using Mathematical and Mechanical Analysis.*

Although wheelchairs in the twenty-first century are lighter and easier to use than those made in earlier years, there are over 40,000 wheelchair related accidents in the United States each year. Tipping and falling from wheelchairs make up approximately seventy-five percent of the total wheelchair related injuries. While the technology of these wheelchairs include anti-tipping and automatic brakes, injuries often occur when the user of the wheelchair leans, which decreases the mechanical static stability in the direction of the lean, and increases the stability of the opposite direction. This study examines the mathematical, computational and physical relationship between the body position (center of gravity) and the dimensions (geometry) of wheelchair to assess the stability by using the force equilibrium equations and moment equilibrium equations. The study provides solutions of the stability by calculating the tipping angles as the total weight of the system changes. To test for the optimized geometry and stability of the wheelchair, varying weights are loaded and the objects are placed on a tilted landscape. We used commercial post processing tools to display the static forward, rear, and lateral stability on tilted platforms. (Received September 23, 2015)

76 ► Fluid mechanics

1115-76-154 **Bogdan G Nita*** (nitab@mail.montclair.edu), 1 Normal Avenue, Montclair, NJ 07043, and **Ashwin Vaidya** and **Ryan Allaire**. *On the three-dimensional interaction between flexible fibers and fluid flow.*

We discuss the deformation of flexible fibers clamped to a spherical body and immersed in a flow of fluid (water) moving with a speed ranging between 0 and $50cm/s$. A three-dimensional model is used to analyze the effects of flow speed and initial configuration angle of the fiber relative to the flow. Both orientation and fiber length are shown to have an effect on the drag and lift forces in the system. We analyze the 3D effects both experimentally and numerically and discuss possible reduction of the dimension of the model. (Received September 14, 2015)

1115-76-219 **Yuan-Nan Young*** (yyoung@njit.edu), 519 Cullimore Hall, Department of Mathematical Sciences, University Heights, Newark, NJ 07102, **On Shun Pak**, Santa Clara University, Santa Clara, CA 95053, **Gary R. Marple**, University of Michigan, Ann Arbor, MI 48109, **Shravan Veerapaneni**, University of Michigan, Ann Arbor, MI 48109, **Zhangli Peng**, University of Notre Dame, Notre Dame, IN 46556, and **Howard A. Stone**, Princeton University, Princeton, NJ 08544. *Gating of a mechanosensitive channel in cellular flows.*

A multiscale continuum model is constructed for a mechanosensitive (MS) channel gated by tension in a lipid bilayer membrane under stresses due to fluid flows. We illustrate that for typical physiological conditions vesicle hydrodynamics driven by a fluid flow may render the membrane tension sufficiently large to gate a MS channel open. In particular, we focus on the dynamic opening/closing of a MS channel in a vesicle membrane under a planar shear flow and a pressure-driven flow across a constriction channel. Our modeling and numerical simulation results quantify the critical flow strength or flow channel geometry for intracellular transport through a MS channel. In particular, we determine the percentage of MS channels that are open or closed as a function of the relevant measure of flow strength. The modeling and simulation results imply that for fluid flows that are physiologically relevant and realizable in microfluidic configurations stress-induced intracellular transport

across the lipid membrane can be achieved by the gating of reconstituted MS channels, which can be useful for designing drug delivery in medical therapy and understanding complicated mechanotransduction. (Received September 19, 2015)

81 ► Quantum theory

1115-81-133 **Timothy Nguyen*** (timothyn@math.msu.edu), 2420 Burnt Tree Lane, Apt 8, East Lansing, MI 48823. *Quantum Yang-Mills Theory in Two Dimensions: Exact versus Perturbative.*

The standard Feynman diagrammatic approach to quantum field theories assumes that perturbation theory approximates the full quantum theory at small coupling even when a mathematically rigorous construction of the latter is absent. On the other hand, two-dimensional Yang-Mills theory is a rare example of a gauge theory whose full quantum theory has a rigorous construction. Indeed, the theory can be formulated via a lattice approximation, from which the continuum limit can be described in terms of white noise measures and Brownian motion on Lie groups. It is therefore fundamental to investigate how the the exact answer for 2D Yang-Mills compares with that of the perturbative approach, which a priori are unrelated. In this talk, we discuss recent work on providing a mathematically rigorous formulation of perturbative 2D quantum Yang-Mills, and we consider Wilson loop expectation values in both (Euclidean) light-cone gauge and in Coulomb gauge with respect to a general metric. For light cone gauge, we show that perturbation theory yields exact agreement with the asymptotics obtained from the continuum limit of the lattice to all orders in the coupling constant, thereby confirming the expectation that perturbation theory accurately captures the asymptotics of the full theory. (Received September 12, 2015)

92 ► Biology and other natural sciences

1115-92-48 **Chuan Xue*** (cxue@math.osu.edu), Columbus, OH 43210. *A stochastic multiscale model that explains cytoskeleton segregation in neurological diseases.*

The shape and function of an axon is dependent on its cytoskeleton, including microtubules, neurofilaments and actin. Neurofilaments accumulate abnormally in axons in many neurological disorders. An early event of such accumulation is a striking radial segregation of microtubules and neurofilaments. This segregation phenomenon has been observed for over 30 years now, but the underlying mechanism is still poorly understood. I will present a stochastic multiscale model that explained these phenomena and generated testable predictions. (Received August 26, 2015)

1115-92-112 **Eduardo Sontag*** (eduardo.sontag@gmail.com), Rutgers University. *Some recent work in systems and synthetic biology.*

In the absence of detailed mechanistic knowledge, biological models are often based on network inference methods. We point out in this lecture that, because of systems-level effects due to sequestration (leading to .retroactivity.), perturbation methods may lead to paradoxical conclusions: for any given pair of two components X and Y, and depending upon the specific intervention on X, either an activation or a repression of Y is inferred. In order to analyze this problem in general, we have developed a new algorithm to characterize sensitivities (inhibitory or activating) under perturbations, and applied this algorithm to several models of biological interest, including one of competitive receptor binding and simple phosphorylation and phosphotransfer models. Specifically, we predicted that ambiguous effects would manifest themselves already in an vitro minimal system. We will outline the theory as well as the experimental results obtained so far. Time permitting, we'll also discuss competition for ribosomes (viewed as another instance of retroactivity) in the context of the ribosome flow model (RFM), and in that context our recent mathematical results on RFM. We will also mention our current work on the design of synthetic gene networks for benchmarking reverse engineering algorithms, in which retroactivity effects appear as well.
(Received September 10, 2015)

1115-92-118 **Yi Sun*** (yisun@math.sc.edu), 1523 Greene Street, Columbia, SC 29208, and **Xiaofeng Yang** and **Qi Wang**. *Kinetic Monte Carlo Simulations of Multicellular Aggregate Self-Assembly in Biofabrication.*

We present a three-dimensional lattice model to study self-assembly and fusion of multicellular aggregate systems by using kinetic Monte Carlo (KMC) simulations. This model is developed to describe and predict the time

evolution of postprinting morphological structure formation during tissue or organ maturation in a novel biofabrication process (or technology) known as bioprinting. In this new technology, live multicellular aggregates as bio-ink are used to make tissue or organ constructs via the layer-by-layer deposition technique in biocompatible hydrogels; the printed bio-constructs embedded in the hydrogels are then placed in bioreactors to undergo the self-assembly process to form the desired functional tissue or organ products. Here we implement our model with an efficient KMC algorithm to simulate the making of a set of tissues/organs in several designer's geometries like a ring, a sheet and a tube, which can involve a large number of cells and various other support materials like agarose constructs etc. We also study the process of cell sorting/migration within the cellular aggregates formed by multiple types of cells with different adhesivities. (Received September 11, 2015)

1115-92-149 **Yuhai Tu***, 1101 Kitchawan Rd./Rt. 134, Yorktown Heights, NY 10598. *Multiscale modeling of E. coli chemotaxis: From molecules to behaviors.*

In 1972, Berg and Brown discovered that *E. coli* cells perform a run-and-tumble style random walk biased towards higher concentrations of attractants. Around the same time, a phenomenological model of chemotaxis was proposed by Keller and Segel based on a drift-diffusion equation. Since then, much progress has been made in uncovering the molecular machinery of the cellular navigation system. In this talk, I will summarize some of our recent work in developing an *ab initio* approach to understand bacterial chemotaxis behaviors from the interactions of the key molecules inside the cell.

Based on a molecularly accurate description of the intracellular chemotaxis pathway, we developed a mutliscale model to explain and predict bacterial chemotaxis behaviors in any given spatio-temporal varying chemical environments as well as in other non-chemical environments (temperature, pH). Our study shows that the bacterial chemotaxis behavior is controlled by the *E. coli*'s working memory. In slow varying environment, the Keller-Segel (KS) equation is derived with the macroscopic motility parameters given by microscopic parameters of the signaling pathway. In fast varying environment, the KS equation breaks down, due to the finite relaxation time of the cell's memory. (Received September 14, 2015)

1115-92-157 **Samuel A Isaacson*** (isaacson@math.bu.edu). *Incorporating Cellular Substructure into Reaction-Diffusion Models.*

Soft X-ray tomographic reconstructions of cells demonstrate the highly heterogenuous nature of both the nuclear and cytosolic spaces. We will use such data to construct detailed models of the cellular environment, and investigate several problems involving the diffusive search and reaction of proteins. Examples involving signal propagation will be used to illustrate how explicitly incorporating cellular substructure into mathematical models can impact predicted biological function. (Received September 14, 2015)

1115-92-193 **John Fricks*** (fricks@stat.psu.edu), 325 Thomas Bldg, Dept of Statistics, University Park, PA 16802. *Deciphering Gold-nanoparticle Tracking with of Kinesin with Brownian Dynamics.* Preliminary report.

Fluorescence techniques, such as FIONA, have enabled experimentalists to tag and track biological structures in vitro with nanometer accuracy at sampling rates of tenths to hundredths of a second. Gold-nanoparticles provide an alternative technique which increases possible sampling rates by one or two orders of magnitude. However, phenomena that had been time-averaged in the FIONA-type experiments now show up as increased fluctuations along with an increased proportion of experimental error in the gold-nanoparticle data. In this talk, in silico experiments tracking the head of a kinesin motor will be used to understand gold-nanoparticle data collected from the lab of William Hancock (Penn State). If time permits, related statistical inferential techniques will also be discussed. This is joint work with Jason Bernstein, William Hancock, Janak Jethva, and Keith Mickolajczyk. (Received September 17, 2015)

1115-92-194 **Sarah D Olson*** (sdolson@wpi.edu), 100 Institute Rd, Department of Mathematical Sciences, Worcester, MA 01570. *Effect of Fluid Resistance on Sperm Motility.*

Micro-organisms can swim in a variety of environments, interacting with chemicals and other proteins in the fluid. Some of these extra proteins or cells may act as friction, possibly preventing or enhancing forward progression of swimmers. The homogenized fluid flow is assumed to be governed by the incompressible Brinkman equation, where a friction term with a resistance parameter represents a sparse array of obstacles. Representing the swimmers with a centerline approximation, we employ regularized fundamental solutions to investigate swimming speeds, trajectories, and interactions of swimmers. Asymmetric waveforms due to an increase in flagellar calcium is known to be important for sperm to reach and fertilize the egg. The trajectories of hyperactivated swimmers are found to have a decreased path curvature. Although attraction of two swimmers is more efficient in the Stokes regime, we find that attraction does not occur for larger resistance. Additionally, resistance changes

the rotation of the swimmer, matching with experimental data. Recent asymptotic and numerical results for cylindrical swimmers with nonplanar bending waves will also be presented. (Received September 17, 2015)

1115-92-195 **Xingye Kan*** (xkan@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455, and **Chang Hyeong Lee** and **Hans G Othmer**. *A Multi-Time-Scale Analysis of Chemical Reaction Networks in Stochastic Setting.*

We consider stochastic descriptions of chemical reaction networks in which there are both fast and slow reactions, and for which the time scales are widely separated. We develop a computational algorithm that produces the generator of the full chemical master equation for arbitrary systems, and show how to obtain a reduced equation that governs the evolution on the slow time scale. This is done by applying a state space decomposition to the full equation that leads to the reduced dynamics in terms of certain projections and the invariant distributions of the fast system. The rates or propensities of the reduced system are shown to be the rates of the slow reactions conditioned on the expectations of fast steps. We also show that the generator of the reduced system is a Markov generator, and we present an efficient stochastic simulation algorithm for the slow time scale dynamics. We illustrate the numerical accuracy of the approximation by simulating several examples. Graph-theoretic techniques are used throughout to describe the structure of the reaction network and the state-space transitions accessible under the dynamics. (Received September 17, 2015)

1115-92-209 **Casey O Diekman*** (diekman@njit.edu), University Heights, Newark, NJ 07182. *Modeling Circadian Rhythmicity of Cardiac Arrhythmias.* Preliminary report.

The circadian (∼24-hour) clock in cardiomyocytes influences multiple intracellular processes, including transcription and contractile function, and has recently been linked to ventricular arrhythmias in mice. Circadian rhythms have also been observed in (I_{to}), the transient outward potassium current that dominates mice action potential (AP) repolarization. We used mathematical modeling to study the dynamical mechanisms underlying secondary oscillations during the repolarization phase of the AP. These oscillations, called early afterdepolarizations (EADs), have significance because they are associated with heart failure and arrhythmias. It can be shown that EADs arise from a Hopf bifurcation and that this can occur for certain ranges of the I_{to} conductance. We investigated how variation of calcium and I_{Ks} potassium conductances affects the range over which EADs occur. This allows us to predict the role circadian regulation of currents other than I_{to} could play in cardiac activity. Finally, we compare our results on daily rhythms in EADs to existing data on the times of day that humans are most likely to suffer sudden cardiac death. (Received September 18, 2015)

1115-92-307 **Sam Walcott*** (samwalcott@gmail.com), Dept. of Mathematics, UC Davis, One Shields Ave., Davis, CA 95616. *Modeling the coupling between molecules that occurs during muscle contraction.*

At the molecular level, muscle contracts when the molecular motor myosin binds to the filamentous protein actin. Single molecule techniques have allowed researchers to characterize, in exquisite detail, how a single myosin interacts with actin. But it is the combined effect of trillions of myosin motors that causes muscular contraction. As motors work together, they apply forces on each other and also deform the actin filament locally. These effects introduce coupling between the motors, so an isolated myosin molecule is not the same as a myosin molecule working in a group.

This coupling falls into two categories: 1) global coupling, where the attachment of one myosin affects all molecules equally; and 2) local coupling, where the attachment of one myosin only affects nearby molecules. We have developed partial differential equation models for both types of coupling. These models allow us to understand experimental results, including i) why groups of myosin move actin more rapidly than an isolated myosin, and ii) how an enigmatic muscle protein (myosin binding protein C) affects myosin's interaction with actin. This work gives insight into how the molecular scale affects macroscale muscle function, an important problem given the prevalence of genetic heart disease. (Received September 21, 2015)

1115-92-350 **Qi Wang*** (qwang@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208, and **Jia Zhao**. *Nonequilibrium models for active matter systems, their numerical treatment and applications to complex biological systems.*

I will present a general approach to the derivation of nonequilibrium models for active matter systems, in particular, hydrodynamic models for active liquid crystal flows, explaining the way to deal with activities due to chemical or biological energy input at the molecular level to the otherwise dissipative system. Then, I will discuss an energy stable scheme for numerically solving the hydrodyamical model consisting of partial differential equations. Then, I will show how this set of moedling and computational tools can be employed to simulate

cytokinesis of animal cells, animal cell oscillation, and traveling waves in swirling school of fish. (Received September 22, 2015)

1115-92-355 **Wenzhao Sun**, **Zhiliang Xu**, **Pavel Brodskiy**, **Ali Nematbakhsh**, **Cody Narciso**, **Jeremiah J. Zartman** and **Mark S. Alber*** (malber@nd.edu), Department of Appl. & Comp. Math. and Stat., University of Notre Dame, Notre Dame, IN 46556. *Multi-scale model of epithelial cells proliferation and mechanics.*

Epithelia are sheets of tightly adherent, asymmetrically organized cells that provide a protective barrier for organs. The close association of epithelial cells through physical interactions and active adhesion leads to tightly packed cellular networks. Several mathematical and computational models have been developed to simulate the dynamics of cell growth, division and neighboring cell-cell interactions and shape changes, which drive tissue morphogenesis. However, cells are typically approximated as polygons to simplify computation effort, resulting in poor descriptions of many morphogenetic processes including mitotic rounding. We will describe in this talk newly developed cell-based subcellular elements (SCE) computational model implemented on high performance Graphical Processing Units (GPUs) cluster. The model represents mechanical properties of both the internal cytoplasm and outer membrane of each cell with subcellular nodes connected by springs and potentials. The model does not require ad hoc rules to simulate cell neighbor changes. Model simulations match cell and tissue properties including the overall distributions of cell neighbor numbers during the cell cycle for a model epithelium, the Drosophila wing disc. (Received September 22, 2015)

97 ► Mathematics education

1115-97-63 **Ken Perko*** (lbrtpl@gmail.com). *Simple Invariants of Tricolored Knots.*

"Fox 3-coloring" dates back more than half a century [Annals of Math. 64 (1956), p. 414] and recent generalizations have produced many new and interesting results [Zbl 06457701]. Easily understood at an elementary level [McLeay, "The Knots Puzzle Book" (Tarquin Publications, 1994), p. 20], it gives rise to covering spaces that have long been at the very frontiers of knot theoretical research [Heegaard, Doctoral Dissertation (1898); Reidemeister, "Knotentheorie" (1932), p. 69]. We shall exhibit some old but easily visualizable examples of linking numbers in such covers, and discuss some of the current results of authors who work with more inscrutable invariants. (Received September 03, 2015)

1115-97-394 **Ziyue Guo*** (zoeyguo@gmail.com), 2582 South Road, Marlboro, VT 05344. *Using 3D-Printing in Teaching Multi-variable Calculus.* Preliminary report.

In this talk, we present student activities in a multi-variable calculus course using a 3D-printer and Mathematica to create surfaces that demonstrate limits and differentiability. We start with classic examples of surfaces that are not differentiable at the origin, such as the graph for $f(x,y) = (xy^2)/(x^2+y^4)$ and the graph for $f(x,y) = (xy^2)/(x^2+y^2)$. By working together on the Mathematica code, students practice using polar coordinates and observe the difference between pathological limits, continuity, and differentiability. Later in the course, students are also assigned a project to design a surface that is smooth on its domain except at one point, and 3D-print the surface with its tangent plane at a differentiable point. (Received September 22, 2015)

2010 MATHEMATICS SUBJECT CLASSIFICATION

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01 History and biography
03 Mathematical logic and foundations
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General algebraic systems
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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
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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
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49 Calculus of variations and optimal control; optimization
51 Geometry
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58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
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70 Mechanics of particles and systems
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80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
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91 Game theory, economics, social and behavioral sciences
92 Biology and other natural sciences
93 Systems theory; control
94 Information and communication, circuits
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0192-5857(2015)36:4;1-0