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> * Indicates who will present the paper at the meeting.

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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
1111	June 10–13, 2015	Porto, Portugal	EXPIRED	NONE
1112	October 3–4, 2015	Chicago, IL	August 11	Vol 36, No. 3
1113	October 17–18, 2015	Memphis, TN	August 25	Vol 36, No. 3
1114	October 24–25, 2015	Fullerton, CA	September 1	Vol 36, No. 4
1115	November 14–15, 2015	New Brunswick, NJ	September 22	Vol 36, No. 4
1116	January 6–9, 2016	Seattle, WA	September 22	Vol 37, No. 1

WASHINGTON, DC, March 7–8, 2015

Abstracts of the 1107th Meeting.

00 ► General

1107-00-2 **Frederico Rodriguez Hertz***, University Park, State College, PA 16801. *Random dynamics and a formula for Furstenberg entropy.*

Joint with Aaron Brown, in our study of stationary measures for random diffeomorphisms we found a formula for the Furstenberg entropy involving Lyapunov exponents and dimensions. In this talk I will describe the formula and give some consequences of it. (Received April 22, 2014)

1107-00-126 **Xuhua He***, Department of Mathematics, University of Maryland, College Park, MD 20742. *Rigid character tables of affine Hecke algebras.*

It is known that the number of conjugacy classes of a finite group equals the number of irreducible representations (over complex numbers). The conjugacy classes of a finite group give a natural basis of the cocenter of its group algebra. Thus the above equality can be reformulated as a duality between the cocenter of the group algebra and the Grothendieck group of its finite dimensional representations. One may define the character table for the finite group. This is an invertible matrix, which describes the duality between the cocenter and the representations.

In recent joint works with Ciubotaru, and with Nie, we study the duality between the cocenter and representations of affine Hecke algebras. We introduce the rigid character table, which play an essential way to understand the cocenter-representation duality. In this talk, I will discuss some properties on the rigid character table and make some conjectures. (Received January 09, 2015)

1107-00-141 **Wenbo Sun*** (`swenbo@math.northwestern.edu`), 2033 Sheridan Road, Evanston, IL 60208-2730. *Partition regularity over Gaussian integers.*

We show that for any finite coloring of the Gaussian integers, there exist distinct nonzero elements x and y of the same color such that $x^2 - y^2 = n^2$ for some Gaussian integer n. We will also explain the connection between this problem with a structure theorem for multiplicative functions on the Gaussian integers. (Received January 11, 2015)

1107-00-145 **Seblework Molalign Alefe*** (`sebliyo2020@yahoo.com`), Dilla University, Dilla, Ethiopia. *Construction of Duality between Boolean Rings and Relatively Complemented Distributive Lattices with least elements.* Preliminary report.

M.H. Stone established duality between Boolean rings with unity and Boolean algebras (bounded complemented distributive lattices). In this paper, we will extend this result to duality between Boolean rings and relatively complemented distributive lattices with least elements. (Received January 13, 2015)

1107-00-146 **Meron Dessalegn Abate*** (merygym2020@yahoo.com), Dilla University, Dilla, Ethiopia. *Construction of the Duality between Boolean Rings and locally compact totally disconnected topological spaces with compact open bases.*

M.H. Stone established duality between Boolean Rings with unity and compact totally disconnected topological spaces. In this paper, we will extend this result to duality between Boolean rings and locally compact totally disconnected topological spaces with compact open bases. (Received January 14, 2015)

1107-00-216 **Anthony J Romano*** (anthony.romano@nrl.navy.mil), 4555 Overlook Ave., SW, WASHINGTON, DC 20375. *An Overview of Waveguide Elastography and its Application to White Matter Classification.*

Waveguide Elastography is a noninvasive method which evaluates the anisotropic material parameters of fibrous structures. It requires knowledge of the pathways along which elastic waves may travel (provided by Diffusion Tensor Imaging) as well as a measurement of the dynamic elastic displacements within the volume surrounding the pathways (provided by Magnetic Resonance Elastography). With knowledge of the position vectors of the pathways, a spatial-spectral filter is applied to the measured displacements to identify only those waves which are traveling at particular angles to, and along the fibers at every point. At this time as well, a Helmholtz decomposition is implemented which separates the total field into its longitudinal and transverse components. An Orthotropic inversion is then performed along the fibers to evaluate the stiffness values. By filtering along six specific directions within the local reference frame of the fibers, the equations of motion decouple allowing for each of the nine elastic coefficients to be solved for independently of one another. This method will be demonstrated in the brains of healthy human volunteers as well as in patients suffering from neurological conditions such as Amyotrophic Lateral Sclerosis and Traumatic Brain Injury. (Received January 15, 2015)

1107-00-233 **Jesse Elliott*** (jesse.elliott@csuci.edu). *A dualist perspective on the axiom of constructibility.*

I will argue that the axiom of constructibility is true from a monist perspective but independent from a pluralist perspective. I will also present a dualist thesis that neither monism nor pluralism ought to be rejected over the other. (Received January 15, 2015)

1107-00-256 **Jason Siefken*** (siefkenj@uvic.ca), 3800 Finnerty Road, Department of Mathematics and Statistics, University of Victoria, Victoria, BC V8P 5C2, Canada. *A Minimal Subsystem of the Kari Culik Tilings.*

The set of 13 Kari Culik tiles is currently the smallest know set of Wang tiles (square tiles with colored edges and the rule that two tiles may lie adjacent iff their common edges share the same color) that tile the plane only in an aperiodic way. They do so for fundamentally different reasons than previously known tilings. A subset of Kari Culik tilings have rows which may be interpreted as Sturmian sequences. This talk will show how this Sturmian-like subset can be thought of as a generalization of rotation sequences and how to get explicit waiting time bounds for $n \times m$ configurations. (Received January 16, 2015)

01 ► History and biography

1107-01-33 **Amy Ackerberg-Hastings*** (aackerbe@verizon.net). *International Influences on American Mathematicians, 1750–1850.* Preliminary report.

Professors of mathematics at colonial and early republican colleges are known to have read European publications and interacted with scientific societies and individuals. For instance, John Winthrop (1714–1779) was a contributing member of the Royal Society, while Jeremiah Day (1773–1867) and John Farrar (1779–1853) read British and French research treatises as well as textbooks. However, work on Americans involved in mathematics tends to consider what they were reading as a series of separate stories rather than as a whole. This talk will make a preliminary effort to survey periodicals and books that were available in North America and to draw general conclusions about Americans as readers of mathematics. (Received November 28, 2014)

1107-01-66 **Chris Rorres*** (crorres@comcast.net). *The Law of the Lever: Archimedes vs. Mach.*

Over a century ago Ernst Mach, the famous Austrian physicist and philosopher of science, wrote a blistering criticism of Archimedes' celebrated proof of the Law of the Lever. Mach accused Archimedes of overusing his "Grecian mania for demonstration" and succeeding in his proof only "by the help of the very proposition he sought to prove". His attack drew the expected objections from many historians and philosophers of science who, in turn, accused Mach of not understanding the subtleties of Archimedes' proof. I will give my own interpretation of this controversy from a mathematician's point of view, concluding with my belief that, while Archimedes did indeed prove something, it can hardly be called a proof of the Law of the Lever. (Received December 27, 2014)

1107-01-82 **Karen V. H. Parshall*** (khp3k@virginia.edu). *Training Women in Mathematical Research: The First Fifty Years of Bryn Mawr College (1885-1935).*

In 1933, the German algebraist, Emmy Noether, joined the Department of Mathematics at Bryn Mawr College just outside of Philadelphia. Byrn Mawr, a women's college, had been founded not quite fifty years earlier in 1885. In fact, the higher education of women in the United States was barely older than that. What developments had taken place by the 1930s to allow arguably the world's then greatest female mathematician to take up a research and teaching position in the United States? This talk will explore the contours of an answer to this question. (Received December 31, 2014)

1107-01-99 **Paul R Wolfson*** (pwolfson@wcupa.edu), Department of Mathematics, West Chester University, West Chester, PA 19383. *Newton, Leibniz–what's the difference?* Preliminary report.

It is generally agreed that the calculus of Newton begins with the concept of continuous motion; his fluxions measure the rate of that motion. By contrast, Leibniz's calculus begins with discrete sequences and the change between terms is measured by their difference. These different approaches to many of the same problems reflect a difference in philosophy of mathematics, one which in Newton's case had developed over two decades. I shall try to describe that philosophy and show why it caused Newton to resist the calculus of differentials, which was so appealing to the most prominent of his contemporaries. (Received January 05, 2015)

1107-01-174 **David Lindsay Roberts*** (robertsdl@aol.com). *Number theory proofs in nineteenth-century American algebra textbooks: the Good, the Bad and the Ugly.* Preliminary report.

College algebra textbooks in the nineteenth-century United States were largely algorithmic; they set out step by step procedures for tasks such as extracting roots, expanding powers of binomials, or solving quadratic equations. But on occasion some textbook writers were moved to attempt the proof of a theorem. Basic properties of prime numbers seem to have been especially likely to inspire efforts at proof. The reasoning varied markedly by modern standards of rigor, with some writers assuming key subtleties to be obvious or even applying outright circularity. In this talk I will discuss some of these proofs, and their authors. (Received January 13, 2015)

1107-01-222 **Andrea Pedeferri*** (apedef@gwu.edu). *Logic in Italy from Peano to WWII.*

In the first half of the last century, logical studies in Italy had been dominated by the figure of Giuseppe Peano, who deeply influenced many logicians worldwide (e.g. Bertrand Russell). The Italian Logic group headed by the Turin logician and mathematician established itself as one of the strongest and most innovative on the international scene. Unfortunately, the school born from this circle never did become a leading one; on the contrary, it died slowly. The aim of this paper is to identify and clarify the cultural, methodological and technical factors in the first half of 20th century which brought about the discontinuity of research in logic in Italy. (Received January 15, 2015)

1107-01-277 **Peggy Aldrich Kidwell*** (kidwellp@si.edu). *Stratification in the American Mathematical Community a Century Ago, Viewed Objectively.* Preliminary report.

The forthcoming centennial celebration of the Mathematical Association of America has drawn renewed attention to the American mathematical community around 1915. Karen Parshall and others are examining interconnections between the M.A.A. and the earlier American Mathematical Society. Several objects associated with charter members of the M.A.A. survive in the collections of the Smithsonian's National Museum of American History. This paper explores these objects and their creators as they reveal divisions within and overlap between the A.M.S. and the M.A.A. Of particular interest are materials associated with Derrick N. Lehmer, Raymond C. Archibald, Olive C. Hazlett, Richard P. Baker, A. Harry Wheeler, and L. Leland Locke. (Received January 17, 2015)

1107-01-285 **Duncan J. Melville*** (dmelville@stlawu.edu), Dept. of Mathematics, St. Lawrence University, Canton, NY 13617. *The Role of Third Millennium Metrology in the Development of the Mesopotamian Sexagesimal Place-Value System.* Preliminary report.

Some recently published metrological tables from the second half of the third millennium indicate a systematic exploration of linkages between length and area metrologies. The extension into small units was something the prevailing metrological systems were particularly ill-equipped to handle. The response was a development of sexagesimally-based sub-units. In this paper we argue that these sexagesimal explorations indicate a stage in the development of sexagesimal numeration towards a fractional and, ultimately, place-value system. (Received January 17, 2015)

1107-01-336 **Lawrence D'Antonio*** (ldant@ramapo.edu). *The Role of Mathematics in the Encyclopédie.* Preliminary report.

One of the greatest intellectual achievements of the 18th century was the *Encyclopédie* edited by Denis Diderot and Jean d'Alembert. The work, comprising 28 volumes with over 70,000 articles written by more than 130 contributors, attempted to give a systematic overview of human knowledge at that time. In this talk we will give an overview of the writing of the *Encyclopédie* and its place in the Enlightenment. We will focus on the more than one thousand mathematical articles in the *Encyclopédie*, many of which were written by d'Alembert. Specifically, we will consider the question of the role played by mathematics in the structure and goals of the *Encyclopédie*. (Received January 18, 2015)

1107-01-364 **Lydia Patton*** (critique@vt.edu), Department of Philosophy, 220 Stanger St., Blacksburg, VA 24061-0126. *"Geometrical figures in physical proofs".*

In the nineteenth century, there was broad use of geometrical figures to model physical phenomena, including Lissajous curves in acoustics and rotating cylinders in Maxwell's electrodynamics. The increasingly algebraic treatment of geometry rendered such models superfluous within geometry itself: geometrical intuition was no longer a source of mathematically rigorous proof. The role of geometrical models in physics is more complex. For instance, a spatial manifold is derived geometrically, but is part of physical explanation. This paper will consider the question of applications of geometrical figures and models in physical proofs, and will propose an account of how such figures function in explanation, in physical proof, and in the building of theories. (Received January 19, 2015)

1107-01-377 **Andrew Fiss*** (afiss@mtu.edu), Michigan Technological University, 341 Walker Arts & Humanities Center, 1400 Townsend Drive, Houghton, MI 49931-1295. *Who's Anna? Burying Mathematics Books in order to Remember the Civil War Dead at Nineteenth-Century New England Colleges.* Preliminary report.

The nineteenth century witnessed the emergence and flourishing of a peculiar student tradition in American colleges: elaborate funerals for mathematics textbooks. First developing in what students at early-century Yale and Williams called "Burials of Euclid," these ceremonies took on added significance in the years immediately following the Civil War, when Americans experienced death and its trappings on an unprecedented scale. This paper focuses on the "Burials of Anna Lytics," events that occurred in 1870s Bowdoin College that increasingly adopted items of funereal practice, including a headstone marked "Anna." In asking, "Who's Anna?" as later students, professors, and college administrators did, this paper argues for the reconceptualization of these student rituals not as mere acts of destruction but as acts of remembrance, as well. In doing so, it brings together strands in the recent scholarship about Civil War death with histories of American mathematics education. (Received January 19, 2015)

1107-01-380 **Judy Green*** (judy.green@marymount.edu). *More about American Women in Mathematics.* Preliminary report.

I will discuss some things about American women in mathematics that have come to my attention since the 2009 publication of my book with Jeanne LaDuke, *Pioneering Women in American Mathematics*. (Received January 19, 2015)

1107-01-473 **Brit Shields***, History & Sociology of Science Department, University of Pennsylvania, 249 South 36th Street, Philadelphia, PA 19104. *"The god Mars helped his fledging endeavor:" World War II, Richard Courant and Mathematics at New York University.*

The Second World War's impact on scientific research and education in the United States has been well documented. At New York University (NYU), Richard Courant led the Graduate Department of Mathematics in contractual work for the National Defense Research Committee's Applied Mathematics Panel. Following the war, the NYU mathematicians maintained contracts with various military and governmental organizations. Decades later, NYU mathematician Cathleen Morawetz reflected, "As Courant himself said years later, the god Mars helped his fledging endeavor." This paper will discuss the efforts to develop mathematics research and education at NYU from the time of Courant's arrival in 1934, during the Second World War, and through the postwar years. Particular attention will be paid to the dynamic relationships between the mathematics faculty, university administrators, and government officials as they negotiated the role of research mathematicians in the war effort. (Received January 20, 2015)

1107-01-506 **K. J. Mourad*** (kjm57@georgetown.edu). *100 Years of Mathematical Logic: From Philosophy to Mathematics (and Back Again?).*

One hundred years ago the first version of the famous Lowenheim-Skolem was proved. Although there was much work in formal logic up to that point, it can be argued that this result sets the stage for many ideas and results in model theory. Gödel's completeness and incompleteness result make much more coherent sense given this setting. In addition further work by Skolem, arguably just as important, set the stage for the construction of the Nonstandard Reals. This roughly corresponds to the Completeness Theorem of Gödel.

This is paralleled by Church and Turing's work for incompleteness. Using documents recently uncovered in the Church Family Archives in The Hudson Historical Society in Hudson, Ohio (also containing historical information about Church's interest in genealogy) will show how strongly Church felt that his work and the work of his student Turing be recognized as rigorous mathematics to be treated not only with the same regard as other mathematics but indeed provide a more rigorous foundation for mathematics as far as was possible (although he was forced to temper his ambitions as we know all too well.) Tracing the Church line we find it goes back directly to Leibniz and that the Lambda Calculus a natural successor of Leibniz's characteristica universalis. (Received January 20, 2015)

03 ► Mathematical logic and foundations

1107-03-32 **K J Mourad*** (kjm57@georgetown.edu), 37th and O Streets NW, Washington, DC 20057. *Ultraproducts of Computable Structures and Diagonailization: Skolem's Legacy.*

2015 marks the centennial anniversary of what is widely regarded as the first result of modern logic, the Lowenheim-Skolem Theorem. However it is less well known that Skolem invented the Ultraproduct construction in 1934 when he introduced non-standard models of arithmetic. Both techniques are fundamental to current day model theory. One method essentially constructs structures one element at a time while the other focuses on the global properties and then defines all the elements in the structure in one fell swoop. In the context of computable structures only Skolem's first method has been explored. We will try to correct this.

In this talk we will establish a few basic results on constructions involving quotient structures of computable functions from integers to integers. We will look at diagonalization procedures to build structures that have or lack a given property. A maximal set construction using movable markers will be presented. A specific application to joint work with Rumen Dimitrov, Valentina Harizanov, and Russell Miller will be given. In addition we will explore the uses of these methods in Reverse Mathematics. (Received December 04, 2014)

1107-03-62 **Alexander Melnikov** and **Antonio Montalban*** (antonio@math.berkeley.edu), Evans Hall #3840, Berkeley, CA 94720. *Computable structure theory as group actions.* Preliminary report.

We discuss how to generalize some classical results in computable structure theory the the general setting of actions of polish groups into polish spaces. (Received December 19, 2014)

1107-03-108 **Moshe Jarden** and **Alexandra Shlapentokh*** (shlapentokha@ecu.edu), Dept Of Mathematics, East Carolina University, Greenville, NC 27858. *Fields with Decidable Existential Theories.* Preliminary report.

Let K be an infinite algebraic extension of $\mathbb{Q}$ with decidable existential theory. Assume we have a computable presentation of $\bar{\mathbb{Q}}$, the algebraic closure of $\mathbb{Q}$. By a computable presentation we mean an injective map $j : \bar{\mathbb{Q}} \longrightarrow \mathbb{Z}_{>0}$ such that $j(\bar{\mathbb{Q}})$, $j(\mathbb{Q})$, and the j-image of the graphs of addition and multiplication are decidable. We now construct M such that $M \cong K$ and $j(M)$ is decidable. (Received January 06, 2015)

1107-03-151 **Sergey S. Goncharov*** (s.s.goncharov@math.nsc.ru), pr.Acad. Koptug 4, Novosibirsk, 630090, Russia. *DEFINABILITY AND INDEX SETS OF COMPUTABLE MODELS.* Preliminary report.

The main subject of my talk is the study of complexity for definability of classes of computable (=constructive) models [1]. We discuss the problem on complexity for classes of constructive models. We will presented some results about complexity of index sets for classes of autostable models relative to strong constructivizations [2]. We will presented some results of our work with S.Friedman, V.Harizanov, D. Turetsky, E. Fokina about autostable relative to m-computable representations and autostable. We will consider some open problems in this approach: the complexity of computable models with strong constructivization, the complexity of computable models non-autostable but with finite algorithmic dimension n. The research of author was partially supported by grant RFBR 14-01-00376.

References

[1] Ershov Y. L., Goncharov S. S., Constructive models. N. Y. Consultants Bureau. 2000. 305 p.

[2] S. S. Goncharov, M.I.Marchuk, "Index set of constructive models that are autostable relative under strong constructivizations ", J. Math. Sci., New York, Vol. 205, No. 3, March, 368-388 (2015).

(Received January 12, 2015)

1107-03-156 **Mariya I Soskova*** (msoskova@fmi.uni-sofia.bg), Faculty of Mathematics and Informatics, Sofia University, 5 James Bourchier Blvd., 1164 Sofia, Bulgaria, and **Theodore A. Slaman**. *An automorphism analysis for the Δ_2^0 Turing degrees.*

We prove that the structure of the Δ_2^0 Turing degrees has a finite automorphism base. We apply this result to show that the automorphism group of this structure is countable and all its members have arithmetic presentations. We show that the structure is atomic and that every relation induced by an arithmetically definable degree invariant relation is definable with finitely many parameters. We prove that rigidity for the structure is equivalent to its biinterpretability with first order arithmetic. (Received January 12, 2015)

1107-03-181 **Andrey Morozov*** (morozov@math.nsc.ru), Sobolev Institute of Mathematics, of the Siberian Branch of the Russian Academy, of Sciences, Koptyug Ave. 4, Novosibirsk, 630090, Russia. *Structures without Σ–presentations over hereditarily finite superstructures.* Preliminary report.

We define a class of Steinitz existential structures, which in particular contains the fields of real and complex numbers.

We prove a general result on non–Σ–presentability of structures in hereditarily finite superstructures over such structures. As a corollary of this general result, we obtain that, if $\mathfrak{M}$ is a Steinitz existential structure then the following structures cannot be embedded into a structure Σ–presentable over $\mathbb{HF}(\mathfrak{M})$ with trivial equivalence: the Boolean algebra of all subsets of ω, its factor modulo the ideal of finite sets, the group of all permutations on ω, its factor modulo the subgroup of all finitary permutations, semigroup of all mappings from ω to ω, the lattice of all open and the lattice of all closed sets of reals, the group of all Σ–definable permutations over $\mathbb{R}$, the group of all Σ–definable mappings from $\mathbb{R}$ to $\mathbb{R}$.

We also discuss some methods and open problems. (Received January 14, 2015)

1107-03-182 **Gregory Igusa** and **Julia F. Knight*** (knight.1@nd.edu), 255 Hurley Hall, Mathematics Department, University of Notre Dame, Notre Dame, IN 46556, and **Noah D. Schweber**. *Computing power of the ordered field of real numbers.* Preliminary report.

The third author defined a reducibility that lets us compare the computing power of uncountable structures. We have $\mathcal{A} \leq_w^* \mathcal{B}$ if in a generic extension of V in which both $\mathcal{A}$ and $\mathcal{B}$ countable, every copy of $\mathcal{B}$ computes a copy of $\mathcal{A}$. Using this reducibility, we compare the reals with some related structures. Let $\mathcal{R}$ be the ordered field of real numbers. Let $\mathcal{R}^*$ be an ω-saturated extension of $\mathcal{R}$, and let $\mathcal{R}_{exp}$ be the expansion of $\mathcal{R}$ by the exponential function. The first two authors showed that $\mathcal{R}$ lies strictly above $\mathcal{R}^*$ under $\leq_w^*$. The extra computing power of $\mathcal{R}$ comes from the fact that it is Archimedean. The structures $\mathcal{R}$ and $\mathcal{R}_{exp}$ turn out to be equivalent. Some other expansions of $\mathcal{R}$ also turn out also not to have added computing power. (Received January 14, 2015)

1107-03-218 **Rebecca M. Steiner*** (rebecca.m.steiner@vanderbilt.edu), 4500 Post Road, Unit #74, Nashville, TN 37205. *Automorphism Spectra of Size $2^n - 1$.* Preliminary report.

The automorphism spectrum of a structure is the set whose elements are the Turing degrees of the nontrivial automorphisms of the structure.

It has been shown that if d_1 and d_2 are incomparable degrees, then there is no computable structure with automorphism spectrum $\{d_1, d_2\}$. It has also been shown that there exist pairwise incomparable degrees d_1, d_2, and d_3 and a computable structure with automorphism spectrum $\{d_1, d_2, d_3\}$.

We show that for any natural number n there are pairwise incomparable degrees $d_1, d_2, \ldots, d_{2^n-1}$ and a computable structure with automorphism spectrum $\{d_1, d_2, \ldots, d_{2^n-1}\}$. (Received January 15, 2015)

1107-03-244 **Wesley Calvert*** (wcalvert@siu.edu), Department of Mathematics, Mail Code 4408, 1245 Lincoln Drive, Carbondale, IL 62901. *PAC Learning, VC Dimension, and the Arithmetic Hierarchy.*

We compute that the index set of PAC-learnable concept classes is m-complete Σ_3^0 within the set of indices for all concept classes of a reasonable form. All concept classes considered are computable enumerations of computable Π_1^0 classes, in a sense made precise here. This family of concept classes is sufficient to cover all standard examples, and also has the property that PAC learnability is equivalent to finite VC dimension. (Received January 16, 2015)

1107-03-257 **Karen Lange*** (karen.lange@wellesley.edu), Wellesley College, 106 Central St., Wellesley, MA 02481, and **Abigail Raz**. *Scott sentences and index sets of some computable groups.* Preliminary report.

Scott sentences, infinitary formulas that describe a single isomorphism class $\mathcal{C}$ of countable models, help us to understand the structure and complexity of elements of $\mathcal{C}$. Partially building on work in [1], Knight and Saraph [2] give Scott sentences for computable examples of torsion free abelian groups of rank 1 and certain finitely generated groups. In many cases, they show that their Scott sentences are of the least possible complexity by examining the corresponding index sets. We work to close some of the complexity gaps in the remaining cases and generalize their work to a wider class of examples.

[1] J. Carson, V. Harizanov, J. Knight, K. Lange, C. McCoy, A. Morozov, S. Quinn, C. Safranski, and J. Wallbaum, "Describing free groups", *Trans. Amer. Math. Soc.*, vol. 364, (2012), pp. 5715-5728.

[2] J. Knight and V. Saraph "Scott sentences for certain groups", preprint. (Received January 16, 2015)

1107-03-267 **Alexandra A. Soskova*** (asoskova@fmi.uni-sofia.bg), Faculty of Mathematics and Informatics, Sofia university, 5 James Bourchier blvd, 1164 Sofia, Bulgaria, and **Stefan V. Vatev** and **Alexander A. Terziivanov**. *Some applications of Marker's extensions for a sequence of structures.* Preliminary report.

In his last paper Soskov gives a generalization of the notion of Marker's extensions for a sequence of structures. Soskov demonstrates that for any sequence of structures its Marker's extension codes the elements of the sequence so that the n-th structure of the sequence appears positively at the n-th level of the definability hierarchy.

We will present some applications of these results based on the notions of conservative extensions of structures and of jump of a structure. We call two structures $\mathfrak{A}$ and $\mathfrak{B}$ equivalent: $\mathfrak{A} \equiv \mathfrak{B}$ if they have the same relatively intrinsically c.e. subsets of the common part of the domains. Given a sequence of structures $\mathcal{A} = \{\mathfrak{A}_i\}_{i<\omega}$ the n-th polynomial of $\mathcal{A}$ is a structure defined inductively: $\mathcal{P}_0(\mathcal{A}) = \mathfrak{A}_0$, and $\mathcal{P}_{n+1}(\mathcal{A}) = \mathcal{P}_n(\mathcal{A})' \oplus \mathfrak{A}_{n+1}$. Here the jump of a structure is appropriately defined. We show that for every sequence of structures $\mathcal{A}$, there exists a structure $\mathfrak{M}$ such that for every n we have $\mathcal{P}_n(\mathcal{A}) \equiv \mathfrak{M}^{(n)}$. Actually $\mathfrak{M}$ is the Marker's extension of $\mathcal{A}$. (Received January 17, 2015)

1107-03-293 **Douglas Cenzer*** (cenzer@ufl.edu) and **Francis Adams**, University of Florida. *Weakly ultrahomogeneous structures.*

A structure M is ultrahomogeneous if any isomorphism between finitely generated substructures may be extended to an automorphism of M. We say that M is weakly ultrahomogeneous if there is a finite (exceptional) set of elements such that M becomes ultrahomogeneous when constants representing these elements are added to the language. Characterizations are obtained for weakly ultrahomogeneous linear orderings, equivalence structures, injection structures and trees. Minimal exceptional sets are determined for many of the structures. The effective categoricity of weakly ultrahomogeneous structures is studied. (Received January 17, 2015)

1107-03-326 **Jennifer C Chubb*** (jcchubb@usfca.edu), USF Dept. of Math, 2130 Fulton St., San Francisco, CA 94117. *Spaces of orderings of computable groups.*

A group is called computable if membership in the structure (as a set) can be effectively determined and there is an effective algorithm for computing the group operation. An ordering of the elements of a group is called a bi-ordering if it is invariant under the left and right actions of the group on itself. The collection of orderings of a group has a natural topology, and we will discuss topological properties of the space of bi-orderings of computable groups. (Received January 18, 2015)

1107-03-353 **Michael C. Laskowski*** (mcl@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742. *On Borel complexity and constants.*

We will survey the (few) results that are known about the Borel complexity of $Mod(T)$, where T is a complete, first-order theory. Results of Koerwien, Marker, Rast, Rast-Sahota, and Laskowski-Shelah will be highlighted.

We will also discuss the difficulties of extending this classification and, in contrast to computable model theory, the potential effect of naming a constant. (Received January 19, 2015)

1107-03-354 **Reed Solomon*** (david.solomon@uconn.edu), University of Connecticut, U-3009, Department of Mathematics, 196 Auditorium Road, Storrs, CT 06269. *Computable ordered abelian groups and generalized power series.* Preliminary report.

Julia Knight and Karen Lange, together with various coauthors, have recently produced a number of results on the complexity of integer parts and other associated algebraic objects for computable real closed fields. These results are based on Mourges and Ressayre's proof of the existence of integer parts for real closed fields using an embedding of such fields into fields of generalized power series. In this talk, we will discuss related computability questions in the context of ordered abelian groups rather than real closed fields, and in particular, how embeddings into generalize power power series are used in the context of ordered groups. (Received January 19, 2015)

1107-03-355 **Leah Marshall*** (lbm@gwmail.gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *Nested Equivalence Structures and Trees of Finite Height.* Preliminary report.

A nested equivalence structure consists of a set of natural numbers and a finite number of equivalence relations, which are nested inside of each other. We explore ways of representing nested equivalence structures as trees and utilize the tools of category theory to build computable functors between nested equivalence structures and full trees of finite height. This gives us the framework in which we can transfer existing results about computable isomorphisms between finite height trees to similar notions of nested equivalence structures. (Received January 19, 2015)

1107-03-371 **Matthew Harrison-Trainor*** (matthew.h-t@berkeley.edu), **Alexander Melnikov**, **Russell Miller** and **Antonio Montalbán**. *Computable functors and effective interpretability.*

It is well-known in model theory that an interpretation of $\mathcal{A}$ in $\mathcal{B}$ induces a functor from copies of $\mathcal{B}$ to copies of $\mathcal{A}$. If the interpretation is effective—that is, if the formulas involved are all computable Σ_1 formulas—then the functor is computable, i.e. it is given by a Turing functional. I will talk about some recent work where we show that the converse is also true: if there is a computable functor from $\mathcal{B}$ to $\mathcal{A}$ then we can construct an interpretation of $\mathcal{A}$ in $\mathcal{B}$. I will also talk about bi-interpretations and give some examples. (Received January 20, 2015)

1107-03-388 **Ekaterina Fokina*** (efokina@logic.univie.ac.at), Währingerstr. 25, 1090 Vienna, Austria. *Reverse model theory.*

In this talk we will discuss some model-theoretical results from the point of view of reverse mathematics. We will present several new results that deal with the question about the number of models of a theory, in particular the question of existence of the Ryll-Nardzewski function. We will also examine the strength of statements about existence of universal and saturated models. This is a joint work with Li Wei and Daniel Turetsky. (Received January 19, 2015)

1107-03-407 **Victor A Ocasio*** (victor.ocasio1@upr.edu), University of Puerto Rico at Mayagüez, Department of Mathematical Sciences, CALL BOX 9000, Mayagüez, PR 00681-9018. *Degree spectra in the class of Real Closed Fields.*

It is currently not known if there is any degree spectra that cannot be realized by Real Closed Fields. We show that a particular subclass of Real Closed Fields satisfy Richter's Theorem. That is, we show that if the degree spectra of a field in this subclass has a least degree then the least degree is $\mathbf{0}$. (Received January 19, 2015)

1107-03-409 **Barbara Csima***, Department of Pure Mathematics, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, and **Keng Meng (Selwyn) Ng**. *Isomorphism notions restricted to particular classes of structures.* Preliminary report.

We say a computable structure $\mathcal{A}$ is $\mathbf{d}$-categorical if there exists a $\mathbf{d}$-computable isomorphism between any two computable copies of $\mathcal{A}$. We say a Turing degree $\mathbf{d}$ is a *degree of categoricity* if there is a structure $\mathcal{A}$ such that $\mathcal{A}$ is $\mathbf{d}$-categorical and $\mathbf{d}$ is the least such degree. We say that $\mathbf{d}$ is *low for isomorphism* if for any computable structure $\mathcal{A}$, whenever there is a $\mathbf{d}$-computable isomorphism between computable copies of $\mathcal{A}$, there is also a computable isomorphism. Finally, we say a degree $\mathbf{d}$ is *low for categoricity* if every $\mathbf{d}$-categorical structure is computably categorical.

In this talk, we investigate the notions of degree of categoricity, low for isomorphism, and low for categoricity when restricted to particular classes of structures, such as equivalence structures and linear orderings. (Received January 19, 2015)

1107-03-413 **Damir D Dzhafarov*** (damir@math.uconn.edu) and **Joseph R Mileti**. *The complexity of primes in computable UFDs.*

In many simple integral domains, such as $\mathbb{Z}$ or $\mathbb{Z}[i]$, there is a straightforward procedure to determine if an element is prime by simply reducing to a direct check of finitely many potential divisors. Despite the fact that such a naive approach does not immediately translate to integral domains like $\mathbb{Z}[x]$ or the ring of integers in an algebraic number field, there still exist computational procedures that work to determine the prime elements in these cases. In contrast, we will show how to computably extend $\mathbb{Z}$ in such a way that we can control the ordinary integer primes in any Π^0_2 way, all while maintaining unique factorization. As a corollary, we establish the existence of a computable UFD such that the set of primes is Π^0_2-complete in every computable presentation. (Received January 19, 2015)

1107-03-432 **Daniel Turetsky*** (turetsd4@univie.ac.at). *Relatively Categorical Metric Spaces.*

Traditionally, computable model theory is interested in countable first-order structures, and the field has many results concerning these. We can gain insight into these theorems by studying a different class of objects and attempting to prove analogous theorems. Frequently, issues that would be trivialities in the original context provide unexpected difficulty, and understanding these issues improves our understanding of the original theorem.

This talk will discuss separable metric spaces as an analog of first-order structures. In particular, it will focus on the classifications of relatively categorical structures and the corresponding results for metric spaces. (Received January 20, 2015)

1107-03-460 **Jacob Suggs*** (jacob.suggs@uconn.edu). *Lowness for Isomorphism.*

One of the many notions of lowness for the Turing degrees is lowness for isomorphism: a degree is low for isomorphism iff whenever it can compute an isomorphism between two computable structures, there is also a computable isomorphism between those structures. If we restrict to a class of structures $\mathcal{C}$, we have the related property of being low for $\mathcal{C}$-isomorphism. This property is highly related to the interaction between degrees and the specific structural properties of members of $\mathcal{C}$, and we will present results which are both of interest in their own rights and which illustrate a few of the ways that this interaction can occur. (Received January 20, 2015)

05 ▶ Combinatorics

1107-05-16 **Mohamed Hanafy Sayed Radwan*** (mohamed_hanafy@mentor.com), 78 El Nozha St., Heliopolis, Cairo, 11361, Egypt. *New Summation Series Form Presenting Mathematical Permutations and Combinations for Powerful Parallel Computing.*

The mathematical computing of permutations and combinations is one of the heavy computing operations. It consumes much time and memory resources as it depends on excessive multiplication operations. In this paper, a new summation series equation is contributed to represent both permutations and combinations in an addition form. The new form is more efficient for parallel computing techniques, where the summation terms can be distributed on separate computing clusters. The new contributed form is proved by the "Proof by induction" method. It can be used as a new efficient technique to compute multiple multiplication operations like the factorial of large integers with multiple addition terms computed separately. (Received October 26, 2014)

1107-05-25 **Laszlo A. Szekely*** (szekely@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *Biplanar and k-planar crossing numbers.* Preliminary report.

I'll discuss the following relaxation of the concept of the ordinary crossing number: partition the edge set of the graph into k graphs, so that the sum of the ordinary crossing numbers of the k graphs is minimized. The minimum sum is the k-planar crossing number of the graph, and the $k = 2$ case is called the biplanar crossing number of the graph. I'll discuss some old and new results on how the k-planar crossing number is related to the ordinary crossing number. The old work is with Czabarka, Shahrokhi, Sýkora and Vrt'o, while the new work is with Pach, Géza Tóth and Csaba Tóth. (Received November 17, 2014)

1107-05-26 **Marcus G Schaefer*** (mschaefer@cdm.depaul.edu), Chicago, IL 60604, and **Daniel Stefankovic**, Rochester, NY 14627. *The Degenerate Crossing Number and Higher-Genus Embeddings.*

Suppose a graph can be embedded in a surface with k crosscaps. Is there always an embedding (in the same surface) in which every edge passes through each crosscap at most once? This well-known open problem can be restated using crossing numbers: the degenerate crossing number, $\mathrm{dcr}(G)$ of G equals the smallest number k so that G has an embedding in a surface with k crosscaps in which every edge passes through each crosscap at most once. The genus crossing number, $\mathrm{gcr}(G)$ of G equals the smallest number K so that G has an embedding in a surface with k crosscaps. The original question then asks whether $\mathrm{dcr}(G) = \mathrm{gcr}(G)$.

We show that $\mathrm{dcr}(G) \leq 6\,\mathrm{gcr}(G)$, and $\mathrm{dcr}(G) = \mathrm{gcr}(G)$ as long as $\mathrm{dcr}(G) \leq 3$. We can separate dcr and gcr for (single-vertex) graphs with embedding schemes, but it is not clear whether the separating example can be extended into separations on simple graphs. Finally, we show that if a graph can be embedded in a surface with crosscaps, then it has an embedding in that surface in which every edge passes through each crosscap at most twice. (Received November 17, 2014)

1107-05-52 **Eddie Cheng**, **Justin Kelm**, **Roi Orzach*** (rorzach@oakland.edu) and **Brian Xu**. *Strong Matching Preclusion of Burnt Pancake Graphs.*

The strong matching preclusion number of a graph is the minimum number of vertices and edges whose deletion results in a graph that has neither perfect matchings nor almost-perfect matchings. This is an extension of the matching preclusion problem that was introduced by Park and Ihm. The burnt pancake graph is a more complex variant of the pancake graph. In this paper, we examine the properties of burnt pancake graphs by finding its strong matching preclusion number and categorizing all optimal solutions. (Received December 15, 2014)

1107-05-74 **Derek Levin**, **Peter Nugent** and **Lara Pudwell*** (lara.pudwell@valpo.edu), Department of Mathematics and Statistics, 1900 Chapel Drive, Valparaiso, IN 46383, and **Manda Riehl** and **ML Tlachac**. *Pattern-avoiding forests.* Preliminary report.

A heap is a rooted, ordered tree with integer-labeled vertices such that each child has a larger label than its parent. We associate a permutation to a heap by reading the labels from left to right by levels, starting with the root. A forest is an ordered collection of heaps where all vertices in the forest have distinct labels. We associate a permutation to a forest by reading the permutation associated to each heap and then concatenating. In this talk, we consider forests whose associated permutation avoids a single pattern of length 3. In particular, we highlight connections between pattern-avoiding forests and restricted lattice paths. (Received December 29, 2014)

1107-05-75 **Shalosh B. Ekhad** and **Doron Zeilberger*** (zeilberg@math.rutgers.edu). *The Generating Functions Enumerating 12..d-Avoiding Words with r occurrences of each of 1,2, ..., n are D-finite for all d and all r.*

We will explain why the title is correct. Recall that a formal power series is D-finite if it satisfies a linear differential equation with polynomial coefficients. For example $\cos(x)$, $\sin(x)$, $exp(x+x^2)$ are D-finite, but $\tan(x)$ is not. (Received December 29, 2014)

1107-05-85 **Heiko Harborth*** (h.harborth@tu-bs.de), Bienroder Weg 47, 38106 Braunschweig, Germany, Germany. *Crossing Problems for Complete Graphs.*

Different drawing types - nonisomorphic drawings - min and max numbers of crossings - gaps in numbers of crossings - cycle drawings - max number of crossings on an edge - a least number of crossings on every edge - empty triangles - drawing Ramsey number - multiple crossings. (Received January 02, 2015)

1107-05-88 **Rachel E Locke** (rlocke2@masonlive.gmu.edu), Department of Mathematical Sciences, George Mason University, 4400 University Drive, Fairfax, VA 22030, and **Walter D Morris*** (wmorris@gmu.edu), Department of Mathematical Sciences, George Mason University, 4400 University Drive, Fairfax, VA 22030. *A Mihalisin - Klee Theorem for Fans.*

The Mihalisin - Klee Theorem states that an orientation of a 3-polytopal graph is induced by an affine function on some 3-polytope realizing the graph if the orientation is acyclic, has a unique source and a unique sink, and admits three independent monotone paths from the source to the sink. We replace the requirement that the orientation is acyclic with the assumption that it has no directed cycle contained in a face of the orientation, and show that such orientations are induced by 3-dimensional fans. (Received January 05, 2015)

1107-05-106 **Matthew Yancey*** (mpyancey1@gmail.com). *Bipartite Communities.*

A recent trend in data-mining is to find communities in a graph. Generally speaking, a community of a graph is a vertex set such that the number of edges contained entirely inside the set is "significantly more than expected." These communities are then used to describe families of proteins in protein-protein interaction networks, among other applications. We present a new goal in community detection: to find good *bipartite communities*. A bipartite community is a pair of disjoint vertex sets S, S' such that the number of edges with one endpoint in S and the other endpoint in S' is "significantly more than expected." We claim that this additional structure is natural to some applications of community detection. In fact, using other terminology, they have already been used in two different studies on distinct biological networks.

We will present a new algorithm for finding many bipartite communities using spectral methods. Classical community detection is known to be **NP**-hard; our algorithm is an approximation method with rigorous bounds. Additionally, we will present how the algorithm performs on public-source data sets. (Received January 06, 2015)

1107-05-130 **Fu Liu***, fuliu@math.ucdavis.edu, and **Federico Castillo**. *Ehrhart positivity for generalized permutohedra.*

The Ehrhart polynomial $i(P,m)$ of an integral polytope P counts the number of lattice points in dilations of P. It is well known that the leading, second, and last coefficients of $i(P,m)$ are the volume of P, one half of the volume of the boundary of P and 1, respectively, and thus are all positive. However, it is not true that all the coefficients of $i(P,m)$ are positive.

There are few families of polytopes that are known to have positive Ehrhart coefficients. De Loera et al conjectured that matroid polytopes have this property. In our work, we consider generalized permutohedra, which contain matroid polytopes, and conjecture they all have positive Ehrhart coefficients.

We first reduce our conjecture to another conjecture which only concerns regular permutohedra, a smaller family of polytopes. The key ingredients in the reduction are perturbation methods and a valuation on the algebra of rational pointed polyhedral cones constructed by Berline and Vergne. Then we are able to show that the third and fourth Ehrhart coefficients of regular permutohedra are always positive by explicitly computing Berline-Vergne's valuation for our polytopes. We also obtain partial results on the coefficients of the linear terms. (Received January 09, 2015)

1107-05-143 **Andrew M Baxter***, Penn State University Mathematics Dept., State College, PA 16802. *Wilf-classification for vincular patterns.* Preliminary report.

Classifying classical patterns by Wilf-equivalence has stalled in recent years, but progress is being made for the analogous problem for vincular patterns. In this talk we outline the status of the problem of Wilf-classification for vincular patterns. We then highlight the major tools which have proven useful, as well as the conjectured equivalences that have resisted these techniques. (Received January 11, 2015)

1107-05-169 **David Bevan*** (david.bevan@open.ac.uk), Department of Mathematics and Statistics, The Open University, Milton Keynes, MK7 6AA, United Kingdom. *Geometric grid classes of permutations and the matching polynomial.*

A *geometric grid class* consists of those permutations that can be drawn on a specified set of line segments of slope ±1 arranged in a rectangular pattern governed by a matrix.

A k-*matching* of a graph is a set of k edges, no pair of which have a vertex in common. If, for each k, $m_k(G)$ denotes the number of distinct k-matchings of a graph G with n vertices, then the *matching polynomial* $\mu_G(z)$ of G is defined to be

$$\mu_G(z) \ = \ \sum_{k\geqslant 0}(-1)^k m_k(G) z^{n-2k}.$$

It turns out that the growth rate of a geometric grid class is given by the square of the largest root of the matching polynomial of a certain graph associated with the geometric grid class. We will explore a proof of this result and consider some of its implications. (Received January 13, 2015)

1107-05-215 **Geir Agnarsson*** (math.geir@gmail.com), George Mason University, Dept. of Math., 4400 University Drive, MS: 3F2, Fairfax, VA 22030. *General permutahedra.* Preliminary report.

We first derive an exponential *generating flag function* of the standard permutahedron Π_{n-1}. We then investigate the flags of a Minkowski sum of all the standard simplices Δ_{k-1} in $\mathbb{R}^n$ for fixed k and n. These polytopes are all simple and naturally generalize both the standard simplex Δ_{n-1} and the permutahedron Π_{n-1} both of dimension $n-1$. (Received January 15, 2015)

1107-05-232 **Mohamad Abdallah*** (mkabdall@oakland.edu) and **Eddie Cheng**. *Fault-Tolerant Hamiltonian Connectivity of 2-Tree Generated Networks.*

In this paper we consider a class of Cayley graphs that are generated by a certain 3-cycles on the alternating group A_n. These graphs are generalizations of the alternating group graph AG_n. We look at the case when the 3-cycles form a 2-tree, and analyze the fault-tolerant Hamiltonian connectivity of such graphs. We prove that these graphs are $(2n-7)$-fault-tolerant Hamiltonian connected. (Received January 15, 2015)

1107-05-234 **Nathaniel Shar***, Nathaniel Shar, Department of Mathematics, Rutgers University, 110 Frelighuysen Rd., Piscataway, NJ 08854-8019. *A quick method for counting permutations avoiding 4231 and 4123.* Preliminary report.

Although no explicit formula or generating function is known for the number of permutations of length n avoiding {4231, 4123}, the value can be computed by a relatively simple recursive function that runs in polynomial time. The same method also yields polynomial-time recurrences, of progressively higher degree, for an infinite family of permutation classes. (Received January 16, 2015)

1107-05-250 **Jonathan Bloom*** (jbloom314@gmail.com), Department of Mathematics, Rutgers University, Piscataway, NJ 08854. *On two recent conjectures involving permutation patterns and statistics.*

In this talk we will settle two recent conjectures in the area of enumerative combinatorics. First, we answer a conjecture of B. Sagan by finding a multi-statistic preserving bijection between 1423-avoiding permutations and 2413-avoiding permutations. This new bijection also generalizes a classical result, in the area of pattern avoidance, due to Stankova. In the second part of the talk, we employ the techniques used to construct the aforementioned bijection to also prove a conjecture of E. Egge from 2011. In particular, we show that certain pattern classes are, surprisingly, counted by the large Schroder numbers. (Received January 16, 2015)

1107-05-252 **Paul C. Kainen*** (kainen@georgetown.edu). *Cogenus-1-drawings of complete bipartite graphs.*

In 1965, Ringel determined the genus γ_r of $K_{r,r}$, $\gamma_r = (1/4)(r-2)^2$. We show how to extend Zarankiewicz's plane drawing of $K_{r,r}$ to a drawing on the orientable surface of genus $-1+\gamma_r$ with exactly r crossings, provided that 4 divides r and $r \geq 8$. E.g., $K_{8,8}$ has crossing number at most 8 on the surface obtained from the sphere by attaching 8 handles. The construction involves attaching handles to the plane (or sphere) such that handles carry the edges of a $K_{2,2}$ subgraph. Our method is incremental, building the representation of $K_{r+4,r+4}$ from that of $K_{r,r}$. Furthermore, there is a vertex-disjoint covering of the vertices by crossing-free quadrilaterals which bound disks, so one can obtain low crossing number drawings of $K_{r,r} \times Q_d$ as in Kainen and White(J. Graph Theory, 1978). Other advantages of the new drawing scheme are that it is easier to visualize and can be adapted to deal with irregular graphs. (Received January 21, 2015)

1107-05-260 **Eric H. Kuo*** (ehkuo@alum.mit.edu), 1400 Worcester Road Apt. 7407, Framingham, MA 01702. *Condensation Approach to Enumerating Cyclically Symmetric Plane Partitions.*

The number of cyclically symmetric plane partitions that fit in an $n \times n \times n$ box is equal to the number of perfect matchings of a particular bipartite graph G_n. With the aid of a theorem that generalizes graphical condensation, we can express this number of perfect matchings of G_n as a determinant of a matrix M_n whose entries are the numbers of perfect matchings of subgraphs of G_n. The entries in M_n can be computed recursively, and determinants of submatrices of M_n also have a combinatorial interpretation. (Received January 16, 2015)

1107-05-281 **Michael Albert**, **Cheyne Homberger**, **Jay Pantone** and **Vincent Vatter*** (vatter@gmail.com), Department of Mathematics, 1400 Stadium Rd, University of Florida, Gainesville, FL 32611. *Sorting with $\mathcal{C}$-machines.* Preliminary report.

A C-machine is a machine for generating permutations (or, run in the other direction, for sorting them). Here C is a fixed permutation class. The input to the C machine is the permutation 12...n, and the C-machine may store any permutation order isomorphic to a member of C. At any step in the process one may choose to either output the first entry in the machine or to insert the next entry from the input into any allowable position in the machine. For example, as a very special case, the Av(12)-machine is equivalent to a stack. Using dynamic programming, one can often get a large number (sometimes thousands) of terms enumerating the permutations a given C-machine can generate. In addition to presenting some general theoretical results, I will survey some interesting classes which are generated by C-machines and share some functional equations we don't know how to solve. (Received January 17, 2015)

1107-05-288 **Michael H Albert**, **Mike D Atkinson**, **Cheyne Homberger*** (cheyne.homberger@gmail.com) and **Jay Pantone**. *Deflatability of Permutation Classes.*

Simple permutations can be considered the building blocks of permutation classes, and have been at the heart of many recent advances in the area. Classes which have resisted analysis for years have been fully enumerated with the following approach: first investigate the set of simples in the class, then use this structure to generate and describe the full class. This approach relies on the idea that the set of simples within a class is easier to understand than the class itself. This idea, however, proves false for many classes.

We say that a class C is *deflatable* (to its simples) if the smallest class containing the simples of C is a proper subclass of C. Equivalently, a class C is non-deflatable if every permutation $\pi \in C$ is contained within a simple of C. For example, the class of permutations avoiding the pattern 132 is deflatable, while the class avoiding the pattern 123 is not.

In this talk we explore the notion of deflatability. We establish theorems which guarantee the non-deflatability of certain families of principal classes, show that there are infinitely many principal classes of each type, and provide examples of each. (Received January 17, 2015)

1107-05-302 **Benjamin Braun*** (benjamin.braun@uky.edu), 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506. *Unimodality problems in Ehrhart theory.* Preliminary report.

The h* polynomial of a convex lattice polytope P is a subtle invariant related to geometric and algebraic properties of P. Unimodality of the coefficient sequence of the h* polynomial occurs often, yet the reasons for this are not well-understood. We will survey a selection of recent results regarding h*-unimodality and discuss some interesting open problems in this area. (Received January 18, 2015)

1107-05-318 **E Czabarka*** (czabarka@math.sc.edu). *Graph orientation lower bounds for crossing numbers.* Preliminary report.

There are several lower bound techniques for crossing numbers - Euler formula, Leighton's bound, etc. These frequently give better bounds on a suitable subgraph. The best such subgraph can be found by linear optimization. Interestingly, finding this bound is equivalent with finding a certain orientation on a graph. Joint work with D. Bokal, M. Bracic and L.A. Szekely (Received January 18, 2015)

1107-05-338 **Csaba D. Toth*** (csaba.toth@csun.edu), Los Angeles, CA 91330. *Flip distances and Hamiltonian triangulations.*

It is shown that every triangulation (maximal planar graph) on $n \geq 6$ vertices can be flipped into a Hamiltonian triangulation using a sequence of less than $n/2$ combinatorial edge flips. The previously best upper bound uses 4-connectivity as a means to establish Hamiltonicity. But in general about $3n/5$ flips are necessary to reach a 4-connected triangulation. Our result improves the upper bound on the diameter of the flip graph of combinatorial triangulations on n vertices from $5.2n-33.6$ to $5n-23$. It is also shown that for every triangulation on n vertices there is a simultaneous flip of less than $2n/3$ edges to a 4-connected triangulation. The bound on the number of edges is tight, up to an additive constant. (Joint work with Jean Cardinal, Michael Hoffmann, Vincent Kusters, and Manuel Wettstein.) (Received January 18, 2015)

1107-05-340 **Alexander Woo*** (awoo@uidaho.edu), Department of Mathematics, University of Idaho, 875 Perimeter Drive, MS 1103, Moscow, ID 83844-1103. *Depth for signed permutations.* Preliminary report.

Given an reflection t in a Coxeter group W, Petersen and Tenner define its depth to be $d(t) = (\ell(t)+1)/2$, where $\ell(t)$ is the Coxeter length of t. Given an arbitrary element $w \in W$, they define its depth $\min_{w=t_1\cdots t_k} \sum_{i=1}^{k} d(t_i)$, the minimum of the sum of the depths of the t_i in any factorization of w into reflections $t_1 \cdots t_k$. For permutations, they showed that depth equals the sum of the sizes of the excedences. We prove a similar result for the Coxeter group of signed permutations.

Just as for permutations, certain properties, such as having equal length and depth, are characterized by pattern avoidance.

Eli Bagno, Riccardo Biagioli, and Moti Novick have independently found identical results by almost identical methods. (Received January 20, 2015)

1107-05-366 **Jefffrey Remmel B. Remmel*** (jremmel@ucsd.edu), Department of Mathematics, University of California, San Diego, La Jolla, CA 92093-0112, and **Ran Pan** (r1pan@ucsd.edu), Department of Mathematics, University of California, San Diego, La Jolla, CA 92093-0112. *Patterns in Young tableaux of rectangular shape.* Preliminary report.

We will discuss some recent results on pattern matching in $k \times n$ rectangular arrays which contain the numbers $1, \ldots, kn$ and are increasing in columns. We study patterns in such arrays which have various restrictions on the rows. Such restrictions allow us to study patterns in generalized Euler permutations and Young tableaux of rectangular shape. (Received January 19, 2015)

1107-05-370 **Brant C Jones*** (jones3bc@jmu.edu). *Affine permutation patterns.*

We consider the number of affine permutations that avoid a finite permutation pattern. This subject was introduced by Crites and has also been investigated in papers of Hanusa-Jones and Biagioli-Jouhet-Nadeau. Since the affine symmetric group is infinite we use the Coxeter length statistic to obtain a generating function. In this talk, we will survey prior results and present a new methodology for enumeration in this setting. (Received January 19, 2015)

1107-05-378 **Dan McQuillan*** (dmcquill@norwich.edu), Norwich University, 158 Harmon Drive, College of Science and Mathematics, Northfield, VT 05663, and **R B Richter**. *On the crossing number of the complete graph, without computer assistance.*

Hill's conjecture for the crossing number of the complete graph with n vertices has been verified up to n=12. After briefly describing a standard approach, including its reliance on computers, we outline an alternative. Our approach involves the interplay between optimal drawings and drawings which are far from optimal. Our general results are enough to provide a complete proof that the crossing number of K_9 is 36. This is joint work with R. Bruce Richter. (Received January 19, 2015)

1107-05-398 **Steven Schluchter*** (sschluch@gmu.edu), Department of Mathematical Sciences, Geroge Mason University, 4400 University Drive, MS:3F2, Fairfax, VA 22030, and **Justin Z Schroeder** (jzschroeder@gmail.com), Department of Mathematical Sciences, George Mason University, 4400 University Drive, MS:3F2, 22030. *Self-dual embeddings of $K_{4m,4n}$ in pseudosurfaces.* Preliminary report.

A direct construction of a self-dual embedding of the complete bipartite graph $K_{4m,4n}$ in an orientable pseudosurface is given for an infinite number of values of m and n. These embeddings are shown to maximize the number of umbrellas at each vertex. A surgery of Edmonds is then applied to build self-dual embeddings of $K_{4m,4n}$ in nonorientable pseudosurfaces with fewer umbrellas. If time permits, a new and relevant surgery will be described. (Received January 19, 2015)

1107-05-410 **Tom Enkosky***, tenkosky@gmail.com, and **Branden Stone**. *M-sequences, the Fibonacci sequence, and integer partitions.*

We found a connection between M-sequences, the Fibonacci sequence, and integer partitions into distinct parts. A *multicomplex* $\mathcal{M}$ is a set of monomials in d variables closed under division. Let m_i be the number of monomials in $\mathcal{M}$ of degree i. The associated *M-sequence* is $(m_0, m_1, m_2, \dots)$. Let L_n be the number of M-sequences where the terms of the sequence sum to n. That is, L_n counts the number of multicomplexes with n monomials. The first terms of the sequence $\{L_n\}_{n\geq 0}$ are $1, 1, 2, 3, 5, 8, 12, \dots$. We used a Fibonacci recurrence to show that this sequence is bounded above by the Fibonacci sequence. We restricted to the case $m_1 = 2$ to show that the sequence is bounded below by the number of integer partitions into distinct parts. (Received January 19, 2015)

1107-05-414 **Derek Levin**, **Lara Pudwell** and **Manda Riehl*** (riehlar@uwec.edu), HHH 512, 105 Garfield Ave, Eau Claire, WI 54701-4004, and **Andrew Sandberg**. *Pattern Avoidance on k-ary Heaps.*

A *k-ary heap* is a labelled tree with n nodes with two properties: a)it is a complete k-ary tree: all the levels of the tree are fully filled except possibly the last level, and the nodes on that level are filled from left to right, and b) the nodes are labelled with 1 to n and every path from root to leaf forms an increasing sequence of labels. For each k-ary heap, we associate a permutation by reading the labels on the heap from left to right by levels, starting at the root. We present several results on pattern avoidance for patterns of length 3 in binary heaps, as well as their generalizations to k-ary heaps, and also present several conjectures for further study. (Received January 19, 2015)

1107-05-421 **Joshua Alman*** (jalman@stanford.edu), **Cesar Cuenca** and **Jiaoyang Huang**. *Laurent Phenomenon Sequences.*

We undertake a systematic study of recurrences of the form $x_{m+n}x_m = P(x_{m+1}, ..., x_{m+n-1})$ which exhibit the Laurent phenomenon. Some of the most famous among these sequences come from the Somos and the Gale-Robinson recurrences. Our approach is based on finding period 1 seeds of Laurent phenomenon algebras of Lam-Pylyavskyy. We completely classify polynomials P that generate period 1 seeds in the cases of $n = 2, 3$ and of mutual binomial seeds. We also find several other interesting families of polynomials P whose generated sequences exhibit the Laurent phenomenon. Our classification for binomial seeds is a direct generalization of a result by Fordy and Marsh, that employs a new combinatorial gadget we call a double quiver. (Received January 20, 2015)

1107-05-424 **Brian Nakamura*** (bnaka@dimacs.rutgers.edu) and **Elizabeth Yang**. *Competition graphs and permutation patterns.* Preliminary report.

Given a directed graph D, its corresponding competition graph G is the undirected graph with the same vertex set as D and the edge set $E(G)$ where there exists an edge uv in $E(G)$ if and only if there exists a vertex w such that arcs (u, w) and (v, w) are both in $V(D)$. In this talk, we will introduce the notion of permutations inducing competition graphs and show interesting connections that these graphs have with patterns in permutations. (Received January 20, 2015)

1107-05-443 **Miklos Bona** and **Rebecca Smith*** (rnsmith@brockport.edu). *An involution on involutions.* Preliminary report.

We consider the involution on involutions obtained by first applying the Robinson-Schensted-Knuth Algorithm to a given involution π to obtain the associated Standard Young Tableau $P(\pi)$, then taking the transpose of $P(\pi)$, and finally applying the inverse of the RSK Algorithm to $P(\pi)^T$. We will be very original in our naming of this bijection and call it f.

As we are dealing exclusively with involutions, we will classify each entry as a fixed point, a small entry, or a large entry. Fixed points will be defined as per usual. All other entries of a permutation will be in 2-cycles with the smaller entry of any given 2-cycle being a small entry and the larger entry being a large entry.

In the case when the the reverse of π is also an involution, Schensted showed that $f(\pi) = \pi^r$. We look to define this bijection in general without relying on the RSK algorithm. To this end, we look at some other special cases to learn more. (Received January 20, 2015)

1107-05-445 **Sergi Elizalde** and **Megan Martinez*** (megan.a.martinez.gr@dartmouth.edu).
Equivalence Classes of Patterns in Random Walks.

In the past decade, the use of ordinal patterns in the analysis of time series and dynamical systems has become an important and rich tool. Ordinal patterns (otherwise known as a permutation patterns) are found in time series by taking n data points at evenly-spaced time intervals and mapping them to a length-n permutation determined by relative ordering. The frequency with which certain patterns occur is a useful statistic for such series; however, the behavior of the frequency of pattern occurrence is unstudied for most models. We briefly present a characterization of patterns that occur with equal probability regardless of distribution and discuss characteristics of permutations in the same equivalence classes. (Received January 20, 2015)

1107-05-449 **Brian Miceli**, **Jay Pantone*** (jay.pantone@gmail.com) and **Vincent Vatter**.
Equivalence of Words in the Generalized Factor Order.

The generalized factor order has been studied frequently in recent years. In this talk, we survey results on enumerative equivalence among words in the generalized factor order over the positive integers, including progress toward proving the Rearrangement Conjecture of Kitaev, Liese, Remmel, and Sagan. We further provide new conditions guaranteeing equivalence of certain rearrangements. (Received January 20, 2015)

1107-05-457 **Dan Archdeacon*** (dan.archdeacon@uvm.edu). *Gauss sentences.* Preliminary report.

Let C be a curve immersed in the plane such that all multiple points involve two segments of the curve crossing transversally. Label the intersections $1 \leq i \leq n$. As we walk along C and record the intersections we get a cyclic word in which each $1 \leq i \leq n$ occurs exactly twice. Gauss asked: which do such double occurrence words come from an immersed curve? Gauss' problem was solved in the 1970's.

A Gauss sentence is a set of words collectively containing each $1 \leq i \leq n$ exactly twice. A collection of multiple curves simultaneously immersed in the plane give rise to a Gauss sentence: each curve generates a word. The problem now is to characterize Gauss sentences arising from multiple curves. We discuss various solutions to this problem. We also discuss a relation with the thrackle conjecture. (Received January 20, 2015)

1107-05-490 **Scott Garrabrant*** (coscott@math.ucla.edu) and **Igor Pak** (pak@math.ucla.edu).
Recent progress on the Noonan-Zeilberger Conjecture.

Let $R = \{\pi_1, \ldots, \pi_k\}$ be a list of patterns, and let $m_1, \ldots, m_k$ be a list of nonnegative integers. Denote by $A_n(R; m_1, \ldots, m_k)$ the number of permutations $\sigma \in S_n$ such that σ contains π_i exactly m_i times, for all $1 \leq i \leq k$. The Noonan-Zeilberger Conjecture states that $A_n = A_n(R; m_1, \ldots, m_k)$ is always a polynomial-recursive sequence of n, meaning that it satisfies a nontrivial recurrence relation of the form $p_0(n)A_n = p_1(n)A_{n-1} + \ldots + p_m(n)A_{n-m}$, where each p_i is a polynomial. We present some recent progress on this conjecture. (Received January 20, 2015)

1107-05-496 **Nafiseh Jahanbakht*** (nafiseh1383@gmail.com) and **Kourosh Tavakoli**. *Relationship between the energy of a directed graph and the energy of its underlying graph.*

The energy of a directed graph is defined to be the sum of the absolute values of the real parts of the eigenvalues of its adjacency matrix. The energy of a graph (undirected) is the sum of the absolute values of the eigenvalues of its adjacency matrix. Could there be any relation between the energy of a directed graph and the energy of its underlying graph? Under some conditions, the answer is yes. The question is still open in the general case. (Received January 20, 2015)

1107-05-500 **Sam A Miner*** (samminer@math.ucla.edu), UCLA Mathematics Department, Box 951555, Los Angeles, CA 90095. *The limit shape of Grassmannian permutations.* Preliminary report.

Grassmannian permutations, permutations which contain at most one ascent, were first defined by Lascoux and Schutzenberger in the context of Schubert polynomials. Since, the class of Grassmannian permutations of length n has been enumerated and found to be in bijection with Dyck paths of semilength n with at most one long ascent, among other combinatorial objects.

We view Grassmannian permutations as permutation matrices in $M_n(\{0,1\})$, and consider the probability distribution created when we choose a Grassmannian permutation of length n uniformly at random. As $n \to \infty$, and as we scale the dimensions of the matrix to keep its side lengths constant, the probability distribution approaches a "limit shape". We prove detailed results about the limit shape of Grassmannian permutations, as well as the expected behavior of certain statistics on such a permutation.

As a corollary, we obtain the limit shape for **321**-avoiding vexillary permutations, first analyzed by Billey, Jockusch, and Stanley. Somewhat surprisingly, this shape is substantially different from that of **321**-avoiding permutations. The proofs come from asymptotic and bijective combinatorics - we will sketch the reasoning behind these proofs and mention potential generalizations. (Received January 20, 2015)

1107-05-502 **Farhad Shahrokhi*** (farhad@cse.unt.edu). *Crossing Number and Congestion of Tree Decompositions.* Preliminary report.

Let $H = (V, E)$ be a hypergraph on vertex set V and the edge set E. Define the *congestion* of H, denoted by $\mu(H)$, to be the maximum minimum cardinality of any edge, where the maximum is taken overall subhypergraphs of H. The congestion can be shown to be the dual parameter to the *degeneracy* of a hypergraph. Now let $G = (V, E)$ be a graph and let T be a tree decomposition of G. Clearly, T is a hypergraph on the vertex set V whose edges are *bags* of T. We establish a connection between the crossing number of G and the congestion of T, or $\mu(T)$, that generalizes and strengthens some of the existing results for the crossing numbers. (Received January 20, 2015)

11 ► Number theory

1107-11-56 **Emilie Hogan*** (emilie.hogan@pnnl.gov). *Sufficient conditions for integrality of sequences produced by a certain non-homogeneous non-linear family of recurrences.*

Consider a the three parameter family of non-linear recurrences inspired by the Somos recurrences:

$$x_n x_{n-k} = x_{n-i} x_{n-k+i} + x_{n-j} + x_{n-k+j}$$

where $i < k - i < k$, $j < k - j < k$, and initial conditions are $x_l = 1$ for $1 \leq l \leq k$. In 2011 I proved sufficient conditions on k, i, j for this recurrence to produce a sequence of integers. These conditions are also conjectured to be necessary. In this talk I will discuss techniques for proving integrality of sequences such as these including Fomin and Zelevinsky's Caterpillar Lemma and finding an associated linear recurrence. (Received December 18, 2014)

1107-11-125 **Michael E Hoffman*** (meh@usna.edu), U. S. Naval Academy, Annapolis, MD 21402. *Labeled Posets, Iterated Integrals, and Nested Sums.* Preliminary report.

Recently S. Yamamoto has developed an elegant way to represent iterated integrals involving the forms dt/t and $dt/(1-t)$ using 2-labeled posets. We consider two extensions. First, we extend Yamamoto's notion to get a correspondence between $(r+1)$-labeled posets and iterated integrals involving dt/t and $dt/(\epsilon^{-i}-t)$, $0 \leq i \leq r-1$, where ϵ is a primitive rth root of unity. Second, we develop an analogous formalism giving a correspondence between nested sums and posets labeled with the positive integers. (Received January 09, 2015)

1107-11-148 **William Kang*** (williamkang531@gmail.com). *Efficient Covering Systems of Congruences and Perfect Powers Riesel Numbers.* Preliminary report.

A *Sierpiński* number is an odd integer k such that $k \cdot 2^n + 1$ is composite for all positive integer values of n. A *Riesel* number is defined similarly; the only difference is that $k \cdot 2^n - 1$ is composite for all positive integer values of n.

It is easy to construct Sierpiński (Riesel) numbers k such that k^q is also Sierpiński (Riesel) for every positive odd integer q. Chen asked whether this remains true for even values of q. Recently, Filaseta et al. solved the problem for the Sierpiński case in the affirmative. They also constructed odd numbers k, l, m such that k^2, l^4, and m^6, respectively, are Riesel numbers.

In 2009, Wu and Sun showed the existence of an odd k such that k^q is a Riesel number for all positive integers q such that $\gcd(q, 3\cdot 5\cdot 7\cdot 11\cdot 13)$. In particular, k^{2^s} is Riesel for all $s \geq 0$. In this paper we improve these results as follows:

We construct Riesel numbers k^2, l^4, and m^6 much smaller than those found by Filaseta, Finch, and Kozek.

We show the existence of an odd positive integer k such that k^q is a Riesel number for all positive integers q such that $\gcd(q, 3\cdot 5\cdot 7\cdot 11)$. This improves Wu and Sun's construction. (Received January 11, 2015)

1107-11-153 **Abraham Bourla***, 4400 Massachusetts Ave. NW, Washington, DC 20016. *Numeration systems on rotation maps.* Preliminary report.

We explore the connections between the Ostrowski and Sturmian numeration systems and the irrational rotation map on the circle. (Received January 12, 2015)

1107-11-231 **Michael Somos*** (ms639@georgetown.edu). *Observations on Somos-4 polynomials.* Preliminary report.

Starting from the Somos-4 sequence, the speaker will discuss the progression to generalized Somos-4 sequences, Somos-4 polynomials, and generalized Somos-4 polynomials. The last can be described as a sequence of polynomials in six variables. If the six variables are replaced by specific simple rational combinations of these variables, the resulting homomorphism shifts the sequence by one term and thereby generates the entire sequence. (Received January 15, 2015)

1107-11-236 **Dinesh S Thakur*** (dinesh.thakur@rochester.edu). *Multizeta and mixed Carlitz-Tate-Anderson t-motives.*

We will describe multizeta values and their period interpretation in terms of mixed Carlitz-Tate-Anderson t-motives. We will explain recent results and conjectures about relations the multizeta values satisfy (describing some works of the author, Greg Anderson, of author's current and past students: Alejandro Lara Rodriguez, Huei Jeng Chen, George Todd, as well as of Cheih-Yu Chang, Matthew Papanikolas and Jing Yu). (Received January 16, 2015)

1107-11-279 **Chieh-Yu Chang**, Department of Mathematics, National Tsing Hua University, Hsinchu, Taiwan, **Matthew A. Papanikolas*** (map@math.tamu.edu), Department of Mathematics, 3368 TAMU, Texas A&M University, College Station, TX 77843, and **Jing Yu**, Department of Mathematics, National Taiwan University, Taipei, Taiwan. *Eulerian multiple zeta values over function fields.*

A classical multiple zeta value (MZV) is said to be Eulerian if it is a rational multiple of a power of π. Examples of Eulerian MZV's abound and date back at least to Euler. In the setting of function fields over a finite field, Thakur defined multizeta values in direct analogy with classical MZV's, and Anderson and Thakur showed that they arise as periods of iterated extensions of the Carlitz motive. In this talk we will investigate a new criterion for determining when a function field MZV is Eulerian, in this case meaning that it is a rational multiple of a power of the Carlitz period. Furthermore we will discuss how this criterion can be used effectively to show whether or not a given MZV is Eulerian and present computational findings that confirm conjectures of Thakur and Lara Rodríguez. (Received January 17, 2015)

1107-11-342 **R. Wm. Gosper**, **Hilarie Orman** (hilarie@purplestreak.com) and **Rich Schroeppel*** (rcs@xmission.com). *Cryptographic Applications for Somos Sequences.*

We present a Diffie-Hellman key exchange and an ElGamal style signature scheme based on Somos Sequences over finite fields. The sequences have novel formulas for computing "giant steps" without relying on cyclic group structures. Our schemes use index addition instead of multiplication. (Received January 19, 2015)

1107-11-448 **Ivan Horozov*** (horozov@math.wustl.edu), Washington University in St. Louis, Department of Mathematics, 1 Brookings Dr, CB 1146, Saint Louis, MO 63130. *Non-commutative Hilbert modular symbols.*

In this talk I will present a construction of (non-)commutative Hilbert modular symbols using a type of two-dimensional iterated integrals which I call iterated integrals on membranes. In many cases, the ingredients of such symbols are periods related to Hilbert modular surfaces. They also have a natural action of the Hecke operators in the case when the narrow class group is trivial; (roughly speaking, when we have unique factorization in the ring of integers in the number field). A similar construction can be used to define multiple Dedekind zeta values, which are a number theoretic analogue of Euler's multiple zeta values. The relation between non-commutative Hilbert modular symbols and and multiple Dedekind zeta values is similar to the relation between Manin's non-commutative modular symbol and Euler's multiple zeta values.

One current research topic of mine is to drop the restriction that the narrow class group is trivial. That requires working with iterated integrals over the adeles. So far I have a representation of Euler's multiple zeta values as iterated integrals over the adeles, which leads naturally to double shuffle relations. (Received January 20, 2015)

1107-11-481 **Patrick Joseph Dynes*** (pdynes@clemson.edu), 110 Cherry Hill Avenue, Goose Creek, SC 29445, and **Brian J McDonald** (bmcdon11@u.rochester.edu) and **Kimsy Tor** (ktor.student@manhattan.edu). *Gaussian Behavior of Generalized Zeckendorf Decompositions over Small Scales.*

A beautiful theorem of Zeckendorf states that every positive integer can be written uniquely as a sum of non-consecutive Fibonacci numbers $\{F_n\}$, with initial terms $F_1 = 1$, $F_2 = 2$. We consider the distribution of the number of summands involved in such decompositions. Previous work proved that as $n \to \infty$ the distribution of the number of summands in the Zeckendorf decompositions of $m \in [F_n, F_{n+1})$, appropriately normalized, converges to the standard normal.

We generalize these results to subintervals of $[F_n, F_{n+1})$ as $n \to \infty$. Explicitly, fix an integer sequence $\alpha(n) \to \infty$. As $n \to \infty$, for almost all $m \in [F_n, F_{n+1})$ the distribution of the number of summands in the Zeckendorf decompositions of integers in the subintervals $I_{m;n} := [m, m + F_{\alpha(n)})$, appropriately normalized, converges to the standard normal. The proof follows by showing that, with probability tending to 1, m has at least one appropriately located large gap between indices in its decomposition. We then use a correspondence between this interval $I_{m;n}$ and $[0, F_{\alpha(n)})$ to obtain the result, since the summands are known to have Gaussian behavior in the latter interval. We also prove the same result for more general linear recurrences. (Received January 20, 2015)

1107-11-484 **Matthew C Russell***, russell2@math.rutgers.edu. *Automated exploration of Somos-like sequences, noncommutative recursions, and the Laurent phenomenon.*

The Somos sequences are recurrence relations that surprisingly produce only integers. Their integrality turns out to be a special case of the Laurent phenomenon. Since their initial discovery, additional families of sequences with this property have been discovered. We will discuss methods for searching for new sequences with the Laurent phenomenon - with the conjecturing and proving both automated. Examination of the computer-generated proofs in individual cases can then lead to human proofs for new infinite families. Finally, we will also exhibit a family of sequences of noncommutative variables, recursively defined using monic palindromic polynomials in $\mathbb{Q}[x]$, and show that each possesses the Laurent phenomenon. (Received January 20, 2015)

1107-11-503 **K. J. Mourad*** (kjm57@georgetown.edu), Dept. of Mathematics, Georgetown University, Washington, DC 20057. *Integrality of Terms in Somos Sequences.*

Let $S(k)$ denote the Somos sequence of order k for $k \geq 4$. Now let $f(n,k)$ denote the n'th element of $S(k)$ for any $n \geq 0$ and $k \geq 4$. It is well known that for $k < 8$ that $f(n,k)$ is an integer for all $n \geq 0$. Examples show that this is no longer true when $k \geq 8$.

However, as far as we know, it has not been proved that there is no lower bound, B, such that $f(n,k)$ is an integer when both n and k are larger than B. In other words that there are infinitely many counterexamples to integrality.

After proving this fact we investigate periodicity properties (mod m) first investigated by Raphael M Robinson for k small which imply integrality for such k and we observe that these properties are no longer true for large k.

Lastly, we observe relationships between rational points on elliptic curves and generalized Somos sequences for small k. This relationship can't hold for arbitrarily large k and n perhaps explaining the phenomena we are studying. (Received January 20, 2015)

12 ► *Field theory and polynomials*

1107-12-165 **Yasanthi Kottegoda*** (ykottegoda@newhaven.edu). *The zeros of linear recurring sequences over finite fields.* Preliminary report.

I discuss the bounds for the cardinality of the set of possible number of zeros of a homogeneous linear recurring sequence over a finite field $\mathbb{F}_q$, based on the characteristic polynomial of degree d and order m. Here I give upper and lower bounds on the cardinality of the set of number of zeros. The set of zeros and the cardinality of the set is explicitly determined when $t = \frac{q^d-1}{m}$ has the forms $q^a + 1$ (quadratic form case) and $q^{2a} - q^a + 1$ (Kasami Welch case) where $a \in \mathbb{N}$ and applications of quadratic forms over finite fields of odd and even characteristics is used for the first case. The connection with algebraic coding theory is a key ingredient. (Received January 12, 2015)

13 ► Commutative rings and algebras

1107-13-36 **Janet Striuli***, North Benson Rd, Fairfield, CT 06825, and **Ian Aberbach** and **Aline Hosry**. *Uniform Artin Rees for free resolutions.*

Let (R, m, k) be a local noetherian ring. The classical Artin-Rees Lemma states that, given an ideal I, and modules $N \subseteq M$, there exists an integer such k such that $I^n M \cap N \subseteq I^{n-k} N$ for all $n \geq k$. A uniform version of the lemma, where the integer does not depend on the ideal I, has been given by Huneke. In this talk we present a uniform Artin-Rees Lemma where the same integer k works for all ideals I and for all modules $M_i \subseteq F_i$ where the M_i are the syzygies of a given free resolution and the F_i are the free modules appearing in the free resolution. (Received December 04, 2014)

1107-13-46 **David A. Buchsbaum*** (buchsbau@brandeis.edu). *The More I Think of Hilbert. . . .*

We survey Hilbert's 1890 paper in which, to prove results in representation theory, he proved his famous Basis Theorem and Syzygy Theorem. We then show how, since the 1950s, work has been done following the inverse arc of that paper, applying syzygy theory (homological algebra) to commutative noetherian rings, and finally coming back to representation theory – the theory that his paper was reputed to have "killed off." (Received December 12, 2014)

1107-13-59 **Tony Joseph Puthenpurakal*** (tputhen@gmail.com), Department of Mathematics, IIT-Bombay, Powai, Mumbai, 400076, India. *Associated primes of Local cohomology modules over Regular rings.*

Let R be an excellent regular ring of dimension d containing a field K of characteristic zero. Let I be an ideal in R. We show that $Ass\ H^{d-1}_I(R)$ is a finite set. As an application we show that if I is an ideal of height g with $height\ Q = g$ for all minimal primes of I then for all but finitely many primes $P \supseteq I$ with $height\ P \geq g + 2$, the topological space $Spec^\circ(R_P/IR_P)$ is connected. (Received December 19, 2014)

1107-13-122 **Kuei-Nuan Lin*** (kul20@psu.edu), PA. *Cohen-Macaulay Rees Algebras of Modules.* Preliminary report.

Rees algebras of modules include multi-Rees rings, which correspond to the case where the module is a direct sum of ideals. They provide the rings of functions on the blow up of a scheme along several subschemes. We want to prove for Rees algebras of modules many of the results that have been obtained in the cases of ideals, the Cohen-Macaulayness of Rees rings. As it turns out the generalization from ideals to modules is not just a routine generalization, but requires a great deal of technical development. We use the technique of generic Bourbaki ideals introduced by Simis, Ulrich and Vasconcelos to obtained the Cohen-Macaulayness of Rees algebras of modules. (Received January 09, 2015)

1107-13-132 **Denise A. Rangel Tracy*** (detracy@syr.edu), NY. *A Description of the Isomorphism Classes of Totally Reflexive Modules for a Class of non-Gorenstein Rings.*

Totally reflexive modules over a non-Gorenstein ring are an analog to maximal Cohen-Macaulay modules over a Gorenstein ring. It is known that the category of totally reflexive modules over a non-Gorenstein ring is either trivial (consisting only of free modules) or is infinite. When it is infinite it is quite often of wild representation type. In this talk, we will investigate the nontrivial category over rings of the form $S_i = k[x, y_1, \ldots, y_i]/(x^2, (y_1 \ldots, y_i)^2)$. We will show that the isomorphism classes of totally reflexive modules are in bijection with the ith-wise conjugacy classes of certain square matrices. That is, for any invertible matrix P and a fixed i-tuple of matrices, we have that $P(B_1, B_2, \ldots, B_i)P^{-1} = (PB_1P^{-1}, PB_2, P^{-1}, \ldots, PB_iP^{-1})$ corresponds to an isomorphism class of totally reflexive S_i-modules. (Received January 09, 2015)

1107-13-149 **Naoki Taniguchi*** (taniguti@math.meiji.ac.jp), 1-1-1 Higashi-mita, Tama-ku, Kawasaki, 214-8571, Japan. *Almost Gorenstein rings of higher dimension.*

My talk is based on the joint work with S. Goto and R. Takahashi. The aim of this research is to find a new class of Cohen-Macaulay rings, which may not be Gorenstein, but sufficiently good next to Gorenstein. One of the candidates for such a ring is almost Gorenstein, which was originally introduced by B. Barucci and R. Fröberg in the case where the local rings are analytically unramified of dimension one. After that S. Goto, N. Matsuoka and T. T. Phuong extended the notion of almost Gorenstein property over one-dimensional Cohen-Macaulay local rings which are not necessarily analytically unramified. Now a question is what is a possible definition of almost Gorenstein rings of higher dimension, which I would like to talk in my lecture and our proposal is as follows.

Let R be a Cohen-Macaulay local ring with maximal ideal $\mathfrak{m}$ possessing the canonical module K_R. Then we say that R is *an almost Gorenstein local ring*, if there exists an exact sequence

$$0 \to R \to \mathrm{K}_R \to C \to 0$$

of R-modules with $\mu_R(C) = \mathrm{e}^0_{\mathfrak{m}}(C)$, where $\mu_R(C)$ (resp. $\mathrm{e}^0_{\mathfrak{m}}(C)$) stands for the number of elements in a minimal system of generators for C (resp. the multiplicity of C with respect to $\mathfrak{m}$). (Received January 12, 2015)

1107-13-177 **Janet Cowden Vassilev*** (jvassil@math.unm.edu), Albuquerque, NM 87131.
Radical-like Closures. Preliminary report.

We consider closure operations defined on the set of ideals of a commutative ring which are defined via various properties on the set of ideals which share the same radical. In particular if I is a radical ideal and $\mathcal{P}$ is the set of ideals with radical I, we say a closure c is *weakly I-bounded* if there exists an ideal J in $\mathcal{P}$ such that for all ideals $K \in \mathcal{P}$ such that $K \subseteq J$, $K^c = J^c$. A closure c is *I-DCC* if for any chain of ideals in $\mathcal{P}$ the chain induced by the closures of the ideals consists of finitely many ideals. We compare weakly I-bounded and I-DCC closures and show that all I-DCC closures are weakly I-bounded. However, we give examples of closures which are weakly I-bounded which are not I-DCC. (Received January 13, 2015)

1107-13-188 **Carles Bivià-Ausina*** (carbivia@mat.upv.es), Inst. Univ. de Matemàtica Pura i Aplicada, Universitat Politècnica de València, Camí de Vera, s/n, 46022 València, Spain.
Multiplicities and Łojasiewicz exponents of generic linear sections of ideals.

Let I denote an ideal of finite colength of the ring of convergent power series around the origin in $\mathbb{C}^n$. We show an inequality that relates the multiplicity of I and the sequence of mixed Łojasiewicz exponents of I, that is, the sequence of Łojasiewicz exponents of generic linear sections of I. We characterize the corresponding equality under the hypothesis that the integral closure $\overline{I}$ is generated by monomials. As a consequence, there appears a wide class of monomial ideals that can be characterized combinatorially. Some inequalities that relate mixed multiplicities and log canonical thresholds of ideals of arbitrary codimension will also be presented. (Received January 14, 2015)

1107-13-200 **Luchezar L Avramov*** (avramov@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588, **Alexandra Seceleanu**, Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588, and **Zheng Yang** (s-zyang8@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Polynomial growth of Betti sequences over local rings.* Preliminary report.

The asymptotic patterns of the Betti sequences of the finitely generated modules over a local ring R reflect and affect the singularity of R. For instance, these sequences are eventually zero if and only if R is regular (Auslander and Buchsbaum, Serre) and they are eventually constant if and only if R is a hypersurface (Shamash, Gulliksen, Eisenbud). We describe those rings over which the next simplest pattern occurs—each Betti sequences is eventually arithmetic. More generally, when c is a non-negative integer we obtain sufficient conditions and necessary conditions for each Betti sequences to be eventually given by some polynomial of degree less than c. These conditions coincide when $c \leq 3$ or when R is homogeneous. (Received January 14, 2015)

1107-13-230 **Jesse Elliott*** (jesse.elliott@csuci.edu). *Closure operations in commutative algebra as quantic nuclei.*

We study properties of nuclei on quantales that generalize properties of closure operations in commutative algebra, including star and semistar operations, semiprime operations, and closure operations relating to tight closure. (Received January 15, 2015)

1107-13-238 **Dario Spirito*** (spirito@mat.uniroma3.it). *Semistar operations and topology.*

Let R be an integral domain and $\mathrm{SStar}(R)$ be the set of semistar operations on R. We introduce a topology on $\mathrm{SStar}(R)$ such that the set $\mathrm{Over}(R)$ of overrings of R (with the Zariski topology) becomes a subspace of $\mathrm{SStar}(R)$. We show that this topology can be used in particular to study finite-type semistar operations: we show that the infimum of a compact set Δ of finite-type operations is still of finite type, and that the converse is true if Δ is induced by localizations of R or by valuation domains. We also explore the relationship between the sets of spectral and of eab semistar operations, showing that, while their topological structure is very similar, there are concrete differences in their algebraic properties. Finally, we show that the sets of finite-type semistar operations, of finite-type spectral semistar operations and finite-type eab semistar operations are spectral, that is, they are homeomorphic to the prime spectrum of some ring.

This is a joint work with Carmelo Finocchiaro and Marco Fontana. (Received January 16, 2015)

1107-13-240 **Adela Vraciu*** (vraciu@math.sc.edu). *On generalized Hilbert-Kunz multiplicities.*

We prove that under certain assumptions, generalized Hilbert-Kunz multiplicities of ideals of positive dimension can be computed as linear combinations of (usual) Hilbert-Kunz multiplicities of certain auxiliary m-primary ideals. (Received January 16, 2015)

1107-13-241 **Adela Vraciu*** (vraciu@math.sc.edu). *Examples of rings that do not have any non-free totally reflexive modules.* Preliminary report.

Totally reflexive modules are the basis of the homological theory of G-dimension (similar to the way in which projective modules are the basis of the theory of projective dimension). It is known by a result of Christensen, Piepmeyer, Striuli and Takahashi that a Cohen-Macaulay non-Gorenstein ring has either infinitely many isomorphism classes of indecomposable totally reflexive modules, or else is has none (except for the free module). No criterion is known for deciding when a given ring falls into one of these categories or the other. This talk will present some examples of Artinian rings that are in some sense close to Gorenstein (but not Gorenstein) that do not have any non-free totally reflexive modules. (Received January 16, 2015)

1107-13-242 **Kai Fong Ernest Chong*** (kc343@cornell.edu), Department of Mathematics, 310 Malott Hall, Cornell University, Ithaca, NY 14850. *Macaulay-Lex Rings and the Hilbert Functions of Colored Quotient Rings.*

In 1927, Macaulay characterized the Hilbert functions of graded ideals of polynomial rings in terms of lexicographic ideals. Motivated by Macaulay's theorem, Mermin and Peeva asked if there is an analogous characterization of the Hilbert functions of graded ideals in quotients of polynomial rings, thereby introducing the notion of Macaulay-Lex rings. In this talk, I will define Macaulay-Lex rings and discuss the rich interplay between such rings and various generalizations of a well-known result in combinatorics known as the Kruskal-Katona theorem. I will introduce the notion of colored quotient rings, explain its combinatorial significance, and give a complete characterization of all Macaulay-Lex colored quotient rings. I will also explain how this characterization is a simultaneous generalization of not only Macaulay's theorem and the Kruskal-Katona theorem, but also of several extensions of these two theorems. (Received January 16, 2015)

1107-13-253 **Thomas Dunn*** (thomas.dunn@ndsu.edu), Department of Mathematics #2750, PO Box 6050, Fargo, ND 58108. *Integral Closure and Achilles-Manaresi Multiplicity Sequence.*

When R is a local noetherian ring and I is an ideal we have the Achilles-Manaresi multiplicity sequence $c_i(I)$ for $i = 0, ..,$dim R. We will give a formula for this multiplicity sequence using local j multiplicities. Under certain other restrictions, if $I \subseteq J$ are ideals with the same multiplicity sequence, then we have that I and J have the same integral closure. (Received January 16, 2015)

1107-13-273 **Alberto Chiecchio**, **Florian Enescu**, **Lance E Miller** and **Karl Schwede*** (schwede@math.utah.edu), 155 S 1400 E ROOM 233, Department of Mathematics, University of Utah, Salt Lake City, UT 84112. *Test ideals in rings with finitely generated anti-canonical algebras.*

Test ideals measure singularities of schemes in characteristic p by quatifying the failure of the flatness of Frobenius. Surprisingly, they are closely tied with multiplier ideals in characteristic zero which are defined by completely different means. Like multiplier ideals, the theory of test ideals is much better understood when the ambient ring is Q-Gorenstein. In this paper, we show that if the Q-Gorenstein hypothesis is replaced with the hypothesis that the anticanonical section ring is finitely generated, then many results still hold (note that this condition is expected to hold in every strongly F-regular ambient ring). In particular, we obtain discreteness and rationality of F-jumping numbers, we obtain global generation results for test ideals, we show that multiplier ideals turn into test ideals under reduction mod p, we obtain descriptions of test ideals via alterations, and in particular we reprove as a special case an unpublished result of Singh showing that splinters are strongly F-regular in this setting. This is joint work with Alberto Chiecchio, Florian Enescu, and Lance Miller. (Received January 17, 2015)

1107-13-287 **Greg Piepmeyer***, Columbia Basin College, 2600 N 20th Rd, Pasco, WA 99301. *Gorenstein projectives and Gorenstein flats.* Preliminary report.

This talk discusses a homological algebra problem. Projective modules are flat modules. Might the analogue hold in Gorenstein homological algebra?

This problem is prominent in joint work with Celikbas, Christensen, and Li, though the problem is recognized earlier by Holm and Emmanouil among others. (Received January 17, 2015)

1107-13-299 **Evan Houston*** (eghousto@uncc.edu). *Star operations on Noetherian domains.* Preliminary report.

A star operation on an integral domain R is a closure operation on the ideals of R that behaves well with respect to principal ideals. One shows easily that the domain R has all nonzero ideals divisorial if and only if R has only one star operation. Motivated by results of Heinzer and Bass/Matlis, which characterize domains with only one star operation in the integrally closed and Noetherian cases, we were motivated to study domains with only finitely many star operations. We have a complete characterization in the integrally closed case. The Noetherian case easily reduces to the local case, where we have a characterization in the infinite residue field case. In this talk, we recall these characterizations and report on progress in the local finite residue field case. (Received January 18, 2015)

1107-13-348 **Katharine Shultis*** (s-kshulti1@math.unl.edu). *Systems of Parameters 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 January 19, 2015)

1107-13-356 **Rebecca R.G.*** (rirg@umich.edu). *Closures That Give Big Cohen-Macaulay Modules and Algebras, and Smallest Closures.* Preliminary report.

Geoffrey Dietz has introduced a set of axioms for a closure operation on a complete local domain R so that if such a closure operation exists, the ring is guaranteed to have a balanced big Cohen-Macaulay module. These are called Dietz closures. In characteristic $p > 0$, solid closure, tight closure, and plus closure all satisfy the axioms. I will discuss a new axiom that, together with the Dietz axioms, is equivalent to the existence of a big Cohen-Macaulay algebra. This new axiom holds for large classes of closures, including those listed above. Further, any Dietz closure is trivial on regular rings. I will also discuss the existence of smallest closure operations satisfying certain sets of axioms, including the Dietz axioms. There are many open questions about the nature of various smallest closures. (Received January 19, 2015)

1107-13-395 **Catalin Ciuperca*** (catalin.ciuperca@ndsu.edu), North Dakota State University, Department of Mathematics #2750, PO BOX 6050, Fargo, ND 58108-6050. *Integral closure of equimultiple ideals.*

Let (R, m) be a formally equidimensional local ring and $J \subseteq I$ ideals of R with J equimultiple of height h. We begin by observing that the multiplicity function $e(I^n/J^n)$ is eventually a polynomial function $P_{J,I}(n)$ of degree at most h, with equality if and only if $J \subseteq I$ is not a reduction. As a consequence, we are able to show that for each $k = 0, \ldots, h$ there exists a largest ideal $J_{[k]}$ containing J such that the degree of $P_{J,J_{[k]}}(n)$ is at most $h - k - 1$, extending a construction of Shah originally done for m-primary ideals. We are also able to show that if the Rees algebra $R[Jt]$ satisfies Serre's S_2 property, then the degree of $P_{J,I}(n)$ is either $h - 1$ (when $J \subseteq I$ is a reduction) or otherwise h. (Received January 19, 2015)

1107-13-405 **K Alan Loper*** (loper.4@osu.edu), 1179 University Drive, Newark, OH 43055. *Star Operations defined by quadratic transforms and comparable ring extensions.* Preliminary report.

Let D be an integral domain and let x and y be elements of D such that neither x/y nor y/x is in D. Then a star operation on D can be defined by extending ideals of D to both D[x/y] and D[y/x] and intersecting. This can be extended naturally to more than two elements and can also be iterated. We examine properties of the resulting star operations. (Received January 19, 2015)

1107-13-419 **Bruce Olberding*** (olberdin@nmsu.edu), Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003-8001. *Ringed space structures on spaces of valuation rings.* Preliminary report.

Let F be a field, let D be a subring of F and let $\mathfrak{X}$ denote the set of valuation rings having quotient field F. Then $\mathfrak{X}$ admits the Zariski, inverse and patch topologies, all of which are spectral and have been well studied in recent years. This point of view can be further enriched by viewing $\mathfrak{X}$ as a ringed space with respect to appropriate sheaves of D-algebras for each of these topologies. Viewing $\mathfrak{X}$ with an appropriate locally ringed space structure and considering morphisms into the projective line then makes it possible to distinguish properties of intersection of valuation rings (i.e., integrally closed rings) such as whether the intersection is Prüfer or irredundant. Other sheaf structures shed additional light on these intersections. We discuss some aspects of these constructions and consider them also in the context of star operations. (Received January 20, 2015)

1107-13-422 **Javid Validashti***, Department of Mathematics, Cleveland State University, and **Neil Epstein**, Department of Mathematics, George Mason University. *Hilbert-Kunz multiplicity of products of ideals.* Preliminary report.

We provide linear-type bounds for the Hilbert-Kunz multiplicity of product of two zero-dimensional ideals and we explore necessary and sufficient conditions for achieving the bounds. Joint work with Neil Epstein, George Mason University. (Received January 20, 2015)

1107-13-425 **Neil Epstein*** (nepstei2@gmu.edu), Fairfax, VA 22030, and **Jay Shapiro**. *Perinormal integral domains.*

We introduce a new class of integral domains, the *perinormal* domains, which fall strictly between Krull domains and weakly normal domains. They are defined in terms of relationships between their prime spectra and those of rings between the given domain and its fraction field. We establish basic properties of the class and give equivalent characterizations of perinormal domains in the Noetherian context. We also introduce and explore briefly the related concept of global perinormality, including a surprising relationship with divisor class groups. Examples arise in algebra, geometry, and number theory. (Received January 20, 2015)

1107-13-426 **C-Y. Jean Chan*** (chan1cj@cmich.edu), Department of Mathematics, PE 214, Central Michigan University, Mt. Pleasant, MI 48859, and **Kazuhiko Kurano** (kurano@isc.meiji.ac.jp), Meiji Univesrity, Japan. *Cohen-Macaulay cone and an application in positive characteristic.*

Let R be a Noetherian local domain. In his paper appeared in Invent. Math. (2004), with a mild condition on R, Kurano defined and proved that $\overline{G_0(R)}$ is a finitely generated torsion-free Abelian group where $\overline{G_0(R)}$ denotes the Grothendieck group of finitely generated R-modules, modulo the numerical equivalence. Hence $\overline{G_0(R)} \times_{\mathbb{Z}} \mathbb{R}$ is a finite dimensional vector space over $\mathbb{R}$.

In this talk, we will introduce the notion of the *Cohen-Macaulay cone* of a Cohen-Macaulay local domain R. It is a cone spanned by the image of all maximal Cohen-Macaulay R-modules in the finite dimensional vector space $\overline{G_0(R)} \times_{\mathbb{Z}} \mathbb{R}$ just mentioned.

This new notion is motivated by the study of the Hilbert-Kunz functions. Some of the basic properties of the Cohen-Macaulay cone will be presented. We will also show that examples of the Hilbert-Kunz functions of certain shape can be produced. The existence of the desired ring is proved by using Segre products to construct a Cohen-Macaulay ring whose Chow group is of certain simplicity. This is a joint work with Kazuhiko Kurano. (Received January 20, 2015)

1107-13-429 **H Ananthnarayan*** (ananth@math.iitb.ac.in), Department of Mathematics, I.I.T Bombay, Powai, Mumbai, MH 400076, India, and **Ela Celikbas** and **Zheng Yang**. *Decomposing Gorenstein rings as connected sums.*

In 2012, Ananthnarayan, Avramov and Moore gave a new construction of Gorenstein rings from two Gorenstein local rings, called their connected sum. Given a Gorenstein ring, one would like to know whether it can be decomposed as a connected sum and if so, what are its components.

In the case of a Gorenstein Artin local algebra over a fi eld, these objects have been studied under different names and from different perspectives by various authors starting with Sah (1974) in the graded case and, in the local case, by Lescot (1982). A topologically influenced version was also studied in recent work by Smith and Stong, and quite a few authors approach this area via Macaulay's inverse systems.

In this talk, we look at intrinsic properties of the ring and its de fining ideal to give a characterization for such rings to be connected sums. In the process, we identify some properties that prevent the ring from being decomposable as a connected sum, and show that some classes of Gorenstein Artin rings, such as compressed algebras and complete intersection rings, are indecomposable as a connected sum. (Received January 20, 2015)

1107-13-434 **A. Tchernev*** (atchernev@albany.edu) and **M. Varisco** (mvarisco@albany.edu). *Betti categories.* Preliminary report.

We introduce the notion of a Betti category. We show that for graded modules with sufficiently good combinatorial description the corresponding Betti category completely determines the Betti numbers and also the structure of the minimal free resolution of the module in the following sense: if two such modules have isomorphic Betti categories then the minimal free resolution of one can be obtained from the minimal free resolution of the other by a functorial procedure. When applied to monomial ideals, this recovers a previous result of the authors about Betti posets of monomial ideals. When applied to toric ideals, this result shows that the Betti category of a toric ideal is a discrete combinatorial object that plays a role analogous to the role played by the lcm-lattice for monomial ideals. (Received January 20, 2015)

1107-13-442 **Louiza Fouli*** (lfouli@math.nmsu.edu), Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003, and **Paolo Mantero** and **Yu Xie**. *Conjectures on Symbolic Powers.* Preliminary report.

Given a finite set of points X in the projective space $\mathbb{P}_k^N$, for some N, it is natural to ask what is the least degree, α_m, of a hypersurface $F \neq 0$ passing through all the points with a given multiplicity m. Chudnovksy conjectured in 1981 that $\frac{\alpha_m}{m} \geq \frac{\alpha(X)+N-1}{N}$, where $\alpha(X)$ is the minimum degree of a hypersurface passing through every point in X. He established his conjecture in the case $N = 2$, but the conjecture is still open in full generality. We will discuss known results and some further progress towards this conjecture. This is joint work with Paolo Mantero and Yu Xie. (Received January 20, 2015)

1107-13-453 **George E Whelan*** (gwhelan@masonlive.gmu.edu), 4400 University Drive, Fairfax, VA 22030. *A bijection in prime characteristic algebra.* Preliminary report.

Let R be a reduced commutative Noetherian ring of prime characteristic $p > 0$. Let R^∞ denote the perfect closure of R wherein the Frobenius map $f : R^\infty \to R^\infty$, $f(r) = r^p$ is bijective. The extension $R \to R^\infty$ has two important qualities: *a*) the map $f : \mathrm{Spec}(R^\infty) \to \mathrm{Spec}(R)$ where $f(Q) = Q \cap R$ is a bijection, and *b*) R^∞ will no longer retain Noetherianness. The concept of an associated prime will generalize in the extension to weakly associated primes and strong Krull primes, which arise in the non-Noetherian context. In this talk we will investigate an arbitrary ideal $I = (x_1, x_2, \ldots x_n) \subset R$ and find a one-to-one correspondence between the strong Krull primes (over R^∞) of its extension IR^∞, and associated primes of Frobenius closures of $I^{[q]} = (x_1^q, x_2^q, \ldots x_n^q) \subset R$ for $q = p^e$ with $e \in \mathbb{N}$. Furthermore, we generalize to strong Krull primes $\mathrm{sK}_{R^\infty}(R^\infty \otimes_R M)$ for any finitely generated R-module M, with a similar result. (Received January 20, 2015)

1107-13-468 **William Heinzer** and **Youngsu Kim*** (youngsu.kim@ucr.edu), 900 University Avenue, Riverside, CA 92521, and **Matthew Toeniskoetter**. *Blowing up finitely supported complete ideals in a regular local ring.*

Let R be a regular local ring and I a finitely supported R-ideal. We investigate singularities of $\mathrm{Proj}\,\overline{R[It]}$, where $\overline{R[It]}$ denotes the integral closure of the Rees algebra $R[It]$. We are able to prove that for a local ring S on $\mathrm{Proj}\,\overline{R[It]}$, if S is a UFD, then S is regular. This is a generalization of a result of Lipman and Huneke-Sally in dimension 2. Furthermore, we show that if $\mathrm{Proj}\,\overline{R[It]}$ is factorial, then it is the non-singular model obtained by a finite number of blowups at the non-singular closed points that correspond to the base points of I. In particular, if $\mathrm{Proj}\,\overline{R[It]}$ is factorial, then it is non-singular. (Received January 20, 2015)

1107-13-487 **Claudiu Raicu** and **Jerzy M Weyman***, 196 Auditorium Rd, Storrs, CT, Algeria. *D-modules supported in orbit closures.* Preliminary report.

In this talk I will discuss joint results with Claudiu Raicu on equivariant D-modules supported in the symmetric determinantal varieties. Other representations with finitely many orbits will also be discussed. (Received January 20, 2015)

1107-13-488 **Joe Buhler*** (buhler@ccrwest.org). *Robbins p-adic stability for Somos sequences.* Preliminary report.

David Robbins conjectured that Dodgson condensation has a surprising "p-adic stability" when computed with finite precision p-adic floating point arithmetic. This appears to extend to much more general contexts, including (suitable) cluster algebras and, in particular, to certain Somos sequences. Moreover, there is a natural purely algebraic conjecture that implies the Robbins-like conjectures. We consider this circle of ideas for Somos sequences, proving the algebraic conjecture for Somos-4 and Somos-5, and giving interesting empirical observations for related sequences. (This is joint work with Kiran Kedlaya.) (Received January 20, 2015)

1107-13-498 **Angela Kohlhaas*** (angela.kohlhaas@loras.edu). *Coefficient Ideals and Cores in Dimension Two.*

Let I be an (x, y)-primary monomial ideal in $k[x, y]$ or an $\mathfrak{m}$-primary ideal in a regular local ring $(R, \mathfrak{m})$ of dimension two. The coefficient ideal of I is the largest ideal $\mathfrak{a}$ satisfying $\mathfrak{a}I = \mathfrak{a}J$, where J is any minimal reduction of I, and the core is the intersection of all reductions of I. We find an explicit formula for the coefficient ideal of I by linking it to a certain ideal of reduction number one. In the monomial case, this leads

to an Alexander-like duality between exponent sets, which we in turn use to explicitly describe the core of I.
(Received January 20, 2015)

14 ► Algebraic geometry

1107-14-68 **James F. McEnerney*** (mcenerney1@llnl.gov). *A real nullstellensatz with multiplicity.* Preliminary report.

Let A be a ring containing the rationals. Let S be a multiplicatively closed subset such that $1 \in S$ and $0 \notin S$, T a cone in A such that $S \subset T$ and I an ideal in A. Then

$$\rho_{S,T} I = \{a \mid sa^{2m} + t \in I^{2m} \text{ for some } m \in \mathbb{N}, s \in S \text{ and } t \in T\}$$

is an ideal. For a commutative ring the collection of non-reduced orders (total cones) is a fibration of the real spectrum. Both of these concepts carry information regarding multiple solutions in the constructible set associated with I, T and S. A non-reduced nullstellensatz that extends the real nullstellensatz and relates these concepts when the ring is a Cohen-Macaulay domain is presented.

Keywords: Multiplicity, Nullstellensatz, semi-algebraic closure, graded ring.
(Received December 26, 2014)

1107-14-163 **Patrick Graf*** (patrick.graf@uni-bayreuth.de). *The generalized Lipman-Zariski problem.*

We propose and study a generalized version of the Lipman-Zariski conjecture: let $(x \in X)$ be an n-dimensional singularity such that for some integer $1 \leq p \leq n-1$, the sheaf $\Omega_X^{[p]}$ of reflexive differential p-forms is free. Does this imply that $(x \in X)$ is smooth? We give an example showing that the answer is no even for $p = 2$ and X a terminal threefold. However, we prove that if $p = n-1$, then there are only finitely many log canonical counterexamples in each dimension, and all of these are isolated and terminal. As an application, we show that if X is a projective klt variety of dimension n such that the sheaf of $(n-1)$-forms on its smooth locus is flat, then X is a quotient of an Abelian variety.

On the other hand, if $(x \in X)$ is a hypersurface singularity with singular locus of codimension at least three, we give an affirmative answer to the above question for any $1 \leq p \leq n-1$. The proof of this fact relies on a description of the torsion and cotorsion of the sheaves Ω_X^p of Kähler differentials on a hypersurface in terms of a Koszul complex. As a corollary, we obtain that for a normal hypersurface singularity, the torsion in degree p is isomorphic to the cotorsion in degree $p-1$ via the residue map. (Received January 12, 2015)

1107-14-171 **Uli Walther***, Dept of Math, Purdue University, West Lafayette, IN 47907. *The logarithmic complex of an Euler homogeneous divisor.*

The Liouville form on the tangent space of a complex manifold can be used to write down an interesting type of complex, one for each Euler homogeneous divisor, which we call "logarithmic complexes".

It is an open problem to determine the homlogy of logarithmic complexes, at present none is known that is not a resolution.

We discuss applications of this complex (for special kinds of divisors) to D-module theoretic singularity invariants. (Received January 13, 2015)

1107-14-217 **Harry Tamvakis*** (harryt@math.umd.edu). *Theta polynomials and the cohomology of symplectic Grassmannians.*

The cohomology of the usual Grassmannian X has been studied for well over a century. The classes of the Schubert varieties form an additive basis for the cohomology ring of X, and Giambelli proved that the Schur S-polynomials serve as algebraic representatives of these classes. The corresponding objects which represent the Schubert classes on symplectic Grassmannians are called theta polynomials, and were introduced six years ago in joint work with Anders Buch and Andrew Kresch. These polynomials interpolate naturally between Jacobi-Trudi determinants and Schur Pfaffians, and have rich combinatorial and geometric properties. When coupled with the companion theory of eta polynomials, they are key ingredients in the solution of the Giambelli problem for the torus-equivariant cohomology of any classical G/P space. I will give a brief introduction to this theory, and discuss some open questions. (Received January 15, 2015)

1107-14-219 **Evgeny Gorskiy***, Department of Mathematics, Columbia University, 2990 Broadway, New York, NY 10027, and **Andras Nemethi**. *Heegaard-Floer homology of algebraic links.*

Campillo, Delgado and Gusein-Zade proved that the coefficients of the multivariable Alexander polynomial of an algebraic link agree with the Euler characteristics of certain projectivized hyperplane arrangements in the space of functions on the corresponding curve. We prove a categorification of their result: homology of these arrangements agree with the minus-version of the Heegaard-Floer link homology. (Received January 15, 2015)

1107-14-347 **Richard Rimanyi*** (`rimanyi@email.unc.edu`). *Degeneracy loci formulas in iterated residue form.*

In a family of geometric objects (e.g. map germs, quivers, matroids) certain objects are forced to be singular by the topology of the family. There are universal polynomials in characteristic classes expressing the (cohomology or K-theory) fundamental class of degeneracy loci. Some of these polynomials are known, and they display remarkable stabilization and (conjectured) positivity properties. Recently found iterated residue formalism prove some of these properties. (Received January 19, 2015)

1107-14-379 **Dima Arinkin**, **Andrei Caldararu*** (`andreic@math.wisc.edu`) and **Marton Hablicsek**. *An algebraic proof of the Barannikov-Kontsevich theorem.*

We present a new algebraic proof of a claim of Barannikov-Kontsevich, which was first proved with analytic methods by Sabbah. This result is conceptually the analogue of the Hodge-de Rham degeneration statement (which applies for complex Kahler manifolds), but applied to a dg category of matrix factorizations. Our proof relies on reducing to positive characteristic and then applying our earlier results on formality of derived intersections in Azumaya spaces (spaces endowed with an Azumaya algebra). (Received January 19, 2015)

15 ► *Linear and multilinear algebra; matrix theory*

1107-15-110 **Anthony Iarrobino**, **Leila Khatami*** (`khatamil@union.edu`), **Bart Van Steirteghem** and **Rui Zhao**. *Nilpotent matrices having a given Jordan type as maximum commuting nilpotent orbit.*

Let B be an $n \times n$ nilpotent matrix with Jordan block sizes given by the partition P of n. It is well-known that the nilpotent commutator of B consisting of all nilpotent matrices that commute with B is an irreducible variety. So there is a unique partition $\mathcal{Q}(P)$ that is the Jordan partition of a generic element of the nilpotent commutator of B. In this talk we report the results of a joint work with Anthony Iarrobino, Bart Van Steirteghem and Rui Zhao in which we study the inverse map $\mathcal{Q}^{-1}$. We prove that if $Q = (u, u-r)$, with $r \geq 2$, is a partition with two parts, then partitions in $\mathcal{Q}^{-1}$ can be arranged in an $(r-1) \times (u-r)$ table where the entry in the k-th row and ℓ-th column has $k+\ell$ parts. The set $\mathcal{Q}^{-1}$ is known to be empty when $r \leq 1$. Our result confirms a conjecture by P. Oblak from 2012 and a refinement of her conjecture by R. Zhao. We also generalize the statement to propose a Box Conjecture for the set of partitions $\mathcal{Q}^{-1}(Q)$ for a partition Q with an arbitrary number of parts. (Received January 07, 2015)

1107-15-235 **yeonhyang kim*** (`kim4y@cmich.edu`), 906 Southmoor Rd, Mt. Pleasant, MI 48858, and **Rachel Domagalski**, **Sivaram K. Narayan**, **Hong Suh** and **Xingyu Zhang**. *Structures of minimal scalings in R^n.* Preliminary report.

A tight frame in R^n is a redundant system which has a reconstruction formula similar to that of an orthonormal basis. Given a spanning set of vectors $\{f_i\}_{i=1}^k$ in R^n satisfying a certain property, one can manipulate the length of the vectors to obtain a tight frame. Such a spanning set is called a scalable frame. A scaling w is a minimal scaling if $\{w(i)f_i : w(i) > 0\}$ has no proper scalable subframes. In this talk, we present the uniqueness of the orthogonal partitioning property of any set of minimal scalings, and provide a construction of scalable frames by extending the standard orthonormal basis. (Received January 16, 2015)

1107-15-300 **Christopher Jones*** (`ckrtj@unc.edu`) and **Naratip Santitissadeekorn** (`ckrtj@unc.edu`). *A Bimodality Trap in Model Projections.*

We expose a phenomenon that can occur in the process of joint state and parameter estimation. Such estimation is crucial in tuning parameters for climate models and offline parameterizations used in the models. We show how a bimodal distribution can temporarily appear during this process and that a scheme relying on linear and Gaussian approximations may cause it to get trapped in the wrong mode and hence lead to faulty estimation. We propose a practical and effective resolution using a two-stage filtering process. (Received January 18, 2015)

16 ► Associative rings and algebras

1107-16-43 **Nicolas Guay*** (nguay@ualberta.ca), University of Alberta, Deparment of Mathematical and, Statistical Sciences, Edmonton, AB T6G 2G1, Canada, and **Vidas Regelskis** (v.regelskis@surrey.ac.uk), University of Surrey, Department of Mathematics, Guildford, GU2 7XH, United Kingdom. *Twisted Yangians for symmetric pairs of types B,C,D.*

Let $\mathfrak{g}$ be a complex semisimple Lie algebra. Yangians are quantum groups attached to the current Lie algebra $\mathfrak{g} \otimes_{\mathbb{C}} \mathbb{C}[t]$. Twisted Yangians are coideal subalgebras of Yangians associated to a twisted current Lie algebra, the twist coming from an involution on $\mathfrak{g}$. When $\mathfrak{g} = \mathfrak{sl}_n$, their representation theory has been studied a lot in the past twenty years. I will introduce new twisted Yangians when $\mathfrak{g}$ is an orthogonal or symplectic Lie algebra, I will present some of their properties and explain how they can be equivalently defined using the reflection equation. (Received December 08, 2014)

1107-16-90 **Ivan Loseu***, 360 Huntington Avenue, Boston, MA 02115. *Holonomic modules and Bernstein inequality.*

I will introduce the notion of a holonomic module for a filtered algebra whose associated graded has spectrum with finitely many symplectic leaves and discuss the generalized Bernstein inequality for such algebras. (Received January 03, 2015)

1107-16-133 **Thomas - Tradler***, New York City College of Technology, Department of Mathematics, Room N711, 300 Jay Street, Brooklyn, NY 11201. *Equivariant holonomy via iterated integrals.*

We will explain how iterated integrals may be used in the setting of vector bundles and abelian gerbes to define Bismut's equivariant Chern character which crucially includes their holonomy information. For this, local Hochschild complexes as well as 2-dimensional Hochschild complexes will be defined and studied as the main tool. (Received January 09, 2015)

1107-16-160 **Jeffrey Pike** and **Alistair Savage*** (alistair.savage@uottawa.ca), University of Ottawa, Department of Mathematics & Statistics, Ottawa, Ontario K1N 6N5, Canada. *Twisted Frobenius extensions.*

Frobenius algebras are finite-dimensional unital associative algebras with a certain type of bilinear form giving the algebras nice duality properties. They are of vital in importance in topological quantum field theory. Frobenius extensions are generalizations of Frobenius algebras, where one does not require the base ring to be a field. We will introduce an even more general concept, that of a twisted Frobenius extension, that involves automorphisms of the base ring and the extension. In the case that these automorphisms are trivial, we recover the usual notion of a Frobenius extension. The motivation for our definition comes from categorification, where one is often interested in the adjointness properties of induction and restriction functors. We show that A is a twisted Frobenius extension of B if and only if induction of B-modules to A-modules is twisted biadjoint to restriction of B-modules to A-modules. A large (non-exhaustive) class of examples is given by the fact that any time A is a Frobenius algebra and B is a subalgebra that is also a Frobenius algebra, then A is a twisted Frobenius extension of B. (Received January 12, 2015)

1107-16-205 **Maciej Karpicz** and **Marju Purin*** (purin@stolaf.edu), Northfield, MN 55057. *The Generalized Auslander-Reiten Condition for n-Symmetric Algebras.*

A ring Λ is said to satisfy the Generalized Auslander-Reiten Condition if for each Λ-module M with $\mathrm{Ext}^i(M, M \oplus \Lambda) = 0$ for all $i > n$ the projective dimesion of M is at most n. We prove that this condition holds for all n-symmetric algebras of quasitilted type– a broad class of self-injective algebras where every module is ν-periodic. Here ν denotes the Nakayama automorphism. (Received January 15, 2015)

1107-16-213 **Chun-Ju Lai*** (cl8ah@virginia.edu) and **Li Luo**. *An elementary approach to monomial and canonical bases of quantum affine $\mathfrak{gl}_n$.*

In 1990 Beilinson, Lusztig and MacPherson provided a geometric realization of modified quantum $\mathfrak{gl}_n$ and its canonical basis. An essential step of their work is a construction of a monomial basis. Recently, Du and Fu provided an algebraic construction of canonical basis for modified quantum affine $\mathfrak{gl}_n$, which among other results used an earlier difficult construction of a monomial basis using Ringle-Hall algebra of the cyclic quiver. In this talk, we will give an elementary algebraic construction of a monomial basis and hence canonical basis for modified quantum affine $\mathfrak{gl}_n$. This is a joint work with Li Luo (Shanghai). (Received January 15, 2015)

1107-16-278 **You Qi*** (you.qi@yale.edu), 442 Dunham Lab, 10 Hillhouse Ave., New Haven, CT 06511. *A New Year Resolution.*

We construct a braid group action on the p-DG derived category of a zig-zag algebra. This is joint work with J. Sussan. (Received January 17, 2015)

1107-16-304 **Zhaobing Fan*** (fanz@math.ksu.edu), 138 Cardwell Hall, Kansas State University, Manhattan, KS 66506, and **Yiqiang Li** (yiqiang@buffalo.edu), 244 Mathematics Building, University at Buffalo, Buffalo, NY 14260. *Geometric Schur duality of type D.*

We establish a duality between the Iwahori-Hecke algebras of type D and two new algebras arising from the geometry of N-step isotropic flag varieties of type D, in analogue with Schur-Jimbo duality of type A and Bao-Wang duality of type B/ C. We construct canonical bases for these two algebras. (Received January 18, 2015)

1107-16-359 **Arkady Berenstein** (arkadiy@uoregon.edu) and **Jacob Greenstein*** (jacob.greenstein@ucr.edu). *Double canonical bases.*

The aim of this talk is to introduce a new class of bases for quantized universal enveloping algebra and other doubles attached to semisimple and Kac-Moody Lie algebras. These bases contain dual canonical bases of upper and lower halves of the quantum group and are invariant under many symmetries including, in the semisimple case, all Lusztig's symmetries. It also turns out that a part of a double canonical basis of spans its center. We expect that double canonical bases carry a cluster-like structure extending that on the upper and lower halves. (Received January 19, 2015)

1107-16-382 **Samuel Mendelson*** (smendels@gmu.edu), Department of Mathematical Sciences, 4400 University Drive, MS: 3F2, Exploratory Hall, room 4400, Fairfax, VA 22030, and **Geir Agnarsson**. *Matrix Algebras: Equivalent Ring Relations and Special Presentations.*

A classic result in noncommutative ring theory states that a ring R is an $n \times n$ matrix ring if, and only if, R contains n^2 matrix units $\{e_{ij}\}_{1 \leq i,j \leq n}$, in which case $R \cong M_n(S)$ where S is a subring of R that can be described completely in terms of the matrix units. A lesser known result states that a ring R is an $(m+n) \times (m+n)$ matrix ring,so $R \cong M_{m+n}(S)$ for some ring S, if, and only if, R contains three elements a, b, and f satisfying the two relations $af^m + f^n b = 1$ and $f^{m+n} = 0$. In this talk, we investigate algebras over a commutative ring (or field) with elements c and f satisfying the two relations $c^i f^m + f^n c^j = 1$ and $f^{m+n} = 0$. Surprisingly little is known here about the structure of these algebras and about the underlying ring S for most cases of the integers i, j,m, and n. Questions whether S is non-trivial or not turn out to be surprisingly difficult to answer, let alone describing the structure of these algebras or of S in general. (Received January 19, 2015)

1107-16-387 **Jose Simental*** (simentalrodriguez.j@husky.neu.edu). *Harish-Chandra bimodules for Rational Cherednik Algebras.*

Rational Cherednik algebras are a certain class of associative algebras associated to complex reflection groups. They depend on a collection of complex numbers, and their representation theory is in some sense similar to that of universal enveloping algebras of semisimple Lie algebras. In particular, there is a notion of Harish-Chandra bimodules for these algebras. In my talk, I will describe irreducible maximally supported Harish-Chandra bimodules over rational Cherednik algebras associated to Coxeter groups. (Received January 19, 2015)

1107-16-389 **Jason Gaddis*** (gaddisjd@wfu.edu) and **Kenneth L. Price**. *Some Algebras Similar to the 2×2 Jordanian Matrix Algebra.*

The impetus for this study is the work of Dumas and Rigal on the Jordanian deformation of the ring of coordinate functions on 2×2 matrices, denoted $M_J(2)$. This algebra presents an interesting automorphism group and representation theory, and so we are motivated to find other examples of algebras exhibiting similar behavior. In this talk, I will discuss the construction of a family of algebras containing $M_J(2)$ along with results on their structure. (Received January 19, 2015)

1107-16-396 **Joshua Sussan***, joshuasussan@gmail.com. *Braid group actions and Heisenberg categorification.*

Associated to a simply laced Dynkin diagram there is a corresponding affine Lie algebra and a Heisenberg subalgebra. On the Fock space representation of this Heisenberg algebra we construct an action of a braid group. We also categorify this action by constructing functors on a certain category of modules and show that these functors satisfy the braid group relations. This is joint work with S. Cautis and A. Licata. (Received January 19, 2015)

17 ► Nonassociative rings and algebras

1107-17-10 **V Chari**, **Peri Shereen*** (shereen@math.ucr.edu), **R Venkatesh** and **J Wand**. *A Steinberg type decomposition theorem for higher level Demazure modules.*

We study Demazure modules which occur in a level ℓ irreducible integrable representation of an affine Lie algebra. We also assume that they are stable under the action of the standard maximal parabolic subalgebra of the affine Lie algebra. We prove that such a module is isomorphic to the fusion product of "prime" Demazure modules, where the prime factors are indexed by dominant integral weights which are either a multiple of ℓ or take value less than ℓ on all simple coroots. Our proof depends on a technical result which we prove in all the classical cases and G_2. Calculations with mathematica show that this result is correct for small values of the level. Using our result, we show that there exist generalizations of Q–systems to pairs of weights where one of the weights is not necessarily rectangular and is of a different level. Our results also allow us to compare the multiplicities of an irreducible representation occurring in the tensor product of certain pairs of irreducible representations, i.e., we establish a version of Schur positivity for such pairs of irreducible modules for a simple Lie algebra. (Received October 11, 2014)

1107-17-89 **Yiqiang Li*** (yiqiang@buffalo.edu), Department of Mathematics, University at Buffalo, SUNY, 244 Mathematics Building, Buffalo, NY 14051, and **Weiqiang Wang** (ww9c@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22904. *Positivity vs negativity of canonical bases.*

I'll report some progress on the positivity and negativity of canonical bases of quantum $\mathfrak{sl}_n$ and its associated coideal subalgebra. (Received January 03, 2015)

1107-17-183 **Naihuan Jing*** (jing@ncsu.edu), Dept of Mathematics, N. C. State University, Raleigh, NC 27695-8205, and **Jian Zhang**, School of Mathematical Sciences, South China Univ. of Technology, Guangzhou, Guangdong 510640, Peoples Rep of China. *Quantum determinants and quantum Pfaffians.*

We use quantum exterior algebras to give a new and elementary formulation of quantum Pfaffians and generalized quantum Pfaffians based on quantum Pluecker relations. In this approach, the quantum Pfaffians are for any square matrix satisfying a simple quadratic relation. In particular, we prove the fundamental identity expressing any quantum determinant as a quantum Pfaffian. (Received January 14, 2015)

1107-17-192 **Huanchen Bao*** (hb4tb@virginia.edu), 141 Cabell Drive, Kerchof Hall, Charlottesville, VA 22904. *Canonical bases arising from quantum symmetric pairs.*

The canonical bases of quantum groups have been discovered by Lusztig twenty years ago and they have played an important role in representation theory. Recently, motivated by a new formulation of a Kazhdan-Lusztig theory of (super) type B, Weiqiang Wang and I initiated a theory of canonical bases arising from quantum symmetric pairs. There has also been further geometric construction of such canonical bases (joint with Yiqiang Li and Jon Kujawa). In this talk, I will describe the construction of these canonical bases and some further development if time permitting. (Received January 14, 2015)

1107-17-477 **Valerio Toledano Laredo***, 360 Huntington Ave., Boston, MA 02115. *Yangians, quantum loop algebras and elliptic quantum groups.*

The Yangian Yg and quantum loop algebra Uq(Lg) of a complex semisimple Lie algebra g are infinite-dimensional quantum groups which were introduced by Drinfeld in the mid 80s, and deform the current algebra g[s] and loop algebra g[z,z^{-1}] of g.

Although they share very many similarities, and were long thought to have the same representations, no precise relation between them existed until recently.

I will explain how to construct a faithful functor from the finite-dimensional representations of Yg to those of Uq(Lg) which restricts to an equivalence on an explicitly defined subcategory of Yg.

A similar construction yields a faithful functor from representations of U_q(Lg) to those of the elliptic quantum group corresponding to g.

This is joint work with Sachin Gautam. (Received January 20, 2015)

1107-17-479 **Cristian Lenart*** (clenart@albany.edu), State University of New York at Albany, **Satoshi Naito**, Tokyo Institute of Technology, Japan, **Daisuke Sagaki**, University of Tsukuba, Japan, **Anne Schilling**, University of California Davis, and **Mark Shimozono**, Virginia Polytechnic Institute. *Kirillov-Reshetikhin modules, Macdonald polynomials, and categorification.*

The (symmetric) Macdonald polynomials are Weyl group invariant polynomials with rational function coefficients in q, t, which specialize to the irreducible characters of semisimple Lie algebras upon setting $q = t = 0$. Kirillov-Reshetikhin (KR) modules are certain finite-dimensional modules for affine Lie algebras. We showed that a Macdonald polynomial specialized at $t = 0$ equals the graded character of a corresponding tensor product of (one-column) KR modules. The proof is based on exhibiting a common combinatorial model, called the quantum alcove model, for the two objects. I will also mention the work of Chari-Ion and Khoroshkin based on our result, leading to a categorification of Macdonald polynomials. (Received January 20, 2015)

18 ► Category theory; homological algebra

1107-18-194 **Ben Webster*** (bwebste@gmail.com), Department of Mathematics, University of Virginia, 141 Cabell Drive, Charlottesville, VA 22904. *Skew Howe duality and comparison of knot invariants.*

One very important collection of invariants for any knot or link are those associated by Reshetikhin and Turaev to the representations of $\mathfrak{sl}_n$. Over the past decade or so, mathematicians have had a lot of success at defining categorifications of these invariants, and a lot less success at figuring out whether they've defined one categorification in a bunch of different ways, or a bunch of different ones. Luckily, we now know that the former is true. I'll explain how, based on work of many people including Cautis, Mackaay, Yonezawa, Rose, Queffelec, Lauda and of course, myself. (Received January 14, 2015)

1107-18-195 **Ben Webster*** (bwebster@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22904. *Uniqueness (or lack thereof) for categorical modules.* Preliminary report.

Whenever one tries to explain categorification to a mathematician unfamiliar with it, there's one question that essentially unavoidable: "Is there a unique way of categorifying X, Y or Z? If there isn't how do you know you have the right one?"

This is a fair (if somewhat annoying) question. At this point we know many objects that don't have a unique categorification, but they do have ones which are in some sense "best." The examples we know seem to suggest a representation will have a "best class" of categorifications if it is the restriction of an irreducible representation under a good inclusion of subalgebras. While this is still preliminary work, I'll try to give some theoretical justification for this assertion. (Received January 14, 2015)

1107-18-207 **Radmila Sazdanovic*** (rsazdanovic@math.ncsu.edu), NCSU Department of Mathematics, 3120 SAS Hall 2311 Stinson Drive, PO Box 8205, Raleigh, NC 27695, and **Mikhail Khovanov**. *A categorification of the polynomial ring.*

We introduce a categorification of the one-variable polynomial ring Z[x], based on the geometrically defined graded algebra. This construction is generalized to the categorification of some basic special functions. (Received January 15, 2015)

1107-18-208 **Yin Tian*** (ytian@scgp.stonybrook.edu), Simons Center for Geometry and Physics, Stonybrook, NY 11794. *A diagrammatic categorification of quantum sl(1,1) via contact topology.*

The Alexander polynomial of knots can be recovered as Witten-Reshetikhin-Turaev invariant associated to quantum sl(1,1). Knot Floer homology categorifies the Alexander polynomial. In this talk, we present a diagrammatic categorification of quantum sl(1,1). Our construction is motivated from *contact categories* introduced by Ko Honda, which study 3-dimensional contact strucutures on thickened surfaces. (Received January 15, 2015)

19 ► K-theory

1107-19-67 **Michael Brown*** (mbrown15@math.unl.edu). *Matrix Factorizations and the K-theory of the Milnor Fiber.* Preliminary report.

Let Q denote the polynomial ring $\mathbb{C}[x_1,\ldots,x_n]$, and suppose f is a nonzero element of the homogeneous maximal ideal of Q. One may associate to the pair (Q,f) a triangulated category $[\mathrm{MF}(Q,f)]$, the *homotopy category of matrix factorizations* of f over Q. I will discuss a homomorphism from the Grothendieck group of this triangulated category into the topological K-theory of the Milnor fiber of f, and I will show how one may use this map to demonstrate precise senses in which various algebraic properties of the ring $Q/(f)$ are manifestations of topological properties of the Milnor fiber of f. (Received December 26, 2014)

1107-19-323 **Mahmoud Zeinalian*** (mzeinalian@liu.edu), **Scott O. Wilson** (scott.wilson@qc.cuny.edu) and **Thomas Tradler** (ttradler@citytech.cuny.edu). *Loop Differential K-theory.*

We introduce an equivariant extension of the Chern-Simons form, associated to a path of connections on a bundle over a manifold M, to the free loop space LM, and show it determines an equivalence relation on the set of connections on a bundle. We use this to define a ring, loop differential K-theory of M, in much the same way that differential K-theory can be defined using the Chern-Simons form in the work of Simons and Sullivan. We show loop differential K-theory yields a refinement of differential K-theory, and in particular incorporates holonomy information into its classes and enjoys several good properties. Additionally, loop differential K-theory is shown to be strictly coarser than the Grothendieck group of bundles with connection up to gauge equivalence.
(Received January 18, 2015)

20 ► Group theory and generalizations

1107-20-49 **Alexander Suciu** and **He Wang*** (wang.he1@husky.neu.edu), Department of Mathematics, Northeastern University, Boston, MA 02115. *Cohomology jump loci of configuration spaces.*

In his thesis, K.T. Chen studied the lower central series quotients of the maximal metabelian quotient G/G'' of a finitely generated group G. Later on, K. Murasugi used these groups, which he called the Chen groups, to study Milnor's invariant of links, while W.S. Massey and L.Traldi investigated the relationship between the Chen groups and the Alexander module of a link group. D.Cohen and A. Suciu extended Massey's method, and used it to compute the Chen groups of the pure braid groups. In this talk, I will present several results relating the resonance varieties and the ranks of the Chen groups of the welded braid groups, the virtual braid groups and the pure braid groups on Riemann surfaces. Motivated by these examples, we investigate possible generalizations of the Chen ranks conjecture, which relates the Chen ranks of a finitely generated group to the geometry of its first resonance variety. (Received December 15, 2014)

1107-20-349 **Dror Bar-Natan*** (drorbn@math.toronto.edu). *When does a group have a Taylor expansion?*

It is insufficiently well known that the good old Taylor expansion has a completely algebraic characterization, which generalizes to arbitrary groups (and even far beyond). Thus one may ask: Does the braid group have a Taylor expansion? (Yes, using iterated integrals and/or associators). Do braids on a torus ("elliptic braids") have Taylor expansions? (Yes, using more sophisticated iterated integrals / associators). Do virtual braids have Taylor expansions? (No, yet for nearby objects the deep answer is Probably Yes). Do groups of flying rings (braid groups one dimension up) have Taylor expansions? (Yes, easily, yet the link to TQFT is yet to be fully explored).

Handout/Video/Links at http://www.math.toronto.edu/~drorbn/Talks/Georgetown-1503/ (Received January 19, 2015)

22 ► Topological groups, Lie groups

1107-22-447 **Thomas H. Lenagan** (t.lenagan@ed.ac.uk), Maxwell Institute for Mathematical Sciences, School of Mathematics, University of Edinburgh, Edinburgh, Scotland , and **Milen T Yakimov*** (yakimov@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70808. *Cluster structures on quantum Richardson varieties.*

Richardson varieties play an important role in Schubert calculus and total positivity for flag varieties. Leclerc defined a cluster algebra inside the coordinate ring of each open Richardson variety for a symmetric Kac-Moody group, and Muller and Speyer studied these cluster algebras in the case of Richardson varieties in Grassmannnians. We will show how to realize the quantized coordinate ring of each open Richardson variety as a normal localization of a prime factor of a quantum Schubert cell algebra. Using a combination of ring theoretic and representation theoretic methods we produce large families of toric frames for all quantum Richardson varieties by constructing sequences of normal elements in chains of subalgebras. This gives a method to control the size of Leclerc's cluster algebras from below and ultimately to relate them to the coordinate rings of the Richardson varieties (for all symmetrizable Kac-Moody algebras). (Received January 20, 2015)

1107-22-470 **Nick J Davidson*** (ndavidso@uoregon.edu), Department of Mathematics, University of Oregon, Eugene, OR 97403. *Categorical crystal tensor products.* Preliminary report.

I'll revisit some results of I. Losev about crystals arising from categorical actions of Kac-Moody algebras on highest weight categories. Combined with the notion of tensor product categorification introduced by Losev and Webster, one gets a categorical version of Kashiwara's crystal tensor product rule. I have extended these results to include categorifications of lowest-tensored-highest modules, and to super categorical actions based on odd nil-Hecke algebras and quiver Hecke superalgebras. (Received January 20, 2015)

28 ► Measure and integration

1107-28-29 **Cagin Ararat*** (cararat@princeton.edu), Charlton Street, Sherrerd Hall, Princeton, NJ 08544, and **Birgit Rudloff**, Charlton Street, Sherrerd Hall, Princeton, NJ 08544. *A Daniell-Stone characterization for Aumann integrals.*

The Aumann integral of a measurable set-valued function is defined as the set of all (Bochner) integrals of its integrable selections. In this work, a special structure is assumed for the values of set-valued functions: these values are upper sets, that is, they are invariant under the addition of a fixed ordering cone. Upper set-valued functions appear in some recent developments in set optimization and financial mathematics. The main result is a Daniell-Stone type characterization theorem for Aumann integrals of upper set-valued functions. More precisely, the result characterizes the conditions under which a functional that maps from a certain collection of measurable functions into the set of all closed convex upper sets can be written as the Aumann integral with respect to a measure. While the set-valued analogues of the linearity and monotone convergence properties of the classical Lebesgue integral are among these conditions, the remaining properties are of geometric nature and peculiar to the set-valued framework. (Received November 19, 2014)

1107-28-337 **Trubee Hodgman Davison*** (trubee.davison@colorado.edu). *Generalizing the Kantorovich Metric to Projection-Valued Measures: With Applications to Iterated Function Systems.*

Given a compact metric space X, the collection of Borel probability measures on X can be made into a compact metric space via the Kantorovich metric. We partially generalize this well known result to projection-valued measures. In particular, given a Hilbert space $\mathcal{H}$, we consider the collection of projection-valued measures from X into the projections on $\mathcal{H}$. We show that this collection can be made into a complete and bounded metric space via a generalized Kantorovich metric. We develop new properties and applications of this metric. Indeed, we provide an alternative method for proving a fixed point result due to P. Jorgensen. This fixed point, which is a projection-valued measure, arises from an iterated function system on X, and is related to Cuntz algebras. (Received January 18, 2015)

30 ► Functions of a complex variable

1107-30-14 **Pritha Chakraborty*** (`pritha.chakraborty@ttu.edu`), Texas Tech University, Department of Mathematics & Statistics, Broadway & Boston, Lubbock, TX 79409, and **Alexander Yu. Solynin**. *Extremal Problems in Bergman spaces.* Preliminary report.

In 1991, Boris Korenblum conjectured and Walter Hayman proved in 1992 that for $f,\ g \in \mathcal{A}^2(\mathbb{D})$, there is a constant c, $0 < c < 1$, such that if $|f(z)| \le |g(z)|$ for all z such that $c < |z| < 1$, then $\|f\|_2 \le \|g\|_2$, where the Bergman space $\mathcal{A}^2(\mathbb{D})$ is the set of analytic functions whose modulus is square integrable with respect to area measure with norm $\|f\|_2 = \left(\int_{\mathbb{D}} |f(z)|^2 \, dA(z)\right)^{\frac{1}{2}}$. The largest possible value of such c is called the Korenblum's constant. The exact value of this constant, which is denoted by κ, remains unknown. In this talk, I will discuss some non-linear extremal problems in the Bergman space and prove some preliminary results which will shed some light on the Korenblum's problem. (Received October 27, 2014)

1107-30-368 **Gerardo R Chacon*** (`grchacon@gmail.com`), 800 Florida Avenue NE, Department of Science, Technology, and Mathematics, HMB S340G, Washington, DC 20002. *Variable Exponent Bergman Spaces.*

Let $\mathbb{D}$ denote the open unit disk in the complex plane and dA the normalized Lebesgue measure on $\mathbb{D}$. For a given $1 \leqslant p < \infty$ define the *Bergman space* $A^p(\mathbb{D})$ as the space of all analytic functions on $\mathbb{D}$ that satisfies:

$$\|f\|_{A^p}^p := \int_{\mathbb{D}} |f(z)|^p dA(z) < \infty.$$

The theory of Bergman spaces were introduced by S. Bergman and since the 1990s it has gained a lot of attention mainly due to some major breakthroughs at the time. Variable Lebesgue spaces are a generalization of Lebesgue spaces where we allow the exponent to be a measurable function and thus the exponent may vary.

We will define variable exponent Bergman spaces and show some fundamental properties. We consider this to be an interesting topic since the classical approach to Bergman spaces seems to fail in the variable framework. To circumvent this problem, we rely on techniques from real harmonic analysis, variable exponent spaces and complex function theory. (Received January 19, 2015)

1107-30-493 **Kourosh Tavakoli*** (`ktavakoli@okcu.edu`). *On Properties of Conformal-Like Metrics.*

In this talk I consider hyperbolic domains and define some conformal-like metrics on them. I will study several important properties related to these metrics. I will also compare these metrics in different aspects. (Received January 20, 2015)

32 ► Several complex variables and analytic spaces

1107-32-239 **David B. Massey*** (`d.massey@neu.edu`), Dept. of Mathematics, Northeastern University, Boston, MA 02115. *A New Invariant for 1-dimensional Hypersurface Singularities.*

We define and explore a new numerical invariant for hypersurfaces with 1-dimensional critical loci: the beta number. The beta number is an invariant of the ambient topological-type of the hypersurface, is non-negative, and is algebraically calculable.

The beta number being zero places strong restrictions on the vanishing cycles of the hypersurface; exactly how strong the restrictions are remains an open question. (Received January 16, 2015)

34 ► Ordinary differential equations

1107-34-12 **Michael Victor Klibanov*** (`mklibanv@uncc.edu`), Department of Mathematics and Statistics, University of North Carolina at Charlotte, Charlotte, NC 28223. *Globally convergent numerical methods for coefficient inverse problems with experimental data.*

Conventional numerical methods for Coefficient Inverse Problems (CIPs) do not have a rigorously guaranteed convergence, unless their starting points are located in a small neighborhood of the solution. In other words, those are locally convergent methods.

Thus, the most important question to address when solving a CIP is: How to rigorously obtain at least one point in a small neighborhood of the solution, provided that no a priori information is available about this neighborhood?

The author calls any numerical method addressing this question "globally convergent numerical method".

The topic of global convergence has been studied by the author in 1995-1997 with renewed interest in 2008-2015. His ideas have strong roots in the Bukhgeim-Klibanov method (1981) of Carleman estimates, which enables to prove global uniqueness and stability results for a wide class of CIPs.

Two types of globally convergent numerical methods for CIPs will be presented. For the first type, successful results of working with experimental data will be presented as well. This is because numerical studies for this type are most advanced at this moment.

For the second type, successful results of numerical experiments with computationally simulated data will be presented. (Received October 17, 2014)

1107-34-87 **Carey Caginalp***, Brown University, Applied Mathematics, 182 George St, Providence, RI 02912. *Effects of White Noise in Multistable Dynamics in Differential Equations.*

The concept of stable equilibrium plays a key role in the theory of ordinary and partial differential equations. A given initial condition uniquely determines how the system evolves to a particular stable equilibrium point. An important question that one can ask involves introducing white noise into the problem, and how even a perturbation by a very small amount of noise can influence which particular equilibirum point to which the system will evolve. Multiscale dynamics are well-known to describe practical examples such as patterns in physics, chemistry, and biology. Mathematically, a prototypical multistep dynamics can be described by $u' = 4\,(u-\alpha)\left(1-u^2\right)$, where $\alpha \in [0,1)$, and $u = \pm 1$ are stable equilibria. In particular, for $0 < \alpha < 1$, the equilibrium $u = -1$ is regarded as more stable than $u = 1$, since the probability of ending up at -1 is greater. This is joint work with Xinfu Chen, Jianghao Hao, and Yajing Zhang. (Received January 02, 2015)

1107-34-127 **Nourridine Siewe***, nourridine@aims.ac.za, and **Abdul-Aziz Yakubu**, **Abhay R Satoskar** and **Avner Friedman**. *Immune Response to Infection by Leishmania: A Mathematical Model.*

Leishmaniasis is a disease caused by the Leishmania parasites. The injection of the parasites into the host occurs when a sand fly, which is the vector, bites the skin of the host. The parasites, which are obligate, take advantage of the immune system response and invade both the classically activated macrophages (M1) and the alternatively activated macrophages (M2). In this paper we develop a mathematical model to explain the evolution of the disease. Simulations of the model show that, initially, M2 macrophages are dominant over M1 macrophages, but there exists a “switching time” (approximately two months) by which the M1 become dominant. The model also shows that the infection first increases but eventually decreases to a steady state in which only the M1 macrophages and the parasites within them remain as residuals. (Received January 09, 2015)

1107-34-142 **James Walsh*** (jawalsh@oberlin.edu) and **Christopher Rackauckas**. *New Budyko-type models of a slushball Earth.*

We present two new Budyko-type models appropriate for the extensive glacial periods of the Neoproterozoic Era. In each case we prove the existence of a stable ice sheet with ice edge in tropical latitudes (a “slushball” climate state). Tools used in the analysis include geometric singular perturbation theory and Filippov’s theory of differential inclusions. (Received January 11, 2015)

1107-34-147 **Donald L. DeAngelis*** (ddeangelis@bio.miami.edu), Biology Department, University of Miami, 1301 Memorial Drive, Coral Gables, FL 33124, **Bo Zhang** (bo@bio.miami.edu), Biology Department, University of Miami, 1301 Memorial Drive, Coral Gables, FL 33124, and **Wei-Ming Ni** (wmni@umn.edu), School of Mathematics, Univesity of Minnesota, Minneapolis, MN 55455. *Modeling Allee Effect on Population Invasion of a Patchy, Heterogeneous Environment.* Preliminary report.

A recent result for a reaction-diffusion partial differential equation is that a population diffusing at an intermediate rate in an environment in which resources vary spatially will reach a higher total equilibrium biomass than the population in an environment in which the same total resources are distributed homogeneously. This result, originally proven for the case in which the reaction term has only one parameter, m(x) (x is spatial distance), that is both the growth rate coefficient and carrying capacity of the population, has been extended to the logistic reaction term, with independent parameters, r(x) for intrinsic growth rate, and K(x) for carrying capacity. When r(x) and K(x) are proportional, the earlier results still hold. Here we add an Allee effect to the logistic model, in which the Allee threshold, A, for a population to invade is the same at each point in space, but the growth rate of the population varies spatially. When there is diffusion in space, invasion can occur even though the initial population averaged across space is less than the population level needed to exceed the Allee threshold. Criteria for invasion of a patchy environment are presented and studied with simulations. (Received January 11, 2015)

1107-34-176 **David Colton*** (colton@math.udel.edu). *Transmission Eigenvalues for Spherically Stratified Media.*

The transmission eigenvalue problem plays a central role in the qualitative approach to inverse scattering theory (c.f. F. Cakoni and D. Colton, A Qualitative Approach to Inverse Scattering Theory, Springer, 2014). In this talk we consider the transmission eigenvalue problem for spherically stratified media such that the eigenfunctions are also spherically stratified. Even this simple case has a surprisingly rich analytic theory. In this talk we will show that, for non-absorbing media, complex eigenvalues exist in general (but not always!) and under certain conditions lie in a strip parallel to the real axis (but under other conditions do not lie in a strip!). In general real eigenvalues always exist but there are examples for which real eigenvalues do not exist. We will also briefly consider the case of absorbing media and will conclude our talk with the inverse spectral problem for non-absorbing media. This is joint work with Y.J. Leung and S. Meng. (Received January 13, 2015)

1107-34-472 **Raquel Hontecillas**, **Monica Viladomiu**, **Vida Abedi**, **Casandra Philipson**, **Stefan Hoops** and **Josep Bassaganya-Riera*** (jbassaga@vt.edu), Blacksburg, VA 24060. *Computational modeling of mechanisms underlying immune responses to Helicobacter pylori.*

Modeling Immunity to Enteric Pathogens (MIEP) has developed the computational modeling infrastructure and experimental systems to generate computational hypotheses that guide validation immunology experiments. Multiscale modeling (MSM) allows simulating intra-cellular signaling pathways, molecular-cellular interaction networks, cell-cell interaction networks and host-pathogen interaction networks simultaneously. Enteric Immunity Simulator (ENISI) MSM was engineered to develop models at four scales of spatiotemporal magnitude: from microseconds for biochemical reactions, to hours for cellular phenotype change, and to days for induction of immune responses; and from nanometer for molecules, to micrometer for cells, and to millimeter for host-pathogen interactions. Through the development of novel computational models of immune responses to Helicobacter pylori and modeling tools MIEP greatly enhanced our understanding of the dual role of this bacterium as a commensal versus pathogenic organism and characterized the underlying immune responses. We are using MIEP's ENISI modeling platform to investigate cell-specific immune responses to H. pylori in the stomach that lead to chronicity of infection versus efficient eradication of the organism. (Received January 20, 2015)

1107-34-483 **Juliann Leifeld*** (leif0020@umn.edu). *Smooth and Nonsmooth Bifurcation Structures in an Ocean Convection Model.*

In conceptual climate modeling, nonsmooth models are prolific. However, it has been demonstrated that there are challenges to bifurcation analysis in nonsmooth systems, which do not arise in their smooth counterparts. We explore the bifurcation structure in a low dimensional ocean convection model, in which oscillatory behavior depends on an abrupt transition between mixing states. We put particular emphasis on the relationship between the smooth model and the limit as the transition becomes nonsmooth. (Received January 20, 2015)

35 ► Partial differential equations

1107-35-11 **Yuri A. Melnikov*** (yuri.melnikov@mtsu.edu), 1301 E. Main Street, Murfreesboro, TN 37132, and **Volodymyr Borodin** (vb2m@mtmail.mtsu.edu). *Green's functions for boundary-value problems simulating potential fields in regions of irregular configuration on surfaces of revolution.*

An intensive effort had been undertaken in recent decades on the construction of Green's functions and their incorporation into numerical schemes of the classical boundary integral equation method and its numerous modifications. Accumulated so far extensive database explicitly demonstrates computational potential of the already developed Green's-function-based numerical algorithms. In the present study, a specific class of boundary-value problems is targeted that simulate potential fields induced in thin-walled structures of irregular configuration. The latter represent either single thin shell fragments or assemblies of those made of homogeneous isotropic materials. Elements of the considered assemblies might be weakened with apertures. The targeted problems are tackled by the Green's function modification [2] of the functional equation method [1]. Required for that resolving Green's functions are analytically constructed prior to the actual computer work.

1. V.D. Kupradze and M.A. Aleksidze, The method of functional equations for the approximate solution of certain boundary-value problems, USSR CMMP, 4 (1964) 82-126; 2. Yu.A. Melnikov, Some applications of the Green's function method in mechanics, Int. J. of Solids and Structures, 13 (1977) 1045-1058. (Received November 11, 2014)

1107-35-13 **Muhammad Shabeer*** (m.shabeer@qu.edu.qa), Department of Mathematics, Foundation Program, Qatar University, Doha, 2713, Qatar, and **Muhammad Tahir Mustafa** (tahir.mustafa@qu.edu.qa), Department of Math, Physics and Statistics, Qatar University, Doha, 2713, Qatar. *New non-travelling wave solutions of porous Fisher equation using symmetries and sinh-cosh function ansatze.*

The main aim of this work is to investigate solutions of porous Fisher equation of the form

$$\frac{\partial u}{\partial t} - \frac{\partial}{\partial x}\left(u\frac{\partial u}{\partial x}\right) = u\,(1-u) \qquad (1).$$

Such equations are relevant in understanding physical models where the population disperses to regions of lower density more rapidly as the population gets more crowded. Travelling wave solutions of Equation (1) have been widely studied. We investigate for non-travelling wave type solutions of Equation (1) and obtain some new explicit analytic solutions. The scheme for construction of these solutions utilizes a combination of similarity transformations and ansatze involving sinh or cosh functions. The new non-travelling wave type solutions obtained here may provide a new perspective in understanding the Biological models represented by Fisher equation (1). Furthermore, the results suggest that the sinh-ansatz or cosh-ansatz seem natural ansatze for reaction diffusion type equations and provide good candidates for determining solutions of such equations via similarity transformations. (Received January 01, 2015)

1107-35-15 **Isaac Harris*** (iharris@udel.edu), Department of Mathematical Sciences, University of Delaware, 501 Ewing Hall, Newark, DE 19716, and **Fioralba Cakoni** (cakoni@math.udel.edu), Department of Mathematical Sciences, University of Delaware, 501 Ewing Hall, Newark, DE 19716. *The Factorization Method for a Defective Region in an Anisotropic Material.*

In this presentation we consider the inverse acoustic or electromagnetic scattering problem of reconstructing possibly multiple defective penetrable regions in a known anisotropic material of compact support. We develop the factorization method for a non-absorbing anisotropic background media containing penetrable defects. In particular, under appropriate assumptions on the anisotropic material properties of the media we develop a rigorous characterization for the support of the defective regions form the given fair eld measurements. Finally we present some numerical examples in the two dimensional case to demonstrate the feasibility of our reconstruction method including examples for the case when the defects are voids (i.e. subregions with refractive index the same as the background outside the inhomogeneous hosting media). (Received October 22, 2014)

1107-35-24 **Yongjin Lu*** (ylu@vsu.edu), Department of Mathematics and Economics, PO Box 9068, Petersburg, VA 23806. *Uniform stabilization to equilibria of a nonlinear fluid structure interaction model.*

We consider uniform stability to a nontrivial equilibrium of a nonlinear fluid structure interaction (FSI) defined on a two or three dimensional bounded domain. It is shown that interior fully supported feedback applied to the fluid equation and a boundary or localized feedback applied to the wave does produce exponential decay rates to an unstable equilibrium of FSI with static interface. This is achieved by building multipliers based on Stokes-Dirichlet solver fed to the fluid via boundary traces on the interface. (Received November 14, 2014)

1107-35-42 **Alain Miranville*** (miranv@math.univ-poitiers.fr), Universite de Poitiers, Mathematiques, SP2MI, Futuroscope, 86962. *The phase-field crystal model with a logarithmic nonlinear term.*

Our aim in this talk is to discuss the well-posedness of the phase-field crystal model with a logarithmic nonlinear term. In particular, we prove the existence and uniqueness of variational solutions, based on a variational inequality. (Received December 08, 2014)

1107-35-44 **Michael Renardy*** (mrenardy@math.vt.edu), Department of Mathematics, 225 Stanger St., Virginia Tech, Blacksburg, VA 24061-0123. *From the maximum principle to inverting the future.*

We prove that a C_0-semigroup of operators $\exp(At)$ satisfies backward uniqueness if the resolvent of A exists on a ray $z = re^{i\theta}$ in the left half plane ($\pi/2 < \theta \leq \pi$) and satisfies a bound $\|(A - zI)^{-1}\| \leq C\exp(|z|^\alpha)$, $\alpha < 1$ on this ray. The proof of this result is based on the Phragmen-Lindelöf theorem.

The result can be applied to PDE systems which in a sense perturb problems for which backward uniqueness does not hold. Examples include the linearized compressible Navier-Stokes equations in one space dimension and the wave equation with linear damping and absorbing boundary condition. (Received December 10, 2014)

1107-35-63 **Gunduz Caginalp*** (caginalp@pitt.edu), Math Dept, Univ of Pittsburgh, Pittsburgh, PA 15260. *Scaling and renormalization methods for higher order differential equations.*

Higher order (than two) equations arise in applications such as crsytal growth and phase field models. Methodology for equations higher than second order are scarce. This talk will focus on adapting methodology of statistical mechanics and quantum field theory to approximate solutions to an arbitrary order differential equation boundary value problem by a second order equation. In particular, we study equations involving the derivative of a double-well potential such as u-u^3 or -u+2u^3. Using momentum (Fourier) space variables we average over short length scales and demonstrate that the higher order derivatives can be neglected within the first cumulant approximation, once length is properly rescaled, yielding an approximation to solutions of the higher order equation from the second order. The results are confirmed using numerical computations. Additional numerics confirm that the main role of the higher order derivatives is in rescaling the length. Most of the talk will be on work in collaboration with Dr. Emre Esenturk. (Received December 21, 2014)

1107-35-84 **jiuyi zhu*** (jzhu43@math.jhu.edu), Department of Mathematics, Johns Hopkins University, Baltimore, MD 21218. *Quantitative uniqueness of elliptic equations.*

Based on a variant of frequency function, we improve the vanishing order of solutions for Schrödinger equations which describes quantitative behavior of strong uniqueness continuation property. For the first time, we investigate the quantitative uniqueness of higher order elliptic equations and show the vanishing order of solutions. Furthermore, strong unique continuation is established for higher order elliptic equations using this variant of frequency function. (Received January 15, 2015)

1107-35-104 **Mihaela Ifrim*** (ifrim@math.berkeley.edu) and **Daniel Tataru**. *The lifespan of small data solutions in two dimensional water waves.*

We consider water wave equations in two space dimensions expressed in position-velocity potential holomorphic coordinates, and prove that small data solutions have at least cubic lifespan, while small localized data leads to global solutions. (Received January 06, 2015)

1107-35-105 **László Székelyhidi, Jr.** and **Emil Wiedemann*** (emil.wiedemann@hcm.uni-bonn.de). *Measure-Valued Solutions of the Euler Equations.*

Measure-valued solutions of the incompressible Euler equations were first considered by DiPerna and Majda to describe effects of oscillation and concentration in ideal fluids. Although measure-valued solutions appear a priori as much weaker objects than distributional solutions, we have been able to show that both notions are in a sense equivalent. An important open question concerns the relation between weak and measure-valued solutions for compressible Euler models. (Received January 06, 2015)

1107-35-107 **Nets Hawk Katz** and **Andrew Tapay*** (atapay@indiana.edu). *A model for studying double exponential growth in the two-dimensional Euler equations.*

We introduce a model for the two-dimensional Euler equations that is designed to study whether or not double exponential growth can occur at an interior point of the flow. (Received January 06, 2015)

1107-35-109 **Justin T Webster*** (jtwebste@ncsu.edu), SAS Hall, Department of Mathematics, North Carolina State University, Raleigh, NC 27695, and **Irena Lasiecka** (lasiecka@memphis.edu), Memphis, TN 38152. *Panel flutter: Asymptotic-in-time regularity or uniform-in-time Hadamard continuity.*

Panel flutter is a well-known aeroelastic instability prevalent in the engineering literature. The canonical model couples a thin plate to a perturbed wave equation (potential flow) in the over-body half space. Well-posedness and global attraction properties for this model (in the absence of dissipation mechanisms) have been established recently. The results use of state-of-the art techniques for von Karman equations, PDEs with delay, and dissipative dynamical systems. Here we present stabilization results for the full flow-plate dynamics in the presence of control-theoretic damping. These address the problem of panel flutter from the PDE model, and corroborate physical observations that panel flutter does not occur in subsonic flows. We show that finite-energy subsonic flow-plate trajectories converge asymptotically to the set of stationary states (in the presence of viscous damping scaled according to plate loading). We show a decoupling of the plate dynamics into an asymptotically regular component and a component exhibiting uniform exponential decay. From this we infer a dichotomy: for a given flow-plate trajectory, the plate velocity decays exponentially (yielding Hadamard continuity on the infinite-time horizon) OR the trajectory is eventually smooth. (Received January 07, 2015)

1107-35-114 **Mahamadi Warma*** (mjwarma@gamil.com), University of Puerto Rico, Rio Piedras Campus, College of Natural Sciences, Department of Mathematics, San Juan, PR 00936.
The Pohozaev identity for the regional fractional Laplacian with fractional Neumann type boundary conditions

Let $\Omega \subset \mathbb{R}^N$ be a bounded open set of class $C^{1,1}$ with boundary $\partial\Omega$. We obtain the fractional version of the Pohozaev identity associated with the regional fractional Laplace operator defined on the open set Ω and satisfying a fractional Neumann type boundary conditions. An application to the existence of solutions of some semi-linear elliptic problem and some controllability and orbservability results of some evolution equations involving the regional fractional Laplace operator with fractional Neumann type boundary conditions are given.

The work of the author is partially supported by the Air Force Office of Scientific Research, Air Force Material Command, USAF under the Award No: FA9550-15-1-0027. (Received January 08, 2015)

1107-35-116 **James Nolen*** (nolen@math.duke.edu). *A simple PDE argument for the logarithmic term in the asymptotics of branching Brownian motion.*

I'll describe the asymptotic behavior of solutions to a KPP equation with variable coefficients. One can interpret the solution to the PDE in terms of a branching Brownian motion with variable branching rate. It is well-known that solutions to the Cauchy problem may behave asymptotically like a traveling wave. On the other hand, for certain initial data, M. Bramson proved that the solution to the Cauchy problem may lag behind the traveling wave by an amount that grows logarithmically in time. Using PDE arguments, we have extended this statement about the logarithmic delay to the case of periodic, spatially varying reaction rate; this corresponds to a branching Brownian motion with spatially-varying branch rate. The PDE approach involves the study of the linearized equation with Dirichlet condition on a moving boundary. The method also gives refined asymptotics for the solution to the equation with time-varying coefficients. This is joint work with Francois Hamel, Jean-Michel Roquejoffre, and Lenya Ryzhik. (Received January 08, 2015)

1107-35-117 **Wenxiong Chen**, **Lorenzo D' Ambrosio** and **Yan Li*** (yali3@mail.yu.edu), 500 West 185th Street, New York, NY 10033. *Some Liouville theorems for the fractional Laplacian.*

In this paper, we prove the following result. Let α be any real number between 0 and 2. Assume that u is a solution of

$$\begin{cases} (-\Delta)^{\alpha/2} u(x) = 0, \quad x \in \mathbb{R}^n, \\ \underline{\lim}_{|x|\to\infty} \dfrac{u(x)}{|x|^\gamma} \geq 0, \end{cases}$$

for some $0 \leq \gamma \leq 1$ and $\gamma < \alpha$. Then u must be constant throughout $\mathbb{R}^n$.

This is a Liouville Theorem for α-harmonic functions under a much weaker condition.

For this theorem we have two different proofs by using two different methods: One is a direct approach using potential theory. The other is by Fourier analysis as a corollary of the fact that the only α-harmonic functions are affine. (Received January 08, 2015)

1107-35-118 **Wenxiong Chen*** (wchen@yu.edu), 2495 Amsterdam Av, New York, NY 10033, and **Congming Li** (cli@colorado.edu) and **Yan Li** (yali3@yu.edu). *A direct method of moving planes for the fractional Laplacian.*

In this talk, we will introduce a direct *method of moving planes* for the fractional Laplacian. Instead of using the conventional extension method introduced by Caffarelli and Silvestre, we work directly on the non-local operator. Using the integral defining the fractional Laplacian, by an elementary approach, we first obtain the key ingredients needed in the *method of moving planes* either in a bounded domain or in the whole space, such as *strong maximum principles for anti-symmetric functions*, *narrow region principles*, and *decay at infinity.* Then, using simple examples, semi-linear equations involving the fractional Laplacian, we illustrate how this new *method of moving planes* can be employed to obtain symmetry and non-existence of positive solutions.

We firmly believe that the ideas introduced here can be applied to more general non-local operators with much more general nonlinearities. (Received January 08, 2015)

1107-35-119 **Sergio P. Frigeri** and **Joseph L. Shomberg*** (jshomber@providence.edu), 1 Cunningham Square, 212 Howley Hall, Providence, RI 02918. *Attractors for Damped Semilinear Wave Equations with a Robin–Acoustic Boundary Perturbation.* Preliminary report.

Under consideration is the damped semilinear wave equation

$$u_{tt} + u_t - \Delta u + u + f(u) = 0$$

on a bounded domain Ω in $\mathbb{R}^3$ with a perturbation parameter $\varepsilon > 0$ occurring in an acoustic boundary condition, limiting ($\varepsilon = 0$) to a Robin boundary condition. With minimal assumptions on the nonlinear term f, the existence and uniqueness of global weak solutions is shown for each $\varepsilon \in [0, 1]$. Also, the existence of a family of global attractors is shown to exist (re: J. Ball's generalized semiflows). After proving a general result concerning the upper-semicontinuity of a one-parameter family of sets, the result is applied to the family of global attractors. No further regularity from the global attractors is needed in order to obtain this upper-semicontinuity result. With more relaxed assumptions on the nonlinear term f, we are able to show the global attractors possess optimal regularity and prove the existence of an exponential attractor, for each $\varepsilon \in [0, 1]$. This result insures that the corresponding global attractor inherits finite (fractal) dimension; however, the dimension is *not* necessarily uniform in ε. (Received January 08, 2015)

1107-35-136 **Fabio Pusateri*** (fabiop@math.princeton.edu). *Capillary water waves in 2d.*
We consider the irrotational water waves system in infinite depth and discuss a global regularity result for perturbations of a flat one dimensional interface in the presence of surface tension. (Received January 10, 2015)

1107-35-139 **Alexander Kiselev**, **Lenya Ryzhik**, **Yao Yao*** (yaoyao@math.wisc.edu) and **Andrej Zlatos**. *Finite time singularity of a vortex patch model in the half plane.*
The question of global regularity vs. finite time blow-up remains open for many fluid equations. In this talk, I will discuss an active scalar equation which is an interpolation between the 2D Euler equation and the surface quasi-geostrophic equation. We study the patch dynamics for this equation in the half-plane, and prove that the solutions can develop a finite-time singularity. (Received January 10, 2015)

1107-35-155 **Tarek M Elgindi***, PACM, Fine Hall, Washington Road, Princeton, NJ 08544. *Some results on singular transport equations.*
The talk will focus on transport equations with singular-integral forcing. These are equations of the form:

$$\partial_t f + b \cdot \nabla_x f = R_x(f)$$

where b is a given divergence-free vector field and R_x is a singular integral operator. This type of transport equation shows up often in the study of fluid equations and can be seen as a prototype for many equations which exhibit local and non-local forces. We are interested in solutions in L^p spaces.

When b is a Lipschitz function:

(1) The singular transport equation may be ill-posed in L^∞ in the sense that bounded initial data may become unbounded immediately.

(2) The singular transport equation is well-posed in the class of functions of bounded mean oscillation (BMO).

(3) The singular transport equation exhibits "well-behaved" growth properties in L^p.

When b is only taken to be bounded:

(1') The singular transport equation may have what we call "cascading solutions" starting from smooth initial data. These solutions belong to L^p for all $p < \infty$ with L^p norms growing on the order of $exp(p)$.

We will discuss most of these results quickly and then focus on the constructions which lead to (1'). (Received January 12, 2015)

1107-35-158 **Chiu-Yen Kao**, **Alexander Kurganov**, **Zhuolin Qu** and **Ying Wang*** (wang@math.ou.edu). *A Fast Explicit Operator Splitting Method for Modified Buckley-Leverett Equations.*
In this talk, I will discuss a fast explicit operator splitting method to solve the modified Buckley-Leverett equations which include a third-order mixed derivatives term resulting from the dynamic effects in the pressure difference between the two phases. The method splits the original equation into two equations, one with a nonlinear convective term and the other one with high-order linear terms so that appropriate numerical methods can be applied to each of the split equations: The high-order linear equation is numerically solved using a pseudo-spectral method, while the nonlinear convective equation is integrated using the Godunov-type central-upwind scheme. A variety of numerical examples in both one and two space dimensions show that the solutions may have many different saturation profiles depending on the initial conditions, diffusion parameter, and the third-order mixed derivatives parameter. The results are consistent with the study of traveling wave solutions and their bifurcation diagrams. This is a joint work with C.-Y. Kao, A. Kurganov, and Z.-L. Q (Received January 12, 2015)

1107-35-159 **Kristina Martin*** (kmmarti6@ncsu.edu), Department of Mathematics, Box 8205 NC State University, Raleigh, NC 27695-8205, and **Lucas Castle**, **Lorena Bociu**, **Daniel Toundykov** and **Jean-Paul Zolesio**. *Optimal Control in a Free Boundary Fluid-Elasticity Interaction.* Preliminary report.

We consider an optimal control problem involving a free boundary fluid-elasticity interaction described by Navier-Stokes coupled with the equations of nonlinear elastodynamics. We prove that turbulence in the fluid flow can be minimized using a distributed control and discuss the first order necessary optimality conditions. This is work in progress in collaboration with Lorena Bociu, Lucas Castle (North Carolina State University), Daniel Toundykov (University of Nebraska, Lincoln), and Jean-Paul Zolesio (INRIA and CNRS-INLN, Sophia-Antipolis, France). (Received January 12, 2015)

1107-35-168 **Keith Leitmeyer***, kl2ju@virginia.edu. *Enstrophy Cascade in Physical Scales for the 3D Navier-Stokes Equations.*

An enstrophy cascade is exhibited for the 3D Navier-Stokes equations in physical scales independently of boundary conditions under physically reasonable assumptions on the flow. (Received January 13, 2015)

1107-35-175 **Robert Stephen Cantrell*** (rsc@math.miami.edu) and **Daniel Ryan**. *Avoidance behavior in intraguild communities: A cross-diffusion model.*

A cross-diffusion model of an intraguild predation community where the intraguild prey employs a fitness based avoidance strategy is examined. The avoidance strategy employed is to increase motility in response to negative local fitness. Global existence of trajectories and the existence of a compact global attractor is proved. It is shown that if the intraguild prey has positive fitness at some point in the habitat when trying to invade, then it will be uniformly persistent in the system if its avoidance tendency is sufficiently strong. This type of movement strategy can lead to coexistence states in which the intraguild prey is marginalized to areas with low resource productivity while the intraguild predator maintains high densities in regions with abundant resources, a pattern observed in many real world intraguild predation systems. (Received January 13, 2015)

1107-35-178 **Xuecheng Wang*** (xuecheng@math.princeton.edu), 408 Fine Hall, Washington Road, Princeton, NJ 08544. *Global infinite energy solutions for the 2D gravity water waves system.*

We consider the infinite depth gravity water waves system (without surface tension) in dimension two and prove the global existence and the modified scattering properties of solution for a class of initial data, which has arbitrary large energy and is small at the level above the Hamiltonian. More precisely, for the gravity water waves system, the Hamiltonian is at level $L^2 \times \dot{H}^{1/2}$, we only require smallness above the level $\dot{H}^{1/5} \times \dot{H}^{1/5+1/2}$ to derive global solution. Here 1/5 is an absolute constant, it doesn't depend on the pre-assumed appropriate growth rate of Sobolev norm. Equivalently, for this class of initial data, the growth rate is subpolynomial and a typical example of initial data is that, it has a small, nonzero amplitude and flat for a long range and then goes to zero at infinity. (Received January 13, 2015)

1107-35-185 **Yu Deng*** (yudeng@math.princeton.edu), Fine Hall, Princeton University, Princeton, NJ 08544. *Global solutions to 3D Klein-Gordon systems.*

Consider a quasilinear Klein-Gordon system
$$(\partial_t^2 - b_j^2\Delta + c_j^2)u_j = \mathcal{N}_j(u, \partial^2 u), \qquad 1 \le j \le A$$
with a suitable symmetry assumption on the nonlinearity. We prove that, for *all* parameters (b_j, c_j), the system has global solutions for small initial data. This extends a previous result of Ionescu-Pausader to allow for degenerate interactions. (Received January 14, 2015)

1107-35-186 **Francesca Bucci*** (francesca.bucci@unifi.it), Dipartimento di Matematica e Informatica, Via S. Marta, 3, 50139 Firenze, Italy. *Stability analysis and control theoretic properties of a fluid-structure interaction.*

The talk will deal with certain analytical properties of a well-recognized mathematical model for a fluid-structure interaction (FSI). The Partial Differential Equation (PDE) system comprises linearized Navier-Stokes equations for the dynamics of a (viscous, incompressible) fluid in a container $\mathcal{O}$, and an elastic plate equation for the displacements of a part of its boundary. We will report recently obtained results about uniform stability properties of solutions to the PDE problem, in the absence of dissipation in the plate equation, whose proof is based on a frequency domain analysis rather than on energy/multiplier methods.

In addition, we will discuss the distinct features of the FSI under significant boundary control actions, along with the consequent challenges which are encountered in the study of associated optimal control problems (with

quadratic functionals). A comparison with different FSI will be provided.
(The talk is based on joint work with George Avalos (University of Nebraska-Lincoln, USA)) (Received January 14, 2015)

1107-35-191 **Fioralba Cakoni*** (fcakoni@udel.edu), 505 Ewing Hall, Department of Mathematical Sciences, University of Delaware, Newark, DE 19716. *A Qualitative Approach to the Inverse Scattering Problem for Inhomogeneous Media.*

Since the introduction of the linear sampling method in 1996 followed by the factorization method in 1998 and later the first proof of the existence of transmission eigenvalues in 2008, qualitative methods have become a popular method for solving inverse scattering problems. Interest in this area has exploded and the vast amount of literature currently available is an indication of the myriad directions that this research has taken. In this talk we consider the inverse scattering problem for an inhomogeneous (possibly anisotropic) media and show how to obtain information about the support as well as the physical properties of the media based on the investigation of the corresponding far field operator. In particular, we will discuss the relevance and state of the art of the transmission eigenvalue problem and present what type of information transmission eigenvalues provide about the inhomogeneity. (Received January 14, 2015)

1107-35-193 **Stephen Pankavich*** (pankavic@mines.edu), Dept. of Applied Mathematics and Statistics, Colorado School of Mines, 1500 Illinois St., Golden, CO 80401. *The Spatially Heterogeneous Dynamics of HIV in-vivo.* Preliminary report.

The Human Immunodeficiency Virus type-1 (HIV) is one of the most intensely studied viral pathogens in human history. Despite this vast effort, many aspects of HIV infection dynamics and disease pathogenesis within a host are still not understood. Here, we propose a new model of viral propagation in-vivo that generalizes the standard lumped population model by allowing susceptible and infected T-cells, as well as HIV virions, to move diffusively throughout a host region. In particular, we will elucidate the contributions of spatial fluctuations, correlations, and preferential infection to viral propagation in vivo using mathematical results concerning the long-time dynamics of the system. A few well-posedness results for this model, comprised of a nonlinear system of three parabolic PDEs, will also be briefly discussed. (Received January 14, 2015)

1107-35-198 **Steven J Derochers*** (sjderoch@ncsu.edu). *On the Semigroup Generator for the Total Linearization of a Hydro - Elasticity Model.*

We investigate the semigroup generator for the total linearization of a hydrodynamic model with respect to a forcing term. One of the key differences from the classical Stokes-elasticity system is that the elastic component gives rise to an elliptic problem with an oblique derivative, where the coefficients dependent on the curvature of the fluid-structure interface. We examine numerically and analytically the maximality of the evolution generator and the ellipticity of the elastic sub-problem. (Received January 14, 2015)

1107-35-209 **Changfeng Gui*** (changfeng.gui@uconn.edu). *Evaen Symmetry of Axially Symmetric Solutions of the Allen-Cahn Equation.*

In this talk, we will discuss the even symmetry in the direction of the axis for axially symmetric solutions of Allen-Cahn equation. The dimension of the space will play an important role in the proof, which is based on the asymptotic behavior of nodal sets of such solutions and the moving plane method. (Received January 15, 2015)

1107-35-224 **Nancy Rodriguez*** (nrod@unc.edu), **Henri Beretycki** and **Jean-Pierre Nadal**. *A model of riots dynamics: shocks, diffusion and thresholds.*

The need to understand how protests or riots are initiated and how they spread has been highlighted by many current events. A great example being the recent Ferguson, Missouri riots. In this talk I will introduce and analyze several variants of a system of differential equations which model the dynamics of social outbursts, such as riots. The systems involve the coupling of an explicit variable representing the intensity of rioting activity and an underlying (implicit) field of social tension. These models include the effects of exogenous and endogenous factors as well as various propagation mechanisms. From numerical and mathematical analysis of these models we show that the assumptions made on how different locations influence one another and how the tension in the system disperses play a major role on the qualitative behavior of bursts of social unrest. I analyze here various properties of these systems, such as the existence of traveling wave solutions and the effect of some heterogeneous environments. (Received January 15, 2015)

1107-35-227 **Robert Stephen Cantrell**, **Chris Cosner** and **King-Yeung Lam***, Department of Mathematics, The Ohio State University, 231 W 18th Ave, Columbus, OH 43210.
Resident-invader dynamics in infinite-dimensional dynamical systems.

We study the resident-invader dynamics for a class of models of spatial population with a one-dimensional trait, or strategy. We generalize the "tube theorem" by Geritz et. al. to infinite-dimensional setting and move on to prove various global dynamical results on coexistence and exclusion, based on local invasibility criterions including the notions of evolutionary stability and convergence stability in adaptive dynamics. Applications of our abstract results includes reaction-diffusion-advection models and nonlocal dispersal models. This leads to the novel conclusion that a recently established evolutionarily stable dispersal strategy in [Lam-Lou, J. Math. Biol. (2013)] is a neighborhood invader strategy. This is joint work with R.S. Cantrell (Miami) and C. Cosner (Miami). (Received January 15, 2015)

1107-35-228 **Xiang Wan*** (xiangwan@virginia.edu) and **Irena Lasiecka** (lasiecka@memphis.edu).
Global Wellposedness and Uniform Stability of a Quasilinear Thermo-elastic PDE system. Preliminary report.

We consider a nonlinear thermoelastic system defined on an open bounded set $\Omega \in \mathbb{R}^n, n = 2$ or 3:

$$\begin{cases} w_{tt} - \gamma\Delta w_{tt} + \Delta^2 w + \alpha\Delta((\Delta w)^3) = \Delta\theta \\ \theta_t - \Delta\theta = -\Delta w_t \\ \gamma \geq 0 \end{cases} \tag{1}$$

with simply supported boundary conditions imposed on $\Gamma = \partial\,\Omega$. The main goal of this talk is to discuss the wellposedness of suitable solutions to the system defined above.

I will first introduce the background of this model, and then talk about the work on the case $\gamma = 0$. Our challenge is to consider the case $\gamma > 0$, which is of hyperbolic type-rather than of parabolic type. From a mathematical point of view the most important message is that the *analyticity* and *maximal regularity* of the associated linear system are *gone*. We will show the technique to overcome this difficulty. (Received January 15, 2015)

1107-35-245 **E. M. Lunasin*** (lunasin@usna.edu), United States Naval Academy, Department of Mathematics, 572C Holloway Road, Chauvenet Hall, Annapolis, MD 21402, and **E. S. Titi**, Department of Mathematics, Texas A&M University, College Station, TX 77843.
Finite determining parameters feedback control for distributed nonlinear dissipative systems – a computational study.

We present a numerical study of a new algorithm for controlling general dissipative evolution equations using determining systems of parameters like determining modes, nodes and volume elements. We implement the feedback control algorithm for the Chafee-Infante equation, a simple reaction diffusion equation and the Kuramoto-Sivashinsky equation, a model for flame front propagation or flowing thin films on inclined surface. Other representative applications include catalytic rod, chemical vapor deposition and other defense-related applications. We also discuss stability analysis for the feedback control algorithm and derive sufficient conditions, for the stabilization,, relating the relaxation parameter, number of controllers and sensors, and other model parameters. (Received January 16, 2015)

1107-35-247 **Alexey Cheskidov** and **Karen Zaya*** (kzaya2@uic.edu). *Lower Bounds for Sobolev Norms of Potential Blow Up Solutions to the Three-dimensional Navier-Stokes Equations.* Preliminary report.

We improve previous known lower bounds for Sobolev norms of potential blow up solutions to the three-dimensional Navier-Stokes equations. (Received January 16, 2015)

1107-35-248 **Guozhen Lu*** (gzlu@wayne.edu), Department of Mathematics, Wayne State University, Detroit, MI 48202, **Hanli Tang**, School of Mathematical Sciences, Beijing Normal University, and **Maochun Zhu**, School of Mathematical Sciences, Beijing Normal University. *Sharp Moser-Trudinger inequality on hyperbolic spaces and Adams inequality with the exact growth condition.*

In this talk, we will report some recent works on best constants for sharp Moser-Trudinger inequalities on high dimensional hyperbolic spaces with exact growth. This part is joint work with Hanli Tang. We will also present best constants for sharp Adams inequality with the exact growth condition in the entire Euclidean spaces. This part of the talk is joint work with Hanli Tang and Maochun Zhu. (Received January 16, 2015)

1107-35-254 **George Avalos*** (gavalos@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, Nebraska 68588, Lincoln, NE 68588. *Concerning the Nonlinear Analysis of a Fluid-Structure Interactive PDE Model.*

In this talk we shall focus on current work involving the wellposedness for a coupled partial differential equation model which governs a certain fluid-structure interaction. The basis of our approach is an argumentation thematically similar to that of Z. Yosida and Y. Giga, which was originally invoked for the (uncoupled) Navier-Stokes equations. This is joint work with Pelin Güven Geredeli of Hacettepe University (Turkey). (Received January 16, 2015)

1107-35-261 **Luis Silvestre** and **Vlad Vicol*** (vvicol@math.princeton.edu), Fine Hall, Washington Road, Princeton, NJ 08544. *On a transport equation with nonlocal drift.*

Cordoba, Cordoba, and Fontelos proved that for some initial data, the following nonlocal-drift variant of the 1D Burgers equation does not have global classical solutions

$$\partial_t\theta + u\partial_x\theta = 0, u = H\theta,$$

where H is the Hilbert transform. We provide four essentially different proofs of this fact. Moreover, we study possible Holder regularization effects and conjecture that solutions which arise as limits from vanishing viscosity approximations are bounded in the Holder class in $C^{1/2}$ for all positive time. (Received January 16, 2015)

1107-35-262 **Tristan Buckmaster*** (buckmaster@cims.nyu.edu). *Onsager's Conjecture.*

In 1949, Lars Onsager in his famous note on statistical hydrodynamics conjectured that weak solutions to the Euler equation belonging to Hölder spaces with Hölder exponent greater than 1/3 conserve energy; conversely, he conjectured the existence of solutions belonging to any Hölder space with exponent less than 1/3 which dissipate energy.

The first part of this conjecture has since been confirmed (cf. Eyink 1994, Constantin, E and Titi 1994). During this talk we will discuss recent work by Camillo De Lellis, László Székelyhidi Jr., Philip Isett and myself related to resolving the second component of Onsager's conjecture. In particular, we will discuss the construction of weak non-conservative solutions to the Euler equations whose Hölder $1/3 - \epsilon$ norm is Lebesgue integrable in time. (Received January 16, 2015)

1107-35-265 **Francois Hamel*** (francois.hamel@univ-amu.fr), Institut de Mathematiques de Marseille, Aix Marseille Université, 39 rue Frederic Joliot-Curie, 13453 Marseille, France. *Bistable transition fronts.*

The standard notions of reaction-diffusion fronts can be viewed as examples of generalized transition fronts describing the invasion of a state by another one. These notions involve uniform limits, with respect to the geodesic distance, to a family of hypersurfaces which are parametrized by time. The existence of transition fronts has been proved in various contexts where the standard notions of fronts make no longer sense. Even for homogeneous equations, fronts with various non-planar shapes or with varying speeds are known to exist. In this talk, I will report on some recent existence results and qualitative properties of transition fronts for bistable equations. I will also discuss their mean speed of propagation. (Received January 17, 2015)

1107-35-271 **Dana Mendelson*** (dana@math.mit.edu). *Symplectic non-squeezing for the cubic nonlinear Klein-Gordon equation on $\mathbb{T}^3$.*

We consider the periodic defocusing cubic nonlinear Klein-Gordon equation in three dimensions in the symplectic phase space $H^{\frac{1}{2}}(\mathbb{T}^3) \times H^{-\frac{1}{2}}(\mathbb{T}^3)$. In this space, the global well-posedness of this equation is still open and there is no uniform control on the local time of existence of solutions. We present a local in time non-squeezing result and a global in time non-squeezing result for certain open subsets of the phase space, with no smallness condition on the size of the initial data. We will first discuss how to define a subset of the phase space which has full measure, with respect to a suitable randomization, and on which the flow is globally defined. The proof of non-squeezing then relies on Gromov's non-squeezing theorem and an approximation result for the flow, which uses probabilistic estimates for the nonlinear component of the flow map and deterministic critical stability theory. (Received January 17, 2015)

1107-35-274 **Nguyen Lam*** (nhlam@pitt.edu), Department of Mathematics, 301 Thackeray Hall, Pittsburgh, PA 15260. *Sharp Moser-Trudinger-Adams inequalities and Applications to PDEs.*

In this talk, we will discuss the border-line cases of the Sobolev embedding theorems and their applications in partial differential equations. In particular, we will describe the sharp Moser-Trudinger and Adams inequalities and their best constants for the inequalities to hold on Euclidean spaces and Heisenberg groups. Recent development in this direction will be surveyed. This talk is based on joint works with Guozhen Lu and Hanli Tang. (Received January 17, 2015)

1107-35-276 **Rafael de la Llave***, 686 Cherry St., Atlanta, GA 30332, and **Yannick Sire**. *An a-posteriori KAM theorem that applies even to ill-posed Hamiltonian PDE.*

We consider the existence of quasi-periodic solutions in Hamiltonian PDE. We formulate an invariance equation for an embedding. We show that if there functions that satisfy this equation up to an small errror and that they satisfy some non-degeneracy conditions, then, there is a true solution close to the approximate one.

Note that this does not require that the PDE is well posed.

We present some applications to some well known ill posed equations. (Received January 17, 2015)

1107-35-282 **P. Jameson Graber*** (pjg140130@utdallas.edu), Naveen Jindal School of Management, The University of Texas at Dallas, 800 West Campbell Rd, SM30, Richardson, TX 75080. *Systems of quasilinear parabolic equations in mean field games.*

We consider systems of quasilinear parabolic equations of Hamilton-Jacobi/Fokker-Planck type. In contrast to standard mean field games, in which there is only one pair of equations, we consider multiple equations coupled by way of the quasilinear term. The model therefore characterizes a mean field Nash equilibrium multiple populations, each characterized by a different strategy. Combining the methods developed by Bensoussan and Frehse for Nash games with more recent techniques from mean field game theory, our goal is to show the existence of smooth solutions under standard assumptions on the coupling. (Received January 17, 2015)

1107-35-286 **Philip Isett***, isett@math.mit.edu. *Regularity in time along the coarse scale flow for the incompressible Euler equations.*

A remarkable feature of known, nonstationary solutions to incompressible Euler is the phenomenon that fine scale velocity fluctuations are carried along the coarse scale flow of the solution. We will discuss how this phenomenon is captured in the proofs of several time regularity results that hold for incompressible Euler flows (possibly with low regularity). Among these results are a proof of the smoothness of trajectories in a regime just below the threshold for well-posedness, and improved time regularity results for the pressure and kinetic energy profile. We will also discuss a strengthening of Onsager's conjecture proposed in the work, which offers an explanation as to why the failure of anomalous dissipation for Euler flows with spatial regularity less than 1/3 should be generic. (Received January 17, 2015)

1107-35-291 **Benjamin G Dodson*** (bdodson4@jhu.edu). *The I - method and the radial cubic nonlinear Schrodinger equation in three dimensions.*

In this talk we will discuss how the I - method obtains a well - posedness result for the radial, cubic nonlinear Schrodinger equation in three dimensions. This gives a global well - posedness result that is almost sharp at high frequencies. The main new ingredient is the long time Strichartz estimates. (Received January 17, 2015)

1107-35-294 **Benjamin Harrop-Griffiths*** (benhg@math.berkeley.edu), **Mihaela Ifrim** and **Daniel Tataru**. *Asymptotic behavior via testing against wave packets.*

We discuss some recent progress on the asymptotic behavior of dispersive PDE using the the method of testing by wave packets, originally developed by Ifrim and Tataru in the context of the 1d NLS and 2d water waves. (Received January 17, 2015)

1107-35-295 **Peter Constantin** and **Vlad Vicol*** (vvicol@math.princeton.edu), Fine Hall, Washington Road, Princeton, NJ 08544, and **Jiahong Wu**. *Analyticity of Lagrangian trajectories for well-posed inviscid incompressible fluid models.*

We discuss general incompressible inviscid models, including the Euler equations, the surface quasi-geostrophic equation, incompressible porous medium equation, and Boussinesq equations. All these models have classical unique solutions, at least for short time. We show that they have real analytic Lagrangian paths. More precisely, we show that as long as a solution of any of these equations is in a class of regularity that assures Holder continuous gradients of velocity, the corresponding Lagrangian paths are real analytic functions of time. The method of proof is conceptually straightforward and general, and we address the combinatorial issues head-on. (Received January 17, 2015)

1107-35-296 **Susan Friedlander**, **Nathan Glatt-Holtz** and **Vlad Vicol*** (vvicol@math.princeton.edu), Fine Hall, Washington Road, Princeton, NJ 08544. *Inviscid limits for a stochastically forced shell model of turbulent flow.*

We establish the anomalous mean dissipation rate of energy in the inviscid limit for a stochastic shell model of turbulent fluid flow. The proof relies on viscosity independent bounds for stationary solutions and on establishing ergodic and mixing properties for the viscous model. The shell model is subject to a degenerate stochastic forcing in the sense that noise acts directly only through one wavenumber. We show that it is hypo-elliptic (in the sense of Hormander) and use this property to prove a gradient bound on the Markov semigroup. (Received January 17, 2015)

1107-35-297 **Zhiwu Lin*** (zlin@math.gatech.edu) and **Chongchun Zeng**. *Linear instability and invariant manifolds for Hamiltonian PDEs.* Preliminary report.

We will discuss a general framework to study instability of coherent states (traveling waves, standing waves, steady states etc) for general Hamiltonian PDEs with an energy functional bounded from below. First, an instability index theorem is obtained for the eigenvalues of the linearized problem. Then, it is used to prove the exponential trichotomy estimate for the linearized equation. Applications to construct invariant manifolds will be briefly discussed. Some examples include Gross-Pitaevskii equation for superfluids, generalized KDV and Boussinesq equations, and 2D Euler equation for ideal fluids. This is a joint work with Chongchun Zeng. (Received January 17, 2015)

1107-35-311 **Jacob P Bedrossian*** (jacob@cscamm.umd.edu). *Nonlinear echo cascades in fluids and plasmas.*

Incompressible fluids and weakly collisional plasmas near certain kinds of equillibria experience a resonance phenomenon known as an echo. These arise from the interaction between the nonlinearity and the mixing/unmixing driven by the background equillibrium, for example, a shear flow or vortex in the case of fluids. They are considered the primary impediment to mixing and Landau or inviscid damping near these equillibria. We will discuss this resonance in fluids and plasmas and the various mathematical tools that have been developed to deal with them in different settings to deduce positive Landau/inviscid damping results. (Received January 18, 2015)

1107-35-314 **Theodore Dimitrios Drivas*** (thdrivas@gmail.com), 1 E. University Parkway, Apt 410, Baltimore, MD 21218, and **Gregory Eyink** (thdrivas@gmail.com). *Necessity of Spontaneous Stochasticity for Anomalous Scalar Dissipation.*

The "zeroth-law" of scalar turbulence states that scalar dissipation becomes independent of diffusivity in the infinite Peclet-number limit. This phenomenon has been rigorously proved to occur in the Kraichnan model where the Lagrangian mechanism was revealed to be spontaneous stochasticity of fluid particle trajectories.Here we show that for any advecting velocity field, including a Navier-Stokes solution, spontaneous stochasticity is both necessary and sufficient for anomalous scalar dissipation in domains without boundaries. In wall-bounded domains, spontaneous stochasticity is sufficient for anomalous dissipation. More generally, the time-integrated scalar dissipation must be greater than a volume-average variance of the initial scalar field sampled by backward in-time stochastic fluid trajectories. This provides a lower bound on the Nusselt number in the Rayleigh-Bénard setting. (Received January 18, 2015)

1107-35-319 **Shijun Zheng*** (szheng@georgiasouthern.edu), Department of Mathematical Sciences, Georgia Southern University, Statesboro, GA 30460. *Long time existence for magnetic nonlinear Schrödinger equations.*

Denote by $\mathcal{L} = -\frac{1}{2}\nabla_A^2 + V$ the Schrödinger operator with electromagnetic potentials, where A is sublinear and V subquadratic. The NLS mechanism generated by $\mathcal{L}$ in the semiclassical regime obeys the Newton's law

$$\dot{x} = \xi$$
$$\dot{\xi} = -\nabla V(x) - \xi \times B(x)$$

in the transition from quantum to classical mechanics, which can be derived by the Euler-Lagrange equation. Here $B = \nabla \times A$ is the magnetic field induced by A and the Lorentz force is given by $-\xi \times B$. The energy density $H(t) := \frac{1}{2}|\xi(t)|^2 + V(x(t))$ is conserved in time. We study the fundamental solution for $e^{-it\mathcal{L}}$ and consider the threshold for the global existence and blowup for the NLS. (Received January 18, 2015)

1107-35-322 **Nguyen Lam**, **Guozhen Lu** and **Lu Zhang*** (eu4347@wayne.edu), Department of Mathematics, Detroit, MI 48201. *Sharp singular Trudinger-Moser inequality with exact growth and its extremals.*

In our work, we study a sharp version of the Trudinger-Moser inequality of Adachi-Tanaka type with exact growth on $D^{1,N}(\mathbb{R}^N) \cap L^q(\mathbb{R}^N)$. We establish the inequalities with a polynomial decay and show actually we are able to get a critical equality without using the restriction of full norm. Moreover, we will see that decay allowed is the best possible. In addition, we study the existence of the extremal functions for the inequality in a subcritical case. (Received January 18, 2015)

1107-35-324 **M. Ignatova*** (ignatova@math.princeton.edu), **I. Kukavica**, **I. Lasiecka** and **A. Tuffaha**. *Well-posedness for an interface damped free boundary fluid-structure model.*

We address a fluid-structure system which consists of the incompressible Navier-Stokes equations and a damped linear wave equation defined on two dynamic domains. The equations are coupled through transmission boundary conditions and additional boundary stabilization effects imposed on the free moving interface separating the two domains. First, we will discuss the local in time existence and uniqueness of solutions. In the second part, we also address the global in time existence for small initial data. This is a joint work with I. Kukavica, I. Lasiecka, and A. Tuffaha. (Received January 18, 2015)

1107-35-325 **M. Ignatova*** (ignatova@math.princeton.edu) and **V. Vicol**. *Almost global existence for the Prandtl boundary layer equations with small tangentially analytic initial datum.*

We address the Prandtl boundary layer equations on the half space with real-analytic initial datum with respect to the tangential variable. The boundary traces of the horizontal Euler flow and pressure are taken to be constants. We establish that if the initial datum is of size ϵ, then the time of existence for the solution is $\exp(\epsilon^{-1/2})$. This is a joint work with V. Vicol. (Received January 18, 2015)

1107-35-327 **Nathan Glatt-Holtz*** (negh@vt.edu). *Inviscid Limits for the Stochastic Navier-Stokes Equations and Related Systems.*

We will discuss some recent work on the statistical and ergodic properties of the stochastic Navier-Stokes equations (and related systems) in the inviscid limit. Connections to the Komogorov and Kraichnan-Batchelor theories of turbulence and will be made. This represents ongoing work with P. Constantin (Princeton), S. Friedlander (USC), V. Sverak (Minnesota), V. Vicol (Princeton). (Received January 18, 2015)

1107-35-328 **Nathan Glatt-Holtz*** (negh@vt.edu). *The Stochastic Boussinesq Equations and Applications in Turbulent Convection.*

Buoyancy driven convection plays a ubiquitous role in physical applications: from cloud formation to large scale oceanic and atmospheric circulation processes to the internal dynamics of stars. Typically such fluid systems are driven by heat fluxes acting both through the boundaries (i.e. heating from below) and from the bulk (i.e. internal 'volumic' heating) both of which can have an essentially stochastic nature in practice.

In this talk we will review some recent results on invariant measures for the stochastic Boussinesq equations. These measures may be regarded as canonical objects containing important statistics associated with convection: mean heat transfer, small scale properties of the flow and pattern formation. We discuss ergodicity, uniqueness and singular parameter limits in this class of measures. Connections to the hypo-ellipticity theory of parabolic equations and to Wasserstein metrics will be highlighted.

This is joint work with J. Foldes, G. Richards and E. Thomann. (Received January 18, 2015)

1107-35-329 **Svetlana Roudenko***, Department of Mathematics, Washington, DC 20052. *Scattering vs. blow-up in the focusing dispersive equations.* Preliminary report.

We study the focusing nonlinear Schrodinger equation in R^N, in the L^2-supercritical regime with finite energy and finite variance initial data and investigate solutions above the energy (or mass-energy) threshold. We extend the known scattering versus blow-up dichotomy above the mass-energy threshold for finite variance solutions in the energy-subcritical and energy-critical regimes, obtaining scattering and blow-up criteria for solutions with arbitrary large mass and energy. We also investigate other equations in a similar manner. (Received January 18, 2015)

1107-35-332 **Justin Holmer***, 151 Thayer St, Mathematics Department, Box 1917, Providence, RI 02912, and **Xuwen Chen**. *The derivation of 1D focusing NLS from 3D quantum many-body evolution.*

We consider the focusing 3D quantum many-body dynamic which models a dilute bose gas strongly confined in two spatial directions. We assume that the microscopic pair interaction is attractive and given by $a^{3\beta-1}V(a^{\beta}\cdot)$

where $\int V \leqslant 0$ and a matches the Gross-Pitaevskii scaling condition. We derive rigorously the 1D focusing cubic NLS as the mean-field limit of this 3D focusing quantum many-body dynamic and obtain the exact 3D to 1D coupling constant. (Received January 18, 2015)

1107-35-334 **Andrea R Nahmod*** (nahmod@math.umass.edu), MA 01003. *Long time dynamics of nonlinear Schrodinger equations with randomized data.* Preliminary report.

We review recent work for 3D periodic quintic NLS with randomized infinite energy data and discuss work in progress in other regimes. (Received January 18, 2015)

1107-35-344 **Marcello Lucia***, mathematics department, College of Staten Island at CUNY, 2800 Victory Blvd, New York, NY 10314. *One-dimensional symmetry for some nonlinear problems on the torus.*

On the torus we consider the nonlinear problem

$$-\Delta u = \lambda(e^u - 1)$$

We prove that below a critical value of the parameter, the solutions depend only on one variable. (Received January 19, 2015)

1107-35-345 **Nung Kwan Yip*** (yip@math.purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907, and **Chaoqun Huang** (cqhuang@hnu.edu.cn), Hunan University, 2 Lushan South Road, Yuelu, Changsha, Hunan , Peoples Rep of China. *Bifurcation of Singularly Perturbed Transition Layer Problem in Inhomogeneous Medium.*

We present results of a one-dimensional singularly perturbed transition layer problem (such as Allen-Cahn equation) in inhomogeneous media that undergo some bifurcation phenomena. The quantitative connection (similarities and differences) between the diffuse layer and reduced problems are demonstrated. It is the first result that simultaneously takes into account the presence of singular perturbation, spatial inhomogeneity and bifurcation. (Received January 19, 2015)

1107-35-352 **Leiga Zhao**, **Fukun Zhao** and **Junping Shi*** (jxshix@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23187. *Elliptic Systems of Schrödinger type with quadratic nonlinearities.*

It is known that Second Harmonic Generation (SHG) can occur when the optical material has a $\chi(2)$ (i.e. quadratic) nonlinear response instead of conventional Kerr $\chi(3)$ material. Here we consider the soliton solutions of nonlinear SHG Schrödinger system in a higher dimensional space. We prove the existence of a positive ground state solution for all parameter range, and we also study the continuity of the ground states and the asymptotic behavior of the ground state when the parameter approaches zero or infinity. The uniqueness of positive solution is also proved in some cases. We also consider the multiplicity of the solutions and the case of system on a bounded domain using a new bifurcation approach. (Received January 19, 2015)

1107-35-362 **Victor Isakov*** (victor.isakov@wichita.edu), Wichita State University, Wichita, KS 67260-0033. *Increasing stability in inverse scattering and inverse source problems.*

We give an explicit bound on the near field from the scattering pattern which is improving when the wave number is growing. The crucial part of the proof is a new estimate of Hankel functions. In the recovery of a source term in the Helmholtz equation from the lateral Cauchy data at an interval (0,K) on wave numbers we demonstrate better stability for larger K by using sharp bounds of the analytic continuation from (0,K) onto the real line and exact observability inequalities for the wave equation. (Received January 19, 2015)

1107-35-365 **Irena Lasiecka** and **Xiaojun Wang*** (xwang13@memphis.edu), 366 Dunn Hall, Department of Mathematical Sciences, University of Memphis, Memphis, TN 38111. *The decay study of Moore-Gibson-Thompson(MGT) equation with memory.*

Moore-Gibson-Thompson(MGT) equation arises as a linear model for wave propagation in viscous thermally relaxing fluids. With memory, the Moore-Gibson-Thompson(MGT) equation reads

$$\tau u_{ttt} + \alpha u_{tt} + c^2 \mathcal{A}u + b\mathcal{A}u_t - \int_0^t g(t-s)\mathcal{A}w(s)ds = 0. \tag{1}$$

The convolution term $\int_0^t g(t-s)\mathcal{A}w(s)ds$ reflects the memory effects of materials with fading memory.

We classify the memory terms into three kinds and study how the memory creates damping mechanism and how it causes energy decay. (Received January 19, 2015)

1107-35-376 **Anna L Mazzucato*** (alm24@psu.edu) and **Christophe La Cave**. *The vanishing viscosity limit in porous media.* Preliminary report.

We consider the flow of a viscous, incompressible, Newtonian fluid in a perforated domain in the plane. We study the simultaneous limit of vanishing pore size and distance, and vanishing viscosity. Under suitable conditions on the pore size, pore distance, and viscosity, we prove that solutions of the Navier-Stokes system in the perforated domain converges to solution of the Euler system in the full plane. That is, the flow is not disturbed by the porous medium and becomes inviscid in the limit. (Received January 19, 2015)

1107-35-392 **Mohamed H Amsaad*** (mamsaad@math.wvu.edu). *On continuous case of the Lagrangian description of absolutely continuous curves in the Wasserstein space on the line.*

The Lagrangian description of absolutely continuous curves of probability measures on the real line is analyzed in the case of continuous densities and velocities, which is mainly from my joint work with A. Tudorascu of West Virginia University. Whereas each such curve admits a Lagrangian description as a well-defined flow of its velocity field, further conditions on the curve and/or its velocity are necessary for uniqueness. We identify the joint continuity in time-space of the velocity field that ensures that the continuity equation has unique solution within a reasonably general class of solutions whose density is jointly continuous in time-space. Also, we obtain concomitantly from our method of proof that the only flow map associated to the curve consists of a time-independent rearrangement of the generalized inverses of the cumulative distribution functions of the measures on the curve, i.e. uniqueness of the Lagrangian description of such jointly continuous solutions may also be a consequence of some continuity enjoyed by the densities in time-space. (Received January 20, 2015)

1107-35-402 **Theodore Tachim Medjo*** (tachimt@fiu.edu), Department of Mathematics/Statistics, Florida International University, MM Campus, Miami, FL 33199. *Averaging of a multi-layer quasi-geostrophic equations with oscillating external forces.*

We consider a non-autonomous multi-layer quasi-geostrophic equations of the ocean with a singularly oscillating external force depending of a small parameter epsilon in [0,1). Under suitable assumptions on the external force, we prove the boundness of the uniform global attractor. When the external force is small enough or the viscosity is large enough, we derive the rate of convergence of the attractors of the singular systems to the averaged system in term of the parameter epsilon. (Received January 19, 2015)

1107-35-404 **Andrea Corli** (andrea.corli@unife.it), Via Machiavelli, 35 - 44100, Ferrara, Italy, and **Haitao Fan***, Department of Mathematics, 37 & O St. NW, Washington, DC 20057. *Phase Transitions for Laminar-Turbulent Flow in a Pipeline or through Porous Media.*

Phase changes in a fluid flow through a porous medium or a pipeline are considered. In particular, the model covers both laminar and turbulent flows. The presence of both laminar and turbulent flows causes jump discontinuities in the friction coefficient. Classical trajectories of traveling waves terminate when they intersect the discontinuity. We construct traveling wave solutions by monotonically smoothing the discontinuity and then taking a limiting process. The limit is independent of the monotone-preserving smoothing. This uniqueness justifies the construction of the traveling wave via this smoothing and limiting approach. Existence of traveling waves is established in a wide range of situations; in particular, the end states may be formed either by pure phases or mixtures. (Received January 19, 2015)

1107-35-415 **Boris Levant**, **Fabio Ramos** and **Edriss S. Titi*** (titi@math.tamu.edu), Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77843. *On the Statistical Properties of the 3D Incompressible Navier-Stokes-Voigt Model.*

The Navier-Stokes-Voigt (NSV) model of viscoelastic incompressible fluid has been recently proposed as a regularization of the 3D Navier-Stokes equations for the purpose of direct numerical simulations. In this talk we present its statistical properties by employing phenomenological heuristic arguments, in combination with Sabra shell model simulations of the analogue of the NSV model. For large values of the regularizing parameter, compared to the Kolmogorov length scale, simulations exhibit multiscaling inertial range, and the dissipation range displaying low intermittency. These facts provide evidence that the NSV regularization may reduce the stiffness of direct numerical simulations of turbulent flows, with a small impact on the energy containing scales. (Received January 19, 2015)

1107-35-418 **Juraj Foldes**, **Nathan Glatt-Holtz** and **Geordie Richards*** (g.richards@rochester.edu), 915 Hylan Building, University of Rochester, Rochester, NY 14627, and **Enrique Thomann**. *Ergodicity results for stochastic Boussinesq equations.*

We will discuss the uniqueness and attraction properties of an ergodic invariant measure for the 2-d Boussinesq equations - used to model bouyancy driven convection - in the presence of a spatially degenerate stochastic forcing. First we will present results in the periodic domain using arguments which generalize recent progress of Hairer and Mattingly for the stochastic Navier-Stokes equations. Then, with a less degenerate forcing but more general boundary conditions, we will present a simplified proof of uniqueness. (Received January 20, 2015)

1107-35-463 **Yuanwei Qi*** (yuanwei.qi@ucf.edu), Department of Mathematics, University of Central Florida, 4000 Central Florida BLVD, Orlando, FL 32816, **Xinfu Chen** (xinfu@pitt.edu), Department of Mathematics, University of Pittsburgh, Pittsburgh, PA PA 15260, and **YJ Zhang**, Department of Mathematics, Shanxi University, Taiyuan, Shanxi , Peoples Rep of China. *Existence of multiple traveling waves in an isothermal diffusion system with linear decay.*

In this talk, I shall report some most recent progress on an important model in chemical reaction for which we prove existence of multiple traveling waves.

This is a joint work with Xinfu Chen and others. (Received January 20, 2015)

1107-35-476 **Ze Cheng***, University of Colorado Boulder, Boulder, CO 80309, **Genggeng Huang** (genggenghuang1986@gmail.com), Shanghai Jiao Tong University, Shanghai, 80309, Peoples Rep of China, and **Congming Li** (congmingli@gmail.com), Shanghai Jiao Tong University, Shanghai, Peoples Rep of China. *Hardy-Littlewood-Sobolev type systems and the Lane-Emden conjecture.*

We give a brief discussion about the Hardy-Littlewood-Sobolev type systems:

$$\begin{cases} (-\Delta)^{\gamma/2}u = v^q, \;\; u > 0, \text{ in } R^n, \\ (-\Delta)^{\gamma/2}v = u^p, \;\; v > 0, \text{ in } R^n. \end{cases} \tag{1}$$

These are also sometimes called Lane-Emden type systems. Beyond the existence, non-existence, and classification of positive solutions, we also study the integrability, asymptotic at infinite, and symmetries of postive solutions. (Received January 20, 2015)

37 ► Dynamical systems and ergodic theory

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1107-37-76 **MOUSSA DOUMBIA*** (doumbiassa@gmail.com), MD. *Malaria Incidence and Anopheles Mosquito Density in Irrigated and Adjacent Non-Irrigated Villages of Niono in Mali*

In this paper, we extend the mathematical model framework of Dembele *et al.* and use it to study malaria disease transmission dynamics and control in irrigated and non-irrigated villages of Niono in Mali. As case studies, we use our "fitted" models to show that in support of the survey studies of Dolo *et al.*, the mosquito density in irrigated villages of Niono is much higher than that of the adjacent non-irrigated villages. Many parasitological surveys have observed higher incidence of malaria in non-irrigated villages than in adjacent irrigated areas. Our "fitted" models support these observations. That is, there are more malaria cases in non-irrigated areas than the adjacent irrigated villages. In addition, we use the extended "fitted" models to determine the drug administration protocols that lead to fewest first episode of malaria in both irrigated and adjacent non-irrigated villages of Niono during the wet season.
(Received January 20, 2015)

1107-37-93 **Jane Hawkins*** (jmh@math.unc.edu), Mathematics Department, CB #3250, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599. *Lattices, elliptic functions, and dynamics.* Preliminary report.

We discuss the important roles of elliptic functions in dynamics. Specifically we review how the Weierstrass elliptic P function leads to ergodically interesting rational maps of the sphere and we also iterate elliptic functions as meromorphic maps of the plane. We make some number theoretic connections along the way. (Received January 04, 2015)

1107-37-98 **Aminur Rahman*** (ar276@njit.edu), 323 Martin Luther KIng Jr.Blvd, Department of Mathematical Sciences, Culimore Hall, Newark, NJ 07102. *Discrete Model and Mechanical Analog of the n-Bounce Resonance of Solitary Waves.*

The n-bounce resonance and chaotic scattering in solitary wave collisions is presented. In these phenomena, the speed at which a wave exits a collision depends in a complicated fractal way on its input speed. The method of collective-coordinate ordinary differential equations is a useful tool in simplifying partial differential equation models. These ODE models are further reduced to discrete-time iterated separatrix maps and from this it is possible to obtain new quantitative results unraveling the fractal structure of the scattering behavior. Furthermore, from the collective-coordinates model a mechanical analog is derived for which an experiment is constructed. (Received January 05, 2015)

1107-37-101 **Robert L. Benedetto*** (rlbenedetto@amherst.edu), Amherst College, **Dvij Bajpai**, Amherst College, **Ruqian Chen**, University of Illinois, **Edward Kim**, Amherst College, **Owen Marschall**, Amherst College, **Darius Onul**, Amherst College, and **Yang Xiao**, Brown University. *Computing the entropy of certain p-adic dynamical systems.*

Let $\mathbf{Q}_p$ denote the field of p-adic rationals. We will consider the dynamics of a p-adic rational function $f(z) \in \mathbf{Q}_p(z)$ acting on the Berkovich space $\mathbf{P}^1_{Ber}$, which is a p-adic analog of the Riemann sphere. Inspired by a question of Favre and Rivera-Letelier, we compute both the topological and the measure-theoretic entropy of this dynamical system for certain choices of f. Our computation makes use of Markov processes on countably many symbols.

No prior knowledge of p-adic numbers or Berkovich spaces will be assumed for this talk. (Received January 05, 2015)

1107-37-154 **Michael Sylvester Keane*** (mkeane@wesleyan.edu), 307 Lakeridge Dr, San Antonio, TX 78229-3604. *Dynamical Classification of Primitive Constant Length Substitutions.* Preliminary report.

Primitive substitutions give rise to unique minimal dynamical systems, and isomorphisms between such systems are simply given by finite data in the form of a sliding block code. For primitive substitutions having the same constant length (but possibly different alphabets), we have developed an algorithm deciding whether they are isomorphic or not; in addition, we can for a given such substitution make a list of all isomorphic injective substitutions of the same length in an algorithmic manner. For example, for the Toeplitz substitution the list contains (when counted properly) two other substitutions, one on a two-symbol alphabet and one on a three-symbol alphabet, and the Thue-Morse substitution list contains exactly twelve members, including two on a six-symbol alphabet. Moreover, for any primitive constant length substitution the list is finite and in principle can be generated by a machine. I would very much like to explain a similar theory for primitive substitutions of nonconstant length, but up until now we have not met with success. For instance, we know nothing about the class of the Fibonacci substitution. This lecture is based on joint work with Ethan Coven and Michel Dekking. (Received January 12, 2015)

1107-37-206 **Kari V Eloranta*** (kari.v.eloranta@gmail.com). *Sequences with long range exclusions.*

Given an alphabet S, we consider the size of the subsets of $S^{\mathbf{Z}}$ determined by the additional restriction that $x_i \neq x_{i+f(n)},\ i \in \mathbf{Z},\ n \in \mathbf{N}$. Here f is a positive, strictly increasing function. We review an alternate graph theoretic formulation due to Erdös and then the known results covering various combinations of f and the alphabet size. This connects the problem to results in additive combinatorics and in recurrence. In the second part we turn to the fine structure of the allowed sequences in the particular case where f is a polynomial. The generation of sequences leads naturally to consider the problem of their maximal length, which exhibits both number theoretic hard obstructions and highly random behavior asymptotically in the alphabet size. (Received January 15, 2015)

1107-37-255 **Vitaly Bergelson** and **Donald Robertson*** (robertson@math.osu.edu), Department of Mathematics, 231 West 18th Avenue, Columbus, OH 43210. *Polynomial multiple recurrence over rings of integers.*

It is an open problem to determine those families of polynomials for which the multidimensional polynomial Szemeredi theorem holds. In this talk I will describe joint work with Vitaly Bergelson that makes partial progress on this problem by considering polynomials over rings of integers of algebraic number fields. (Received January 16, 2015)

1107-37-264 **D. Sanz-Alonso*** (d.sanz-alonso@warwick.ac.uk), **A. M. Stuart**, **A. Shukla** and **K. J.H. Law**. *Analysis of the 3DVAR Algorithm for Chaotic Systems and Implications for the Filtering Distribution.*

Predicting the state of a chaotic signal whose initial condition is slightly uncertain is problematic even in short time intervals. The question arises as to whether the initial uncertainty can be kept small in the infinite time horizon by using sufficiently frequent, but noisy and partial, observations of the system. We will show that, despite its simplicity, the 3DVAR filtering algorithm successfully tracks the signal for a range of chaotic systems; our analysis includes the Lorenz 63 and 96 models, as well as the 2D Navier Stokes equation. The initial analysis requires the observational noise to have bounded support. We will then introduce a modified 3DVAR algorithm for which we can prove similar results for any sufficiently small noise, removing the assumption of bounded support. We conclude by showing that these desirable properties of 3DVAR-like filtering algorithms can be used to establish properties of the true filtering distribution itself. Understanding the true filtering distribution is helpful in the design of algorithms to approximate it, and hence the analysis of the true filtering distribution is not only of theoretical interest, but also potentially of practical use. (Received January 17, 2015)

1107-37-269 **Francesco Cellarosi*** (fcellaro@illinois.edu), 1409 W Green Street, Altgeld Hall, Champaign, IL 61820. *Quadratic Weyl Sums, Automorphic Functions, and Invariance Principles.*

In 1914, Hardy and Littlewood published their celebrated approximate functional equation for quadratic Weyl sums. Their result provides, by iterative application, a powerful tool for the asymptotic analysis of such sums.

We construct a related, almost everywhere non-differentiable automorphic function, which approximates quadratic Weyl sums up to an error of order one, uniformly in the summation range. This not only implies the approximate functional equation, but allows us to replace Hardy and Littlewood's renormalization approach by the dynamics of a certain homogeneous flow. The great advantage of this construction is that the approximation is global, i.e., there is no need to keep track of the error terms accumulating in an iterative procedure.

Our main application is a new functional limit theorem, or invariance principle, for theta sums. The interesting observation is that the paths of the limiting process share a number of key features with Brownian motion (scale invariance, invariance under time inversion, non-differentiability), although time increments are not independent, the value distribution at each fixed time is distinctly different from a normal distribution. Joint work with Jens Marklof. (Received January 17, 2015)

1107-37-270 **Karma Dajani*** (k.dajani1@uu.nl), Mathematics Department, Utrecht University, Budapestlaan 6, Utrecht, Netherlands. *On univogue points for self-similar sets.*

Let $K \subseteq \mathbb{R}$ be the unique attractor of an iterated function system. We consider the case where K is an interval and study those elements of K with a unique coding. We prove under mild conditions that the set of points with a unique coding can be identified with a subshift of finite type. As a consequence of this, we can show that the set of points with a unique coding is a graph-directed self-similar set in the sense of Mauldin and Williams. The theory of Mauldin and Williams then provides a method by which we can explicitly calculate the Hausdorff dimension of this set. (Received January 17, 2015)

1107-37-275 **Svetlana Katok*** (katok_s@math.psu.edu), Department of Mathematics, The Pennsylvania State University, University Park, PA 16802. *The Fried average entropy for smooth group actions and connections with algebraic number theory.*

In a joint work with A. Katok and F. Rodriguez Hertz we study numerical entropy-type invariants suitable for smooth actions of higher rank abelian groups on n-dimensional compact smooth manifolds by smooth transformations preserving a Borel probability measure (the standard notion of entropy assigns value zero to the entropy of such actions). One such invariant, based on averaging approach, was introduced by D. Fried in 1983 and for many years was essentially forgotten. We rediscovered it, but later found Fried's paper and now call this invariant the Fried average entropy. Arithmeticity of maximal rank smooth abelian actions proved by A. Katok and F. Rodriguez Hertz implies that the Fried entropy for maximal rank positive entropy actions is closely related to regulators of totally real number fields. This leads to striking conclusions: (i) for maximal rank actions the Fried entropy can only take countably many values, (ii) in the weakly mixing case the Fried entropy is either equal to zero or is bounded away from zero by a positive function that depends only on the dimension n and grows exponentially with it; we use algebraic number theory to obtain the latter result. (Received January 17, 2015)

1107-37-306 **Anatole Katok*** (katok_a@math.psu.edu), Department of Mathematics, Pennsylvania State University, University Park, PA 16802. *Non-uniform Measure Rigidity.*

The original measure rigidity program concerns with the description of all invariant measures for various classes of algebraic (homogeneous and affine) actions on locally symmetric spaces. While this was completely successful in the parabolic (unipotent) case, virtually all progress up-to-date in the more subtle normally hyperbolic and partially hyperbolic cases relies on some sort of positive entropy assumption. The most general results in that direction are due to Einsiedler and Lindenstrauss.

Two new directions have developed during the recent years. They use ideas developed in the measure rigidity in combination with smooth ergodic theory (aka Pesin theory) to study general smooth actions of several classes of groups from the point of view of ergodic theory, geometry, and topology. Most attention was paid to actions of higher rank abelian groups. I will discuss results in that direction joint with Federico Rodriguez Hertz obtained during the last few years as well as remaining open problems. Related work on rigidity of entropy-type invariants will be discussed in the talk by Svetlana Katok. (Received January 18, 2015)

1107-37-367 **Dominik Kwietniak**, **Jian Li** and **Piotr Oprocha*** (oprocha@agh.edu.pl), AGH University of Science and Technology, Faculty of Applied Mathematics, al. A. Mickiewicza 30, 30-059 Krakow, Poland, and **Xiangdong Ye**. *On multi-recurrence and families of sets of integers.*

In 1970s Furstenberg observed that there are tight connections between recurrence in dynamics and properites of sets of integers. A classical application of this approach is Multiple Recurrence Theorem which can be used to provide "dynamical" proof of van der Waerden theorem, and at the same time can be derived from this theorem (in this sense both theorems are equivalent).

We say that a point $x \in X$ is *multi-recurrent* if it satisfies the conclusion of the topological multiple recurrence theorem, that is for any $d \in \mathbb{N}$ there is a strictly increasing sequence $\{n_k\}_{k=1}^{\infty}$ in $\mathbb{N}$ with $T^{in_k}x \to x$ as $k \to \infty$ for every $i = 1, 2, \ldots, d$.

In this talk we will characterize some properties of multi-recurrent points and their relations to families of sets of integers. Among other things, it leads to another proof on the existence of a C-set with zero Banach density. (Received January 19, 2015)

1107-37-373 **Kathleen A Hoffman*** (khoffman@umbc.edu), 1000 Hilltop Circle, Baltimore, MD 21250, and **Nicole Massarelli**, **Christina Hamlet**, **Eric Tytell** and **Tim Kiemel**. *Understanding Lamprey Locomotion.*

Lampreys are model organisms for vertebrate locomotion because they have the same types of neurons as higher-order vertebrates, but with fewer numbers. Lamprey locomotion requires combining the electrical activity in the spinal cord, that inervates muscle, which in turn contracts the body, propelling the animal through the water.The resulting motion exerts a force on the fluid, and the fluid exerts forces on the body. I will present results of a longterm interdisciplinary collaboration that combines mathematical models and computational fluid dynamics with biological and fluid experiments to understand locomotion through the water. (Received January 19, 2015)

1107-37-374 **Joseph Rosenblatt*** (joserose@iupui.edu), 402 N. Blackford St., LD270, Indianapolis, IN 46202-3216. *Optimal Norm Approximation in Ergodic Theory.*

Given an ergodic transformation τ, and a mean-zero $f \in L_r(X)$, $1 \leq r < \infty$, the ergodic averages $A_n^\tau f = \frac{1}{n}\sum\limits_{k=1}^{n} f \circ \tau^k$ converge in L_r-norm to zero. However, for a fixed value of n, there could be other powers $m_1, \ldots, m_n$ such that the norm $\|\frac{1}{n}\sum\limits_{k=1}^{n} f \circ \tau^{m_k}\|_r$ is much smaller than the norm $\|\frac{1}{n}\sum\limits_{k=1}^{n} f \circ \tau^k\|_r$. For specific functions and transformations, with n fixed, we seek to compute, or estimate, the infimum of the norms $\|\frac{1}{n}\sum\limits_{k=1}^{n} f \circ \tau^{m_k}\|_r$. Various aspects of dynamical systems come into play here including the asymptotic vanishing of correlations for weakly mixing maps, the behavior of discrete spectrum maps, and constructions using diophantine approximation. One general fact does hold: for the generic dynamical system, given in addition the generic function, the usual ergodic averages are infinitely often very far from giving the optimal L_2-norm approximation, and yet at the same time the usual ergodic averages are infinitely often very close to giving the optimal L_2-norm approximation. (Received January 19, 2015)

1107-37-386 **Kelly B Yancey*** (kyancey@umd.edu) and **Giovanni Forni**. *Dynamics of Self-Similar Interval Exchange Transformations.* Preliminary report.

In this talk I will discuss dynamics on interval exchange transformations and specifically those transformations that are self-similar. A self-similar interval exchange transformation is one that is periodic under Rauzy induction. I will show that self-similar IETs on three intervals cannot be weakly mixing and rigid. (Received January 19, 2015)

1107-37-400 **Scott Schmieding*** (schmiedi@math.umd.edu), College Park, MD , and **Mike Boyle**, College Park, MD. *Strong shift equivalence and algebraic K-theory.*

Let R be a ring. Two square matrices A, B are elementary strong shift equivalent (ESSE-R) over R if there are matrices U, V over R such that $A = UV$ and $B = VU$. Strong shift equivalence over R (SSE-R) is the equivalence relation generated by ESSE-R. Shift equivalence over R (SE-R) is a more tractable equivalence relation which is refined by SSE-R. The refinement is trivial if $R = \mathbb{Z}$ (Williams), a principal ideal domain (Effros 1981) or a Dedekind domain (Boyle-Handelman 1993), but no results have appeared since then. We show that this refinement is captured precisely by the group $NK_1(R)$ of algebraic K-theory. It follows that for very many, but

not all rings R, the relations SE-R and SSE-R are the same. There are applications.
This is joint work with Mike Boyle. (Received January 19, 2015)

1107-37-403 **Vitaly Bergelson** (vitaly@math.ohio-state.edu) and **Joel Moreira*** (moreira@math.ohio-state.edu). *On $\{x+y, xy\}$ patterns in large sets of infinite fields.*

An old and fundamental open question in combinatorial number theory asks whether, for an arbitrary finite partition $\mathbb{N} = C_1 \cup \cdots \cup C_r$ of the natural numbers, there exist $x, y \in \mathbb{N}$ whose sum $x+y$ and product xy both belong to the same C_i. In a recent joint work with Vitaly Bergelson we answer an analogue of this question in infinite fields, using ergodic theory methods pioneered by Furstenberg. (Received January 19, 2015)

1107-37-417 **Erblin Mehmetaj*** (em1109@georgetown.edu), Georgetown University, Department of Mathematics and Statistics, 37th and O Streets, NW, Washington, DC 20057. *On the r-Continued Fraction Expansions of Real Numbers.*

Parry proved that a sequence is admissible as the β-expansion of a real number if and only if all of the shifts of the sequence are dominated lexicographically by the sequence obtained from the β-expansion of 1. I prove a similar result for r-continued fraction expansions. I prove that a sequence is admissible, that is, it comes from the r-continued fraction map $T_r(x) = r/x \pmod 1$ if and only if all of its shifts are alternating-lexicographically less than the sequence obtained from the r-continued fraction expansion of 1. (Received January 20, 2015)

1107-37-433 **Ayse Sahin**, **Michael Schraudner** and **Ilie Ugarcovici*** (iugarcov@depaul.edu). *A strongly aperiodic subshift of finite type on the Heisenberg group.*

We construct an example of a strongly aperiodic nearest-neighbor subshift of finite type on the discrete Heisenberg group. The term strongly aperiodic refers to the fact that the stabilizer of any valid symbolic configuration with respect to the shift action is trivial. The explicit construction starts with the $\mathbb{Z}^2$ Robinson SFT and uses several techniques from multidimensional symbolic dynamics to extend it to the Heisenberg group. (Received January 20, 2015)

1107-37-465 **Evelyn Kamaria Thomas*** (ekthomas@umbc.edu) and **Jonathan Bell**. *An Examination of Social Migration within a Cholera Outbreak.*

We present a system of ordinary differential equations that models the spread of Cholera between two populations: one containing healthcare resources, the other deficient of such services. We examine the affect migration based on social factors; specifically the fear of becoming infected and possible mortality when infected, has on the spread of the disease in this system. We utilize such factors to determine intervention strategies for the control and eradication of the disease. (Received January 20, 2015)

1107-37-478 **Mike Boyle*** (mmb@math.umd.edu) and **Scott Schmieding**. *Group extensions for shifts of finite type: K-theory, Parry and Livsic.*

(Joint work with Scott Schmieding.) We extend and apply algebraic invariants and constructions for mixing finite group extensions of shifts of finite type. Up to topological conjugacy, such an extension can be presented by a square matrix A over Z_+G, the nonnegative part of the integral group ring of the group G. Topological conjugacy of the extensions is equivalent to strong shift equivalence over Z_+G of their defining matrices. Certain dynamical features are captured as algebraic invariants of these matrices. For G abelian, $\det(I - tA)$ captures the periodic data of the extension (of course); the nonabelian case is more interesting but quite managable. The classification of these extensions is greatly clarified by the identification of a strong shift equivalence class of matrices over ZG the ring with the group $NK_1(ZG)$ of algebraic K-theory. For example, Parry asked for nontrivial finite abelian G if only finitely many topological conjugacy classes of G-extension of a fixed nontrivial mixing shift of finite type could arise compatible with fixed periodic data. We show when $NK_1(ZG)$ is nontrivial that the answer is no regardless of the shift and periodic data. We also show for every G there is prescribed periodic data for which the answer is No. (Received January 20, 2015)

39 ► Difference and functional equations

1107-39-50 **Murat Adivar*** (murat.adivar@ieu.edu.tr), Izmir University of Economics, Department of Mathematics, Balcova, 35330 Izmir, Turkey. *A generalized almost periodicity notion for functions on hybrid domains.*

We introduce new periodicity notion, called almost periodicity in shifts, for the functions defined on hybrid domains that are not necessarily (additive) translation invariant. This new approach enables investigation of almost periodic solutions of dynamic systems on a large class of hybrid domains including $\pm\overline{q^{\mathbb{Z}}} := \{\pm q^n : n \in \mathbb{Z}$ and $q > 1\} \cup \{0\}$.

We use exponential dichotomy and prove the uniqueness of projector of exponential dichotomy to get some limit results for principal fundamental matrix solutions of the system

$$x^{\Delta}(t) = A(t)x(t),\ x(t_0) = x_0.$$

Using the obtained limit results we implement our constructed theory to system of nonlinear neutral delayed dynamic equations to reveal some sufficient conditions for existence of almost periodic solutions in shifts. Hence, we obtain some new results for the discrete case $\mathbb{T} = \mathbb{Z}$ and extend the existing theory to $q-$difference equations.
(Received January 03, 2015)

1107-39-71 **Youssef Naim Raffoul*** (yraffoul1@udayton.edu), 300 College Park, None, Dayton, OH 45469-2316, and **Ernest Yankson**. *Existence of bounded solutions for almost linear Volterra difference equations using fixed point theory and Lyapunov functionals.*

We obtain sufficient conditions for the boundedness of solutions of the almost linear Volterra difference equation

$$\Delta x(n) = a(n)h(x(n)) + \sum_{k=0}^{n-1} c(n,k)g(x(k))$$

using Krasnoselskii's fixed point theorem. Also, we will display a Lyapunov functional that yield boundedness of solution and compare both methods.
(Received December 28, 2014)

1107-39-100 **Gro Hovhannisyan*** (ghovhann@kent.edu), 6000 Frank ave NW, North Canton, OH 44720. *Representation of the delta function via the exponential function on a space scale.* Preliminary report.

We prove the representation of Dirac delta function in terms of the nabla exponential function on a space scale for some special cases (discrete and continuous space scales). We discuss possible generalizations and applications to the solutions of nonlinear dynamic equations on a time-space scale. (Received January 05, 2015)

1107-39-128 **H. Sedaghat*** (hsedagha@vcu.edu), Department of Mathematics, 1015 Floyd Ave, Harris Hall, Virginia Commonwealth University, Richmond, VA 23284-2014, and **N. Lazaryan**. *Global Dynamics of Discrete Planar Systems that Model Stage-structured Populations.* Preliminary report.

We discuss a system of two nonlinear difference equations as an abstraction of some commonly known, stage-structured population models. In particular, we show that with the well-known Ricker function for a vital rate such a model is capable of generating chaotic orbits as well as multiple periodic and aperiodic orbits that can be reached from different initial points. (Received January 09, 2015)

1107-39-140 **Steven Miller*** (sjm1@williams.edu), 18 Hoxsey St, Williamstown, MA 01267, and **Minerva Catral**, **Pari Ford**, **Pamela Harris** and **Dawn Nelson**. *From the Kentucky Sequence to Benford's Law through Zeckendorf Decompositions.*

Zeckendorf proved every positive integer can be written uniquely as a sum of non-adjacent Fibonacci numbers; not only can this be generalized to other recurrence relations, but it turns out to be an equivalent definition of Fibonacci numbers. Previous work required the recurrence to have first coefficient non-zero; in this work we explore a related one, the Kentucky sequence, where that coefficient vanishes. This leads to interesting new behavior, as we lose uniqueness of decomposition and the greedy algorithm no longer yields a decomposition for each integer. If time permits we discuss connections between generalized Zeckendorf decompositions and Benford's law. (Received January 11, 2015)

1107-39-243 **Nika Lazaryan*** (lazaryans@vcu.edu), Richmond, VA , and **Hassan Sedaghat** (hsedagha@vcu.edu), Richmond, VA. *Global Stability and Periodic Solutions for a Second Order Rational Equation.*

We study a second order rational difference equation with quadratic terms. We investigate the global stability profile and the boundedness of solutions for positive parameters and nonnegative initial values. We establish that when the function defining the difference equation is monotone in its arguments, the equation does not have any periodic solutions of period greater than two. In addition, under the above assumptions, if the equation has no two-cycles, the solutions converge to the unique positive fixed point. (Received January 16, 2015)

1107-39-358 **Candace M. Kent*** (cmkent@vcu.edu), 3510 Hanover Avenue, Richmond, VA 23221. *Piecewise-Defined Difference Equations: Open Problem.*

We consider difference equations of the form

$$x_{n+1} = f_n(x_n, x_{n-1}, \ldots, x_{n-k}),$$

where $k \in \{0, 1, \ldots\}$, $f_n : D^{k+1} \to \mathbf{R}$ is piecewise-defined and for the most part continuous, whose bhavior of solutions is such that every solution is eventually periodic. There exist numerous such examples of piecewise-defined equations whose every solution is eventually periodic. We present four categories containing these examples, but also containing examples of exceptions. We then present some speculative properties that our examples of piece-defined equations, whose every solution is eventually periodic, seem to have in common, as well as some speculative properties that the examples of exceptions have. Hence the words, "Open Problem," in our title. (Received January 19, 2015)

1107-39-361 **Ying Zhou***, zhou.494@mbi.osu.edu, and **William Fagan**. *Expanding and contracting habitats: comparison of dispersal strategies.* Preliminary report.

In this talk, I will present an integrodifference equation model for the spatiotemporal dynamics of a population living in habitats with time-dependent sizes. I will show the conditions required for the resulting integral operator to be completely continuous. Bifurcation results will follow. It can be shown in some examples and under some conditions that the dominant eigenvalue of the integral operator will monotonically decrease with larger temporal changes in the habitat sizes. In the mean time, the dominant eigenvalue may not be monotonic with respect to mean dispersal distances. (Received January 19, 2015)

1107-39-406 **Michael A. Radin*** (michael.radin@rit.edu), Rochester Institute of Technology, College of Science, School of Mathematical Sciences, Rochester, NY 14623. *Periodic & Eventually periodic solutions of piecewise and max type difference equations.*

We examine the 3X+1 conjecture, the tent map, the max type equations, non-autonomous max type equations and non-autonomous piecewise equations. The patterns of periodic solutions and boundedness of solutions. Furthermore, we study applications as neuron models. (Received January 19, 2015)

1107-39-444 **Pari L Ford*** (fordpl@unk.edu), NE, and **Minerva Catral**, **Pamela Harris**, **Steven J Miller** and **Dawn Nelson**. *This Fibonacci Quilt Sequence.* Preliminary report.

Abstract: The (s, b)-Generacci sequences are constructed by listing the numbers that cannot be decomposed as a sum of previous entries following a generalized Zeckendorf condition: the entries are partitioned into bins of size b and a legal decomposition prohibits having two summands from any s consecutive bins. In this talk we expand to a 2-dimensional construction using the Fibonacci quilt, where the entries of our sequence are chosen so that a_n is the smallest number that cannot be written as a sum of earlier entries of the sequence such that no two elements of the decomposition share a wall in the quilt. The resulting numbers satisfy a linear recurrence where the leading term is zero, and thus previous results do not apply. This leads to some interesting complications and new behavior. In particular, while every number is legally decomposable most numbers have multiple choices; among other results we show that the average number of decompositions grows exponentially fast and that the greedy algorithm yields a legal decomposition for approximately 92% of the integers.

This work is joint with Minerva Catral, Pamela Harris, Steven J. Miller, and Dawn Nelson. (Received January 20, 2015)

40 ► Sequences, series, summability

1107-40-507 **Paul Barry*** (pbarry@wit.ie), School of Science, Waterford Institute of Technology, Cork Road, Waterford, Waterford 000000, Ireland. *Riordan arrays and Catalan numbers as a source of Somos sequences.* Preliminary report.

The link between elliptic curves, Hankel determinants and Somos 4 sequences is well understood. Another approach to Somos 4 sequences, which also employs Hankel determinants, is to use Riordan arrays to find combinatorially significant sequences whose Hankel transforms are Somos 4 sequences. We relate this Riordan array approach to recent research on Somos sequences. The Catalan numbers play a central role in this approach. Links with continued fractions are also explored. (Received January 21, 2015)

41 ► Approximations and expansions

1107-41-45 **Nguyet T Nguyen***, Department of Mathematics & Statistics, Youngstown State University, Youngstown, OH 44555. *Using Gradient Descent to Calibrate Parameters for Variance Gamma Model.*

In this talk I will introduce Variance Gamma Model (VG) for pricing European call options and apply the gradient descent method to calibrate parameters for the model. Suppose we need to calibrate a vector of VG's parameters, $\xi = (\sigma, \theta, \nu)$, from N option prices for different strikes $\{K_i, i = 1, 2, ..., N\}$, of a stock . Let C_i^{Market} be the market price of the option for strike K_i, and $C_{i,\xi}^{Model}$ be its price calculated by the model. I use the non-linear least squares object function

$$f(\xi) = \Sigma_{i=1}^N (C_{i,\xi}^{Model} - C_i^{Market})^2.$$

The purpose is to find the vector of parameters ξ such that the model calculated prices, $C_{i,\xi}^{Model}$, are close to the market prices, $C_i^{Market}, i = 1, 2, ..., N$. The parameter calibration problem becomes the unconstrained optimization problem: finding the minimizer ξ of the objective function $f(\xi)$. (Received December 11, 2014)

42 ► Fourier analysis

1107-42-47 **Joseph D Lakey*** (`jlakey@nmsu.edu`) and **Jeffrey A Hogan** (`jeff.hogan@newcastle.edu.au`). *Prolate shift frames and bandpass prolate functions.*

In the early 1960s, Landau, Slepian and Pollak established the fundamental role of zero order prolate spheroidal wavefunctions in the theory of time and frequency limiting. In particular, when ordered by time concentration, these prolates are the the basic elements of the space of "approximately time and band limited signals." Prolate shift frames are frames for the Paley-Wiener space of square-integrable functions bandlimited to an interval that are generated by the shifts of a finite number of the most time-concentrated prolate functions. Some elementary properties of such frames were recently established by Hogan and Lakey. Here we will extend some of those frame properties to the case of what we call bandpass prolates, which are eigenfunctions of an operator that first time-limits to an interval then frequency-limits to a pair of intervals of equal length. (Received December 12, 2014)

1107-42-72 **Roza Aceska*** (`raceska@bsu.edu`). *Scalability of a multi-Wilson frame.* Preliminary report.

The constructed multi-Wilson frame $\mathcal{W}$ is an example of a quilted frame, whose dual frame is not of multi-Wilson structure. Since the dual frame of $\mathcal{W}$ cannot be easily computed, it is beneficial to scale $\mathcal{W}$ and produce a tight frame. We give a theoretical criterion on the scalability of $\mathcal{W}$ and exact scaling coefficients. (Received December 28, 2014)

1107-42-214 **Jean-Pierre Gabardo*** (`gabardo@mcmaster.ca`) and **Chun-Kit Lai** (`cklai@sfsu.edu`). *Frames of exponentials on small sets.* Preliminary report.

If $x_1, \dots, x_m$ are finitely many points in $\mathbb{R}^d$, let $E_\epsilon = \cup_{i=1}^m x_i + B_\epsilon$, where $B_\epsilon = \{x \in \mathbb{R}^d,\ |x| \le \epsilon\}$. and let $\hat{f}$ denote the Fourier transform of f. Given a positive Borel measure μ on $\mathbb{R}^d$, we provide a necessary and sufficient condition for the inequalities

$$A\,\|f\|_2^2 \le \int_{\mathbb{R}^d} |\hat{f}(\xi)|^2\, d\mu(\xi) \le B\,\|f\|_2^2, \quad f \in L^2(E_\epsilon),$$

to hold for some $A, B > 0$ and for some $\epsilon > 0$ sufficiently small. If G is a (possibly dense) subgroup of $\mathbb{R}$, we characterize those measures μ for which the inequalities above hold whenever $x_1, \dots, x_m$ are finitely many points in G (with ϵ depending on those points, but not A or B). We also point out an interesting connection between this problem and the notion of well-distributed sequence. (Received January 15, 2015)

1107-42-258 **Sivaram K Narayan*** (`sivaram.narayan@cmich.edu`), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859. *Inverse Factor Poset Problem for Finite Frames.*

A *frame* in an n-dimensional Hilbert space H_n is a possibly redundant collection of vectors $\{f_i\}_{i\in I}$ that span the space. A *tight* frame is a generalization of an orthonormal basis. We define the *factor poset* of a frame $\{f_i\}_{i\in I}$ to be a collection of subsets of I ordered by inclusion so that nonempty $J \subseteq I$ is in the factor poset if and only if $\{f_j\}_{j\in J}$ is a tight frame for H_n. The *inverse factor poset problem* inquires when there exists a frame whose factor poset is some given poset P. We determine a necessary condition for solving the inverse factor poset problem in H_n which is shown to be sufficient for H_2. We address how factor poset structure is preserved under orthogonal projections. Furthermore, we discuss how many non-isomorphic factor posets are there for a fixed dimension n and number of vectors k and how large can these factor posets be. This is a joint work with Alice Chan, Martin Copenhaver, Logan Stokols, and Allison Theobold. (Received January 16, 2015)

1107-42-309 **Akram Aldroubi** and **Keri Kornelson*** (kkornelson@ou.edu). *Dynamical sampling with a constant forcing term.* Preliminary report.

We use the dynamical sampling structure, in which a signal being sampled is evolving over time via a known bounded operator A. Given this information, it may be that samples taken at fewer points, but repeated at incremental times, can be used to stably reconstruct the initial signal. The reconstruction depends on what is known about the evolution operator A. In this work, we consider the presence of an additive forcing agent influencing the system. We give conditions under which reconstruction can still occur with stability. (Received January 18, 2015)

1107-42-335 **Alex Iosevich*** (iosevich@math.rochester.edu), 145 Dunrovin Lane, Rochester, NY 14618, and **Steen Pedersen** and **Yang Wang**. *Density of frames and spectra.*

We will show that if $E \subset \mathbb{R}^d$ of Hausdorff dimension $s > 0$ and if μ is the restriction of the s-dimensional Hausdorff measure to E such that $L^2(\mu)$ possesses a frame of exponentials $\{e^{2\pi i x\cdot a}\}_{a\in A}$, then under additional mild assumptions on μ,

$$\#(A \cap B(x,r)) \leq CR^s.$$

(Received January 18, 2015)

1107-42-437 **Darrin Speegle*** (speegled@slu.edu) and **Robert Steward**. *Tiling the line by affine shifts of a prototile.* Preliminary report.

We present conditions on a set $\Gamma = \{x(t), y(t)\}$, where x and y are continuous functions, such that there exists a sampling $\{t_n\}_{n=1}^{\infty}$ and a set E such that

$$\{x(t_n)^{-1}\big(E + y(t_n)\big) : 1 \leq n \leq \infty\}$$

is a measurable tiling of the line. Special attention is paid to the case when E can be chosen an interval or the union of two intervals. Relationship of this problem to the existence of wave packet frames will also be discussed.
(Received January 20, 2015)

43 ► Abstract harmonic analysis

1107-43-454 **David E Weirich*** (dweirich@unm.edu), 87110. *Haar Basis in Spaces of Homogeneous Type.*

We first look at geometric properties of so-called spaces of homogeneous type – sets equipped with a quasi-metric and a doubling measure. We then use these properties to explicitly describe a collection of "Haar-like" functions defined over such spaces and show that they form an othonormal basis for L^2 functions. We finally look at some applications of these Haar functions. (Received January 20, 2015)

45 ► Integral equations

1107-45-201 **Fang Li*** (fangli0214@gmail.com), No. 500 Dongchuan Road, East China Normal University, Shanghai, 200241, Peoples Rep of China. *Global dynamics of the Lotka-Volterra competition system with nonlocal diffusion.*

In this talk, we study the global dynamics of the following Lotka-Volterra competition model with nonlocal dispersals:

$$\begin{cases} u_t = d\left(\int_\Omega k(x,y)u(y,t)dy - \int_\Omega k(y,x)dy u(x,t)\right) + u(m(x) - u - cv), \\ v_t = D\left(\int_\Omega p(x,y)v(y,t)dy - \int_\Omega p(y,x)dy v(x,t)\right) + v(m(x) - bu - v), \\ u(x,0) = u_0(x) \geq 0, \quad v(x,0) = v_0(x) \geq 0 \end{cases}$$

where $k(x,y)$, $p(x,y) > 0$, $m \in L^\infty$ and $\int_\Omega m(x)dx > 0$. Our main results consist of two parts. First, when both $k(x,y)$ and $p(x,y)$ are symmetric, the global dynamics can be completely classified provided that $0 < bc \leq 1$. Secondly, when $k(x,y)$ is non-symmetric, while $p(x,y)$ is symmetric, then the global dynamics can be characterized provided that $0 < b < 1$, $0 < c < 1$ and d is sufficiently small. This is the joint work with Xueli Bai. (Received January 14, 2015)

1107-45-210 **Hatim Farouq Alqadah*** (hatim.alqadah.ctr@nrl.navy.mil), 4555 Overlook Avenue, SW, Washington, DC 20375-5320. *A Compressive Multi-Frequency Linear Sampling Method.*

The linear sampling method (LSM) is a qualitative inverse scattering technique that circumvents the non-linearity of the inverse scattering problem to reconstruct the support of a scatterer without the need to resort to any linearizing wave approximations. The method relies on computing approximate solutions to a set of Fredholm integral equation of the first kind which we refer to as the Herglotz density. In this work we discuss a multi-frequency variant of the LSM which aims to provide improved stability for reconstructing the Herglotz density, particularly in the case of limited and under-sampled observation aperture data. We show that when the frequency step-size is small enough the total frequency variation of the Herglotz density is well approximated by a sparse vector where the non-zero entries correspond to the interior modes of the scatterer within the bandwidth. This result motivates the use of sparse regularization techniques for inverting the far-field equations. We discuss the use of ℓ_1 minimization algorithms for computing this minimum frequency variation solution. Imaging results using numerically computed forward scattering data will be presented. (Received January 15, 2015)

46 ► Functional analysis

1107-46-73 **Palle E.T. Jorgensen*** (palle-jorgensen@uiowa.edu), Dept Math, MLH, University of Iowa, Iowa City, IA 52242. *Parseval-frames in Hilbert spaces over infinite networks of resistors.*

We discuss natural systems of Parseval-frame vectors for Hilbert spaces induced by infinite networks of resistors. More precisely, an infinite network of resistors is an infinite graph G with vertices and edges (countable), and with resistors assigned to each edge in G. We assume further that G is connected. From this assignment we may then define a Hilbert space H of finite energy voltage functions (voltage distribution on the vertex set V.) We show that the finite energy Hilbert space H is a relative reproducing kernel Hilbert space; specifically the dipoles form a non-orthogonal system of vectors in H. Moreover, these dipole vectors can be re-scaled to yield a Parseval frame for H. Details and applications will be presented in the talk. (Received December 28, 2014)

47 ► Operator theory

1107-47-6 **Safeer Hussain Khan*** (safeer@qu.edu.qa), Department of Mathematics, Statistics and, Physics, Qatar University, Doha, 2713, Qatar, and **Fukhar ud-din Hafiz**. *Common fixed points of three contractive-like operators by a three-step iterative algorithm.*

Imoru and Olatinwo extended the concept of quasi-contractive type operators given by Berinde to contractive-like operators. Contractive-like operators are more general than quasi-contractive type operators and Zamfirescu operators (including contractions). This kind of operators are helpful in proving results in normed spaces in contrast with (uniformly convex) Banach spaces. Xu and Noor introduced a three-step-one-mapping iterative algorithm which can be seen as a generalization of Mann and Ishikawa iterative algorithms. Such algorithms have been applied in finding the approximate solution of elastoviscoplasticity problems, eigen value problems and liquid crystal theory. In this paper, keeping in mind the importance of common fixed points, we first extend the iterative algorithm of Xu and Noor to the case of three-step-three-mappings and then prove a strong convergence result using contractive-like operators for this iterative algorithm. This generalizes corresponding results using Mann, Ishikawa and Xu-Noor iterative algorithms with quasi-contractive type operators. It is pointed out that our result can also be proved with iterative algorithm involving error terms. (Received September 05, 2014)

1107-47-34 **Shamaila Waheed** and **Muhammad Akram*** (maahmed@kfu.edu.sa), College of Science, Department of Mathematics and Statistics, King Faisal University, Al-Ahsa, Saudi Arabia. *A Fixed Point Result for Matkowski Cyclic Contractions in Partial Metric Spaces.*

Abstract: The purpose of this paper is to study fixed point result for Matkowski type cyclic contraction in complete partial metric spaces. The effectiveness of the result is also illustrated through an example.
(Received December 07, 2014)

1107-47-41 **Kalim Raza Kazmi** and **Shakeel Ahmad Alvi*** (salvi@kfu.edu.sa), Al-Ahsa, Saudi Arabia. *Sensitivity analysis for a parametric multi-valued implicit quasi variational-like inclusion.*

In this paper, using proximal-point mapping of strongly maximal P-η-monotone mapping and the property of the fixed-point set of multi-valued contractive mapping, we study the behaviour and sensitivity analysis of the solution set of a parametric generalized implicit quasi-variational-like inclusion involving strongly maximal P-η-monotone mapping in real Hilbert space. Further, under suitable conditions, we discuss the Lipschitz continuity of the solution set with respect to the parameter. The technique and results presented in this paper can be viewed as extension of the techniques in the existing literature. (Received December 07, 2014)

1107-47-170 **Akram Aldroubi*** (akram.aldroubi@vanderbiltedu). *Bases and frames from iterates of operators.*

Let $\mathcal{A} = \{A_k : k = 0, \dots, N\}$ be a set of operators in $\ell^2(\mathbb{N})$ and S a subset of $\ell^2(\mathbb{N})$. We consider the problem of finding conditions on $\mathcal{A}$ and S so that the set $E = \{A_k^j S : k = 0, \dots, N,\ j = 0, \dots, L\}$ form a bases/frame for $\ell^2(\mathbb{N})$. (Received January 13, 2015)

1107-47-187 **Zeljko Cuckovic** and **Trieu Le*** (trieu.le2@utoledo.edu). *Adjoints of linear fractional composition operators on weighted Hardy spaces.* Preliminary report.

It is well known that on the Hardy space $H^2(\mathbb{D})$ or weighted Bergman space $A^2_\alpha(\mathbb{D})$ over the unit disk, the adjoint of a linear fractional composition operator equals the product of a composition operator and two Toeplitz operators. On $S^2(\mathbb{D})$, the space of analytic functions on the disk whose first derivatives belong to $H^2(\mathbb{D})$, Heller showed that a similar formula holds modulo the ideal of compact operators. I will discuss what the situation is like on other weighted Hardy spaces. (Received January 14, 2015)

1107-47-204 **Jordi Pau** and **Ruhan Zhao*** (rzhao@brockport.edu), Department of Mathematics, SUNY Broockport, Brockport, NY 14420. *Weak factorization and Hankel forms for weighted Bergman spaces on the unit ball.*

In this talk we establish weak factorizations for a weighted Bergman space A^p_α, with $1 < p < \infty$, into two weighted Bergman spaces on the unit ball of $\mathbb{C}^n$. To obtain this result, we characterize bounded Hankel forms on weighted Bergman spaces on the unit ball of $\mathbb{C}^n$. This is a joint work with Jordi Pau. (Received January 15, 2015)

1107-47-211 **Pratibha Ghatage** and **Maria Tjani***, Department of Mathematical Sciences, University of Arkansas, Fayetteville, AR 72701. *Closed range composition operators on Hilbert function spaces.*

We show that a Carleson measure satisfies the reverse Carleson condition if and only if its Berezin symbol is bounded below on the unit disk $\mathbb{D}$. We provide new necessary and sufficient conditions for the composition operator to have closed range on the Bergman space. The pull-back measure of area measure on $\mathbb{D}$ plays an important role. A new proof is given in the case of the Hardy space. We provide an example of a closed range composition operator on both the Hardy and the Bergman space with a non inner symbol. (Received January 15, 2015)

1107-47-263 **Gabriel T Prajitura*** (gprajitu@brockport.edu), **Lingyang Jiang** and **Ruhan Zhao**. *Composition operators on the Fock space in several complex variables.* Preliminary report.

We characterize certain properties of composition operators on the Fock space on Cn, including the essential norm, essentially normality, spectra and cyclicity. (Received January 17, 2015)

1107-47-298 **Waleed K Al-Rawashdeh*** (walrawashdeh@mtech.edu), Montana Tech, Butte, MT 59701. *Composition Operators on Weighted Bergman and S^p Spaces.*

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 composition operator. For each $p \geq 1$, let S^p be the space of analytic functions on $\mathbb{D}$ whose derivatives belong to the Hardy space H^p. For $\alpha > -1$ and $p > 0$ the weighted Bergman space A^p_α consists of all analytic functions in $L^p(\mathbb{D}, dA_\alpha)$, where dA_α is the normalized weighted area measure. In this talk, we characterize boundedness and compactness of composition operators act between weighted Bergman A^p_α and S^q spaces, $1 \leq p, q < \infty$. Moreover, we give a lower bound for the essential norm of composition operator from A^p_α into S^q spaces, $1 \leq p \leq q$. (Received January 18, 2015)

1107-47-316 **Maria Neophytou*** (maria.neophytou@belmont.edu), Department of MTH/CSC, Belmont University, 1900 Belmont Boulevard, Nashville, TN 37212. *Eigenvalues of Adjoints of Certain Composition Operators on the Hardy Space.*

Let H^2 be the Hardy-Hilbert space. If φ is an analytic self-map of the unit disk and ψ is analytic on the disk, the composition operator C_φ with symbol φ is defined by $C_\varphi f = f \circ \varphi$, and the weighted composition operator $W_{\psi,\varphi}$ by $W_{\psi,\varphi} f = \psi(f \circ \varphi)$, for f in H^2. We show that there is an entire disk of eigenvalues for the adjoints of composition operators with certain symbols φ that have a fixed point inside the disk and a fixed point on the boundary. We also show that those eigenvalues have infinite multiplicity, and we identify an invariant subspace for the adjoint on which it acts like a weighted shift. Finally, we generalize these results to weighted composition operators.
(Received January 18, 2015)

1107-47-357 **Paul S. Bourdon*** (psb7p@virginia.edu). *Spectra of Composition Operators with Symbols in $\mathcal{S}(2)$.*

I'll begin by presenting some "spectral lemmas" developed by Trieu Le and me that describe spectra of sums of elements of a unital algebra over a field when certain pairwise products of summands are zero. Some of these lemmas are, no doubt, folklore. Then, I'll show how applying these lemmas in the context of the Calkin Algebra yields descriptions of essential spectra of certain composition operators—those acting on the Hardy space H^2 of the open unit disk whose symbols belong to the class $\mathcal{S}(2)$ introduced by Kriete and Moorhouse. For the composition operators considered, descriptions of the essential spectrum quickly lead to complete characterizations of the spectrum. (Received January 19, 2015)

1107-47-399 **Nina Zorboska***, Department of Mathematics, University of Manitoba, 186 Dysart road, Winnipeg, Manitoba R3T 2N2, Canada. *Hyperbolic distortion, finite Blaschke products and uniform local univalence.*

We will show some connections between the existence of upper and lower bounds on the weighted hyperbolic distortion of a self-map of the unit disk and the maps geometric behaviour, such as its boundary regularity, or uniform local univalence. It is particularly interesting to see how the properties of composition operators on spaces of analytic functions can be used in the proofs of few of these purely geometric results. (Received January 19, 2015)

1107-47-450 **Flavia Colonna** and **Rachel Locke***, 4400 University Drive, MS: 3F2, Exploratory Hall, room 4400, Fairfax, VA 22152. *Multiplication operators on the Zygmund space over a tree.*

In recent years, the operator theory of many functional Banach spaces that arise in complex function theory has been studied extensively. However, very little has been done in a discrete setting. An important class of operators to be discussed in this talk is the *multiplication operators*

$$M_\psi(f) = \psi f,$$

where ψ is a function defined on an infinite rooted tree T and f belongs to a functional Banach space with domain T. An environment for this study is a space $\mathcal{Z}$ of functions on T such that f' belongs to the Lipschitz space $\mathcal{L}$, that is, satisfies

$$|f'(v) - f'(w)| \leq C\, d(v,w), \quad v,w \in T,$$

for some $C > 0$, where $d(v,w)$ is the number of edges in the unique geodesic path from v to w. The space $\mathcal{Z}$ may be considered as a discretization of the familiar Zygmund space of analytic functions on the open unit disk. The main focus of this talk will be on characterizing the bounded and the compact operators M_ψ and describing the spectra. (Received January 20, 2015)

1107-47-461 **Katie Spurrier Quertermous*** (querteks@jmu.edu), Department of Mathematics and Statistics, MSC 1911, James Madison University, Harrisonburg, VA 22807. *Unitary Equivalence of Composition C*-algebras on the Hardy and Weighted Bergman Spaces.*

If φ is an analytic self-map of the unit disk $\mathbb{D}$, then the composition operator $C_\varphi : f \mapsto f \circ \varphi$ is a bounded operator on the Hardy space $H^2(\mathbb{D})$ and on the weighted Bergman spaces $A^2_\alpha(\mathbb{D})$ for $\alpha > -1$. In the Hardy space setting, several authors have investigated the structures of the C*-algebras $C^*(C_\varphi, \mathcal{K})$, where φ is a linear-fractional self-map of $\mathbb{D}$ and $\mathcal{K}$ is the ideal of compact operators. In this talk, we extend some of these results to the weighted Bergman space setting. We show that if φ is a linear-fractional, non-automorphism self-map of $\mathbb{D}$ that fixes a point on the unit circle, then the unital C*-algebra generated by C_φ and the ideal of compact operators on A^2_α is unitarily equivalent to the unital C*-algebra generated by C_φ and the ideal of compact operators on H^2. We also establish a unitary equivalence between constant multiples of related weighted composition operators induced by arbitrary linear-fractional self-maps of $\mathbb{D}$ that fix a point on the unit circle. (Received January 20, 2015)

49 ► *Calculus of variations and optimal control; optimization*

1107-49-92 **Harbir Antil** (hantil@gmu.edu), Department of Mathematical Sciences, George Mason University, Fairfax, VA 22030, **Ricardo Nochetto** (rhn@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742, and **Pablo Venegas*** (pvenegas@umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742. *Optimal control of Magnetic Nanoparticles.* Preliminary report.

Magnetic drug targeting is an important application of ferrofluids where drugs, with ferromagnetic particles in suspension, are injected into the blood stream. The external magnetic field thus concentrates the drug to the most affected areas, for example, solid tumors. Current approaches lack a proper functional analytic framework which is essential to formulate optimization problems and develop stable numerics, both being crucial in practice. In this work we formulate a PDE constrained optimization problem with a tracking type cost. We develop an adjoint based optimization framework with a state equation consisting of an advection-diffusion equation for the concentration. The solenoidal and irrotational magnetic field acts as a control. Its multiplicative nature is a new and major issue in PDE constrained optimization. (Received January 04, 2015)

1107-49-251 **Veronica Bloom**, George Mason University, 4400 University Drive, Fairfax, VA 22030, **Igor Griva*** (igriva@gmu.edu), George Mason University, 4400 University Drive, Fairfax, VA 22030, and **Fabio Quijada**, George Mason University, 4400 University Drive, Fairfax, VA 22030. *Fast Projected Gradient Method for training Support Vector Machines.*

We present a fast projected gradient method (FPGM) for training large dual soft margin support vector machines (SVMs). The FPGM is an augmented Lagrangian method that uses a modification of the fast gradient method with a projection on a box set. The FPGM requires computing only first derivatives, which for the dual soft margin SVM means computing mainly a matrix-vector product. Therefore FPGM being computationally inexpensive may be an attractive alternative to existing quadratic programming solvers for training large SVMs. We discuss convergence of the FPGM and report numerical results for training the SVM with the FPGM on data up to tens of thousands data points from the UC Irvine Machine Learning Repository. (Received January 17, 2015)

1107-49-441 **Maria Emelianenko*** (memelian@gmu.edu), **Igor Griva** and **Jeff Snider**. *Optimization challenges in phase diagram calculation.*

Phase diagrams are used as blueprints for materials design and discovery. Extensive effort in the materials community is dedicated to calculating phase diagrams for multicomponent systems of technological importance. The process amounts to minimizing Gibbs free energy subject to linear and nonlinear constraints and in the presence of multiple local minima, which presents challenges when it comes to identifying globally stable equilibria. Complex interaction between the constraints warrants extra care when designing a reliable computational methodology. This talk will survey existing strategies and compare their results to the optimal solutions delivered by a novel set-based constrained minimization algorithm. Pitfalls and advantages of each method will be discussed. (Received January 20, 2015)

1107-49-495 **Yuri Ledyaev*** (ledyaev@wmich.edu), Department of Mathematics, Western Michigan University, Kalamazoo, MI 49008-5248, and **Robert Kipka**, Department of Mathematics and Statistics, Queens Univerity, Kingston, Ontario , Canada. *Dynamic Optimization on Infinite-Dimensional Manifolds.*

We study optimal control problems in which the state evolves on an infinite-dimensional manifold M which is modeled over Banach space E.

Minimize

$$\ell(q(0), q(T)) + \int_0^T L(q(t), u(t))\, dt$$

subject to dynamic constraint

$$\dot{q}(t) = f(t, q(t), u(t)), \quad q(0) = q_0 \tag{1}$$

and endpoint constraints

$$(q(0), q(T)) \in S \subset M \times M. \tag{2}$$

where $q(t)$ describes a state of the control system (1), $u(t)$ is a control function taking values in a set U, $f(t,q,u)$ is a parametric family of vector fields $f:[0,T]\times M\times U\to TM$ describing a dynamics of the system, the set S describes end constraints for trajectory of (1). We discuss a mathematical framework for analysis of such optimal control problems on manifolds. These problems arise in study of dynamic optimization for partial differential equations with symmetries and they have not been studied before. We develop nonsmooth analysis methods and Lagrangian charts techniques which can be used for study of global variations of optimal trajectories of such control systems and derivation of Pontryagin maximum principle for them. (Received January 20, 2015)

51 ► Geometry

1107-51-69 **Jin Hyup Hong*** (hb2283@gmail.com), 43 Rowe Place, New Hyde Park, NY 11040. *On the Euclidean Dimension of Graphs.*

The Euclidean dimension of a graph G is defined to be the smallest integer d such that the vertices of G can be located in R^{d} in such a way that the two vertices are unit distance apart if and only if they are adjacent to G. In this paper we determine the Euclidean dimension for twelve well-known graphs. Five of these graphs, Durer, Franklin, Desargues, Heawood and Tietze can be embedded in the plane, while the remaining graphs, Chvatal, Goldner-Harrary, Herschel, Fritschr, Grotzsch, Hoffman and Soifer have Euclidean dimension 3. We also present explicit embeddings for all these graphs. (Received December 26, 2014)

1107-51-455 **Lucas Culler*** (lculler@math.princeton.edu), 11 Bank St, Princeton, NJ 08542. *Knot Floer Homology and the Tate Curve.*

I will explain how the knot Floer complex of a knot K in S^3 can be interpreted as an object in the derived category of coherent sheaves on the Tate curve. Under this interpretation, the surgery formula of Oszvath and Szabo becomes a computation of sheaf cohomology. If K admits an L-space surgery then the associated object is an ideal sheaf, which I will describe explicitly. (Received January 20, 2015)

52 ► Convex and discrete geometry

1107-52-23 **Zokhrab Mustafaev*** (mustafaev@uhcl.edu), 2700 Bay Area Blvd, Department of Mathematics, University of Houston-Clear Lake, Houston, TX 77058, and **Horst Martini** (horst.martini@mathematik.tu-chemnitz.de), Faculty of Mathematics, Chemnitz University of Technology, 09107 Chemnitz, Germany. *Centered convex bodies and inequalities for cross-section measures.* Preliminary report.

The purpose of this talk is to establish some new results on cross-section measures of centered convex bodies. More precisely, we show some connections between inequalities referring to cross-section measures and well-known affine isoperimetric inequalities. Based on this, we derive affine inequalities involving also new characterizations of ellipsoids. In addition, some related results on three-dimensional zonoids are obtained. Some of our results are also interesting from the viewpoint of the geometry of finite dimensional real Banach spaces (Received November 10, 2014)

1107-52-30 **Ilya Scheidwasser*** (scheidwasser.i@husky.neu.edu). *Contractions of Polygons in Abstract Polytopes.*

Several well-known constructions exist on abstract polytopes, such as the pyramid and prism constructions. After a brief introduction to abstract polytopes, we present two new local constructions. The first construction, called digonal contraction, allows digonal sections to be removed by merging their two edges into a single edge. The second construction, called polygonal contraction, allows polygonal sections with at least four vertices to be converted to two smaller polygons by merging two non-adjacent vertices. Neither of these contractions can be applied arbitrarily. In the case of digonal contraction, we have necessary and sufficient conditions for its use. In the case of polygonal contraction, we have necessary and sufficient conditions for its use given an assumption on the polygon, and we have necessary conditions for its use in general. We investigate when these contractions can be applied, and how polygonal contraction can be applied on a somewhat global scale in order to preserve some symmetries of the original polytope. (Received November 22, 2014)

1107-52-40 **V. Soltan*** (vsoltan@gmu.edu), George Mason University, 4400 University Drive, MS 3F2, Fairfax, VA 22030. *Convex hypersurfaces with hyperplanar intersections of their homothetic copies.* Preliminary report.

We describe all convex hypersurfaces S in $\mathbb{R}^n$, possibly unbounded, such that the intersection of S and any homothetic copy of S lies in a hyperplane. (Received December 05, 2014)

1107-52-61 **T. Bisztriczky*** (tbisztri@ucalgary.ca), Calgary, Alberta , Canada. *Characterizations of Cyclic Polytopes.*

One of the most studied class of objects in geometry are the cyclic polytopes . The importance of theses polytopes is due to their usefulness not only to geometry and other branches of mathematics but also to other disciplines, such as economics and chemistry. We review some properties of a cyclic polytope and present some of its characterizations. (Received December 19, 2014)

1107-52-121 **Egon Schulte*** (schulte@neu.edu), Northeastern University, Department of Mathematics, Boston, MA 02115. *Colorful Polytopes, Associahedra and Cyclohedra.*

Every n-edge colored n-regular graph G naturally gives rise to a simple abstract n-polytope P(G), called the colorful polytope of G, whose 1-skeleton is isomorphic to G. We describe colorful polytope versions of the associahedron and cyclohedron. Like their classical counterparts, the colorful associahedron and cyclohedron encode triangulations and flips, but now with the added feature that the diagonals of the triangulations are colored and adjacency of triangulations requires color preserving flips. The colorful associahedron and cyclohedron are derived as colorful polytopes from the edge colored graph whose vertices represent these triangulations and whose colors on edges represent the colors of flipped diagonals. Joint work with G.Araujo-Pardo, I.Hubard and D.Oliveros. (Received January 08, 2015)

1107-52-179 **Gabor Toth*** (gtoth@camden.rutgers.edu), Rutgers University, Department of Mathematics, Camden, NJ 08102, and **Qi Guo**, Suzhou University of Science and Technology, Department of Mathematics, Suzhou, Jiangsu 215009, Peoples Rep of China. *Dual Mean Minkowski Measures and the Grünbaum Conjecture.* Preliminary report.

For a convex body $C \subset \mathbb{R}^n$, we define two sequences $\{\sigma_{C,k}\}_{k\geq 1}$ and $\{\sigma^o_{C,k}\}_{k\geq 1}$ of functions on the interior of C. The k-th members are "mean Minkowski measures in dimension k" which are pointwise dual: $\sigma^o_{C,k}(O) = \sigma_{C^o,k}(O)$, where $O \in \operatorname{int} C$, and C^o is the dual of C with respect to O. We have

$$1 \leq \sigma_{C,k}(O), \sigma^o_{C,k}(O) \leq \frac{k+1}{2}.$$

The lower bound is attained iff C has a k-dimensional simplicial slice or simplicial projection. The upper bound is attained iff C is symmetric with respect to O. Klee showed that the condition $m^*_C > n-1$ on the Minkowski measure of C implies that there are $n+1$ affinely independent affine diagonals meeting at a critical point $O^* \in C$. In 1963 Grünbaum conjectured the existence of such point in any convex body. While this conjecture remains open (and difficult), as a byproduct of the properties of the dual mean Minkowski measures, we show that

$$\frac{n}{m^*_C + 1} \leq \sigma_{C,n-1}(O^*),$$

and if sharp inequality holds then the Grünbaum conjecture holds. Our assumption is much weaker than Klee's. (Received January 13, 2015)

1107-52-312 **Karoly Bezdek*** (bezdek@math.ucalgary.ca), University of Calgary, 2500 University Drive NW, Calgary, AL T2N1N4, Canada, and **Muhammad Ali Khan**, University of Calgary, 2500 University Drive NW, Calgary, Alberta T2N1N4, Canada. *The covering index of convex bodies.*

Covering a convex body by its homothets is a classical notion in discrete geometry that has resulted in a number of interesting and long standing problems. Swanepoel [Mathematika 52 (2005), 47–52] introduced the covering parameter of a convex body as a means of quantifying its covering properties. In this talk, we introduce a close relative of the covering parameter called covering index, which turns out to have a number of nice properties. This is a joint work with Muhammad A. Khan (University of Calgary). (Received January 18, 2015)

1107-52-369 **Robert J. MacG. Dawson*** (rjmdawson@gmail.com), Saint Mary's University, 933 Robie St, Halifax, NS B3H 3C3, Canada. *Some results on intangent spreads of convex bodies.* Preliminary report.

By a spread of bodies we will understand a real n-manifold embedded in a (here metric) hyperspace - that is, an n-parameter family of bodies. Monotone spreads (those for which every two bodies are joined by a monotone arc) have been considered elsewhere (by the speaker) in the context of the Chebyshev nearest neighbor property. Here we consider a weaker property, that of *intangency*: a spread of bodies is intangent if no two elements have a common boundary point at which they share a supporting hyperplane (in the same sense). All monotone spreads have this property, as do many others.

We will examine some implications of this property, which is sufficient to explain several observations about monotone spreads. We will see surprising (though elementary) connections to algebraic topology. (Received January 19, 2015)

1107-52-416 **Jim Lawrence*** (`lawrence@gmu.edu`). *Chains of Antiprisms.* Preliminary report.
We relate some interesting facts about sequences of polytopes, each of which (after the first) is an antiprism over its predecessor. (Received January 20, 2015)

1107-52-438 **Carl W. Lee*** (`lee@uky.edu`), Department of Mathematics, 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506, and **Clifford Taylor**. *A Generalization of the Secondary Polytope Induced by Lifting and Deleting.* Preliminary report.
Given a finite set Q of points in $\mathbf{R}^d$, a regular subdivision of $\operatorname{conv} Q$ is formed by taking the convex hull of a lifting of Q into $\mathbf{R}^{d+1}$ and projecting the lower hull back into $\mathbf{R}^d$. It is well known that the poset of regular subdivisions of Q, ordered by refinement, is isomorphic to the face lattice of a convex polytope, the secondary polytope of Q, and that the coordinates of the vertices of this polytope are given by the characteristic vectors defined by Ge'lfand, Kapranov, and Zelevinsky, computed in a simple way from the volumes of the maximal simplices in the corresponding regular triangulations. We generalize some of these results by fixing an integer $0 \leq k \leq |Q|$, and for each lifting of Q considering the family of subdivisions obtained by deleting in turn each of the subsets of Q of size k. Associated with each k will be a polytope with each vertex corresponding to the family of triangulations derived from a lifting. Coordinates of each vertex can be obtained by summing the characteristic vectors of the triangulations in its family. In the simple case of n points on a line and $k = 1$ we can enumerate vertices and edges of these polytopes. (Received January 20, 2015)

1107-52-451 **Wendy Finbow-Singh***, wendy.finbow-singh@smu.ca. *Low Dimensional Neighbourly Simplicial Polytopes.*
Amongst the d-polytopes with v vertices, the neighbourly polytopes have the greatest number of facets. This maximum property has prompted researchers to compose lists of them. In this talk, we will discuss an algorithm for generating the list of simplicial neighbourly d-polytopes with v vertices, for a given dimension d and number of vertices, v. (Received January 20, 2015)

1107-52-452 **András Bezdek** and **Wlodzimierz Kuperberg*** (`kuperwl@auburn.edu`). *Approximating convex disks from inside and out by parallelograms.* Preliminary report.
For each convex disk K we consider the minimum area $P(K)$ of a parallelogram containing K and the maximum area $p(K)$ of a parallelogram contained in K, then we seek the maximum of $P(K)$ and the minimum of $p(K)$ over all convex disks K of area 1. Without assuming central symmetry of K, the naturally anticipated answers will be given, but when we assume central symmetry, the problem of the maximum of $P(K)$ becomes much harder. We state a conjecture and discuss it in a quite broad context that includes the well-known, still unresolved Reinhardt Conjecture on the criticality of the smoothed octagon. (Received January 20, 2015)

1107-52-475 **Dan Ismailescu*** (`dan.p.ismailescu@hofstra.edu`) and **Geoffrey Exoo**. *Improved lower bounds for the chromatic number of several small dimensional Euclidean spaces.* Preliminary report.
The chromatic number of the n-dimensional Euclidean space, denoted $\chi(\mathbb{R}^n)$, is the minimum number of colors that can be assigned to the points of $\mathbb{R}^n$ so that no two points at distance one receive the same color. In this note, we present better lower bounds for $\chi(\mathbb{R}^n)$ for several small values of n. (Received January 20, 2015)

53 ► Differential geometry

1107-53-38 **Jo Nelson*** (`nelson@math.ias.edu`) and **Michael Hutchings**. *Cylindrical Contact Homology: An Abridged Retrospective.*
Cylindrical contact homology is arguably one of the more notorious Floer theoretic constructions. The past decade has been less than kind to this theory, as the growing knowledge of gaps in its foundations have tarnished its claim to being a well-defined contact invariant. However, recent work of Hutchings and Nelson has managed to redeem this theory in dimension 3 for dynamically convex contact manifolds. This talk will highlight our

implementation of intersection theory, non-equivariant constructions, domain dependent almost complex structures, automatic transversality, and obstruction bundle gluing, yielding a homological contact invariant which is expected to be isomorphic to SH^+ under suitable assumptions, though does not require a filling of the contact manifold. By making use of family Floer theory we obtain a S^1-equivariant theory defined over $\mathbb{Z}$-coefficients, which when tensored with $\mathbb{Q}$ yields cylindrical contact homology, now with the guarantee of well-definedness and invariance. (Received December 04, 2014)

1107-53-57 **M. T. Mustafa*** (tahir.mustafa@qu.edu.qa), Mathematics, Statistics and Physics, Qatar University, Doha, 2713, Qatar. *Symmetry classification of heat, wave and Poisson equations on surfaces of revolution.*

A classification of surfaces of revolution according to their isometries was carried out by Eisenhart in 1925. We investigate the corresponding classification question for symmetries of heat and wave equations, and obtain a complete classification of surfaces of revolution according to the symmetries of heat and wave equation. The minimal symmetry algebras are utilized in a unified manner to obtain the solutions, in general integral form, for the heat and wave equations on any surface of revolution. In particular, we compute examples of exact solutions of heat and wave equations on surfaces in different classes of classification including surfaces admitting only minimal symmetry algebra as well as surfaces admitting extra symmetries.
The classification approach is further extended to study group classification problem for Poisson equation. The group classification question for symmetries of Poisson equation on higher dimensional manifolds was answered recently by Bozhkov-Freire. However the question was open for Poisson equation on surfaces. A complete group classification of symmetries of non-linear Poisson equations on surfaces of revolution is carried out. (Received December 18, 2014)

1107-53-268 **Arthur J Parzygnat*** (aparzygnat@gc.cuny.edu), 365 Fifth Avenue, Physics Department, New York, NY 10016. *Two-dimensional iterated integrals and applications in classical gauge theory.*

One-dimensional iterated integrals can be phrased neatly in the language of category theory emphasizing key properties. Higher categories provide a framework for a simple generalization of these properties giving conceptually simple definitions of iterated integrals in higher dimensions. In this talk, we will discuss this generalization to surfaces using string diagrams to illustrate how iterated integrals should be thought of as “higher-dimensional algebra.” We will give a simple example from classical gauge theory by computing the magnetic flux through a sphere for an $SO(3)$-monopole, i.e. by computing the surface holonomy along a sphere equipped with a nontrivial $SO(3)$-bundle. (Received January 17, 2015)

1107-53-283 **Cheyne Miller*** (cmiller@gc.cuny.edu). *Iterated integrals for Local Zig-Zag Hochschild Complexes.* Preliminary report.

We define a new higher Hochschild Complex with an Iterated Integral map to model differential forms on the space of bigons on M. In particular, given a gerbe with structure 2-group coming from a crossed module of matrix-groups, there is an element in our Zig-Zag Hochschild complex associated to the 2-holonomy given by such a gerbe. This paper is introduces an initial construction central to the author’s PhD Thesis. (Received January 17, 2015)

1107-53-307 **David L Duncan*** (duncan42@math.msu.edu). *The quilted Atiyah-Floer conjecture and the Yang-Mills heat flow.*

We will begin by discussing a variant of the Atiyah-Floer conjecture that is well-posed for 3-manifolds with positive first Betti number. Then we will mention some recent progress towards a proof that involves the Yang-Mills heat flow in a crucial way. (Received January 18, 2015)

1107-53-343 **Wei Yuan*** (wyuan2@ucsc.edu), Department of Mathematics, UC Santa Cruz, 1156 High Street, Santa Cruz, CA 95064, and **Jie Qing**. *Rigidity of scalar curvature and vacuum static spaces.*

In this talk, the vacuum static spaces which appears to be spacial slices of a category of very special solutions to Einstein equations will be introduced first. After a brief discussion of classifications and properties of such spaces, the connection between vacuum static spaces and local rigidity with respect to scalar curvature will be revealed. (Received January 19, 2015)

1107-53-390 **Daniel A Cristofaro-Gardiner*** (gardiner@math.harvard.edu). *Symplectic embeddings of four-dimensional toric domains.*

While much is known about when one four-dimensional symplectic ellipsoid embeds into another, symplectic embeddings of other domains are in general poorly understood. I will survey some recent progress concerning symplectic embeddings of four-dimensional "toric domains". It turns out that in many cases, Hutchings' "embedded contact homology" capacities give sharp obstructions. Some of this is joint work with K. Choi, D. Frenkel, M. Hutchings, and V. Ramos. (Received January 19, 2015)

1107-53-420 **Mohammad Ghomi**, Georgia Institute of Technology, School of Mathematics, Atlanta, GA 30332, and **Ralph Howard***, University of South Carolina, Department of Mathematics, Columbia, SC 29208. *Total diameter and area of closed submanifolds.*

The *total diameter* of a closed planar curve C is the integral its antipodal chord lengths. We show this quantity is bounded below by twice the area enclosed by the curve. Furthermore, when the curve is convex or centrally symmetric, the lower bound is twice as large. Both inequalities are sharp and equality holds in the convex case only when the curve is a circle. We generalize these results to the case of m dimensional submanifolds of Euclidean n space where the enclosed *area* is defined in terms of the mod 2 winding numbers of the submanifold about $n-m-1$ affine subspaces. (Received January 20, 2015)

55 ► Algebraic topology

1107-55-202 **Bryce Chriestenson** and **Markus J. Pflaum*** (markus.pflaum@colorado.edu), Department of Mathematics UCB 395, University of Colorado, Boulder, CO 80305.
Whitney functions and the real homotopy type of a semi-analytic set.

In the talk we consider semi-analytic subsets of a real analytic manifold and their homology and real homotopy type. It is well-known that de Rham's Theorem does not hold true in general for singular spaces such as semi-analytic sets. We show that to remedy this one can replace the de Rham complex by the Whitney–de Rham complex to compute the singular homology of such sets. Beyond that, the Whitney–de Rham complex even determines the real homotopy type of a semi-analytic set, which extends a result by Sullivan for the de Rham complex on smooth manifolds. As an application we derive that the Hochschild homology of the differential graded algebra given by the Whitney–de Rham complex is isomorphic to the cohomology of the free loop space of the underlying space. (Received January 15, 2015)

1107-55-303 **Anil B Venkatesh*** (anilbv@math.duke.edu). *Comparison of Regularization Methods for Iterated Integrals of Eisenstein Series.*

We study iterated integrals of Eisenstein series. These integrals naturally arise in studying relations between multiple zeta values that are induced by modular forms. The iterated integral can be understood as parallel transport on a vector bundle over the moduli space of elliptic curves. Using the theory of regular singular points, Hain regularizes these integrals by constructing the Deligne canonical extension of the vector bundle to a singular fiber. By comparison, Brown regularizes iterated integrals of Eisenstein series by first passing to the universal cover. We examine these two regularization methods and assess whether they coincide in all cases. (Received January 18, 2015)

1107-55-499 **Paul M. Alsing**, **Howard A. Blair** and **Matthew Corne***
(matthew.corne.ctr@us.af.mil), Rome, NY 13441, and **Gordon Jones**, **Warner A. Miller**, **Konstantin Mischaikow** and **Vidit Nanda**. *Applications of Persistent Homology to Simplicial Ricci Flow.*

We apply the methods of persistent homology to investigate singularity formation in a selection of two and three–dimensional geometries evolved by simplicial Ricci flow, an unstructured mesh formulation of Hamilton's Ricci flow. To implement persistent homology, we construct a triangular mesh for a sample of points. The scalar curvature along the edges of the triangulation, computed as an average of scalar curvatures at the endpoints of the edges, serves as a filtration parameter at each time step. We present and analyze the results of the application of persistent homology to a two–dimensional rotational solid that collapses and three–dimensional dumbbells that manifest neckpinch singularities. We compare the appearance of critical geometric phenomena in these models with the results of the application of persistent homology and conclude that persistent homology does indicate geometric criticality. Finally, we discuss the interpretation and implication of these results and future applications. (Received January 20, 2015)

57 ► Manifolds and cell complexes

1107-57-5 **Micah W. Chrisman*** (mchrisma@monmouth.edu). *Prime Decomposition and Non-Commutativity in the Monoid of Long Virtual Knots.*

It is well-known that the monoid of long virtual knots is not commutative. This contrasts with the case of classical long knots, where $A\#B \leftrightharpoons B\#A$ for all A, B. In the present paper, we present a new proof that two inequivalent non-classical prime long virtual knots never commute. The original result is due to Manturov. We prove that if A, B, C, D are prime non-classical long virtual knots such that $A\#B$ is non-classical and $A\#B \leftrightharpoons C\#D$, then $A \leftrightharpoons C$ and $B \leftrightharpoons D$. The paper is available at: arXiv:1311.5748[math.GT]. (Received August 09, 2014)

1107-57-22 **Nguyen D Duong*** (ndduong@crimson.ua.edu), Tuscaloosa, AL 35404, and **Lawrence Roberts**. *Planar algebra structure in bordered Khovanov homology.* Preliminary report.

I'll discuss work-in-progress with Lawrence Roberts toward constructing a planar algebra structure in bordered Khovanov homology. We define an invariant (type DA structure) for tangles subordinate to disc configurations. This type DA structure will induce a morphism from the planar algebra of tangle diagrams to the category of A_∞ modules. (Received November 15, 2014)

1107-57-35 **Ying Hu*** (yhu4@math.lsu.edu). *Left-orderability and cyclic branched coverings.*

A group is called left-orderable if one can put a total order $<$ on the set of group elements so that inequalities are preserved by group multiplication on the left. In this talk, we will discuss the left-orderability of fundamental groups of cyclic branched coverings of the three sphere. (Received December 03, 2014)

1107-57-39 **Laura Starkston*** (lstarkston@math.utexas.edu). *Symplectic fillings.*

The classification problem for symplectic manifolds with a given contact boundary has been solved in a number of cases for relatively simple three manifolds. The proofs rely at their core on pseudoholomorphic curve arguments, but the detailed classification problems can be interpreted in different topological ways. I will discuss methods to approach the symplectic filling classification problem and relationships between these methods. (Received December 04, 2014)

1107-57-129 **Tyler Lawson**, **Robert Lipshitz** and **Sucharit Sarkar*** (sucharit@math.princeton.edu). *Khovanov homology and the Burnside category.*

Khovanov homology of links is defined starting from a functor from the cube category to the category of (graded) vector spaces. We will lift this functor to a functor from the cube to the Burnside category. Finally, we will describe how this is useful in constructing a stable homotopy refinement of Khovanov homology. (Received January 09, 2015)

1107-57-134 **Cody Armond** and **Adam M Lowrance*** (adlowrance@vassar.edu). *Turaev genus and alternating decompositions of link diagrams.* Preliminary report.

We present an algorithm for computing the genus of the Turaev surface of a link diagram in terms of its decomposition into alternating regions. Consequently, we obtain a classification of Turaev genus one links. (Received January 10, 2015)

1107-57-166 **Oliver Dasbach*** (kasten@math.lsu.edu), Louisiana State University, Department of Mathematics, Baton Rouge, LA 70803, and **Mustafa Hajij**, Louisiana State University, Department of Mathematics, Baton Rouge, LA 70803. *Generalized connected sums on knots, and knot invariants.* Preliminary report.

Polynomial knot invariants like the Alexander polynomial or the Jones polynomial behave nicely under the connected sum of knots. We will discuss other sums for knots, and the implications for the colored Jones polynomial. (Received January 12, 2015)

1107-57-184 **Masahico Saito*** (saito@usf.edu). *Triangular surfaces with Latin quandle actions.*

For a given (diagonalized) quasigroup, a closed surface consisting of triangles was constructed by Norton and Stein, from its multiplication table (a Latin square). We examine these surfaces, called NS-surfaces, for Latin quandles. They are typically disconnected, and their genera reflect properties of quandles. We show, for example, that the NS-surface for any connected Alexander quandle consists of spheres and tori. On the other hand, it is also shown that arbitrary large genera are realized by NS-surfaces of some connected Latin quandles. Actions of quandles on their NS-surfaces are discussed, and 2-cycles of quandle homology are realized in NS-surfaces. (Received January 14, 2015)

1107-57-197 **Tye Lidman*** (tlid@math.utexas.edu) and **Steven Sivek**. *Contact topology and reducible surgeries.*

The Cabling conjecture is a classical problem in three-manifold topology which attempts to characterize the knots in the three-sphere for which Dehn surgery results in a non-prime manifold. We use standard results in three- and four-dimensional contact and symplectic topology to study this problem. (Received January 14, 2015)

1107-57-199 **Charles Frohman*** (charles-frohman@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242. *Dehn's Algorithm for Simple Diagrams.*

A simple diagram on a surface is a disjoint collection of simple closed curves none of which bounds a disk. If the surface F is noncompact, of finite type and has negative Euler characteristic, then isotopy classes of simple diagrams are classified up to isotopy by admissible colorings of the edges of an ideal triangulation. The weight of a diagram is the sum of its geometric intersection numbers with the edges of the triangulation. If $\hat{F}$ is a closed surface, we can remove a point to get a finite type surface F. Each simple diagram on $\hat{F}$ can be represented by infinitely many simple diagrams on F. We show that if the Euler characteristic of F is negative, any representative of a simple diagram on $\hat{F}$ can be simplified monotonically to have least weight. Also each diagram has finitely many least weight representatives, which are in fact unique unless the diagram admits a structure analagous to a half relator. (Received January 14, 2015)

1107-57-203 **Louis H. Kauffman*** (kauffman@uic.edu), 5530 South Shore Drive, Apartment 7C, Chicago, IL 60637-1946. *Braids and Clifford Algebras.* Preliminary report.

This talk will discuss braid group representations naturally associated with Clifford algebras with n generators $a_1, ..., a_n$ such that $(a_i)^2 = 1$ and every pair of generators anti-commutes. The a_i are called Majorana operators in physics and a pair of Majorana operators $\{a, b\}$ can be combined as$(a + ib)/\sqrt{2}$ and $(a - ib)/\sqrt{2}$ to form the usual operator algebra for a fermion. The braid group representations that we discuss are of interest in their own right, and they are of potential use if physical phenomena corresponding to the Majorana operators are discovered. (Received January 15, 2015)

1107-57-212 **Lenhard Ng*** (ng@math.duke.edu). *Effectiveness of transverse knot invariants.*

Since Olga Plamenevskaya's 2004 definition of an invariant for transverse knots lying in Khovanov homology, a wide range of similarly-flavored invariants have been discovered. These include transverse knot invariants in knot Floer homology and Khovanov-Rozansky homology, as well as a filtration on knot contact homology. I will give a very brief introduction to some of these invariants and discuss what is known about how effective or ineffective they may be. (Received January 15, 2015)

1107-57-221 **Daniel S Silver** and **Susan G Williams*** (swilliam@southalabama.edu). *Infinite Planar Graphs and Medial Link Components.* Preliminary report.

Let G be a locally finite graph with free Z^d-action. We use tools of algebraic dynamics to determine the growth rate of the number of spanning trees of increasingly large subgraphs of G. When $d = 2$ and G is planar, we classify the components of the medial link associated to G. (Received January 15, 2015)

1107-57-223 **Cornelia A. Van Cott*** (cvancott@usfca.edu) and **Charles Livingston**. *Knot signatures, upsilon, and the four-genus of knots.* Preliminary report.

Both the Levine-Tristram signature function and the recently defined Ozsvath-Stipsicz-Szabo upsilon function provide bounds on the four-genus of a knot. We will explore the behavior of these bounds, focusing on their behavior with respect to the connected sums of torus knots. (Received January 15, 2015)

1107-57-308 **R. Inanc Baykur*** (baykur@math.umass.edu) and **Kenta Hayano**. *Multisections of Lefschetz fibrations and topology of symplectic 4-manifolds.*

We initiate an extensive study of multisections of Lefschetz fibrations via positive factorizations in framed mapping class groups. Using our techniques, we can reformulate and tackle various interesting conjectures and problems related to the topology of symplectic 4-manifolds. In this talk we will focus on the conjectural smooth classification of symplectic Calabi-Yaus and their fundamental groups in real dimension 4. If time permits, we will discuss some other applications as well; such as Stipsicz's conjectures on minimality and fiber sum decompositions, constructions of inequivalent Lefschetz fibrations and exotic pencils. (Received January 18, 2015)

1107-57-315 **Jennifer Hom*** (hom@math.columbia.edu). *Knot Floer homology and concordance.*

We will discuss applications of knot Floer homology to concordance. In particular, we will compare the four-ball genus and concordance genus bounds given by ε, $\Upsilon(t)$, τ, and ν^+, which are all numerical invariants associated to the knot Floer complex. Parts of this talk are joint work with Zhongtao Wu. (Received January 18, 2015)

1107-57-320 **Christopher R Cornwell**, **Lenhard Ng** and **Steven Sivek***, Fine Hall, Washington Road, Princeton, NJ 08544-1000. *Obstructions to Lagrangian concordance.*

We investigate the question of the existence of a Lagrangian concordance between two Legendrian knots in $\mathbb{R}^3$. In the case of a concordance from a knot K to the standard Legendrian unknot, we use normal rulings to provide obstructions which can be expressed in terms of the HOMFLY and Kauffman polynomials of K and its cables and thus depend only on the smooth knot type of K. As a consequence, we construct non-reversible Lagrangian concordances from the standard Legendrian unknot to infinitely many other knots. (Received January 18, 2015)

1107-57-351 **John Etnyre*** (etnyre@math.gatech.edu) and **Bulent Tosun**. *Tori in contact 3-manifolds.*

I will discuss the role of tori, both compressible and incompressible, in the understanding of contact structures on 3-manifolds. When studying compressible tori one can use non-thickenable, or partially thickenable, solid tori to classify tight contact structures on some manifolds via surgery. When studying incompressible tori one can show the difficulties in a JSJ type decomposition for contact manifolds. (Received January 19, 2015)

1107-57-372 **Carmen Caprau***, 5245 N. Backer Avenue M/S PB108, Fresno, CA 93740, and **Heather Russell**. *Moves for isotopic singular link cobordisms in 4-dimensional space.* Preliminary report.

A singular link is an immersion of a disjoint union of circles in 3-space, which has finitely many singularities that are all transverse double points. A singular link can be regarded as an embedding in 3-space of a 4-valent graph with rigid disks.

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 to 3-space by taking 2-dimensional cross sections perpendicular to a fixed direction. This talk will be centered on the set of movie moves that are sufficient to connect any two movies of isotopic singular link cobordisms. (Received January 19, 2015)

1107-57-401 **Jing Wang*** (gwjwang@gwu.edu) and **Jozef H. Przytycki** (przytyck@gwu.edu). *Homology of Small Categories and Its Applications to Quiver Cohomology.*

Motivated from knot theory, we introduce a homology theory for small categories with functor coefficients. Under this general framework, different familiar homology theories such as group homology, chromatic homology, poset homology and Khovanov homology can be realized as homology of small categories whose coefficients are specified functors. For the category of an abstract simplicial complex, we define chain groups via two different approaches and prove that these two definitions are equivalent in the sense that homology groups under these two definitions are isomorphic via an interpretation of barycentric subdivision. As an application, we develop cohomology theory for quivers (directed graphs). We introduce quiver cohomology for non-commutative algebras motivated by Wagner and Turner's work. We analyze and speculate on properties of the quiver cohomology groups via some calculations. (Received January 19, 2015)

1107-57-408 **Seung Yeop Yang*** (syyang@gwu.edu) and **Jozef H. Przytycki**. *Torsion subgroups of rack homology groups of some finite quandles.*

It is a classical result in reduced homology of finite groups that the order of a group annihilates its homology. The first general results in this direction were obtained independently about 2001 by R.A.Litherland and S.Nelson, and P.Etingof and M.Grana. The result of Litherland-Nelson is generalized by Niebrzydowski and Przytycki and in particular, they prove that the torsion part of the homology of the dihedral quandle R_3 is annihilated by 3. In Niebrzydowski-Przytycki's paper, it is conjectured that for a finite quasigroup quandle (the special case of connected quandles), torsion of its homology is annihilated by the order of the quandle. The conjecture is proved by T.Nosaka for finite Alexander quasigroup quandles. In this talk, we prove the conjecture in full generality, and find upper bounds for the torsion of rack homology of some finite quandles (including all connected quandles of order up to 14 and some non-connected quandles such as R_4). (Received January 19, 2015)

1107-57-411 **William H. Kazez** and **Rachel Roberts*** (roberts@wustl.edu). *Approximating taut foliations.*

Taut foliations, volume preserving flows, and tight contact structures are important topological structures on 3-manifolds. We will define these structures and describe some of the ways in which they are important. In particular, we will discuss these structures in the context of the following result of Eliashberg and Thurston: any smooth taut co-oriented foliation can be approximated by a pair of tight contact structures, one positive and one negative. I will discuss work, joint with Will Kazez, in which we show that the smoothness assumption on the foliation can be dropped; namely, any continuous co-oriented taut foliation can be approximated by a pair of tight contact structures, one positive and one negative. (Received January 19, 2015)

1107-57-428 **Uwe Kaiser*** (ukaiser@boisestate.edu), Department of Mathematics, Boise State University, 1910 University Drive, Boise, ID 83725. *On Conway and HOMFLYPT Skein Theory.* Preliminary report.

We show how incompressible tori and 2-spheres give rise to torsion in Conway and HOMFLYPT skein modules and how this is related with string topology. We review Cornwell's result on the generating set of the HOMFLYPT skein module of lens spaces $\neq S^2 \times S^1$. We speculate how his approach might be extended to other 3-manifolds using contact geometry, in particular with respect to recent results of Schweitzer and Souza on Legendrian knots in $S^1 \times S^1 \times S^1$. (Received January 20, 2015)

1107-57-486 **Carl Hammarsten*** (chammar@gwu.edu). *Strip Diagrams and Combinatorial Heegaard Floer homology.*

Given a 3-dimensional closed manifold Y presented by its branched spine, we construct a canonical Heegaard decomposition for Y. We present this decomposition graphically in the form of a Strip Diagram. Using strip diagrams we combinatorially construct a chain complex we have shown is homotopically equivalent to the Heegaard Floer chain complex CF-hat of Y, yet significantly smaller. Furthermore, we show that strip diagrams have nice properties which greatly simplify the calculation of Heegaard Floer homology. Finally, we consider the presentation of a branched spine by its O-graph and show that reformulating our definition in these terms gives a clock-state type description for HF-hat of Y. (Received January 21, 2015)

1107-57-492 **Patricia Cahn*** (pcahn@math.upenn.edu) and **Vladimir Chernov**. *Knots Transverse to a Vector Field.*

We study knots transverse to a fixed vector field V on a 3-manifold M up to the corresponding isotopy relation. We show this classification is particularly simple when V is the coorienting vector field of a tight contact structure, or when M is irreducible and atoroidal. We also apply our results to study loose Legendrian knots in overtwisted contact manifolds, and generalize results of Dymara and Ding-Geiges. (Received January 20, 2015)

58 ► Global analysis, analysis on manifolds

1107-58-91 **Xing Wang*** (xwang@math.jhu.edu), Department of Mathematics, Johns Hopkins University, Baltimore, MD 21218, USA, and **Jiuyi Zhu**. *A lower bound for the nodal sets of Steklov eigenfunctions*

In this talk, I'm going to talk about my recent joint work with Jiuyi Zhu. We consider the lower bound of nodal sets of Steklov eigenfunctions on smooth Riemannian manifolds with boundary–the eigenfunctions of the Dirichlet-to-Neumann map. Let N_λ be its nodal set. Assume that zero is a regular value of Steklov eigenfunctions. We show that

$$H^{n-1}(N_\lambda) \geq C\lambda^{\frac{3-n}{2}}$$

for some positive constant C depending only on the manifold. (Received January 04, 2015)

1107-58-196 **Pierre Albin*** (palbin@illinois.edu), **Eric Leichtnam**, **Paolo Piazza** and **Rafe Mazzeo**. *Hodge Cohomology of Cheeger spaces.*

I will report on recent work extending and refining Cheeger's study of ideal boundary conditions for the de Rham operator from the case of isolated conic singularities to arbitrary stratified pseudomanifolds. This leads to a notion of 'mezzoperversity' intermediate between the upper and lower perversities of Goresky-MacPherson. (Received January 14, 2015)

1107-58-292 **Xiangjin Xu*** (xxu@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University-SUNY, 4400 Vestal Parkway East, Binghamton, NY 13902. *Some problems related to the sharp Li-Yau type Harnack estimates on Riemannian Manifolds with Negative Curvature.*

In this talk, we first discuss some new Li-Yau type Harnack estimates for the heat equations on manifolds with $Ric(M) \geq -K$, $K \geq 0$. Then we discuss some problems on the sharp Li-Yau type Harnack estimates. (Received January 17, 2015)

1107-58-339 **Jungang Li*** (fl6532@wayne.edu), Wayne State University, Detroit, MI 48201, and **Guozhen Lu**. *Sharp Moser-Trudinger Inequality on Complete Noncompact Riemannian Manifolds.*

We will consider the sharp Moser-Trudinger inequality on complete noncompact Riemannian manifolds. Namely,

$$\sup_{u \in W^{1,n}(M), ||u||_{1,\tau} \leq 1} \int_M \phi(\alpha_n |u|^{\frac{n}{n-1}}) dV_g \leq C(n, \tau) \tag{1}$$

Where $\phi(t) = \sum_{k=n-1}^{\infty} \frac{t^k}{k!}$, $\alpha_n = n\omega_{n-1}^{\frac{1}{n-1}}$, where ω_{n-1} is the area of the unit sphere in R^n, $||u||_{1,\tau} = (\int_M \tau|u|^n + |\nabla u|^n)^{\frac{1}{n}}$. The inequality is sharp in the sense that for $\alpha > \alpha_n$, the above inequality fails. (Received January 18, 2015)

1107-58-385 **Nancy Hingston***, hingston@tcnj.edu. *Loop Products, Poincaré Duality, and Dynamics.*

A metric on a compact manifold M gives rise to a length function on the free loop space ΛM whose critical points are the closed geodesics on M in the given metric. Morse theory gives a link between Hamiltonian dynamics and the topology of loop spaces, between iteration of closed geodesics and the algebraic structure given by the Chas-Sullivan product on the homology of ΛM. Poincaré Duality reveals the existence of a related product on the cohomology of ΛM.

A number of known results on the existence of closed geodesics are naturally expressed in terms of nilpotence of products. We use products to prove a resonance result for the loop homology of spheres. There are interesting consequences for the length spectrum, and related results in Floer and contact theory.

Mark Goresky, Alexandru Oancea, and Hans-Bert Rademacher are collaborators. (Received January 19, 2015)

1107-58-494 **Aliakbar Daemi*** (adaemi@scgp.stonybrook.edu). *Abelian Gauge Theory and Khovanov Homology.*

Plane Floer homology is a functor from the category of 3-manifolds and cobordisms to the category of modules, defined with the aid of abelian gauge theory. This invariant can be utilized to define plane knot homology, itself an invariant of knots and links in the 3-dimensional sphere. In my talk, after giving the definition of plane Floer homology, I will discuss the relationship between this invariant and various Khovanov-type homologies. (Received January 20, 2015)

60 ► Probability theory and stochastic processes

1107-60-51 **Janos Englander*** (janos.englander@colorado.edu) and **Mine Caglar**, , Turkey, and **Mehmet Oz**. *Conditional Speed of Branching Brownian Motion, Skeleton Decomposition and Application to Random Obstacles.* Preliminary report.

We study a d-dimensional branching Brownian motion, among obstacles scattered according to a Poisson random measure with a radially decaying intensity. Obstacles are balls with constant radius and each one works as a trap for the whole motion when hit by a particle. Considering a general offspring distribution, we derive the decay rate of the annealed probability that none of the particles hits a trap, asymptotically, in time.

This proves to be a rich problem, motivating the proof of a general result about the speed of branching Brownian motion conditioned on non-extinction. We provide an appropriate 'skeleton-decomposition' for the underlying Galton-Watson process when supercritical, and show that the 'doomed particles' do not contribute to the asymptotic decay rate.

This is joint work with Mine Caglar and Mehmet Oz. (Received December 15, 2014)

1107-60-53 **Chia Ying Lee*** (lchiaying@math.ubc.ca), **Rachel Kuske** and **Vivi Rottschafer**. *Pattern formation in the stochastic Swift-Hohenberg equation with delay.*

The Swift-Hohenberg equation is a model equation for studying pattern formation in dynamical systems. It is known that solutions near the Turing bifurcation point are well approximated by a dominant mode with a slowly varying amplitude. In the presence of noise and delayed feedback, we show how the formation and stability of the patterns may be affected, depending on the delay parameters and the strength of the noise. In the regime of Turing bifurcations, the delay causes multiple time scales to develop. Specifically, at near-critical delay parameters without noise, small perturbations exhibit oscillations on one slow time scale and damping on another slower time scale. With noise, this frequency of oscillations are being excited and sustained rather than damped. (Received December 17, 2014)

1107-60-83 **Yuri Bakhtin*** (bakhtin@cims.nyu.edu). *Burgers equation in noncompact setting with space-continuous kick forcing.*

Ergodic theory of randomly forced space-time homogeneous Burgers equation in noncompact setting has been developed in a recent paper by the speaker with Eric Cator and Kostya Khanin. There, the analysis is based on last passage percolation methods that allow to prove existence of a field of coalescing one-sided minimizers and construct the global solution via Busemann functions. We extend this theory to the case of space-continuous kick forcing. In this setting, the minimizers do not coalesce, so for the ergodic program to go through, one must use new soft results on their behavior to define generalized Busemann functions along appropriate subsequences. (Received January 01, 2015)

1107-60-86 **Eulalia Nualart*** (eulalia@nualart.es), Universitat Pompeu Fabra, Barcelona, Spain. *Noise excitability of the stochastic heat equation.*

We consider the following stochastic heat equation on an interval with Dirichlet boundary conditions driven by a space-time white noise:

$$\partial_t u_t(x) = \frac{1}{2}\partial_{xx} u_t(x) + \lambda\sigma(u_t(x))\dot{W}(t,\, x).$$

We show that in the long run, the second moment of the solution grows exponentially fast if λ is large enough. But if λ is small, then the second moment eventually decays exponentially. If we replace the Dirichlet boundary condition by the Neumann one, then the second moment grows exponentially fast no matter what λ is. We also provide various extensions. This talk is based on a joint work with M. Foondun. (Received January 02, 2015)

1107-60-115 **Ciprian Tudor**, Laboratoire Paul Painlevé, Université de Lille 1, F-59655 Villeneuve d'Ascq, France, and **Yimin Xiao*** (xiao@stt.msu.edu), Department of Statistics and Probability, 619 Red Cedar Road, Michigan State University, East Lansing, MI 48824. *Sample paths of the solution to the fractional-colored stochastic heat equation.* Preliminary report.

Let $\{u(t,x), t \in [0,T], x \in \mathbb{R}^d\}$ be the solution to the linear stochastic heat equation driven by a fractional noise in time with correlated spatial structure. We study various path properties of the process u both with respect to the time and to the space variable. In particular, we derive its sharp modulus of continuity and a Chung-type law of iterated logarithm. (Received January 08, 2015)

1107-60-124 **Konstantinos Spiliopoulos*** (kspiliop@math.bu.edu), Boston University, Department of Mathematics and Statistics, 111 Cummington Mall, Boston, MA 02215. *Irreversible Langevin Samplers and Variance Reduction: A Large Deviations Approach and Diffusion on Graphs.*

Monte Carlo methods are very popular methods to sample from high-dimensional target distributions, which very often are of Gibbs type. Markov processes that have the target distribution as their invariant measure are used to approximate the equilibrium dynamics. In this talk, we explore performance criteria based on the related large deviations theory for random measures and we focus on the diffusion setting. We find that large deviations theory can not only adequately characterize the efficiency of the approximations, but it can also be used as a vehicle to design Markov processes, whose time average optimally (in the sense of variance reduction) approximates the quantities of interest. We quantify the effect that added irreversibility has in the speed of convergence to a target Gibbs measure and to the asymptotic variance of the resulting estimator. One of our main finding is that adding irreversibility reduces the asymptotic variance of generic observables and we give an explicit characterization of when observables do not see their variances reduced in terms of a nonlinear Poisson equation. Connections to averaging problems for Hamiltonian systems and diffusion graphs will be given. Theoretical results are supplemented by simulations. Joint work with Luc Rey-Bellet. (Received January 09, 2015)

1107-60-162 **Michael Salins*** (msalins@math.umd.edu), Mathematics Building, University of Maryland, College Park, MD 20742. *Freidlin-Wentzell exit problems for stochastic equations in Banach spaces.*

For a finite dimensional diffusion exposed to a small noise, Freidlin and Wentzell studied the asymptotics of the exit time and exit place from a basin of attraction. Since their work, several authors have studied similar exit problems associated to specific stochastic partial differential equations. Unfortunately, the methods for studying the exit problems for infinite dimensional systems tended to be very equation-specific. In this talk, I present a general method, based on a control theoretic approach, to characterize the exit time and exit place from a basin of a attraction for a large class of stochastic equations in Banach spaces. (Received January 15, 2015)

1107-60-164 **Zsolt Pajor-Gyulai*** (pgyzs@math.umd.edu), 1603 Lincoln Rd, Washington, DC 20002. *Dynamical systems perturbed by a diffusion driven by a null-recurrent fast motion.* Preliminary report.

We consider an ordinary differential equation perturbed by a diffusion that can only move when a one-dimensional null-recurrent fast diffusion is in the neighborhood of the origin. A central limit type theorem is derived for the first correction term in the deviations from the unperturbed system. We also study the special case when the unperturbed system can have a first integral and derive the long time behavior of the vector of these conserved quantities. Joint work with Michael Salins. (Received January 12, 2015)

1107-60-266 **Kayo Ide*** (ide@umd.edu), University of Maryland, Department of Atmospheric and Oceanic Science, College Park, MD 20910. *A Local Method to Hybrid Data Assimilation.*

The use of hybrid covariance models, which combine a fixed climatological estimate with the ensemble-based representation have, has become quite popular for numerical weather prediction and other geophysical prediction problems. While the ensemble-based models represent the time-evolving covariance, it is rank-deficient and due to the under-sampling. The fixed covariance models, in contrast, have full rank but lack any information of underlying dynamics. The use of the hybrid covariance models aims to enhance the advantages and suppresses the disadvantages of these models. One computational method for hybrid approach utilized optimization in the global variational framework through an augmented control variable. In this talk, we present a new local method that solves the optimization problems at every grid without the variational framework. (Received January 17, 2015)

1107-60-272 **Mykhaylo Shkolnikov*** (mykhaylo@math.princeton.edu), 1110 Fine Hall, Department of Mathematics, Princeton University, Princeton, NJ 08540. *On multilevel Dyson Brownian motions.*

I will discuss how Dyson Brownian motions describing the evolution of eigenvalues of random matrices can be extended to multilevel Dyson Brownian motions describing the evolution of eigenvalues of minors of random matrices. The construction is based on intertwining relations satisfied by the generators of Dyson Brownian motions of different dimensions. Such results allow to connect general beta random matrix theory to particle systems with local interactions, and to obtain novel results even in the case of classical GOE, GUE and GSE random matrix models. Based on joint work with Vadim Gorin. (Received January 17, 2015)

1107-60-301 **Michal Branicki*** (m.branicki@ed.ac.uk), Dept. of Mathematics, University of Edinburgh, JCMB 6214, The King's Buildings, Peter Guthrie Tait Road, Edinburgh, EH9 3FD, United Kingdom, and **A. J. Majda**. *Quantifying Bayesian filter performance through path-space information theory.*

I will exploit connections between the filtering problem and information theory in order to revisit the issue of filter optimality in the presence of model error in the filter prior; such a setting is commonplace when designing approximate data assimilation algorithms for high-dimensional systems with a partially observed state. The effects of model error on filter stability and accuracy in this setting are analysed through appropriate information measures which naturally extend the statistical second-order, path-wise estimates of filter performance, like the mean-square error or pattern correlation, to a probabilistic 'superensemble' setting which is not necessarily Gaussian. For simplicity I will focus on the accuracy of various imperfect Kalman filters with particular emphasis is on practically achievable filter skill which requires trade-offs between different facets of filter performance; a new information criterion is introduced in this context and discussed on simple examples. Generalisations of this approach to other filters will also be outlined. (Received January 18, 2015)

1107-60-305 **Amarjit Budhiraja**, **Paul Dupuis*** (paul_dupuis@brown.edu) and **Arnab Ganguly**.
Moderate Deviation Principles for Stochastic Differential Equations with Jumps.

We discuss moderate deviation principles for stochastic differential equations driven by a Poisson random measure (PRM) in finite and infinite dimensions. A main motivation is for use in the design of accelerated Monte Carlo schemes. In comparison with the corresponding large deviation result, the upper bound is in some ways more difficult. Proofs are based on a variational representation for expected values of positive functionals of a PRM. (Received January 18, 2015)

1107-60-310 **hakima Bessaih*** (bessaih@uwyo.edu), Department of Mathematics, 1000 E. University Ave. Dept. 3036, Laramie, WY 82071, and **Florian Maris** and **Yalchin Efendiev**.
Homogenization of the stochastic Navier–Stokes equation in perforated domains. Preliminary report.

Some stochastic models are considered including the two dimensional Navier-Stokes equation in a perforated domain with a dynamical slip boundary condition. The dynamics are driven by a noise on the interior and on the boundary of the domain. Different scalings are considered that give rise to different limit problems.

For a particular scaling used on the Navier-Stokes equations, we obtain a Darcy's law with memory. We mainly use the two scale convergence method to pass to the limit. Moreover, the passage to the limit is performed on the variational formulation. (Received January 18, 2015)

1107-60-317 **Alexei Novikov*** (anovikov@math.psu.edu). *Homogenization in stationary fluid flows.*

I will discuss recent results related to analysis of effective behavior of a passive scalar in incompressible stationary fluid flows in two dimensions. The particle is driven either by the classical Brownian motion or by the fractional Brownian motion. (Received January 18, 2015)

1107-60-363 **B. L. Rozovsky*** (boris_rozovsky@brown.edu), B. Rozovsky, Providence, RI 02912, and **R. Mikulevicius** (mikulvcs@usc.math.edu), R. Mikulevicius, Los Angeles, CA 900089-253.
Distribution Free Approach to Stochastic PDEs.

B. Rozovsky, Brown University, R. Mikulevicius, USC

Historically, stochastic partial differential equations were investigated under the assumption that the driving random noise was either Gaussian or Levy. However, in practice, one can encounter systems driven by all kinds of random perturbations. With this in mind, we will discuss linear SPDE driven by more or less arbitrary noise. We will develop a distribution free version of Malliavin calculus and demonstrate that the system PDEs for the deterministic coefficients of the Chaos expansion of the solution does not depend on the type of randomness involved. On the "practical" side, the aforementioned effect leads to substantial reduction of computational complexity of related numerical methodology. (Received January 19, 2015)

1107-60-427 **Raluca M Balan** and **Daniel Conus*** (daniel.conus@lehigh.edu), Mathematics Department, Christmas-Saucon Hall, 14 East Packer Avenue, Bethlehem, PA 18015.
Intermittency for a family of parabolic and hyperbolic SPDEs driven by fractional noise.

We will describe results related to the notion of "intermittency", i.e. the property that a random field develops large values ("high peaks") when time gets large. We will remind how this phenomenon appears in the context of SPDEs. In particular, we will illustrate how the intermittent behavior of the solution to an SPDE depends on the type of driving noise in the cases of nonlinear stochastic heat and wave equations driven by fractional noise. In the latter case, the results are obtained via a Feynman-Kac representation similar to the one introduced by Dalang, Mueller and Tribe (2008). (Received January 20, 2015)

1107-60-431 **Karine Bertin*** (karine.bertin@uv.cl), Valparaiso, Chile, and **Nicolas Klutchnikoff** (nicolas.klutchnikoff@ensai.fr), Rennes, France. *Pointwise adaptive estimation of the marginal density of a weakly dependent process.*

We studied the estimation of the common marginal density function of weakly dependent stationary processes. The accuracy of estimation is measured using pointwise risks. We propose a data-driven procedure using kernel rules. The bandwidth is selected using the approach of Goldenshluger and Lepski and we prove that the resulting estimator satisfies an oracle type inequality. The procedure is also proved to be adaptive (in a minimax framework) over a scale of Hölder balls for several types of dependence: classical econometrics models such as GARCH as well as dynamical systems and i.i.d. sequences can be considered using a single procedure of estimation. Some simulations illustrate the performance of the proposed method. (Received January 20, 2015)

1107-60-435 **David Nualart*** (nualart@ku.edu). *Stochastic heat equation with rough multiplicative noise.*

In this talk we present some recent results on the one-dimensional stochastic heat equation

$$\frac{\partial u}{\partial t} = \frac{1}{2}\frac{\partial^2 u}{\partial x^2} + \sigma(u)\frac{\partial^2 W}{\partial t \partial x},$$

where W is a zero mean Gaussian noise, which is white in time and it has the covariance of a fractional Brownian motion with Hurst parameter $H \in (1/4, 1/2)$ in the space variable. We will show the existence and uniqueness of a solution with values in some suitable Sobolev space of functions. In the linear case $\sigma(u) = u$, we will establish Feynman-Kac formulas for the solution and for its moments, which lead to moment estimates and intermittency properties. (Received January 20, 2015)

1107-60-436 **Jean-Francois JABIR*** (jean-francois.jabir@uv.cl), 2421 Avenida Pedro Montt, 2362957 Valparaiso, Chile. *Diffusion processes with conditioned distributions.* Preliminary report.

In this talk, I will address the problem of the modeling and the construction of a class of diffusion processes whose time marginal distributions are constrained to lie at any time in a particular subset of the space of probability measures. This type of diffusion processes appeared in various applied situations (such as Finance, stochastic mechanics, fluid dynamics, ...) and their modeling leads to the introduction of a singular class of stochastic differential equations. After a short presentation of the main difficulties raised by these equations, I will present some results concerning the construction of solutions, though suitable penalized approximations, which are obtained by combining stochastic calculus and variational calculus on probability space. This research is funded by the project Fondecyt Iniciación 11130705. (Received January 20, 2015)

1107-60-459 **Antoine Lejay**, **Ernesto Mordecki** and **Soledad Torres*** (soledad.torres@uv.cl), Avenida Pedro Montt 2421, Valparaiso, Chile. *Statistical Inference for Skew Brownian process.*

We study the asymptotic behavior of the maximum likelihood estimator corresponding to the observation of a trajectory of a Skew Brownian motion, through a uniform time discretization. We characterize the speed of convergence and the limiting distribution when the step size goes to zero, which in this case are non-classical, under the null hypothesis of the Skew Brownian motion being an usual Brownian motion. This allows to design a test on the skewness parameter. We show that numerical simulations can be easily performed to estimate the skewness parameter. (Received January 20, 2015)

1107-60-464 **Hector Andres Araya*** (arayahector8@gmail.com), camino del sol 800, departamento D23, Casilla 123-V, 4059 Valparaiso, Chile., Vina del Mar, margamarga 2430000, and **Rolando Biscay** and **Soledad Torres** (soledad.torres@uv.cl). *Geometric stability in numerical methods for stochastic differential equations.* Preliminary report.

We present a necessary condition for the orthogonality of a solution of a Stratonovich SDE. Also, we study the orthogonality in the case of the Stochastic Runge-Kutta (SRK) approximation. Finally, the performance of the method is illustrated by means of numerical simulations. (Received January 20, 2015)

1107-60-466 **Alexandra Chronopoulou*** (achronop@illinois.edu), Dpt of Industrial & Enterprise Systems Eng, 117 Transportation building, 104 South Mathews Avenue, Urbana, IL 61801. *Sequential Monte Carlo with Parameter Learning for Long-Memory Processes.*

We consider a state-space model that is specified up to an unknown vector of parameters and in which the unobserved state process exhibits long-memory. Our goal is to estimate both the state process and the parameter vector. For this, we propose a sequential Monte Carlo method that is based on smoothing of the sample points of model parameters. We establish a central limit theorem for the state and parameter filter and we illustrate our results with a simulation study. Finally, we apply our approach to S& P 500 data in the context of a stochastic volatility model with long memory. This is joint work with Konstantinos Spiliopoulos (Boston University). (Received January 20, 2015)

1107-60-480 **Léo Neufcourt*** (ln2294@columbia.edu) and **Frederi Viens**. *A third moment theorem for quadratic variations of stationary Gaussian sequences.*

Inspired by central limit theorems and Berry-Esseen bound, we explore the convergence of normalized quadratic variations of correlated stationary Gaussian sequences to standard normal distribution. Complementing Nualart and Peccati's fourth moment theorem, which states that a sequence in a fixed Wiener chaos converges to a normal law if and only if its fourth cumulant tends to zero, Biermé, Bonami, Nourdin and Peccati recently proved using Malliavin calculus that the speed of convergence is dominated by the maximum of the fourth cumulant and the absolute value of the third cumulant. We go further and show that in the second Wiener chaos, a third moment theorem holds, in the sense that convergence to normal law occurs if and only if the third moment of the stationary sequence converges to zero. When the limit distribution is normal, we find the exact rate of convergence as a function of the covariance of the stationary sequence. When the quadratic variation process does not converge to normal distribution, we show that it converges 'slowly' to a Rosenblatt distribution, recovering a result from Dubroshin-Major. We finally apply our results to the example of the log-modulated fractional Brownian motion and exhibit critical Hurst parameters. This is joint work with Frederi Viens. (Received January 20, 2015)

1107-60-482 **Jonathan C Mattingly*** (jonm@math.duke.edu), Mathematics department, Physics building, science drive, Durham, NC 27701. *Absolute Continuity for SPDEs.*

I will discuss how the fine scale structure of a class of SPDEs can be determined by proving absolute continuity relative to a simpler SPDE. I will use the 2D navier stokes equation (and related systems) as my motivating example. (Received January 20, 2015)

1107-60-505 **Oana Mocioalca***, Department of Mathematical Sciences, Kent State University, Kent, OH 44242, **Lu Chen**, Department of Mathematical Sciences, Kent State University, Kent, OH 44242, and **Omar De la Cruz Cabrera**, Department of Epidemiology and Biostatistics, School of Medicine, CWRU, Cleveland, OH 44106. *Stochastic processes for modeling compositional data.*

We study a family of stochastic processes in continuous time which take as values vectors with non-negative values adding up to 1, and propose them as useful models for compositional data that changes over time. These processes have Dirichlet marginal distributions.

Our main application is the modeling of ecosystems in which the population proportions of the different species change over time. Of special interest is the study of the composition of microbial communities, in particular the human microbiome, since it has important health implications and can now be studied quantitatively using high throughput sequencing. (Received January 20, 2015)

62 ► Statistics

1107-62-152 **Edward L Boone*** (elboone@vcu.edu), 4123 Harris Hall, 1015 Floyd Ave, Richmond, VA 23284. *Model validation of a single degree-of-freedom oscillator: a case study.*

In this talk, we investigate a validation process in order to assess the predictive capabilities of a single degree-of-freedom oscillator. Model validation is understood here as the process of determining the accuracy with which a model can predict observed physical events or important features of the physical system. Therefore, assessment of the model needs to be performed with respect to the conditions under which the model is used in actual simulations of the system and to speci c quantities of interest used for decision-making. Model validation also supposes that the model be trained and tested against experimental data. In this work, virtual data are produced from a nonlinear single degree of-freedom oscillator, the so-called oracle model, which is supposed to provide an accurate representation of reality. The mathematical model to be validated is derived from the oracle model by simply neglecting the nonlinear term. The model parameters are identi ed via Bayesian updating. This calibration process also includes a modeling error due to model misspecifi cation and modeled as a normal probability density function with zero mean and standard deviation to be calibrated. (Received January 12, 2015)

1107-62-190 **Frédéric Mortier*** (fmortier@cirad.fr), UPR B&sef, Dept. Environnements et Sociétés du CIRAD, Campus International de Baillarguet, TA C-105, 34398 Montpellier, France. *Mixture of inhomogeneous matrix models for species-rich ecosystems.*

Understanding how climate change could impact population dynamics is of primary importance for species conservation. Matrix population models are widely used to predict population dynamics. However, in species-rich ecosystems with many rare species, the small population sizes hinder a good fit of species-specific models. In addition, classical matrix models do not take into account environmental variability. We propose a mixture of regression models with variable selection allowing the simultaneous clustering of species into groups according to vital rate information (recruitment, growth, and mortality) and the identification of group-specific explicative environmental variables. We develop an inference method. We first highlight the effectiveness of the method on simulated datasets. Next, we apply it to data from a tropical rain forest in the Central African Republic. We demonstrate the accuracy of the inhomogeneous mixture matrix model in successfully reproducing stand dynamics and classifying tree species into well-differentiated groups with clear ecological interpretations. (Received January 14, 2015)

1107-62-360 **Jonathan R Stroud*** (stroud@gwu.edu). *Sequential Estimation of Dynamic Spatio-Temporal Models.*

Sequential Monte Carlo methods for state-space models have been successfully applied in many problems. However, standard methods like the SIR particle filter and auxiliary particle filter are known to suffer from particle degeneracy in the presence of outliers, high dimensionality and unknown static parameters. In this talk, we propose a new method for sequential estimation of dynamic spatio-temporal models. The method allows for online Bayesian estimation of states and parameters and works well in nonlinear, high-dimensional models. It is based on a combination of ensemble Kalman filter and Gaussian mixture updates. We illustrate the approach using the Lorenz (1996) 40-variable system, and on a space-time pollution monitoring problem in Mexico City. (Received January 19, 2015)

1107-62-446 **Dave Higdon*** (dhigdon@vbi.vt.edu). *A case study in combining a physical model and experimental measurements for atomic nuclei.* Preliminary report.

Newly discovered heavy elements, astrophysical observations of neutron stars, and increased computational power have led to renewed interest in understanding and modeling the behavior of atomic nuclei. The NUCLEI project, a joint collaboration involving multiple national laboratories and universities, is attempting to develop a reliable model of all nuclei - light, heavy, and superheavy. A part of this project centers on calibrating and assessing accuracy of a density functional theory (DFT) model, which models the behavior of a wide range of atomic nuclei. This talk will describe scientific and statistical aspects of this problem, presenting a Bayesian approach to combine various sources of information to estimate parameter and prediction uncertainties. Finally, predictions produced from this approach will be compared to recently carried out experiments at the rare isotope facility at Argonne National Laboratory. (Received January 20, 2015)

65 ► Numerical analysis

1107-65-55 **Matthias Chung*** (mcchung@vt.edu), **Julianne Chung** and **Dianne O'Leary**. *Optimal Inversion Matrices for Inverse Problems.*

We present a new framework for solving ill-posed inverse problems by compute an optimal regularized inverse matrix. An optimal regularized inverse matrix is obtained by incorporating probabilistic information and solving a Bayes risk minimization problem. We present theoretical results for the Bayes problem and discuss efficient approaches for solving the empirical Bayes risk minimization problem. Our approach is illustrated on examples from image processing. Once computed, the optimal regularized inverse matrix can be used to solve inverse problems very efficiently. (Received December 18, 2014)

1107-65-150 **Wondwosen Gebeyaw Melesse*** (gwondwosen12@gmail.com), Dilla University, Dilla, Ethiopia. *Cubic Spline interpolation with some of its Applications.*

This paper provides the analysis, formulation, and application of cubic spline interpolation. Cubic splines have many applications in different fields of science especially in approximating smooth and continuous real- valued functions defined in a closed interval. The approximation of these functions by using the two most widely used cubic splines namely natural and clamped cubic splines with their advantages over other interpolation techniques are also presented. (Received January 12, 2015)

1107-65-397 **Xiaoming Wang***, Department of Mathematics, Florida State University, Tallahassee, FL 32312. *Approximating long time statistical properties of dissipative complex systems.*

It is well-known that physical laws for large chaotic/turbulent systems are revealed statistically. We consider temporal and spatial approximation of stationary statistical properties of dissipative chaotic dynamical systems. We demonstrate that appropriate discretization viewed as discrete dynamical system is able to capture asymptotically the stationary statistical properties of the underlying continuous dynamical system provided that certain natural conditions are satisfied. Examples that involve the two-dimensional Navier-Stokes system, the infinite Prandtl number model for convection, and convection in karstic geometry will be presented. (Received January 19, 2015)

1107-65-469 **Matthias Chung**, **Justin Krueger*** (kruegej2@vt.edu) and **Mihai Pop**. *Robust Parameter Estimation for Differential Equation Models.* Preliminary report.

When using a traditional parameter estimation method to solve an inverse problem for a differential equation model, the method generally requires the repeated computation of the differential equation solution. This is a numerically intensive step in the parameter estimation process for multiple reasons, and avoiding it is desirable when possible. This preliminary report presents a new method for solving inverse problems involving differential equation models that avoids the calculation of the differential equation solution. Avoiding the differential equation solution makes this method more numerically robust, and the method achieves this robustness by defining a "nearby" inverse problem, which when solved provides parameter estimates suitable for the solution of the original inverse problem. The usefulness of this approach is most notable when applied to parameter estimation for large-scale differential equation models, which continue to grow in prevalence, such as those found in the main application for this research, quantifying the dynamics found in biological communities. (Received January 20, 2015)

1107-65-508 **Muhammad Usman*** (musman1@udayton.edu), 300 College Park, Dayton, OH 45469-2316, and **Nicholas Haynes**, **Kamel Al-khaled** and **William Schiesser**. *A numerical study of eventual periodicity of the Korteweg-de Vries type equation using sinc collocation method.* Preliminary report.

We demonstrate numerically the eventual time periodicity of solutions to the Korteweg-de Vries equation with periodic forcing at the boundary using the sinc-collocation method. This method approximates the space dimension of the solution with a cardinal expansion of sinc functions, thus allowing the avoidance of a costly finite difference grid for a third order boundary value problem. The first order time derivative is approximated with a θ-weighted finite difference method. The sinc-collocation method was found to be more robust and more efficient than other numerical schemes when applied to this problem. (Received January 21, 2015)

68 ► Computer science

1107-68-28 **Emilie Hogan*** (emilie.hogan@pnnl.gov) and **John R Johnson**. *A generalized graph metric for mitigating cyber attacks.*

Cybersecurity is a vibrant research area for many mathematicians and computer scientists. As combinatorialists, we model a cyber network as a directed graph, derived from real cyber network data. In this talk I will present our network model and explain how certain types of attacks can be realized within this model. I will also describe the mathematics behind our mitigation strategy for one specific cyber attack. This will include an integer-valued weight function on user credentials which increases as credentials become more important to an attacker. To prove that our mitigation strategy is computable on a computer with m bits of precision (e.g., $m = 64$) we show that when credentials are distributed uniformly we achieve the largest weighting function. (Received November 18, 2014)

1107-68-259 **Paul C. Kainen*** (kainen@georgetown.edu). *Correcting error in groupoid diagrams.*

In a groupoid category, all morphisms are invertible and diagrams include inverses. We suppose that correct computation should produce commutative diagrams - i.e., the composition of the morphisms in each cycle is an identity. In a hypercube, squares correspond to the 4-cycles. It is shown that commutativity of a groupoid hypercube diagram in dimension $d \geq 3$ cannot fail unless at least $d-1$ of the component squares do not commute. By Hechler and Kainen (Israel J. Math, 1974), for any groupoid-valued commutative diagram $\delta : D \to \mathcal{G}$ on the scheme of acyclic D, there is a subdivision of D embeddable in some hypercube Q_d and there is a commutative diagram $\zeta : Q_d \to \mathcal{G}$ extending δ. Commutativity of a special basis of the hypercube cycles guarantees commutativity of the hypercube and of any diagram embedded there. Arguments utilize topological enrichment of cycle basis. Applications include quantum computing and algebraic models in biology and cognitive science. Such systems could in principle correct error which stays below the threshold and amplify computational power by extrapolating from the squares in the special basis to the exponentially many cycles in the hypercube.
(Received January 21, 2015)

76 ► Fluid mechanics

1107-76-48 **Wenqing Hu*** (huxxx758@umn.edu), Minneapolis, MN 55455, and **Vladimir Sverak**, Minneapolis, MN 55455. *Random motion along co–adjoint orbits.* Preliminary report.

We study Lagrangian motion generated by a random Eulerian motion on the co–adjoint orbit of a (finite dimensional) group G. Our choice of random Eulerian motion preserves the energy. We discuss long–time behavior of the Lagrangian motion. Examples are shown in the case of both compact and non–compact groups. Our attempt could be viewed as an effort (in finite dimensions) towards the understanding of (inviscid) turbulence for ideal incompressible fluids. (Received December 14, 2014)

1107-76-103 **Zachary Bradshaw** and **zoran grujic*** (zg7c@virginia.edu), department of mathematics, kerchof hall, UVA, charlottesville, VA 22904. *Scaling vs. dynamics in the 3D NSE.*

Two regularity criteria for solutions to the 3D NSE residing in two supercritical spaces with *identical scaling* are presented. In order to prevent (possible) formation of singularities, the boundedness in the ambient spaces is naturally supplemented with two *dynamically opposing* conditions exhibiting the signatures of direct (physical) and inverse (non-physical) energy cascades. This illustrates limitations of the scaling considerations when studying dynamical properties of the 3D NS model. The proof is based on the effect of viscous diffusion – via the harmonic measure majorization principle – on suitable super-level sets of the Littlewood-Paley blocks of solutions corresponding to either extremely high or extremely low frequencies. (Received January 05, 2015)

1107-76-226 **Nathan Glatt-Holtz*** (negh@vt.edu). *Numerical Analysis of Stochastic Partial Differential Equations in Fluids.*

We will discuss some recent results concerning the numerical analysis of the stochastic Navier-Stokes Equations and the Primitive Equations, an important model in Geophysical Fluid Dynamics. We consider both explicit and implicit schemes for these systems and develop conditions for stability (in the sprirt of Courant-Friedrichs-Lewy) for the explicit case. Convergence results on finite time intervals and for long time horizons (through statistically stationary states) are established. This is joint work with Roger Temam and Chuntian Wang (IU). (Received January 18, 2015)

1107-76-284 **Alexandru D. Ionescu*** (aionescu@math.princeton.edu), Dept. of Mathematics, Fine Hall, Washington Rd., Princeton, NJ 08540. *On the existence of global solutions of certain fluid models in low dimensions.*

I will discuss some recent work (joint with Y. Deng, F. Pusateri, and B. Pausader) on global existence of smooth solutions of certain water wave models and plasma models in 2 and 3 dimensions. (Received January 17, 2015)

1107-76-290 **Bogdan G. Nita***, 1 Normal Ave, Montclair, NJ 07043, and **Ashwin Vaidya**, **Ryan Allaire**, **Pamela Guerron** and **Peter Nolan**. *On the equilibrium configurations of flexible fibers in a flow.*

We discuss the equilibrium configurations of fibers, of different length and orientation, clamped to a spherical body and immersed in a flow. Experimental and numerical results are presented and the effects of flow speed and positioning of the fiber upon the equilibrium configuration are investigated. Our results reveal that the orientation of the fiber and its length have a significant impact upon its bending and drag experienced by the sphere-fiber system. (Received January 17, 2015)

1107-76-313 **Animikh Biswas*** (abiswas@umbc.edu), Dept. of Math and Stat, UMBC, 1000 Hilltop Circle, Baltimore, MD 21250. *Navier-Stokes equations in a special Constantin-Chen Gevrey class.* Preliminary report.

We discuss existence time for the 3D Navier-Stokes equations (NSE) in a new functional class which belongs to the Constantin-Chen Gevrey class of functions which contains all analytic and non-analytic Gevrey classes and is a subclass of smooth functions. This class appeared recently in the work of Foias, Jolly, Yong and Zhang in the study of the attractors for the 2D NSE. We show that for the 3D case, the differential inequality that one obtains in this class is very nearly linear. This leads to an existence time which is better than the reciprocal of any power of the norm of the initial data. By way of comparison, the best known classical existence time is reciprocal of the fourth power of the H^1 norm of the initial data. This is a joint work with C. Foias. (Received January 18, 2015)

1107-76-321 **Aseel Farhat*** (afarhat@indiana.edu), **Michael S. Jolly** and **Edriss S. Titi**. *A Data Assimilation Algorithm for the Bénard Convection Model and Other Models of Turbulence.*

Data assimilation is the process by which observations are incorporated into a computer model of a real system. Applications of data assimilation arise in many fields of geosciences, perhaps most importantly in weather forecasting. In a joint work with M. Jolly and E. S. Titi, we present a new continuous data assimilation algorithm for the two-dimensional Bénard problem based on an idea from control theory. Rather than inserting the observational measurements directly into the equations, a feedback control term is introduced that forces the model towards the reference solution. We show that the approximate solutions constructed using only observations in the velocity field and without any measurements on the temperature converge in time to the reference solution of the two-dimensional Bénard problem. Similar results for other models of turbulence will be presented. (Received January 18, 2015)

78 ► Optics, electromagnetic theory

1107-78-19 **Fan Yang*** (jackie@math.udel.edu), Department of Mathematical Sciences, University of Delaware, 15 Orchard Road, Rm 501, Newark, DE 19716, and **Peter Monk** (monk@math.udel.edu), Department of Mathematical Sciences, University of Delaware, 15 Orchard Road, Rm 501, Newark, DE 19716. *Linear Sampling Method for Shape Reconstruction in a 3D Electromagnetic Waveguide.*

In this talk we consider the Linear Sampling Method (LSM) used to recover the shape of scatterers in a 3D electromagnetic waveguide. We present mathematical results regarding the justification of the LSM for solving the inverse problem for this geometrical setting. Then we show that the LSM can be adapted to the waveguide configuration by utilizing the tools of functional analysis for Maxwell's equations, dyadic analysis for Green's functions and the factorization of the near field equation. Finally numerical results for the reconstruction of the scatterer will be given. (Received November 03, 2014)

81 ► Quantum theory

1107-81-474 **Matilde Marcolli*** (matilde@caltech.edu), Mathematics Department, Caltech, Mail Code 253-37, 1200 E California Blvd, Pasadena, CA 91125. *Feynman integrals and motives.*

I will survey recent results (based on collaborations with Paolo Aluffi, Ozgur Ceyhan, and Xiang Ni) on motives of algebraic varieties arising from perturbative renormalization in quantum field theory, for Feynman integrals in momentum space and in configuration space. (Received January 20, 2015)

82 ► Statistical mechanics, structure of matter

1107-82-94 **Xiaofeng Ren*** (ren@gwu.edu), 2115 G Street, NW, Washington, DC 20052, and **David Shoup** (shoup@gwu.edu), 2115 G Street, NW, Washington, DC 20052. *The impact of the domain boundary on an inhibitory system: existence and location of a half disc stationary set.*

The nonlocal geometric variational problem derived from the Ohta-Kawasaki diblock copolymer theory is an inhibitory system with self-organizing properties. The free energy of the problem is a sum of a local energy which is the perimeter of Caccioppoli sets, and a nonlocal energy given with the help of the Green's function of Poisson's equation. The system has the property of preventing an interior component of a set from drifting towards the domain boundary. This raises the question whether a stationary Caccioppoli set may have a component that touches the domain boundary. It is proved that a small, half disc like set exists as a stable stationary Caccioppoli set, where the circular part of its boundary is inside the domain and the almost flat part of its boundary coincides with part of the domain boundary. The location of this half disc depends on two quantities: the curvature of the domain boundary, and a remnant of the Green's function after one removes the fundamental solution and a reflection of the fundamental solution. When the nonlocal energy is weighted less against the local energy, the half disc stationary set appears near a maximum of the curvature; when the nonlocal energy is weighted more, the half disc appears near a minimum of the remnant function. (Received January 05, 2015)

85 ► Astronomy and astrophysics

1107-85-54 **Robert J. Vanderbei*** (rvdb@princeton.edu), Operations Research & Financial Engineering, 209 Sherrerd Hall, Princeton, NJ 08544. *Numerical Optimization Applied to Space-Related Problems.*

Techniques for numerical optimization have been wildly successful in an amazingly broad range of applications. In the talk, I will go into some detail about two particular applications that are both "space related". The first application is to the design of telescopes that can achieve unprecendentedly high-contrast making it possible to directly image extra-solar planets even though their host star is billions of times brighter and has a very small angular separation from the planet. The second application is to use optimization to find new, interesting, and often exotic solutions to the n-body problem. Finding such orbits could inform us as to what type of exoplanetary systems might exist around other nearby stars. In these two applications, I will explain enough of the physics to make the optimization problem clear and then I will show some of the results we have been able to find using state-of-the-art numerical optimization algorithms. (Received December 17, 2014)

86 ► Geophysics

1107-86-60 **Bradford S Barrett*** (bbarrett@usna.edu), Oceanography Department, 572C Holloway Road, Annapolis, MD 21402. *Data assimilation challenges: predicting weather and climate on intraseasonal time scales.*

The Madden-Julian Oscillation (MJO) is the leading mode of atmospheric variability on intraseasonal time scales. The MJO has been shown to impact a wide array of climate phenomena across many spatial and temporal scales: the Indian-Australasian monsoon, El Niño, and circulation on the planetary scale to global precipitation, severe convective storm and tropical cyclone activity on the synoptic and mesoscales. Full comprehension and predictability of these phenomena is difficult without realistic representation of the MJO. Global climate models (GCMs) routinely struggle to represent the MJO. Recent work suggests much of the challenge in representing the MJO in GCMs stems from two sources: limitations in physical parameterizations of sub-grid scale processes, and poor data assimilation, particularly of tropical convective heating rates. A seamless data assimilation suite is likely to be the best way forward to improve weather and climate models. In this study, current data assimilation techniques for MJO prediction are presented and critiqued. Additionally, MJO's role in the climate system is explored in context of its predictability and representation in data assimilation schemes. (Received December 19, 2014)

1107-86-249 **Ian Grooms*** (grooms@cims.nyu.edu), Courant Institute of Mathematical Sciences, New York University, 251 Mercer St, New York, NY 10012, and **Yoonsang Lee** and **Andrew J Majda**. *Ensemble filtering and low-resolution model error: Covariance inflation, stochastic parameterization, and model numerics.*

Using under-resolved models in ensemble filters leads to two kinds of model errors: truncation errors associated with discretization of the large-scale dynamics, and errors associated with subgrid scale interactions. Covariance inflation can account for model errors in ensemble Kalman filters, but does not reduce model error. Numerical errors can be reduced by increasing the accuracy of the discretization, and parameterizations can reduce errors associated with subgrid interactions. Stochastic parameterizations reduce the model error and inflate the ensemble spread, so the effectiveness of stochastic parameterizations can be gaged by comparing with covariance inflation. We compare covariance inflation, stochastic parameterization, and model numerics in two regimes of quasigeostrophic turbulence. Fourth-order discretization and stochastic parameterization both have a positive impact when compared with a second-order model with no parameterization. In homogeneous turbulence on an f-plane the improvements from stochastic parameterization exceed theose from multiplicative inflation, which exceed those from fourth-order numerics. With strong zonal jets on a β-plane stochastic parameterizations and fourth-order numerics are both superior to covariance inflation. (Received January 16, 2015)

1107-86-394 **Hans G Kaper*** (kaper@mathclimate.org) and **Hans P Engler** (engler@georgetown.edu). *Introduction to Conceptual Mathematical Climate Models.*

Conceptual mathematical models for the Earth's climate system are obtained by simplifying more complex models through model reduction and clever guessing and retain only some essential aspects of the climate system. They are typically given as systems of ordinary differential equations, sometimes with time lags or with spatial dependence. Such models are often still capable of reproducing faithfully quite complex climate phenomena. They may lead to new scientific questions, can serve as test cases for new methodologies, and have

at times given rise to new terms and concepts in climate science. This talk reviews some well-known examples such as energy balance models that can explain global glaciation phases, box models for oceans that can explain thermohaline circulation, and oscillator models for ocean-atmosphere interaction explaining El Niño - Southern Oscillation. (Received January 19, 2015)

1107-86-423 **Jonah Bloch-Johnson*** (me@jonah.org), 1416 E55th St, Chicago, IL 60615, and **Raymond T Pierrehumbert**. *The Temperature Dependence of Feedbacks and Equilibrium Climate Sensitivity.*

Studies of the Earth's equilibrium climate sensitivity commonly assume that the long-term warming caused by an increase in atmospheric CO_2 will be roughly proportional to the amount of radiative forcing caused by such an increase. This assumption is equivalent to assuming that the overall climate feedback remains unchanged as the planet warms. In this paper, we assess this claim by examining the behavior of a simple conceptual model of climate sensitivity that accounts for temperature-dependent feedbacks over a range of likely parameter values informed by physical arguments and output of general circulation models. We find that the nonlinearity caused by this temperature dependence can greatly alter the warming response to one doubling of CO_2 when the sensitivity is high, and alters the response generally for two doublings. Loss of stability, in particular, is possible for likely parameter values. Our work has several implications: in some cases, model blow-up may be physical; estimates of equilibrium climate sensitivity from observations may give incorrect estimates of the risk of high warming; and it may be possible to rule out the extremes of high warming caused by low cloud feedbacks. (Received January 20, 2015)

1107-86-456 **Hans P Engler**, engler@georgetown.edu, and **John Kerin***, jak247@georgetown.edu. *The Lorenz '96 Model with Spatial Inhomogeneities.* Preliminary report.

The Lorenz '96 model was introduced by Edward Lorenz in 1996 to study questions of predictability in weather forecasting. It consists of a system of ordinary differential equations that model nonlinear advection, dissipation, and external forcing. Its components can be thought of as describing simplified climate states in a circular array of homogeneous identical atmospheric boxes at different longitudes. The model has received much attention as a test case for data assimilation techniques.

For moderate forcing, solutions show spatial oscillations that move "westward" at a constant speed, and for larger forcing, motions become chaotic, while a westward moving wave pattern is still present. This talk will review some basic mathematical properties (global existence and boundedness, bifurcation behavior) that help explain these phenomena. In the second part of the talk, modifications of the model will be examined that include spatially inhomogeneous advection. Such modifications change the regular wave pattern in unexpected ways, for example by damping it in regions of low advection and increasing its amplitude in the "lee" of such regions. These phenomena will be demonstrated numerically, and heuristic explanations will be given. (Received January 20, 2015)

90 ► Operations research, mathematical programming

1107-90-64 **Hande Y Benson*** (benson@drexel.edu), 3141 Chestnut Street, Philadelphia, PA 19104, and **David F Shanno**. *Cubic Regularization in Quasi-Newton Methods.*

Regularization techniques have been used to help existing algorithms solve "difficult" nonlinear optimization problems. Just over the last decade, regularization has been proposed as a remedy to handle equality constraints, equilibrium constraints, and other sources of nonconvexity, to bound Lagrange multipliers, to identify infeasible problems. In this talk, we will focus on the application of cubic regularization in the context of quasi-Newton methods. (Received December 22, 2014)

1107-90-65 **Mituhiro Fukuda*** (mituhiro@is.titech.ac.jp), **Takashi Nakagaki** and **Makoto Yamashita**. *A new nonmonotone spectral projected gradient method for semidefinite program with log-determinant and ℓ_1-norm function.* Preliminary report.

The semidefinite program which has a log-determinant and ℓ_1-norm terms in the objective function can be used to solve the covariance selection problem, that is, a problem to estimate a covariance matrix from few observations compared to the dimension of random variables in statistics. We propose a novel variant of the nonmonotone spectral projected gradient method applied to its dual which can solve the problem with optimality certificate in some simple cases including the covariance selection problem. The implementation is very simple and major computational efforts required per iteration are a Cholesky decomposition and a eigenvalue computation.

Numerical experiments on synthetic data shows that it is more efficient than some known algorithms. (Received December 23, 2014)

1107-90-81 **Florian A Potra*** (potra@umbc.edu), Department of Mathematics and Statistics, University of Maryland, Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250.
Interior point methods for sufficient weighted complementarity problems.

The introduction of the notion of a weighted complementarity problem (wCP) was motivated the fact that wCP can model more general equilibrium problems than the classical complementarity problem (CP). Such a problem depends on a nonnegative weight vector. If the weight vector is zero, the problem reduces to a sufficient linear CP that has been extensively studied. The presence of a nonzero weight vector makes the theory of wCP more complicated than the theory of CP. We give a characterization of sufficient linear wCP and present a corrector-predictor interior point method for its numerical solution. While the proposed algorithm does not depend on the handicap κ of the problem its computational complexity is proportional with $1 + \kappa$. If the weight vector is zero and the starting point is relatively well centered, then the computational complexity of our algorithm is the same as the best known computational complexity for solving sufficient linear CP. (Received December 31, 2014)

1107-90-189 **Stephen G Nash*** (snash@gmu.edu), Volgenau School of Engineering, MS 5C8, Fairfax, VA 22205. *Practical Challenges in Using Multilevel Optimization.*

A PDE-constrained optimization problem can be considered as a family of optimization models obtained by varying the discretization. Multilevel optimization methods can be applied to such problems, and have the potential for dramatically reducing the effort required to find an optimal solution. In principle, applying multilevel optimization is straightforward, since the algorithms can be described in abstract terms and have considerable flexibility. However, there are practical challenges. These include scaling of the individual optimization models, smoothness of constraint surfaces, and gradient computations. These challenges are not insurmountable, but they can be easy to overlook. (Received January 14, 2015)

1107-90-229 **Amitabh Basu*** (basu.amitabh@jhu.edu), 3400 N. Charles Street, Baltimore, MD 21218, and **Robert Hildebrand** and **Matthias Koeppe**. *Techniques for Gomory and Johnson's "Infinite Group" Problem.*

We describe some of the tools recently developed for analyzing Gomory and Johnson's Infinite Group problem. In particular, we will present higher dimensional generalizations of the so-called Interval Lemma, and give the details of the first ever algorithm for testing extremality of piecewise linear functions with rational breakpoints. (Received January 15, 2015)

1107-90-341 **Olga Brezhneva*** (brezhnoa@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056, and **Alexey Tret'yakov**, University of Podlasie in Siedlce, Siedlce, Poland. *Optimality conditions for irregular nonlinear programming problems.* Preliminary report.

In this talk, we present necessary and sufficient optimality conditions for some classes of irregular nonlinear programming problems with inequality constraints. First, we analyze cases when optimality conditions of the Karush-Kuhn-Tucker-type (KKT) hold for irregular problems. We prove new geometric necessary conditions and the KKT-type optimality conditions under some new regularity assumptions. Then we continue with consideration of irregular problems for which the KKT-type of conditions do not hold and propose some new necessary and sufficient optimality conditions. (Received January 19, 2015)

1107-90-391 **Sarah E. Geiger***, s.e.geiger@iup.edu, **Eric T. MacCallum**, e.t.maccallum@iup.edu, and **Gayan Warahena Liyanage** and **Suzanne Z. Smedberg**. *Using Utility Theory for Academic Grouping of Students.* Preliminary report.

Ever had a hard time trying to find a good project or study group? This paper discusses methodology used to pair students for projects or studying based on academic compatibility. Pairing is done through a graphical user interface with results determined via adaptable utility functions, based partially on existing research from popular dating sites. Discussion will include existing research, utility functions, coding, effectiveness of the method, and other potential applications of this method. (Received January 19, 2015)

91 ► Game theory, economics, social and behavioral sciences

1107-91-331 **Elaine T Spiller*** (elaine.spiller@marquette.edu). *Some recent approaches for assimilating data from Lagrangian instruments.*

We discuss a recently proposed hybrid particle-ensemble Kalman filter for assimilating Lagrangian data, and apply it to a high-dimensional quasi-geostrophic ocean model. Effectively the hybrid filter applies a particle filter to the highly nonlinear, low-dimensional Lagrangian instrument variables while applying an ensemble Kalman type update to the high-dimensional Eulerian flow field. We present some initial results from this hybrid filter and compare those to results from a standard ensemble Kalman filter and an ensemble run without assimilation.

We will also discuss the assimilation of data that are collected while Lagrangian ocean instruments are in transit between surfacings. Effectively utilizing such data presents a challenge as the subsurface paths of these instruments are unknown. We introduce an observation operator that takes these data into account in addition to the data that are typically assimilated. A key point is that the subsurface, en-route paths of these ocean instruments are estimated as part of the assimilation scheme. Finally, we will posit how we see these two schemes being used together. (Received January 18, 2015)

1107-91-489 **Russ deForest** and **Andrew Belmonte*** (alb18@psu.edu), Dept of Mathematics, Pennsylvania State University, University Park, PA 16803. *Fitness gradient flux in evolutionary games: numerical and analytic results.*

The replicator dynamics commonly used in evolutionary game theory is consistent with the interpretation of a fitness function defined as the expected payoff for a given strategy played within a population. This fitness characterizes the interactions between individuals playing each strategy, and has a nonlinear dependence on the population densities. We consider the spatial patterns and steady states for partial differential equations (PDEs) which include a fitness gradient flux, defined for two-player symmetric games characterized by a payoff matrix. We find numerically that the fitness gradient flux alters the 1D Hutson-Vickers travelling wave solutions, and leads to spatially structured, stable coexistence states for the prisoner's dilemma. We also present existence results for two strategy games in the "frozen strategy" PDEs, in which migration is due exclusively to the fitness gradient flux (without replicator dynamic or diffusion). We show that there are weak steady state solutions that are in H^1, but not smooth everywhere. (Received January 20, 2015)

92 ► Biology and other natural sciences

1107-92-31 **Erica Flapan*** (eflapan@pomona.edu), 640 N. College Ave., Department of Mathematics, Pomona College, Claremont, CA 91711. *Topological and geometric symmetries of knotted molecules.* Preliminary report.

Symmetries play an important role in confirming the structure of knotted and linked molecules. However, topological, geometric, and molecular symmetries do not always coincide. In this talk, we analyze different types of symmetries and their role in confirming the structure of molecular knots. (Received November 24, 2014)

1107-92-58 **L Courtney Smith*** (csmith@gwu.edu), Department of Biological Sciences, George Washington University, 800 22nd St NW, Suite 6000, Washington, DC 20052. *Innate immunity in the purple sea urchin and diversity of the Sp185/333 system.*

Innate immunity in the purple sea urchin is complex and sophisticated. One example of the immune response genes is the Sp185/333 family, which is composed of about 50 small genes that are tightly clusters. The genes have repeats, mosaic patterns of shared blocks of sequence, and are surrounded by microsatellites. Sp185/333 gene expression is induced by pathogens and single immune cells express a single Sp185/333 gene. This suggests that each cell produces and secretes a single version of the Sp185/333 proteins that may function synergistically with other isoforms in response to pathogen challenge.

The Sp185/333 proteins show significant sequence diversity, yet are structurally similar with a leader, a glycine rich region, RGD motif, and a histidine rich region. The proteins opsonize bacteria, induce phagocytosis, and retard bacterial growth. A recombinant, rSp0032, binds Vibrio, lipopolysaccharide (LPS), flagellin, yeast and beta,1-3,glucan but not Bacillus or peptidoglycan. It binds phosphatidic acid (PA) and deforms liposomes with PA. rSp0032 is intrinsically disordered but switches to alpha helical upon binding LPS or PA. Each of the Sp185/333 isoforms may have overlapping binding capabilities resulting in highly effective host protection against a wide range of pathogens. (Received December 18, 2014)

1107-92-70 **Cecilia Noecker**, Seattle, WA 98195, **Krista Schaefer**, Valparaiso, IN 45383, **Kelly Zaccheo**, Scranton, PA 18510, **Yiding Yang**, Knoxville, TN 37996, **Judy Day**, Knoxville, TN 37996, and **Vitaly V Ganusov*** (vitaly.ganusov@gmail.com), Knoxville, TN 37996. *Simple mathematical models do not accurately predict early SIV dynamics.* Preliminary report.

It remains poorly understood if the standard model for HIV dynamics accurately describes virus dynamics during the first weeks post infection. We analyze the dynamics of the standard model for virus dynamics and its simple extension which includes a cellular eclipse phase. We show that the standard model or its extension do not accurately predict the change in the time to virus appearance in the blood and probability of infection at different viral doses as was observed in experimental infections of monkeys with SIV. Our results suggest that to accurately describe early HIV dynamics, more complex models are needed. (Received December 28, 2014)

1107-92-77 **Isabel K. Darcy*** (idarcymath@gmail.com), MLH 14, Mathematics Department, University of Iowa, Iowa City, IA 52242. *Tangle analysis of protein-DNA complexes.*

Just like local knots can occur in long extension cords, such knots can also appear in DNA. DNA can be be either linear or circular. Some proteins will cut DNA and change the DNA configuration before resealing the DNA. Thus, if the DNA is circular, the DNA can become knotted. Protein-DNA complexes were first mathematically modeled using tangles in Ernst and Sumners seminal paper, Ä calculus for rational tangles: applications to DNA recombination" (Math Proc Camb Phil Soc, 1990). A tangle consists of arcs properly embedded in a ball. In order to model protein-bound DNA, the protein is modeled by the ball while the segments of DNA bound by the protein can be thought of as arcs embedded within the protein ball. This is a very simple model of protein-DNA binding, but from this simple model, much information can be gained. The main idea is that when modeling protein-DNA reactions, one would like to know how to draw the DNA. For example, are there any crossings trapped by the protein complex? How do the DNA strands exit the complex? Is there significant bending? Tangle analysis cannot determine the exact geometry of the protein-bound DNA, but it can determine the overall entanglement of this DNA, after which other techniques may be used to more precisely determine the geometry. (Received December 29, 2014)

1107-92-97 **Brent E Korba*** (korbabe@georgetown.edu), Georgetown University Medical Center, 5600 Reservoir Road, NW, Med-Dent. Building, Room SW319, Washington, DC 20057. *Human Noroviruses Contain Multiple and Diverse Antiviral Targets.*

Noroviruses (NoV) are the leading cause of nonbacterial, acute gastroenteritis worldwide and pose a significant financial burden on healthcare systems. In the USA, noroviruses are responsible for more than 50% of all cases of food-borne illness, over 20 million infections, and 70,000 hospitalizations annually. The NoV replication cycle presents a number of potentially accessible antiviral targets. The viral polymerase (RdRp) contains at least 2 sites for binding of allosteric inhibitors. The nucleoside analogue 2'C-methylcytidine has been shown to be an effective inhibitor of human NoV replication in cell culture and murine norovirus (MNV) in infected animals. NoV chymotrypsin-like cysteine protease has been shown to be inhibited by a divergent series of molecules. The viral protein covalently linked to the 5'-end of the NoV genome (VPg) is required for both the initiation of translation as well as priming for RNA replication, which opens up the potential for different intervention targets. A number of enzymatic and cell culture-based assays are available to evaluate potential inhibitors. Antiviral development for NoV infections is in its infancy in the pharmaceutical field which provides an especially significant opportunity currently for the development of therapeutic agents. (Received January 05, 2015)

1107-92-112 **Yu Jin*** (yjin6@unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588, and **Frank Hilker**, **Mark A. Lewis** and **Peter Steffler**. *Seasonal Invasion Dynamics in a Spatially Heterogeneous River with Fluctuating Flows.*

A key problem in environmental flow assessment is the explicit linking of the flow regime with ecological dynamics. We present a hybrid modeling approach to couple hydrodynamic and biological processes, focusing on the combined impact of spatial heterogeneity and temporal variability on population dynamics. We derive the water depth and current from a hydrodynamic equation for variable stream bed water flows and substitute these quantities into a reaction-diffusion-advection model that governs population dynamics of a river species. We then establish the existence of spreading speeds and the invasion ratchet phenomenon for periodically alternating pool-riffle rivers that are subjected to seasonally varying flows, using a mixture of mathematical approximations and numerical computations. (Received January 08, 2015)

1107-92-113 **Gaël Raoul*** (gael.raoul@cefe.cnrs.fr), 1919, route de Mende, campus du CNRS, 34293 Montpellier, France. *Dynamics of some populations structured by a space variable and a phenotypic trait.*

The spatial structure of populations plays a major role in many recent ecological problems. We will consider two such problems: - Impact of climate change on a species (work with M. Alfaro and H. Beresticky). A simple question that one can ask is wether a species submitted to a climate change will either move its range towards the poles, of stay at the same location and evolve to sustain higher temperatures. In the case of asexual population and for a simple environment, we describe the dynamics of the species, based on a parabolic model with a nonlocal competition term. - Invasion of a species with an evolving dispersion (work with N. Beresticky and C. Mouhot). One of the phenotypes that is susceptible to evolve greatly during an invasion is the dispersion : the more motile individuals will typically be more likely to reach the edge of the invasion front. This leads to accelerating fronts, that typically keep accelerating during the entire invasion process. We provide a description of this dynamics, based on a parabolic model with a nonlocal competition term and a careful analysis of a branching Brownian motion. (Received January 08, 2015)

1107-92-120 **Robert Stephen Cantrell**, **Chris Cosner*** (gcc@math.miami.edu), **Mark Lewis** and **Yuan Lou**. *PDE to ODE: multiple timescales in reaction-advection-diffusion models.* Preliminary report.

Traditional reaction-advection-diffusion models assume that dispersal, population dynamics, and interactions between species all operate on the same time scale. However, in many cases, the time scale of dispersal may be faster than the time scale of population dynamics. One way to address that issue is to assume a pseudo-equilibrium hypothesis for dispersal, so that the spatial distribution of a populations can be described as a fixed spatial profile determined by its dispersal strategy, which is then normalized and multiplied by the total population to yield a population density. Interactions between individuals and species then can be described in terms of spatial averages weighted by the profiles arising from their dispersal strategies. This yields ordinary differential equations that still incorporate some of the effects of the dispersal strategies that organisms use. This talk will describe the formulation of such models and some results on the evolution of dispersal in that modeling context. (Received January 08, 2015)

1107-92-123 **Frithjof Lutscher***, flutsche@uottawa.ca, Ottawa, Canada, **Gabriel A Maciel**, Sao Paulo, Brazil, and **Jeffrey A Musgrave**, Ottawa, Canada. *Biological Invasions, Random Walks, and Interfaces.*

The spatial spread of non-native biological populations (e.g. Emerald Ash borer) is one of the greatest risks to biodiversity worldwide. Mathematical models are indispensable to understand these processes of invasion that occur on large temporal and spatial scales. Commonly used reaction-diffusion equations result as scaling limits from random walks. A particular challenge is to include landscape heterogeneity and individual response to landscape features into these models of movement and growth.

I will present random-walk based derivations of interface conditions to motivate the study of coupled systems of reaction-diffusion equations for population dynamics in patchy landscapes. These conditions represent movement behavior in response to landscape features. I will show that the population spread rate depends critically on the assumptions of how individuals behave at patch interfaces.

One option for managing invasive species is to partially remove their main resources, for example Ash trees for the Emerald Ash borer. As a somewhat surprising application of the theory presented, I will outline three mechanisms by which such a patchy removal of resources could lead to an increase in spread rate rather than the intended decrease. (Received January 09, 2015)

1107-92-135 **Miranda Teboh-Ewungkem**, **Olivia Prosper**, **Katharine Gurski*** (kgurski@howard.edu), **Carrie Manore**, **Angela Peace** and **Zhilan Feng**. *Intermittent Preventive Treatment (IPT) and the spread of drug resistant malaria.*

IPT is a malaria control strategy in which vulnerable asymptomatic individuals are given a full curative dose of an antimalarial medication at specified intervals, regardless of malaria infection status. A mathematical model is developed to explore the effect of IPT use on the malaria prevalence and control under different scenarios. The model includes both drug-sensitive and drug-resistant strains of the parasite as well as interactions between human hosts and mosquitoes. The basic and invasion reproduction numbers for both strains are computed and used to examine the role of IPT on the development of resistant infections. Numerical simulations are performed to examine the effect of treatment of symptomatic infections and IPT on the prevalence levels of both strains. Results suggest that the schedule of IPT may have an important influence on the prevalence of resistant infections and total infections of both strains. The extent to which IPT may influence the development of resistant strains depends also on the half-life of the drug used. A sensitivity and uncertainty analysis indicates the outcomes are most sensitive to the model parameters: reduction factor of transmission for the resistant strain, rate of immunity loss, and the clearance rate of sensitive infections. (Received January 10, 2015)

1107-92-137 **Liwu Li*** (lwli@vt.edu), 970 Washington Street, Department of Biological Sciences, Blacksburg, VA 24061-0910. *Dynamic programming of innate immunity and inflammatory diseases.* Preliminary report.

Host macrophages can be pre-programmed into opposing primed or tolerant states depending upon the nature and quantities of external stimulants. The paradigm of priming and tolerance has significant implications in the pathogenesis and resolution of both acute and chronic inflammatory diseases. However, the responsible mechanisms are not well understood. Here, we report that super low dose bacterial endotoxin LPS primes the expression of pro-inflammatory mediators in macrophages upon a second high dose LPS challenge, although super low dose endotoxin itself does not trigger noticeable macrophage activation. Mice primed with super low dose LPS in vivo experience significantly elevated mortality following a second-hit high dose LPS as compared to saline-primed control mice. Mechanistically, we demonstrate that varying dosages of LPS primes macrophages by differentially modulating cellular and molecular switches inside the cells. The pathway switching and flipping induced by super low vs high dose LPS underscores the importance of competing intracellular circuitry during the establishment of macrophage priming and tolerance. (Received January 10, 2015)

1107-92-138 **Keith A Crandall*** (kcrandall@gwu.edu), Computational Biology Institute, Innovation Hall, Suite 305, Ashburn, VA 20147. *Statistical and computational approaches to microbiome analyses.*

Advances in DNA sequencing technology allow us to collect genomic data at a now cost-effective and efficient manner. Diagnostic companies and hospitals are equipping themselves with next-generation DNA sequencers, yet there remains significant constraint in our ability to manage and analyze these new volumes of data. Here we demonstrate some of the utility of using computational and statistical approaches for pathogen diagnosis as an example of translational research impacting personal medical outcomes. We demonstrate our approach with a variety of applications in human health and agricultural settings. In particular, we show the utility of our methods to identify pathogens, characterize microbial diversity, and test hypotheses associated with functional diversity of both host and pathogen. (Received January 10, 2015)

1107-92-157 **Ariel Cintron-Arias*** (cintronarias@etsu.edu), East Tennessee State University, Department of Mathematics and Statistics, Box 70663, Johnson City, TN 37614-0663. *Sensitivity Analysis and Treatment of Hepatitis C Virus Infection.* Preliminary report.

The interplay between types of immune responses, antibodies and CTL cells, is explored in the context of hepatitis C virus (HCV) infection. The competition between these immune system cells for HCV (necessary for their survival) is explored with sensitivity analyses, considered under three main steady states: co-existence, dominant CTL response, and dominant antibody response. Use of relative sensitivity functions allows temporal ranking of parameters, in relation to their degree of influence in viral load. Moreover, time subintervals where model parameters provide most information are also recorded. Parameter sensitivity is factored in the formulation of an optimal control problem, with the ultimate goal of addressing treatment. Comparisons between regimes with and without treatment are discussed. (Received January 12, 2015)

1107-92-161 **Meagan Herald*** (heraldmc@vmi.edu), Mallory Hall, VMI, Lexington, VA 24450. *Mathematical Model of Classically and Alternatively Activated Macrophage Cells.*

Inflammation is a dynamic process, directed by macrophage cells, that has the potential to both help and hinder infection resolution. Focusing on macrophage activation levels has advanced our understanding of infection resulting in inflammation especially in diseases such as cystic fibrosis where patients could already be colonized with a different species of bacteria such as *Pseudomonas aeruginosa*. To look at the impact alternatively activated macrophage cells have on infection resolution, a nonlinear system of differential equations was created to describe the interactions between the classically and alternatively activated macrophage populations in a chronically infected respiratory tissue during a secondary bacterial challenge. Without a secondary bacterial specie present, the macrophage population tends to one activation level or the other depending on the local cytokine milieu. As the alternative macrophage signal increases, either naturally or artificially, the threshold which divides the paradigm also shifts affecting the system's ability to resolve secondary infections. (Received January 12, 2015)

1107-92-172 **Jonathan Forde*** (forde@hws.edu), **Stanca Ciupe**, **Ariel Cintron-Arias** and **Suzanne Lenhart**. *Optimal Control for a Delay Model of HBV Treatment.* Preliminary report.

Although Hepatitis B Virus (HBV) is vaccine-preventable, there are 240 million chronically infected people, and 780,000 die each year of HBV-associated symptoms. For this reason, there is interest in drug treatment aimed at reducing symptoms and preventing or clearing chronic infection. Building on an existing delay differential equation model of acute HBV infection, we explore the effects of protease inhibitors and interferon-alpha on viral dynamics. Further, we formulate and numerically solve an optimal control problem, providing a framework for evaluating treatment strategies by including the costs of drug treatment, including economic cost and side effects. (Received January 13, 2015)

1107-92-173 **Stanca M Ciupe*** (stanca@vt.edu), Blacksburg, VA 24060, and **Jonathan Forde**. *Bi-stable behavior can explain the differences in disease outcome following SIV infections in rhesus macaques.* Preliminary report.

Experimental studies have shown that the size of viral inoculum from acute and chronic SIV infections correlates with disease outcomes. It is not known if the observed outcomes depend on the site of the infection, immune responses at the site, inoculum size and characteristics (in particular the presence of non-infectious particles), change in virus infectivity, and/or the genetic characteristics of the infected animals. In this study, we developed a model of antibody responses to SIV infection in rhesus macaques that accounts for virus-antibody immune complexes formation. Our model exhibits bi-stable dynamics between clearance and chronic states. Using temporal virus data and known inoculum values, we fitted the model and determined the avidity rate and antibody's carrying capacity that can explain the transition between virus clearance and persistence when initial conditions vary. We used these results to make predictions regarding the minimum amount of virus needed for infection in the presence and absence of a protective antibody response. (Received January 13, 2015)

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1107-92-180 **Kathleen A. Hoffman**, **Hye-Won Kang*** (hwkang@umbc.edu) and **Phyllis R. Robinson**. *Title of abstract: A stochastic model of the melanopsin phototransduction cascade*

Melanopsin is a photopigment expressed in a small subset of intrinsically photosensitive ganglion cells (ipRGCs). Melanopsin signaling is involved in non-image forming vision, and controls circadian rhythms, pupillary light reflex, and sleep. The biochemical cascade underlying the light response in ipRGCs has not been fully understood. We suggest a hypothesized melanopsin phototransduction cascade and develop a stochastic model for the cascade using a continuous-time Markov jump process. Parameter values in the signaling pathway under several different environments are estimated based on the experimental results. Comparing the simulation results to the experimental data, our stochastic model can qualitatively reproduce experimental results. We perform parameter sensitivity analysis using a method of partial rank correlation coefficient (PRCC), which suggests that the melanopsin phototransduction pathway is robust as the one in Drosophila photoreceptors. This is joint work with R.L. Brown, E. Camacho, E.G. Cameron, C. Hamlet, K.A. Hoffman, P.R. Robinson, K.S. Williams, and G.R. Wyrick.

(Received January 13, 2015)

1107-92-220 **Khem Raj Ghusinga*** (khem@udel.edu), 143 Evans Hall, Dept of Elec and Comp Engg, University of Delaware, Newark, DE 19716, and **Abhyudai Singh** (absingh@udel.edu), 143 Evans Hall, Dept of Elec and Comp Engg, University of Delaware, Newark, DE 19716. *Modeling bacteriophage λ lysis time at a single-cell level.*

Lysis of a host *E. coli* cell after being infected from a bacteriophage λ is a precisely timed event. The timing of lysis has profound effects on the fitness of phage progeny and is determined by the phage-encoded protein, holin, which accumulates in the membrane. When a critical holin level is attained, hole formation takes place resulting in immediate lysis of the host cell. Here, we discuss the cell-to-cell variation in lysis time arising due to the inherent stochasticity in gene expression. Lysis time is modeled as the first-passage time for holin levels to cross a critical threshold. Analytical expressions for the first-passage time moments are derived. Model predictions on how different model parameters modulate lysis time moments are verified with experimental data. Lastly, our analysis reveals regulatory motifs that enhance the robustness of lysis timing to cellular noise. (Received January 15, 2015)

1107-92-225 **Alison L Hill*** (alhill@fas.harvard.edu), **Stefany Moreno-Gamez**, **Daniel IS Rosenbloom**, **Mark Freeman**, **Pleuni Pennings** and **Martin A Nowak**. *Viral evolution in heterogeneous host environments.* Preliminary report.

Antiviral therapies can dramatically reduce the mortality of viral infections, but they remain vulnerable to drug resistance. Here I will discuss how temporal and spatial heterogeneity in drug levels within infected individuals can promote the evolution of antiviral resistance. Firstly, I will show how models that incorporate time-varying drug efficacy, due to both pharmacokinetics and pharmacodynamics, can explain patterns of resistance and the effects of suboptimal patient adherence. During combination therapy, this variation can lead to times when only a single drug reaches a therapeutic concentration, and this "temporal monotherapy" promotes resistance. Secondly, I will discuss how periodic fluctuations in drug levels may lead to the evolution of "cryptic" resistance, whereby instead of directly avoiding a drug target, a virus may adapt to synchronize its lifecycle with the pattern of drug treatment. Thirdly, I will present results demonstrating how the evolution of multi-drug resistance can occur rapidly when individual drugs within a combination do not penetrate effectively into certain regions of the body. Even small areas of mismatched drug coverage can create situations of "spatial monotherapy" that allow mutations to accumulate in a stepwise fashion. (Received January 15, 2015)

1107-92-237 **David Chan*** (dmchan@vcu.edu), 1015 Floyd Avenue, P.O. Box 842014, Richmond, VA 23284, **Derek Johnson** (dmjohnson@vcu.edu), 1000 West Cary Street, Room 126, Richmond, VA 23284, and **Candace Kent** (cmkent@vcu.edu), 1015 Floyd Avenue, PO Box 842014, Richmond, VA 23284. *Management of invasive allee species.* Preliminary report.

In this study we analyze a discrete model for an allee species with two patches and examine the effects of different management techniques to control the spread of the invasive species. (Received January 16, 2015)

1107-92-280 **Jessica M Conway***, jmconway@psu.edu, and **Alan S Perelson**. *(Functionally) curing HIV infection: mathematical model predictions.* Preliminary report.

Antiretroviral therapy (ART) for HIV is not a cure. However, recent studies suggest that ART, initiated early during primary infection, may induce post-treatment control (PTC) of HIV infection with HIV RNA maintained at $<$50 copies/ml. We investigate the hypothesis that ART, initiated early, permits PTC by limiting the size of the latent reservoir, which if small enough at treatment termination, may allow immune responses to prevent viral rebound (VR) and control infection. We use an ODE model of within host HIV dynamics to capture interactions between target cells, productively/latently infected cells, virus, and cytotoxic T lymphocytes (CTLs). Bifurcation analysis reveals a range in CTL response strengths where viral loads exhibit bistability between a high viral set point (VR) and a low viral set point (PTC). Below the bistable range, patients will always rebound, while above the range patients are predicted to behave like elite controllers. We show the basins of attraction associated with the VR and PTC viral set points and their dependence on the latent reservoir size at treatment termination. Using data on latent reservoir sizes in patients treated during primary infection, we also predict population-level VR times for non-controllers consistent with observations. (Received January 17, 2015)

1107-92-333 **Carina Curto*** (ccurto@psu.edu), Dept of Mathematics, McAllister Bldg, The Pennsylvania State University, State College, PA 16802. *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 January 18, 2015)

1107-92-346 **Senja Barthel*** (s.barthel11@imperial.ac.uk). *Remarks on the structure of DNA in bacteriophage capsids.* Preliminary report.

Bacteriophages are viruses that infect bacteria. The viral DNA is stored in capsids in a density that is amongst the highest known. It is still a big challenge to illuminate the structure of the DNA inside the capsid although numerous studies have been undertaken.

Toroidal structures of condensed DNA have been reported already 30 years ago. Starting from a naïve model that assumes the DNA to be arranged as an untwisted spool in a torus, we ask what knots arise if the ends of the DNA are joint directly or after passing one end of the DNA through the hole in the middle of the torus. We show that torus knots occur if and only if one end of the DNA strand is passed exactly once through the hole and that knots of extremely high crossing number are generated if one end is passed through several times. This behaviour corresponds to experimentally observed knot types. (Received January 19, 2015)

1107-92-350 **Chuncheng Wang**, **Rongsong Liu** and **Junping Shi*** (jxshix@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23187, and **Carlos Martinez del Rio**. *Spreading of mistletoes and birds.*

The existences of an asymptotic spreading speed and traveling wave solutions for a diffusive model which describes the interaction of mistletoe and bird populations with nonlocal diffusion and delay effect are proved by using monotone semiflow theory. The effects of different dispersal kernels on the asymptotic spreading speeds are investigated through concrete examples and simulations. (Received January 19, 2015)

1107-92-375 **Sivan Leviyang*** (sr286@georgetown.edu), Georgetown University, Department of Mathematics and Statistics. *The Dynamics of Early HIV Infection and CTL Response.*

The first weeks of HIV infection are marked by rapid changes in viral load. At the same time, immune system response mediated through cytotoxic T lymphocytes (CTLs) rises and varies in form and potency. Understanding the interplay between these dynamics, which reflect viral evolution in the presence of immune response mediated selection, presents significant modeling challenges. In this talk, I will discuss some recent work addressing these modeling challenges. (Received January 19, 2015)

1107-92-383 **Yuan Li**, **Laura A.L. Dillon**, **Kacey L. Caradonna**, **V. Keith Hughitt**, **Cecilia F. Dupecher**, **Kwame Okrah**, **Hector Corrada Bravo**, **Barbara A. Burleigh** and **Najib M. El-Sayed*** (elsayed@umd.edu). *Simultaneous interrogation of the transcriptomes of pathogens and their host cells.* Preliminary report.

We have adopted a novel approach aimed at characterizing host-pathogen infectomes. We define the infectome as the component of the pathogen's genome/transcriptome/proteome that allows it to subvert the functions of host cell molecular machineries, receptors, and signaling proteins, as well as the portion of the host cell's -omes that play a role in the infection process. Our screens include the use of a combination of 1) bioinformatic tools aimed at predicting surface and secreted components, 2) simultaneous interrogation of the host and pathogen transcriptomes during infection and intracellular survival and 3) high-throughput protein-protein interaction screens between a selection of host and pathogen proteins informed by the first two steps. The application of this approach to Trypanosoma cruzi and Leishmania major, two intracellular pathogens that parasitize mammalian cells is yielding significant biological insights into host-pathogen interactions. The identification and quantification of co-regulated genes has provided evidence regarding the mechanisms used by each of the two parasites to elude host defenses. We have also gained novel insights into host-pathogen interactions that influence establishment and maintenance of intracellular infection in mammalian host cells. (Received January 19, 2015)

1107-92-384 **LaMont C Cannon**, **Michael J Piovoso** and **Ryan Zurakowski*** (ryanz@udel.edu). *Constrained suboptimal experiment design for HIV cryptic viremia model validation.* Preliminary report.

In treated patients, HIV can continue to replicate in locations where combined antiretroviral therapy (cART) drugs do not penetrate. This is known as cryptic viremia. Cryptic viremia can be revealed by an experiment in which an integrase inhibitor is administered in addition to the background therapy. Virus replication inhibited results in the formation of 2LTR DNA circles. We have previously shown that the measured dynamics of these circles can be used as an indirect measure of the amount of cryptic replication. An experiment is being planned to validate the model developed in our previous work. Institutional Review Board (IRB) guidelines limit both the total number of blood measurements in human trials. In principle, we seek to optimize across the space of sampling schedules that meet the constraints to find the schedule that maximizes the expected Kullback-Leibler divergence relative to the broad priors obtained by fitting our model to data from previous experiments. We search the space using a Genetic Algorithm, and employ several approximations to make the problem numerically feasible. Preliminary results show that optimized schedules are expected to yield several times more information than uniform sampling schedules meeting the same constraints. (Received January 19, 2015)

1107-92-412 **Sharon Bewick*** (sharon_bewick@hotmail.com), **Guoqing Wang**, **Hannah Younes**, **Bingtuan Li** and **William F. Fagan**. *Invasion dynamics of competing species: revisiting the red/grey squirrel system with a spatial, stage-structured model.*

The spread of an invasive species often results in decline and disappearance of native competitors. Several models, primarily based on spatially explicit Lotka-Volterra competition dynamics, have been developed to understand this phenomenon. In general, the goal of these models is to relate fundamental life history traits, for example dispersal ability and competition strength, to the rate of spread of the invasive species, which is also the rate at which the invasive species displaces its native competitor. Stage-structure is often an important determinant of population dynamics, but it has received little attention in the context of Lotka-Volterra invasion models. We develop a spatially explicit, stage-structured Lotka-Volterra competition model. We then apply our model to the classic invasion problem of grey squirrels advancing into red squirrel habitat in Britain. Previously, this system was modeled using single-stage Lotka-Volterra competition equations. By comparing spread speed predictions from our stage-structured model to analogous spread speed predictions from the single-stage model, we are able to determine when stage-structure is important and how stage-dependent behavior can alter the characteristics of an invasion. (Received January 19, 2015)

1107-92-430 **Claus T Kadelka*** (ckadelka@vt.edu), **Seda Arat**, **Ross Donatelli**, **Marschall Furman**, **Madeleine Weinstein**, **Chris Heinen** and **Reinhard Laubenbacher**. *The regulatory effect of microRNAs on the DNA mismatch repair pathway.*

Although failure of DNA Mismatch Repair (MMR) is associated with microsatellite instability and colorectal cancer, little is known about MMR except for its biochemical pathway. By assembling known regulatory interactions, we introduce a novel gene regulatory network of MMR, which uses a recently introduced time- and state-discrete modeling framework that accounts for the cell's inherent stochasticity. This model provides phenotypic predictions for MMR's response to hypoxia and DNA damage. By showing that overexpressing microRNAs increases robustness while knocking them out seems to have the opposite effect, we substantiate the hypothesis that microRNAs can stabilize network dynamics, thus enhancing genomic stability. In addition to providing a gene regulatory network of MMR, our model yields experimentally verifiable predictions and enables further analysis of the potential stabilizing effect of microRNAs on dynamics of biological networks. (Received January 20, 2015)

1107-92-439 **Min Wang**, **Wen Zhou** and **Zhijun Wu*** (zhijun@iastate.edu), 462 Carver Hall, Department of Mathematics, Iowa State University, Ames, IA 50011. *Evolution of Population over Social Network.* Preliminary report.

Species make social contacts and form social networks. The latter may have great impacts on the evolution of a population, such as preserving certain genetic features, sharing knowledge and information, preventing invasions, etc. In this paper, we show that the evolution of a population over a social network can be modeled as a symmetric evolutionary game. Its equilibrium states can therefore be obtained and analyzed by solving an optimization problem called the generalized knapsack problem. We show that an equilibrium state often corresponds to a social clique, when the population is distributed evenly on the clique. However, an equilibrium state may or may not be evolutionarily stable, whether it is on a clique or not. Only those stable ones may be observable or sustainable in nature. We analyze several different types of equilibrium states and prove a set of conditions for their stabilities. We show in particular that the equilibrium states on cliques are evolutionarily stable except for special circumstances, while non-clique equilibrium states are unstable in general. Therefore, the optimal clique strategies should have an evolutionary advantage over the non-clique ones. (Received January 20, 2015)

1107-92-440 **Simon Tavaré*** (director@cruk.cam.ac.uk), Cancer Research UK Cambridge Institute, Li Ka Shing Centre, Robinson Way, Cambridge, CB2 0RE, United Kingdom. *Cancer by the numbers.*

The mathematical sciences have contributed substantially to our understanding of the way cancer evolves. Cancer is a disease of the genome, so the focus of this lecture will be on mutations in DNA and what they tell us about tumor evolution. We will discuss "tumor heterogeneity," the DNA sequence variation observed between tumors and within them, and what this tells us about progression, treatment, and relapse. Along the way we will illustrate some of the underlying mathematics that have helped in this endeavor. (Received January 20, 2015)

1107-92-462 **Donald Seto*** (dseto@gmu.edu), 10900 University Blvd, mail stop 5B3, Manassas, VA 20110. *Genome analysis of human adenoviruses provides insights into their molecular evolution, zoonosis, and emergence of human viral pathogens.*

Ten years of adenovirus genomics and bioinformatics provide remarkable insights into the molecular evolution of human and non-human simian adenoviruses, as well as into the emergence of new human viral pathogens through zoonosis. Remarkable findings include the recognition of HAdV coinfections, viral lateral gene transfer, and extraordinary and unexpected phylogenetic relationships. As an example, the lone HAdV type within the "human species E" clade appears to be a chimpanzee virus that has crossed host barriers and adapted to the human host recently. Bioinformatic analysis shows that the hexon hypervariable regions of HAdV-E4 have high sequence identity with the counterpart sequences from HAdV-B16, suggesting recombination with a human adenovirus. Recombination amongst other HAdV and SAdV genomes are also documented. This should be a consideration in using SAdVs as alternative gene transfer vectors for human gene therapy. (Received January 20, 2015)

1107-92-467 **Irina Kareva** and **Faina Berezovskaya*** (fberezovskaya@howard.edu), Washington, DC 20059. *Predator-prey-shared resource model in tumor-immune interactions.*

In the tumor microenvironment there must exist competition for the common resources between cancer cells and the cells of the immune system, which may drive a lot of the tumor-immune dynamics. Proposed here is a model of tumor-immune-glucose interactions, formulated as a predator-prey-common resource type system, which allows to investigate possible dynamical behaviors that may arise as a result of competition for glucose, including tumor elimination, tumor dormancy and unrestrained tumor growth. The model is then reduced to a predator-prey type model, and a full bifurcation analysis is performed to establish a sequence of regimes that can occur as predator (immune system) and prey (cancer cells) compete for shared resources that are necessary for survival of both. (Received January 20, 2015)

1107-92-471 **Zana A Coulibaly***, 1000 Hilltop Circle, Baltimore, MD 21250, and **Matthias K Gobbert** and **Bradford E Peercy**. *Initiation of intracellular calcium spiral waves in a stochastic fire-diffuse-fire model.* Preliminary report.

We investigate a mechanism that leads to the initiation of spiral waves through the use of lower dimensional approximations of a 3D stochastic fire-diffuse-fire model of intracellular calcium dynamics. From the reduced models, we are able to conduct a directed search and report a range of parameter values that have a high probability of initiating spiral patterns in the 3D model. The intrinsic appearance of such patterns is the result of an interplay between the spatial regularity in the CRUs' locations and amplitude of the calcium release. No artificial spatial heterogeneity is required. (Received January 20, 2015)

1107-92-497 **Paula Grajdeanu*** (pgrajdea@su.edu). *Balancing inflammation to impact disease dynamics.*

Inflammation seems to be at the heart of various health conditions, including cancer, autoimmune diseases, neurodiseases, tuberculosis, and more. Anti-inflammatory medications are therefore used to reduce the inflammation when necessary, most of the time with undesirable long term side effects. Questions arise related to effective balancing of anti-inflammatory vs. pro-inflammatory mediators (cells, cytokines) and the importance of these interactions in defining the disease dynamic (remission, flare). These questions can be addressed by mathematical modeling to effectively temper/control the effects of inflammation, and subsequently improve long term disease management. (Received January 20, 2015)

1107-92-501 **Ashley Sobel*** (ashleyesobel@gmail.com), Biological Sciences Building, 130 Science Drive, Duke University, Durham, NC 27713, and **Micah McClain** (micah.mcclain@dm.duke.edu), **Chris Woods** (chris.woods@dm.duke.edu) and **Katia Koelle** (katia.koelle@duke.edu). *A human challenge experiment points towards the importance of viral load dynamics and viral genetics in driving influenza symptoms.* Preliminary report.

Multiple within-host models of influenza infection have jointly simulated viral load and symptom score dynamics. Few studies, however, have fit these models to empirical data from humans or considered how these dynamics may depend on viral genetics. Here, we fit the within-host model proposed by Canini and Carrat (2011) to time-course measurements of viral load and symptom scores from a human challenge experiment, and show that this model can successfully capture viral load and symptom score patterns of the study's volunteers, as well as certain peripheral cytokine dynamics that were not used in model fitting. Allowing inter-individual variation in two parameters (the rate of viral infection and the ratio of viral production to clearance) improves the model fit, as determined by Akaike information criterion. These results indicate that inter-individual variation in viral load dynamics is the primary source of inter-individual variation in symptom score dynamics. We end by utilizing a unique dataset of temporal influenza virus sequencing within these same hosts to present preliminary 'phylodynamic' analyses that point towards viral genetics in explaining some of the inter-individual variation in viral load dynamics, with downstream consequences for symptom manifestation. (Received January 20, 2015)

93 ► Systems theory; control

1107-93-96 **Kurt Helmes**, **Richard H Stockbridge** and **Chao Zhu*** (`zhu@uwm.edu`), Department of Mathematical Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI 53201. *On Optimal Ergodic Continuous Inventory Control Problems.*

This work examines a control problem when, in the absence of ordering, the single-item inventory process has continuous sample paths. The inventory process is modeled by a one-dimensional diffusion on some interval in which the left boundary is attracting, so as to capture the effect that demand tends to decrease the inventory level, and the right boundary is non-attracting. Orders instantaneously increase the inventory level and incur both positive fixed and level dependent costs. In addition, state-dependent holding/backorder costs are incurred continuously. The manager's influence on the inventory is limited solely to ordering policies that increase the current level. The objective of the manager is to find an ordering policy that minimizes the long-term average holding/backorder and ordering cost.

This work provides minimal conditions on the model which imply that an optimal ordering policy exists in the class of (s,S)-ordering policies. Examination of the steady state behavior of (s,S) policies leads to a two-dimensional nonlinear optimization problem for which a pair of optimizers establishes the levels for an optimal (s,S) policy. This paper's contribution is a set of very mild sufficient conditions for the existence of an optimal (s,S)-ordering policy. (Received January 05, 2015)

1107-93-111 **Matthias Kawski*** (`kawski@asu.edu`), School of Mathematical and Statistical Scienc, Tempe, AZ 85044. *Iterated Integrals in Control and Feedback Transformations.* Preliminary report.

Nonlinear control theory fundamentally rests on noncommuting flows whose geometry is described by Lie and Leibniz algebras. Together with the corresponding iterated integral functionals the underlying structure is now well understood in terms of combinatorial Hopf algebras. These clarify e.g. the factorization of the exponential Lie series that describe solution curves (path planning) and the endpoint map (optimal control) as infinite directed products of exponentials. We investigate some of the combinatorial algebra involved in the step from this, now classical, work, that relies on a choice of controls and vector fields, to a geometric description that involves only distributions and thus is feedback-invariant. (Received January 08, 2015)

1107-93-144 **W. Steven Gray*** (`sgray@odu.edu`), 231 Kaufman Hall, ECE Department, Old Dominion University, Norfolk, VA 23529. *Combinatorial algebras for iterated integrals in nonlinear control theory.*

In nonlinear control theory, input-output systems are interconnected in different ways to form more complex systems found in applications. Normally, each component system is described by a Chen-Fliess functional series expansion, that is, a weighted sum of iterated integrals which can be uniquely represented by a formal power series over a noncommutative alphabet. System interconnections are then characterized in terms of various products of these formal power series. The goal here is to present the underlying combinatorial algebras used to characterize the basic system interconnections found in control theory: the parallel, product, cascade and feedback connections. The feedback connection is perhaps the most interesting case as it is recursive in nature, and the underlying algebraic framework is that of a Faà di Bruno type Hopf algebra involving the composition of iterated integrals. The antipode of this algebra provides a recursive, cancellation-free algorithm for performing system inversion, which is a prerequisite for solving classical control problems such as output tracking and path planning. (Received January 11, 2015)

1107-93-167 **Luis A Duffaut Espinosa***, lduffaut@gmu.edu. *Input-output operators with non-commutative iterated integrals.*

Fliess operators, also known as Chen-Fliess functional series expansions, have been established as descriptors of a broad class of nonlinear input-output maps. A tacit assumption in the standard theory of Fliess operators is that the input functions are mutually commutative. This assumption results in a great deal of simplification and hides certain underlying algebraic structures that are important in applications like control on Lie groups and quantum control. The objective here is to describe the role of non-commutative iterated integrals in the framework of input-output operators. In particular, the algebra of planar binary rooted trees is used to describe the algebra of non-commutative iterated integrals, and thus, a non-commutative version of the shuffle algebra is defined. Also, sufficient conditions for the convergence of the defining series are given. The theory is illustrated with a very simple bilinear system example. (Received January 12, 2015)

97 ► Mathematics education

1107-97-102 **Mulugeta Markos*** (mmarkos@atml.edu), 2150 Southwood Cove SW, APT # 112, Atlanta, GA 30331. *Teaching in College without Calculator.*

There is no clear rule for teachers when to let their students use calculator in the lower level mathematics courses involving basic arithmetic skill. This article analyzes the performances of 198 college students in solving different levels of basic arithmetic skill questions with and without using calculators. Statistical analysis and tests have been conducted to see the correlation and the difference between using and without using calculator. The results of this article indicate that college students do better using calculator when the calculation involves a single operation. Even though most of the students struggle to solve the problems with and without using calculator when the questions involve more than one operation, indices, surds, comparisons, percentages, and approximations, students do better if they are allowed to use calculator. The data in this article provides important information for teachers teaching mathematics and other courses involving basic arithmetic skills, and encourages global study on how and when to use calculator in lower level college classes involving basic arithmetic skill. (Received January 05, 2015)

EAST LANSING, MI, March 14–15, 2015

Abstracts of the 1108th Meeting.

00 ▶ General

1108-00-35 **Ben Adcock*** (ben_adcock@sfu.ca). *Function approximation via infinite-dimensional weighted l^1 minimization.*

In a number of applications one is required to approximate a smooth multivariate function from a small number of pointwise samples. Classically, this task is carried out by methods such as interpolation or least squares. Yet with the advent of compressed sensing there has been an increasing focus on the use alternative techniques based on convex optimization. In this talk I will describe an infinite-dimensional framework for function approximation via weighted l^1 minimization. I will explain why working in infinite dimensions is both theoretically and practically important, and describe the critical role that weights play in the minimization. In the second half of the talk I will address the following question: does weighted l^1 minimization always perform at least as well as classical least squares? An affirmative answer to this question is of practical relevance, since it means that such techniques should always be used in over classical tools in applications where the primary limitation is the amount of data available. I will present a mathematical framework for examining this question, and answer it in the affirmative for the case of polynomials approximations. Finally, I will discuss the role that sparsity plays this framework, and present some open problems. (Received November 28, 2014)

1108-00-49 **Hongli Gao*** (gaohongl@msu.edu), 4382 Okemos Road Apt G214, Okemos, MI 48864. *Minimization and the Gradient Flow of a Non-smooth Convex Functional.*

We first study the existence and property of the minimizer of a non-smooth convex integral functional. After that, the gradient flow of the functional will be calculated. At the end, the minimizer and the gradient flow of a special case will be studied. (Received December 15, 2014)

1108-00-81 **Gezahagne Mulat Addis*** (buttu412@yahoo.com), Dilla University, Dilla, Ethiopia. *Right Invertible Functions.*

A function which has an inverse from the right side is called right invertible. It is obvious that a function is right invertible if and only if it is a surjection; that is, if a function is given to be a surjection then it has at least one right inverse. The question in this case is that, how many right inverses can be there for a given surjective function? This paper will address an independent new approach to derive the formula used to count the number of right inverses of a surjection. (Received December 31, 2014)

1108-00-148 **Bruce K Geist*** (bruce.geist@fcagroup.com), Bruce Geist, Fiat Chrysler Automobiles (FCA US LLC), Auburn Hills, MI 48326. *Better Fuel Economy Through Vibration Control.*

Significant opportunities exist to improve vehicle fuel efficiency through designing vehicles in a way that allows the power train and vehicle to operate together, as a system, more efficiently. The mathematical dependence of friction, pumping and other losses within an operating engine indicate a strategy for improving vehicle fuel efficiency: engine down-speeding. Down-speeding is a strategy of generating requested power at lower engine speeds. To enable lower speed operation, torsional vibration must be managed well. Non-circular path crankshaft pendulums can be deployed to correct torsional surging. The correction works for all speeds, and occurs within the engine. Though crankshaft pendulums offer significant advantages, they must respond well under any circumstance under which the engine may be operated. Given the variety of possible operating circumstances, it is imperative that motion paths for automotive crankshaft pendulums be designated carefully, in a way that ensures pendulums act smoothly and in unison to correct torsional vibrations. Prototype crankshafts function well to remove torsional vibration produced within a four-cylinder engine. A summary of a patented crankshaft design with epicycloidal pendulum paths and test results are presented. (Received January 08, 2015)

1108-00-199 **Lei Gao**, **Yufeng Han**, **Sophia Zhengzi Li*** (zhengzi@msu.edu) and **Guofu Zhou**. *Intraday Momentum: The First Half-Hour Return Predicts the Last Half-Hour Return.*

In this paper, using the intraday data of the S&P 500 ETF from February 1, 1993 to December 31, 2013, we document an intraday momentum pattern that the first half-hour return on the market predicts the last half-hour return on the market. The predictability is both statistically and economically significant, and is stronger on more volatile days, higher volume days, recession days and some macroeconomic news release days. Moreover, the intraday momentum is also strong for ten other most actively traded ETFs. Economically, the trading behavior of daytraders and informed traders seems to be the driving forces behind the intraday momentum. (Received January 12, 2015)

1108-00-229 **Ge Wang*** (ge-wang@ieee.org), Biomedical Imaging Center/Cluster, Rensselaer Polytechnic Institute, Troy, NY 12180. *Future of Multi-modality Imaging.* Preliminary report.

We published the first papers on interior tomography and omni-tomography for grand fusion of all relevant tomographic modalities ("all-in-one") to acquire different datasets simultaneously ("all-at-once") and capture multi-physics interactions ("all-of-couplings"), with simultaneous CT-MRI as a special example. Integrated multimodality imaging systems such as PET-CT and MRI-PET gained acceptance as valuable clinical and research tools after initial skepticism, but CT-MRI has not been attempted largely due to technical challenges, despite its greater promise. CT offers a nearly ideal map of morphology at fine resolution and high speed. MRI captures functional, flow-sensitive, and tissue-specific signals in excellent contrast. Should it be funded to build a simultaneous/contemporaneous CT-MRI scanner, we would be uniquely equipped to image intrinsic complexity and dynamic character of real biological and pathological processes, especially in non-contrast/contrast-enhanced cardiovascular and oncologic applications. In this presentation, we particularly discuss the potential of simultaneous/contemporaneous CT-MRI and collaborative opportunities. (Received January 14, 2015)

1108-00-258 **Scott Wilson Badenoch*** (sbadenoch@badenoch.com), 2 Corporate Drive, Southfield, MI 48076. *Alternative Computational Methods for Optimization of Military Vehicles Design for Human Survivability and other Factors.*

Badenoch LLC designs and develops high performance military vehicles for the United States Department of Defense, and its agencies including DARPA (Defense Advanced Research Projects Agency). The mission of DARPA is not incremental improvement, but game-changing innovation. Examples of DARPA successes are the Internet and stealth technology now used on aircraft and ships. The focus at Badenoch LLC for DARPA is on human survivability, especially in regards to the effects of explosive blast. The process at Badenoch LLC relies upon modeling and simulation (M&S), complimented by extensive blast testing of survivable vehicle technologies. The problem of optimization using M&S is the subject of this AMS presentation. Conventional methods of M&S are computationally accurate, but require long run times even on high performance computers. Badenoch LLC has developed an alternative computational approach, one that offers a significant improvement in computational speed. The improvement in speed allows more factors to be varied, providing a surface plot of the response of the vehicle/human system to blast. For comparison, a conventional M&S calculation requires about forty (40) hours of computer time. The alternative method requires only five (5) seconds. (Received January 16, 2015)

1108-00-297 **Lan Wang*** (lwang17@ford.com), Lan Wang, Mail Drop 7710, Ford Credit, One American Road, Dearborn, MI 48126-2701. *Developing Effective Collection Strategy.* Preliminary report.

Ford Credit provides automotive financial products and services to Ford Motor Company, its dealers and customers – through all economic cycles.Credit losses are expected as normal part of business. We need to collect within contract's loss expectations while managing cost. It is important to develop effective collection strategies. In this talk, we discuss how analytics can help in developing an efficient debt collection strategy for delinquent customer accounts and help reduce organization costs, save time and increase customer satisfaction. (Received January 16, 2015)

1108-00-303 **Kishore Jaganathan*** (kishore@caltech.edu), 1020 E Del Mar Blvd #202, Pasadena, CA 91106. *Phase Retrieval using Masks via Convex Optimization.*

In some applications of the Fourier phase retrieval problem, it is possible to modulate the signal using masks to obtain additional intensity measurements. The best known provable recovery algorithm for this setup involves the use of $c\log^2 n$ random masks. We show that two random masks, which satisfy very mild conditions, are enough to recover almost all signals uniquely from the intensity measurements. Also, for a specific choice of two masks, we develop a provable recovery algorithm based on semidefinite relaxation. We also show that the recovery is stable in presence of measurement noise. (Received January 17, 2015)

1108-00-383 **Adam Metzler*** (ametzler@wlu.ca), 75 University Avenue West, Waterloo, Ontario N2L 3C5, Canada. *Regulatory Concerns Related to CoCo Bonds - Mathematical Modeling.*

A contingent convertible (CoCo) bond begins life as subordinated debt, but converts into common equity when the issuing institution begins to experience financial distress. The rigorous treatment of contingent capital in the academic literature remains in its infancy, and several important questions remain unaddressed. For instance it is not clear (i) whether or not CoCo investors will have incentives to short the issuing institution's stock when conversion is imminent or (ii) how much an objective conversion trigger (i.e. one allowing for regulatory discretion) would add to the cost of contingent capital relative to a purely objective trigger. In this talk we present a structural model that can be used to gain insights into these problems. The model allows for the market price of the firm's stock to temporarily deviate from its fundamental value (incorporating the impact of large scale short-selling) and allows for the conversion time to be the first event time in a Cox process with intensity driven by the firm's asset value (incorporating the uncertainty inherent in a subjective trigger). Valuation of CoCos in the model will be discussed and numerical results, calibrated to balance-sheet data for Canadian institutions, will be presented. (Received January 19, 2015)

1108-00-398 **Patrick H Lukulay*** (phl@usp.org), 12601 Twinbrook Parkway, Rockville, MD 20814. *A Risk-Based Approach to Quality Control Testing of Pharmaceuticals in Emerging Markets.*

The quality of medicines is a major issue in developing countries, resulting in increased morbidity and mortality. Regulators seek to address this problem through quality control testing of medicines prior to registration. However, resource constraints create a backlog of medicines to be tested, limiting a lab's ability to conduct full testing and compromising work quality. This results in delayed access to medicines, increased costs, and loss of stakeholder confidence. Currently, most labs treat all medicines with the same assumed level of risk. Labs work hard instead of smart, conducting full testing. Constraints also mean some labs forgo testing altogether while others make testing decisions arbitrarily. PQM and MSU are therefore developing a risk-based quality control model, which uses logistics regression and other data mining methods to determine which products should be prioritized for testing, over time, learning "best practices". It establishes a precedent for identifying products that either need to undergo full testing or may undergo abbreviated testing because of their lower risk. This model is a paradigm shift in the way labs currently function and will conserve resources, improve work quality and ultimately assure the health of the people these labs serve. (Received January 19, 2015)

1108-00-421 **Meng Meng Yu** (mengmeng.yu@delphi.com), 118 De Lin Road, Shanghai, 200131, Peoples Rep of China, **Guanglin Ma** (guanglin.ma@delphi.com), 118 De Lin Road, Shanghai, Peoples Rep of China, and **Henry Kong*** (henry.kong@delphi.com), 3000 university Drive, Rochester Hills, MI 48326. *360 Surround View System with Parking Guidance.*

In this talk, we present a real-time 360 degree surround system with parking aid feature, which is a very convenient parking and blind spot aid system. In the proposed system, there are four fisheye cameras mounted around a vehicle to cover the whole surrounding area. After correcting the distortion of four fisheye images and registering all images on a planar surface, a flexible stitching method was developed to smooth the seam of adjacent images away to generate a high-quality result. In the post-process step, a unique brightness balance algorithm was proposed to compensate the exposure difference as the images are not captured with the same exposure condition. In addition, a unique parking guidance feature is applied on the surround view scene by utilizing steering wheel angle information as well as vehicle speed information. The challenges include the real world applications with minimum computation power to achieve the optimum performance. The mathematical model and solutions for this application will be explained and discussed. (Received January 19, 2015)

1108-00-423 **Drew Armstrong*** (armstrong@math.miami.edu), Department of Mathematics, University of Miami, Coral Gables, FL 33146. *What is ADE?*

I will give two answers: one historical, one ahistorical. (Received January 19, 2015)

1108-00-477 **Armin Eftekhari*** (armin.eftekhari@gmail.com), **Zhihui Zhu** and **Michael B. Wakin**. *Greed is Super: A New Iterative Method for Super-Resolution.* Preliminary report.

In this talk, we discuss a new greedy algorithm for super-resolution. Given the low-frequency part of the spectrum of a sequence of impulses, our objective is to estimate their positions. The backbone of our work is the fundamental work of Slepian et al. involving discrete prolate spheroidal wave functions and their unique properties. By its greedy nature, our work differs from the approach of Candes et al. based on convex optimization. By its use of prolate functions, our work also differs from the greedy algorithm presented by Fannjiang et al.

We also contribute to the existing theory on duration- and band-limiting operators by producing new asymptotic expressions for prolate functions. (Received January 19, 2015)

1108-00-491 **Katya Malinova*** (katya.malinova@utoronto.ca), **Andreas Park** and **Ryan Riordan**. *The Impact of High Frequency Traders on Retail and Institutional Traders.*

We study the intra-day trading profits and losses of retail and institutional traders from 2006 to 2012, using granular data from the Toronto Stock Exchange. We find that retail traders lose on their market orders, these losses are closely related to the bid-ask spread, and they decline over time. In our sample, retail traders trade

45% of their volume with limit orders, and our findings on retail traders' costs and benefits to limit orders over the long run are mixed. To analyze the causal impact of algorithmic trading activities, we employ a change in regulatory fees in Canada in April 2012 that affected high-frequency quote submissions and cancellations. Following the change, the number of trades, quotes, and cancellations dropped by 30% and market-wide bid-ask spreads rose by 9%. Trading costs for market orders, measured by bid-ask spreads, increased for institutions, but remained unaffected for retail traders. Both groups incur higher adverse selection costs on their limit orders. Retail traders' intraday returns, especially from limit orders, declined, while institutions' returns from market orders increased. (Received January 19, 2015)

05 ► Combinatorics

1108-05-13 **Zoltan Furedi** and **Zeinab Maleki*** (zmaleki@math.iut.ac.ir). *On Erdos' conjecture on the number of edges in 5-cycles.* Preliminary report.

Erdös, Faudree, and Rousseau in 1992 showed that a graph on n vertices and with at least $\lfloor n^2/4\rfloor + 1$ edges comprise at least $2\lfloor n/2\rfloor + 1$ edges on triangles and this result is sharp. They also considered a conjecture of Erdös that such a graph have at most $n^2/36$ non-pentagonal edges. This was mentioned in other paper of Erdös and also in Fan Chung's problem book.

In this talk we give a graph of $\lfloor n^2/4\rfloor + 1$ edges with much more, namely $n^2/8(2+\sqrt{2}) + O(n)$ pentagonal edges, disproving the original conjecture. We also show that this coefficient is asymptotically the best possible. (Received October 27, 2014)

1108-05-27 **Ben Salisbury*** (ben.salisbury@cmich.edu), Department of Mathematics, Central Michigan University, Pearce Hall 206H, Mount Pleasant, MI 48859, and **Travis Scrimshaw** (tscrim@ucdavis.edu), Department of Mathematics, University of California, One Shields Avenue, Davis, CA 95616-8633. *A rigged configuration model for $B(\infty)$.*

The crystal $B(\infty)$ is a combinatorial skeleton of the negative half of the quantum group, and its importance in the theory of crystal bases has been highlighted since Kashiwara's original papers on the subject. Since then, many combinatorial models for $B(\infty)$ have been developed (i.e., tableaux, MV polytopes, quiver varieties, Nakajima monomials, etc). In this talk, we introduce yet another model for $B(\infty)$; one that is somewhat uniform across all symmetrizable types. (Received November 19, 2014)

1108-05-50 **Milagros Izquierdo*** (milagros.izquierdo@liu.se), Department of Mathematics, Linköping University, 58183 Linköping, Sweden, and **Klara Stokes**. *Maps, Point-circle configurations and Pentagonal Geometries from Moore Graphs.*

In tis talk we construct isometric point-circle configurations on complete hyperbolic surfaces from uniform maps, these are generalizations of point-circle configurations on the plane given by Gevay and Pisanski.

This gives one geometric realization in terms of point and circles of the Desargues' configuration in the real projective plane and three distinct geometric realizations of the pentagonal geometry with seven points on each line and seven lines through each point on three distinct dianalytic surfaces of genus 57. (Received December 16, 2014)

1108-05-131 **J Balogh** and **H Liu** (m.sharifzadeh@gmail.com), Champaign, IL 61820, and **M Sharifzadeh*** (sharifz2@illinois.edu) and **A Treglown**. *The number of maximal sum-free subsets of integers.*

Cameron and Erdős raised the question of how many *maximal* sum-free sets there are in $\{1,\ldots,n\}$, giving a lower bound of $2^{\lfloor n/4\rfloor}$. In this paper we prove that there are in fact at most $2^{(1/4+o(1))n}$ maximal sum-free sets in $\{1,\ldots,n\}$. Our proof makes use of container and removal lemmas of Green as well as a result of Deshouillers, Freiman, Sós and Temkin on the structure of sum-free sets. (Received January 07, 2015)

1108-05-132 **Jozsef Balogh**, **Hong Liu*** (hliu36@illinois.edu) and **Maryam Sharifzadeh**. *Subdivisions of a large clique in C_6-free graphs.*

Mader conjectured that every C_4-free graph has a subdivision of a clique of order linear in its average degree. We show that every C_6-free graph has such a subdivision of a large clique.

We also prove the dense case of Mader's conjecture in a stronger sense, i.e., for every c, there is a c' such that every C_4-free graph with average degree $cn^{1/2}$ has a subdivision of a clique K_ℓ with $\ell = \lfloor c'n^{1/2}\rfloor$ where every edge is subdivided exactly 3 times.

Joint work with Jozsef Balogh and Maryam Sharifzadeh (Received January 07, 2015)

1108-05-154 **Harold Williams*** (hwilliams@math.utexas.edu), **Vivek Shende**, **David Treumann** and **Eric Zaslow**. *Legendrian Knots and Cluster Varieties.*

Many cluster varieties of geometric interest, such as Grassmannians and spaces of local systems, can be associated with combinatorial objects on surfaces, for example embedded bipartite graphs. We will consider these varieties from the point of view of symplectic geometry, explaining how they can be interpreted as moduli spaces canonically associated with Legendrian knots. This provides an illuminating new perspective on these cluster structures, which we explain through several examples related to integrable systems. (Received January 08, 2015)

1108-05-176 **David Galvin*** (dgalvin1@nd.edu), Notre Dame, IN , and **John Engbers**, Milwaukee, WI. *H-colouring trees.* Preliminary report.

All trees on n vertices admit the same number of proper q-colourings. But if we broaden our viewpoint a little, and consider, for each graph H, the number of H-colourings admitted by an n-vertex tree, we quickly reach a realm of open questions. [An H-colouring of a graph G is an adjacency-preserving map from the vertices of G to those of H; when H is the complete graph on q vertices, H-colouring and proper q-colouring coincide.]

Siderenko resolved the question of which n-vertex tree admits the greatest number of H-colourings. We describe a new proof of Siderenko's result (valid for large n) that admits extensions beyond the world of trees. In the other direction, we describe some progress on the fairly open question of determining which n-vertex tree admits the least number of H-colourings, extending a result of Prodinger and Tichy. (Received January 10, 2015)

1108-05-177 **Lucas Kramer** and **Ryan R. Martin*** (rymartin@iastate.edu), 396 Carver Hall, Department of Mathematics, Ames, IA 50011. *A new upper bound for the size of diamond-free families.*

In the Boolean lattice, we say that a family $\mathcal{F}$ has a diamond as a (weak) subposet if there are four distinct subsets A, B, C, D such that $A \subset B \subset D$ and $A \subset C \subset D$. There has been a great deal of recent activity on the size of families in the Boolean lattice with no (weak) copy of a fixed subposet. However, the maximum size of a diamond-free family is still unknown, even asymptotically.

Using a method due to Manske and Shen, we have obtained a new upper bound for the size of a diamond-free family in the n-dimensional Boolean lattice of $(2.2067 + o(1))\binom{n}{\lfloor n/2 \rfloor}$. This improves the previous bound of 2.25, which was due to the authors and Michael Young. (Received January 10, 2015)

1108-05-183 **Philippe R Di Francesco*** (philippe@illinois.edu), University of Illinois at Urbana-Champaign, Department of Mathematics, 1409 W Green Street, Urbana, IL 61801. *Integrable Combinatorics.*

Integrability occurs in physical problems with sufficiently many symmetries, and allows for exact, often elegant solutions with deep geometric and algebraic meaning. Such problems often boil down to that of enumerating weighted configurations of particular systems, which can be rephrased in purely combinatorial terms.

In this talk, we review manifestations of integrability in various combinatorial enumeration problems such as Lorentzian Triangulations, Alternating Sign Matrices, Domino Tilings, Current Algebra Tensor Product Multiplicities, and their interplay with the underlying structure of Cluster Algebra and its quantum deformation. (Received January 11, 2015)

1108-05-198 **Nantel Bergeron*** (bergeron@yorku.ca) and **Cesar Ceballos**. *On the Hopf algebra of subword complexes.*

The Hopf algebra of sub word complexes has many interesting properties. Here I will focus on its antipode. Even if it is quite different from the Hopf algebra of Graphs or Matroids, the antipode still has some similar avor. I will present this. [Some of this work was the fruit of discussion with C. Benedetti and B. Sagan] (Received January 12, 2015)

1108-05-206 **Thomas Lam**, **Pavlo Pylyavskyy*** (ppylyavs@umn.edu) and **Reiho Sakamoto**. *Rigged Configurations and Cylindric Loop Schur Functions.*

Rigged configurations are known to provide action-angle variables for remarkable discrete dynamical systems known as box-ball systems. We conjecture an explicit piecewise-linear formula to obtain the shapes of a rigged configuration from a tensor product of one-row crystals. We introduce cylindric loop Schur functions and show that they are invariants of the geometric R-matrix. Our piecewise-linear formula is obtained as the tropicalization of ratios of cylindric loop Schur functions. We prove our conjecture for the first shape of a rigged configuration, thus giving a piecewise-linear formula for the lengths of the solitons of a box-ball system. (Received January 13, 2015)

1108-05-212 **Thomas Lam*** (tfylam@umich.edu). *The uncrossing partial order on matchings.*
The set P_n of matchings of $2n$ points arranged on a circle can be given a partial order, obtained by "uncrossing" strands. This poset arises from the study of planar electrical networks. I will discuss some features of this poset, including a proof that this poset is Eulerian. (Received January 13, 2015)

1108-05-213 **Panupong Vichitkunakorn*** (vichitk1@illinois.edu), 1409 W Green St, Urbana, IL 61801. *Combinatorial solutions to T-systems with principal coefficients.*
The A_∞ T-system is a system of formal variables satisfying the Octahedron relation without boundary conditions. Given a valid set of initial data, many combinatorial solutions have been considered, e.g. dimer solution, non-intersecting path solution. Any T-system can also be interpreted as a particular subtree of a cluster pattern without coefficients.

In this talk, we consider A_∞ T-systems with principal coefficients. Two combinatorial solutions, dimer solutions and non-intersecting path solutions, are introduced. They are generalizations of the solutions in coefficient-free cases. In theory of cluster algebra, this special choice of coefficients gives solutions to all cluster patterns and Y-patterns with arbitrary coefficients on the octahedron quiver, specializations include T-systems with coefficients discussed in Speyer's 2007, Lambda determinants in Di Francesco's 2013 and pentagram maps. (Received January 13, 2015)

1108-05-249 **Tri Lai** (tmlai@indiana.edu), Institute for Mathematics and its Application, Minneapolis, MN 55455, and **Gregg Musiker*** (musiker@math.umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *Combinatorics of the dP3 Quiver: Aztec Castles and Beyond.* Preliminary report.
We consider a specific six-vertex quiver, the dP3 quiver, and toric mutation sequences of it, i.e. mutations which only occur at a vertex with two in-coming arrows and two out-going arrows. Previous work of the second author with REU students I. Jeong and S. Zhang, and later with REU students M. Leoni, S. Neel, and P. Turner, led to combinatorial interpretations for cluster variables arising from a two-dimensional subspace of toric mutations. In the present work, we extend this combinatorial interpretation to a three-dimensional subspace, and study the integrability of these mutation sequences. (Received January 15, 2015)

1108-05-254 **Oliver Pechenik** (pecheni2@illinois.edu), 1409 W. Green St, Urbana, IL 61801, and **Alexander Yong*** (ayong@uiuc.edu), 1409 W. Green St, Urbana, IL 61801. *Genomic tableaux and applications to Schubert calculus.*
We introduce *genomic tableaux*, a generalization of semistandard tableaux. Our main application is to obtain Schubert calculus rules in the (equivariant) K-theory of Grassmannians. (Received January 15, 2015)

1108-05-255 **Benjamin Wyser** (bwyser@illinois.edu), 1409 W. Green St, Urbana, IL 61801, and **Alexander Yong*** (ayong@uiuc.edu), 1409 W. Green Street, Urbana, IL 61801. *Polynomials for symmetric orbit closures in the flag variety.*
An isomorphism of A. Borel '53 presents the cohomology ring of the flag variety as the coinvariant algebra of type A. We discuss K-orbit closures associated to the symmetric pairs (GL_n, K). By analogy with the combinatorial theory of Schubert polynomials established by A. Lascoux–M. P. Schützenberger '82, we describe representatives in Borel's presentation for the class of each closure. (Received January 16, 2015)

1108-05-344 **Tao Jiang*** (jiangt@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056. *Some Hypergraph Turan results.* Preliminary report.
Given an r-graph H, the Turan number $ex(n, H)$ of H is the maximum size of an r-graph on n vertices that does not contain H as a subgraph. We focus on graphs with $ex(n, H)$ on the order of $O(n^{r-1})$. For $r = 2$, the only graphs H with Turan number on the order of $O(n)$ are forests. However for hypergraphs (i.e. $r \geq 3$), there are many graphs H with Turan number on the order of $O(n^{r-1})$ that are not hypertrees. We study the Turan numbers of some of these graphs as well as a class of hypertrees called clusters. Our work continues prior work by Frankl and Füredi, Mubayi and Verstraëte, and Pikhurko and Verstraëte. Some of the work are joint with D. Irwin and X. Liu. (Received January 18, 2015)

1108-05-353 **Joshua Hallam*** (hallamjo@msu.edu), **Jeremy L Martin** and **Bruce E Sagan**. *Increasing Forests.* Preliminary report.
Let G be a graph on the totally ordered vertex set $\{1, 2, \ldots, n\}$. We call a subtree of G increasing if the vertices along any path starting at its minimum vertex increase. Additionally, we say a spanning forest is increasing if each component of the forest is an increasing tree. In this talk we will discuss properties of the generating

function for increasing spanning forests. Time permitting, we will also consider a generalization of this work to simplicial complexes. (Received January 18, 2015)

1108-05-367 **Tri Lai*** (tmlai@ima.umn.edu), 207 Church Street SE, 306 Lind Hall, Minneapolis, MN 55455. *Lozenge tilings of a hexagon with holes on boundary and plane partitions that fit in a special box.*

MacMahon's classic theorem on the number of plane partitions that fit in a given box is equivalent to the fact that the number of lozenge tilings of a centrally symmetric hexagon of side-lengths a, b, c, a, b, c (in cyclic order) on the triangular lattice is equal to

$$\frac{H(a)H(b)H(c)H(a+b+c)}{H(a+b)H(b+c)H(c+a)},$$

where the hyperfactorial function $H(n)$ is defined by

$$H(n) := 0!1!\dots(n-1)!.$$

We generalize MacMahon's theorem by enumerating lozenge tilings of the hexagon when some holes appear along its boundary. This also gives the number of plane partitions that fit in a *special* box consisting of several connected rooms. In addition, we consider a q-analog of the result and its connection to MacMahon's q-formula. (Received January 18, 2015)

1108-05-368 **Pawel Pralat*** (pralat@ryerson.ca), Department of Mathematics, Ryerson University, 350 Victoria St., Toronto, Ontario M5B 2K3, Canada. *Almost all 5-regular graphs have an edge orientation in which every out-degree is either 4 or 1.*

Tutte in 1966 conjectured that every 4-edge connected 5-regular graph has an edge orientation in which every out-degree is either 4 or 1. We show that the assertion of the conjecture holds asymptotically almost surely for random 5-regular graphs. Hence, the conjecture holds for almost all 4-edge connected 5-regular graphs. (Joint work with Nick Wormald.) (Received January 18, 2015)

1108-05-373 **Hao Huang*** (huanghao@ima.umn.edu). *Digraphs of large girth with every small subset dominated.* Preliminary report.

A conjecture of Daskalakis, Mehta and Papadimitriou states that there exists integers k and l, such that if a directed graph D satisfies that every subset of l vertices share a common in-neighbor, then D contains a directed cycle of length at most k. This conjecture naturally arises from problems in game theory on designing polynomial algorithms to find the approximate Nash equilibrium. In this talk, I will discuss a counterexample to this conjecture and its connection with a well-known open problem on tournament coloring. This is joint work with Anbalagan, Lovett, Norin, Vetta and Wu. (Received January 18, 2015)

1108-05-376 **Jozsef Balogh***, University of Illinois at Urbana Champaign, Urbana, IL, and **Shagnik Das**, **Michelle Delcourt**, **Hong Liu** and **Maryam Sharifzadeh**. *Intersecting families of discrete structures are typically trivial.*

The study of intersecting structures is central to extremal combinatorics. A family of permutations $F \subset S_n$ is *t-intersecting* if any two permutations in F agree on some t indices, and is *trivial* if all permutations in F agree on the same t indices. A k-uniform hypergraph is *t-intersecting* if any two of its edges have t vertices in common, and *trivial* if all its edges share the same t vertices. The fundamental problem is to determine how large an intersecting family can be. Ellis, Friedgut and Pilpel proved that for n sufficiently large with respect to t, the largest t-intersecting families in S_n are the trivial ones. The classic Erdős–Ko–Rado theorem shows that the largest t-intersecting k-uniform hypergraphs are also trivial when n is large. We determine the *typical* structure of t-intersecting families, extending these results to show that almost all intersecting families are trivial. We also obtain sparse analogues of these extremal results, showing that they hold in random settings. Our proofs use the Bollobás set-pairs inequality to bound the number of maximal intersecting families, which can then be combined with known stability theorems. (Received January 18, 2015)

1108-05-379 **Oliver Pechenik** (pecheni2@illinois.edu) and **Dominic Searles*** (searles2@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green Street, Urbana, IL 61801. *Deformed cohomology of generalized flag varieties.*

Inspired by recent work of S. Evens-W. Graham, we introduce a deformation of the cohomology of generalized flag varieties. A special case is the Belkale-Kumar deformation, introduced in 2006 by P. Belkale-S. Kumar. This construction yields a new, short proof that the Belkale-Kumar product is well-defined. Another special case picks out triples of Schubert varieties that behave nicely under projections. We also present a new combinatorial rule, due to the second author, for the Belkale-Kumar product for flag varieties of type A (after the puzzle rule of A. Knutson - K. Purbhoo). (Received January 19, 2015)

1108-05-387 **Shamil Shakirov*** (shakirov@berkeley.edu), 1605 Milvia St Apt C, Berkeley CA, 94709, Berkeley, CA 94709. *Graphs on surfaces, Toda equations, and the Arctangent.*

Generating functions for combinatorial data often satisfy interesting non-linear differential equations. Counting graphs on two-dimensional surfaces, for example, gives rise to the Toda equations. The classical result of Harer and Zagier is that the solution to these equations for the case of 1-face graphs is an explicit rational function. We generalize this result to 1,2, and 3-face graphs. While the corresponding generating functions are no longer rational, they are elementary, expressible through the arctangent function. The question if the 4-face and higher generating functions are elementary too, remains open. (Received January 19, 2015)

1108-05-396 **Laura Escobar*** (le78@cornell.edu), 310 Malott Hall, Cornell University, Ithaca, NY 14853, and **Karola Mészáros**. *Realizing subword complexes via triangulations of root polytopes.*

Subword complexes are simplicial complexes introduced by Knutson and Miller to illustrate the combinatorics of Schubert polynomials and determinantal ideals. They proved that any subword complex is homeomorphic to a ball or a sphere and asked about their geometric realizations. We show that a family of subword complexes can be realized geometrically via triangulations of root polytopes. Based on joint work with Karola Mészáros.
(Received January 19, 2015)

1108-05-415 **Rafael S. González D'León*** (rafaeldleon@uky.edu), University of Kentucky, Lexington, KY 40506. *A family of symmetric functions associated with Stirling permutations.* Preliminary report.

We present exponential generating function analogues to two classical identities involving the ordinary generating function of the complete homogeneous symmetric function. After a suitable specialization the new identities reduce to identities involving the first and second order Eulerian polynomials. These results led us to consider a family of symmetric functions associated with the *Stirling permutations* introduced by Gessel and Stanley.
(Received January 19, 2015)

1108-05-416 **Michael Shapiro*** (mshapiro@math.msu.edu), Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48824, and **Michael Gekhtman** and **Alek Vainshtein**. *Generalized cluster transformations in exotic cluster algebras.*

We will discuss examples of generalized cluster transformations in the constructions of exotic cluster algebras.
(Received January 19, 2015)

1108-05-419 **Kenneth W. Barrese*** (barresek@msu.edu), **Nicholas A. Loehr** (nloehr@math.vt.edu), **Jeffrey B. Remmel** (jremmel@ucsd.edu) and **Bruce E. Sagan** (sagan@math.msu.edu). *Transpositions on m-level rook placements.*

Briggs and Remmel developed a generalization of rook placements, called m-level rook placements. Transpositions play a key role in Foata and Schützenberger's construction of explicit bijections between rook placements on rook equivalent Ferrers boards. We define an analogue of transposition, called the l-operator, which fulfills the same role, allowing us to give explicit bijections between m-level rook placements on m-level rook equivalent Ferrers boards. Furthermore, using the l-operator leads to an elegant factorization of the m-level rook polynomial of a Ferrers board, along the lines of the factorizations given by Goldman, Joichi, and White for the rook polynomial of a Ferrers board or by Briggs and Remmel for the m-level rook polynomial of a singleton board.
(Received January 19, 2015)

1108-05-454 **Andrzej Dudek*** (andrzej.dudek@wmich.edu), Department of Mathematics, Western Michigan University, Kalamazoo, MI 49008. *On Hamilton Cycles in Random Hypergraphs.*

In this talk, we present both old and new developments concerning the Hamiltonicity of random hypergraphs. First, we consider random k-uniform hypergraphs of order n (each possible k-tuple appears independently with probability p) and determine the thresholds for the existence of different types of Hamilton cycles (including loose and tight cycles). Next, we discuss some very recent results about Hamiltonicity of random regular hypergraphs (joint work with Alan Frieze, Andrzej Ruciński, and Matas Šileikis). (Received January 19, 2015)

1108-05-468 **Samantha Dahlberg***, Department of Mathematics, Michigan State University C515, 619 Red Cedar Road, East Lansing, MI 48824. *Pattern Avoiding Involutions and the q-analogues for Binomial Coefficients.* Preliminary report.

In their seminal paper, Simion and Schmidt showed that the cardinality of the set of involutions in the symmetric group $\mathfrak{S}_n$ which avoid the pattern 321 is a central binomial coefficient. We show that if one takes the generating function for the major index statistic over these involutions, then one obtains the usual q-analogue of this binomial coefficient. (Received January 19, 2015)

1108-05-472 **Patrick Bennett*** (patrickb@cs.toronto.edu) and **Mike Molloy**. *Resolution Space in Random 3-SAT.*

Resolution is a rule of inference for boolean formulas in conjunctive normal form. Specifically, if the formula contains the clauses $(A \vee x)$ and $(B \vee \bar{x})$ then any satisfying assignment must also satisfy the clause $(A \vee B)$. It turns out that a formula is unsatisfiable if and only if it can be used to derive the empty clause using repeated applications of the resolution rule. Such a derivation is called a resolution refutation for the formula. The total resolution space of an unsatisfiable formula is the least amount of memory required to verify any resolution refutation for the formula. We show that with high probability the resolution space of random instances of 3-SAT (chosen from a distribution where we know the formula is unsatifiable w.h.p.), the total resolution space is quadratic, which is worst possible up to a constant. Our result fills in the gap left by Bonacina, Galesi, and Thapen, who proved the same result for k-SAT when $k \geq 4$. (Received January 19, 2015)

1108-05-475 **Deepak Bal*** (baldc@miamioh.edu) and **Louis DeBiasio**. *Monochromatic Cycle Partitions of Random Graphs.*

We say that a graph G has property $\mathcal{L}$ if in every 2-coloring of the edges of G there exists a red cycle and blue cycle which are vertex disjoint and which partition the vertex set of G. It was conjectured by Lehel that K_n has property $\mathcal{L}$ and this was confirmed for large n by Łuczak, Rödl, and Szemerédi and with a better value of n by Allen. Bessy and Thomassé gave a proof for all n. In this talk we explore property $\mathcal{L}$ and an approximate version when $G \sim G(n,p)$, the Erdős-Rényi random graph. (Received January 20, 2015)

1108-05-516 **Bernard Lidicky*** (lidicky@iastate.edu), Iowa State University, Ames, IA , and **Florian Pfender** (florian.pfender@ucdenver.edu), University of Colorado, Denver, Denver, CO. *Using flag algebras on small Ramsey numbers.*

We show how to compute upper bounds on small Ramsey numbers using flag algebras and we obtain improvements for several cases. Although flag algebras were developed for investigating large graphs, it is possible to use them for small graphs by considering blow-ups. The nice feature of the flag algebra approach is that it allows to attack upper bounds for different Ramsey numbers with only minor modifications. (Received January 20, 2015)

1108-05-539 **Po-Shen Loh*** (ploh@cmu.edu), Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213, and **Jie Ma**, School of Mathematical Sciences, University of Science and Technology of China. *Diameter critical graphs.*

A graph is called diameter-k-critical if its diameter is k, and the removal of any edge strictly increases the diameter. We prove several results related to a conjecture often attributed to Murty and Simon, regarding the maximum number of edges that any diameter-k-critical graph can have. In particular, we disprove a longstanding conjecture of Caccetta and Haggkvist (that in every diameter-2-critical graph, the average edge-degree is at most the number of vertices), which promised to completely solve the extremal problem for diameter-2-critical graphs.

On the other hand, we prove that the same claim holds for all higher diameters, and is asymptotically tight, resolving the average edge-degree question in all cases except diameter-2. We also apply our techniques to prove several bounds for the original extremal question, including the correct asymptotic bound for diameter-k-critical graphs, and an upper bound of $(1/6+o(1))n^2$ for the number of edges in a diameter-3-critical graph. (Received January 20, 2015)

1108-05-548 **Daniel P Johnston*** (daniel.p.johnston@wmich.edu). *On a Twin Edge Coloring Conjecture.*

For a connected graph G of order at least 3 and an integer $k \geq 2$, a twin edge k-coloring of G is a proper edge coloring of G using elements of $\mathbf{Z}_k$ so that the induced vertex coloring in which the color of a vertex v in G is the sum (in $\mathbf{Z}_k$) of the colors of the edges incident with v is a proper vertex coloring. The minimum k for which G has a twin edge k-coloring is called the twin chromatic index of G. It has been conjectured that the twin chromatic index of every connected graph G of order at least 3 lies between the maximum degree of G and 2

plus the maximum degree of G. In this talk, we present recent progress on this conjecture as well as new results in this area of research. (Received January 20, 2015)

1108-05-558 **John Lenz*** (lenz@math.uic.edu). *Hamilton cycles in quasirandom hypergraphs.*

A recent area of interest in extremal hypergraphs is discovering conditions (for example, various degree conditions) which force perfect matchings or various spanning cycles. The minimum 1-degree condition seems to be quite hard; the 1-degree threshold for a perfect matching is known only for 3 and 4 uniform hypergraphs. Extending recent work, we proved that a weak minimum 1-degree condition together with a quasirandomness condition is enough to guarantee a loose Hamilton cycle. In this talk I will overview these recent results together with constructions showing the theorems are asymptotically best possible. (This is joint work with Dhruv Mubayi and Richard Mycroft.) (Received January 20, 2015)

1108-05-570 **Amin Bahmanian*** (mbahman@ilstu.edu), Dept of Math, Illinois State University, Normal, IL 61790, and **Mike Newman** (mnewman@uottawa.ca), 585 King Edward, Dept of Math and Stat, University of Ottawa, Ottawa, Ontario K1N5N5, Canada. *A Generalization of Häggkvist-Hellgren Theorem on Embedding Factorizations.*

We consider when a given r-factorization of the complete uniform hypergraph on m vertices, K_m^h, can be extended to an s-factorization of K_n^h. The case of $r = s = 1$ was first posed by Cameron in terms of parallelisms, and solved by Häggkvist and Hellgren. We extend these results, which themselves can be seen as extensions of Baranyai's Theorem. For $r = s$, we show that the "obvious" necessary conditions, together with the condition that $\gcd(m, n, h) = \gcd(n, h)$ are sufficient. For $r < s$ we provide sufficient conditions. (Received January 20, 2015)

1108-05-574 **Brendan Pawlowski*** (bpawlows@umn.edu). *Catalan combinatorics in a class of positroids.*

Given a permutation w in S_n, the matroid of a generic $n \times 2n$ matrix whose non-zero entries in row i lie in columns $w(i)$ through $n+i$ is an example of a positroid. We enumerate the bases of such a positroid as a sum of certain products of Catalan numbers, these terms being indexed by the 123-avoiding permutations above w in Bruhat order. We give a similar sum formula for their Tutte polynomials. These are both avatars of a structural result building such a positroid out of matroids isomorphic to Catalan matroids. (Received January 20, 2015)

1108-05-575 **Julianna Tymoczko*** (jtymoczko@smith.edu), Department of Mathematics and Statistics, 44 College Lane, Northampton, MA 01063. *Describing Springer varieties with a union of Schubert varieties.*

Springer varieties are a family of subvarieties of the flag variety that are parametrized by partitions. They arise in a prototypical example of a geometric representation: their cohomology carries a natural action of the symmetric group, the top-dimensional cohomology of each Springer variety is an irreducible representation, and all irreducible representations of the symmetric group can be obtained this way.

Schubert varieties are a family of subvarieties of the flag variety that are parametrized by permutations. They form a CW-decomposition of the flag variety and so induce a module basis for the cohomology of the flag variety. They are also closely related to other important combinatorial objects, including Schur functions.

For each Springer variety, we describe a union of Schubert varieties whose Betti numbers agree with the Betti numbers of the Springer variety. We also discuss some natural combinatorial and geometric conjectures and questions that emerge from this work. (Received January 20, 2015)

1108-05-579 **Franco Saliola*** (saliola.franco@uqam.ca) and **A. B. Dieker**. *Spectrum of random-to-random operators.*

Pick a card–any card!–from the deck, and remove it; then put it back anywhere in the deck. Repeating this process leads to a method of shuffling a deck of cards known as the random-to-random shuffle. Its efficiency is controlled by the spectrum of its transition matrix, which turns out to be closely related to the combinatorics of the symmetric group.

We give a combinatorial description of the spectrum and outline some of the ideas that go into the proof. This settles a conjecture made in 2002 by Uyemura-Reyes: after a suitable renormalization, the spectrum is integral. Our analysis makes considerable use of the representation theory of the symmetric group. (Received January 20, 2015)

1108-05-581 **Louis DeBiasio**, **Daniela Kuhn**, **Theodore Molla*** (molla@illinois.edu), **Deryk Osthus** and **Amelia Taylor**. *Arbitrary Orientations of Hamilton Cycles in Digraphs.*

We will discuss the following result. Let n be sufficiently large. Every digraph G on n vertices with minimum indegree and minimum outdegree at least $n/2$ contains every orientation of a Hamilton cycle except when n is even and G is isomorphic to one of two possible digraphs. Furthermore, both of these two exceptional digraphs have minimum indegree and minimum outdegree exactly $n/2$ and contain every orientation of a Hamilton cycle except the orientation in which every pair of consecutive edges alternate direction. Our result improves on an approximate result by Häggkvist and Thomason.

This is joint work with Louis DeBiasio, Daniela Kühn, Deryk Osthus and Amelia Taylor. (Received January 20, 2015)

11 ► Number theory

1108-11-33 **Tony Shaska*** (tshaska@princeton.edu). *Counting algebraic curves with minimal height.*

In this talk we will about counting the algebraic curves of a fixed genus $g \geq 2$ with a bounded height λ. We will use some heuristics to compare results when the height is defined in terms of the coefficients of the curve, the "naive height", or the moduli height. Some new results for superelliptic curves will be presented. (Received November 23, 2014)

1108-11-67 **William C. Abram*** (wabram@hillsdale.edu), 33 East College Street, Hillsdale, MI 49242, and **Artem Bolshakov** and **Jeffrey C. Lagarias** (lagarias@umich.edu). *Intersections of multiplicative translates of 3-adic Cantor sets.*

We discuss a 3-adic generalization of a question of Erdös on the ternary digits of powers of 2. Let $\Sigma_{3,\overline{2}}$ be the 3-adic Cantor set consisting of all 3-adic integers whose expansions omit the digit 2. The exceptional set $\mathcal{E}(\mathbb{Z}_3) \subset \mathbb{Z}_3$ consists of all 3-adic integers λ such that, for infinitely many n, $2^n\lambda$ is in $\Sigma_{3,\overline{2}}$. It is known that the exceptional set has Hausdorff dimension at most $\frac{1}{2}$, and it has been conjectured that it has Hausdorff dimension 0. We attempt to bound the Hausdorff dimension of $\mathcal{E}(\mathbb{Z}_3)$ by studying finite intersections of multiplicative translates $\Sigma_{3,\overline{2}} \cap \frac{1}{M_1}\Sigma_{3,\overline{2}} \cap \cdots \cap \frac{1}{M_n}\Sigma_{3,\overline{2}}$ for integers $1 < M_1 < \cdots < M_n$, and give a method to compute the Hausdorff dimensions of such intersections by first describing them as the one-sided infinite walks in a finite automaton initiating from a distinguished vertex. We obtain an improved upper bound on the Hausdorff dimension of $\mathcal{E}(\mathbb{Z}_3)$. (Received December 22, 2014)

1108-11-128 **Dylan Airey** (dylan.airey@yahoo.com) and **Bill Mance*** (mance@unt.edu). *The Hausdorff dimension of sets of numbers defined by their Q-Cantor series expansions.*

Following in the footsteps of P. Erdős, A. Rényi, and T. Salát we compute the Hausdorff dimension of sets of numbers whose digits with respect to their Q-Cantor series expansions satisfy various statistical properties. In particular, we consider difference sets associated with various notions of normality and sets of numbers with a prescribed range of digits. (Received January 07, 2015)

1108-11-130 **Lubjana Beshaj*** (beshaj@oakland.edu). *Reduction of binary forms.*

We give an introduction to the reduction theory of binary forms starting with quadratic forms with real coefficients, Hermitian forms, and then define the Julia quadratic for any degree n binary form. We develop a reduction algorithm for any degree n binary form with coefficients in some algebraic number field K, based on classical work of Hermite, Julia, and more recent work of Cremona and Stoll. The reduced form has minimal absolute height. (Received January 07, 2015)

1108-11-328 **Dubi Kelmer*** (kelmerdu@gmail.com), Boston College, Carney hall, Chestnut Hill,, MA 02467-3806, and **Alex Kontorovich**. *Equidistribution of translated cuspidal geodesics and applications.*

I will describe new results on the equidistribution of translated cuspidal geodesics on a hyperbolic surface, and its applications to counting integer solutions to certain Diophantine equations, as well as estimating second moments of L-functions. This is based on joint work with Alex Kontorovich. (Received January 17, 2015)

1108-11-354 **Aaron Levin*** (adlevin@math.msu.edu). *Siegel's theorem and the Shafarevich conjecture.*

It is known that in the case of hyperelliptic curves the Shafarevich conjecture can be made effective, i.e., for any number field k and any finite set of places S of k, one can effectively compute the set of isomorphism classes of hyperelliptic curves over k with good reduction outside S. We show that an extension of this result to an effective Shafarevich conjecture for *Jacobians* of hyperelliptic curves of genus g would imply an effective version of Siegel's theorem for integral points on hyperelliptic curves of genus g. (Received January 18, 2015)

1108-11-362 **Shuichiro Takeda*** (takedas@missouri.edu), 202 Math Sciences Bldg, Math Department, Columbia, MO 65211, and **Wee Teck Gan**. *A proof of Howe duality conjecture.*

In this talk, after reviewing basics of the local theta correspondences I will talk about a residue-characteristic-free proof of the Howe duality conjecture. This is a joint work with Wee Teck Gan. (Received January 18, 2015)

1108-11-372 **Lola Thompson*** (lola.thompson@oberlin.edu). *Applications of the Maynard-Tao method.*

We will give an overview of the exciting recent work on bounded gaps between primes and discuss how the approach taken by Maynard and Tao can be adapted to answer some questions about sequences of consecutive primes that were of interest to Erdős. Parts of this talk are based on joint work with subsets of the following co-authors: Abel Castillo, Chris Hall, Robert J. Lemke Oliver, and Paul Pollack. (Received January 18, 2015)

1108-11-397 **Jennifer Balakrishnan*** (balakrishnan@maths.ox.ac.uk). *Variations on quadratic Chabauty.*

We describe variations on the "quadratic Chabauty" method to find integral points on certain elliptic and hyperelliptic curves. In particular, we discuss how to apply the method over quadratic number fields (joint work with Amnon Besser and Steffen Mueller) and how to use it to find rational points on certain bielliptic genus 2 curves (joint work with Netan Dogra). (Received January 19, 2015)

1108-11-426 **Tony Shaska*** (shaska@oakland.edu). *Counting algebraic curves with bounded moduli height.*

The focus of this talk is on counting algebraic curves of a fixed genus $g \geq 2$ with bounded height. We will use some heuristics to compare results when the height is defined in terms of the coefficients of the curve, the "naive height", or the moduli height. This extends on previous work (*L. Beshaj, T. Shaska; Heights of Algebraic Curves, NATO Sci. Peace Secur. Ser. D Inf. Commun. Secur., IOS, 2015*), where the moduli height was defined and tables of genus 2 curves with small height were provided. Further, we will discuss whether such results can be extended to all superelliptic curves. (Received January 19, 2015)

1108-11-501 **Nicholas Miller*** (mille965@purdue.edu). *Some Natural Bijections for Locally Equivalent Fields.*

For a pair of locally equivalent fields, one can construct an isomorphism between their respective Brauer groups. We will briefly recall the definition of the Brauer group for a number field and what it means for a pair of number fields to be locally equivalent. We will then report on joint work with Cox, Linowitz, and McReynolds, exploring several nice features of this isomorphism. Included in these are bijections between orders, maximal arithmetic lattices, and volumes of locally symmetric orbifolds. (Received January 20, 2015)

1108-11-512 **Britain Cox*** (btcox@purdue.edu). *Local Factors of Global Representations.*

Given explicit results on representations of p-adic reductive groups, predictions for global objects are obtained via the trace formula. (Received January 20, 2015)

1108-11-527 **Ivan Horozov*** (horozov@math.wustl.edu), Washington University in St. Louis, Department of Mathematics, 1 Brookings Dr, CB 1146, Saint Louis, MO 63130.
Non-commutative Hilbert modular symbols.

n this talk I will present a construction of (non-)commutative Hilbert modular symbols using a type of two-dimensional iterated integrals which I call iterated integrals on membranes. In many cases, the ingredients of such symbols are periods related to Hilbert modular surfaces. They also have a natural action of the Hecke operators in the case when the narrow class group is trivial; (roughly speaking, when we have unique factorization in the ring of integers in the number field). A similar construction can be used to define multiple Dedekind zeta values, which are a number theoretic analogue of Euler's multiple zeta values. The relation between non-commutative Hilbert modular symbols and and multiple Dedekind zeta values is similar to the relation between Manin's non-commutative modular symbol and Euler's multiple zeta values.

One current research topic of mine is to drop the restriction that the narrow class group is trivial. That requires working with iterated integrals over the adeles. So far I have a representation of Euler's multiple zeta values as iterated integrals over the adeles, which leads naturally to double shuffle relations. (Received January 20, 2015)

1108-11-560 **Harris B Daniels*** (hdaniels@amherst.edu), Department of Mathematics and Statistics, Amherst College Box 2239 P.O. 5000, Amherst, MA 01002. *An Infinite Family of Serre Curves.*

Given an elliptic curve $E/\mathbb{Q}$, the torsion points of E give rise to a natural Galois representation $\rho_E : \mathrm{Gal}(\overline{\mathbb{Q}/\mathbb{Q}}) \to \mathrm{GL}_2(\hat{\mathbb{Z}})$ associated to E. In 1972, Serre showed that $[\mathrm{GL}_2(\hat{\mathbb{Z}}) : \mathrm{Im}\rho_E] \geq 2$ for all non-CM elliptic curves. The main goal of this talk is to exhibit an elliptic surface such that the Galois representations associated to almost all of the rational specialization have maximal image. Further, we find an explicit set $S \subset \mathbb{Q}$, such that if $t \notin S$, then the Galois representation associated to the specialization at t has maximal image, with a bounded number of exceptions. (Received January 20, 2015)

1108-11-565 **Djordje Milićević*** (dmilicevic@brynmawr.edu), 101 North Merion Avenue, Bryn Mawr, PA 19010. *On the sup-norm problem for eigenforms on arithmetic hyperbolic 3-manifolds (joint work with Valentin Blomer and Gergely Harcos).*

Eigenfunctions of the Laplacian are basic building blocks of harmonic analysis on Riemannian manifolds. Of critical importance in analysis, geometry, and physics is their limiting behavior, which is closely related to the geometric and (in arithmetic cases) algebro-arithmetic and functorial structure of the underlying space. For example, while high-energy eigenfunctions on negatively curved manifolds are generically expected to exhibit rather temperate intensity fluctuations, this expectation is known to fail (at special arithmetic points) for a wide class of arithmetic 3-manifolds which contain immersed hyperbolic surfaces and which can be classified in terms of their invariant trace fields and invariant quaternion algebras.

In this talk, we will discuss the state of the art of the sup-norm problem on arithmetic hyperbolic manifolds and in particular present our recent upper bound for the sup-norm of Hecke-Maass cusp forms on a family of arithmetic hyperbolic 3-manifolds of squarefree level, with a power saving over the local geometric bound simultaneously in the Laplacian eigenvalue and the volume. By a novel combination of diophantine and geometric arguments in a noncommutative setting, we obtain bounds as strong as the best corresponding results on arithmetic surfaces. (Received January 20, 2015)

13 ► Commutative rings and algebras

1108-13-120 **Michael Gekhtman***, Department of Mathematics, Notre Dame, IN 46556. *Examples of exotic cluster structures on SL(n).*

Examples of exotic cluster structures compatible with Poisson-Lie structures on SL(N) associated with nontrivial Belavin-Drinfeld data will be discussed. Based on a joint project with M. Shapiro and A. Vainshtein. (Received January 06, 2015)

1108-13-234 **Sergey Fomin*** (fomin@umich.edu) and **Pavlo Pylyavskyy**. *Webs on surfaces, rings of invariants, and clusters.*

We construct and study cluster structures in rings of SL_3-invariants of collections of vectors, covectors, and matrices, using combinatorics of webs on marked surfaces with boundary. (Received January 14, 2015)

14 ► Algebraic geometry

1108-14-41 **Luigi Lombardi** and **Sofia Tirabassi*** (sofia@math.utah.edu), Deprtment of Mathematics - University of Utah, 155 South 1400 East, JWB 233, Salt Lake City, UT 84112. *Deformations of minimal cohomology classes on abelian varieties.*

We show that, given C a smooth non-hyperelliptic curve, there is a one-to-one correspondence between infinitesimal deformations of the Brill–Noether locui $W_d(C) \subset J(C)$ and the infinitesimal deformation of C. As an application we provide evidence for a conjecture of Debarre classifying ppav admitting a subscheme representing the minimal cohomology class. (Received December 07, 2014)

1108-14-75 **Qile Chen** (q_chen@math.columbia.edu), Rm 628, MC 4421, 2990 Broadway, New York, UT 10027, and **Yi Zhu*** (yzhu@math.utah.edu), Math Department, 155 S 1400 E ROOM 233, Salt Lake City, UT 84112. *Log rationally connected varieties.*

A smooth quasiprojective complex variety is *log rationally connected* if a general pair of points is contained in the image of a morphism from the affine line. This generalizes the class of rationally connected varieties to the non-proper setting. In this talk, I will report the recent progress on the geometry, topology and arithmetics of log rationally connected varieties. (Received December 29, 2014)

1108-14-83 **Jie Wang*** (jiw254@ucsd.edu) and **Elham Izadi** (eizadi@ucsd.edu). *The primitive cohomology of theta divisors.*

The primitive cohomology of the theta divisor of a principally polarized abelian variety of dimension g is a Hodge structure of level g-3. In this talk, I will present some general facts and questions (eg. the Hodge Conjecture) about the primitive cohomology and discuss a recent result (joint with E. Izadi) that the primitive cohomology is an irreducible Hodge structure for the theta divisor in a general abelian fivefold. (Received December 31, 2014)

1108-14-105 **Nicolas Addington*** (adding@math.duke.edu). *Recent developments in rationality of cubic fourfolds.*

The question of which cubic 4-folds are rational is one of the foremost open problems in algebraic geometry. I will discuss three approaches to answering it – one due to Hassett (1996) using Hodge theory, one due to Kuznetsov (2008) using derived categories, and one due to Galkin and Shinder (2014) using the Grothendieck ring of varieties – as well as my own work relating the three approaches to one another, and the troubles that have befallen each approach. (Received January 05, 2015)

1108-14-114 **Patricio Gallardo*** (gallardo@uga.edu) and **Jesus Martinez-Garcia**. *On the moduli space of cubic surfaces and their anticanonical divisor.*

We describe compactifications of the moduli space of pairs given by cubic surfaces and their anticanonical divisor. We related these compactifications with the (conjectural) moduli space of log K-semistable pairs. (Received January 06, 2015)

1108-14-115 **Mihnea Popa*** (mpopa@math.northwestern.edu). *Recent results on holomorphic one-forms.*

I will describe a number of basic results on holomorphic one-forms on complex manifolds, ranging from the existence of zeros to numerical inequalities and invariance under derived equivalence. These results have only recently come to light due to progress in an area of algebraic geometry called generic vanishing theory, which I will briefly survey. (Received January 05, 2015)

1108-14-129 **S. Allen Broughton*** (brought@rose-hulman.edu), Department of Mathematics, Rose-Hulman Institute of Technology, 5500 Wabash Ave, Terre Haute, IN 47803. *Quasi-platonic actions of PSL(2,q) and their dessins.* Preliminary report.

A quasi-platonic action of the group G on the Riemann surface S is a conformal action of G on S such that S/G is a sphere and the projection $S \to S/G$ is branched over three points. In this talk we describe the quasi-platonic actions of $PSL(2,q)$. Quasi-platonic actions are interesting since each surface with a quasi-platonic action must have a defining equation with coefficients in a number field. Additionally, each quasi-platonic action defines a regular *dessin d'enfant* on S, namely an embedded bipartite graph whose complement is a collection of rotationally symmetric, hyperbolic polygons. The group G is an automorphism group of the dessin. The absolute Galois group acts on the set of all dessins by acting on the coefficients of the defining equation of S. We discuss the Galois action on the dessins arising from quasi-platonic actions of $PSL(2,q)$. (Received January 07, 2015)

1108-14-193 **Yuchen Zhang***, Mathematics Department, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *A generic vanishing theorem on Cartier modules.*

The generic vanishing theorem by Green and Lazarsfeld is the main tool in studying the geometry of varieties of maximal Albanese dimension. The theorem was generalized by Hacon, Pareschi and Popa using a derived category approach. Although the theorem is still valid in positive characteristic, one can not apply it to $R^i a_* \omega_X$ due to the failure of vanishing theorems. We will talk about a possible generalization of generic vanishing theorem in the context of Cartier modules, which is a joint work with A. Watson. (Received January 12, 2015)

1108-14-200 **Jiwon Kim*** (kim609@indiana.edu). *Fixed Points on Period Spaces and Conjugacy Classes.*

Let $\mathcal{F}^{wa} = \mathcal{F}^{wa}(\mathbb{G}, \mathcal{N})$ be a p-adic period space, and $J^{\mathbb{G}} = \underline{Aut}^{\otimes}(N^{\mathbb{G}})$ be the associated automorphism group of the G-isocrystal. Then we can assume that $J^{\mathbb{G}}$ is an inner form of G. Let j be a regular elliptic element $J^{\mathbb{G}}(\mathbb{Q}p)$, and denote by $\mathrm{Fix}(j|\mathcal{F}^{wa})$ the set of fixed points of j on $\mathcal{F}^{wa}$. Let $x_0 \in \mathrm{Fix}(j|\mathcal{F}^{wa})$ be a 'base point'. One can then associate to any $x \in \mathrm{Fix}(j|\mathcal{F}^{wa})$ of j a rational conjugacy class in $G_{\mathcal{F}_{x_0}}$. We study this map from $\mathrm{Fix}(j|\mathcal{F}^{wa})$ to the set of rational conjugacy classes in $G_{\mathcal{F}_{x_0}}$. (Received January 13, 2015)

1108-14-208 **Katrina Honigs*** (honigska@math.berkeley.edu). *Derived equivalence, canonical bundles and zeta functions.*

This talk will focus on using information from the canonical bundles of derived equivalent varieties over finite fields to compare their zeta functions. (Received January 13, 2015)

1108-14-209 **Morgan Brown**, **James McKernan** and **Roberto Svaldi*** (rsvaldi@math.mit.edu), 50 Ames St, E18-401W, Cambridge, MA 02142, and **Hong Runpu Zong**. *A geometric characterization of toric varieties.*

For a log canonical pair $(X, \Delta = \sum a_i D_i)$, such that X is $\mathbb{Q}$-factorial and $-(K_X + D)$ is nef, Shokurov conjectured that the quantity

$$c(X, \Delta) = \dim X + \rho(X) - \sum_i a_i$$

is non-negative, where $\rho(X)$ is the rank of the Picard group of X. He also conjectured that when $c(X, \Delta) = 0$ then X is a toric variety and Δ is a toric invariant divisor.

We show that a more refined version of Shokurov's conjecture is true based on the techniques of the Minimal Model Program and the study of the geometry of the Cox ring.

We show also a sufficient criterion for the rationality of pairs (X, Δ) in the above framework. (Received January 13, 2015)

1108-14-219 **Yuchen Zhang***, Mathematics Department, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *A generic vanishing theorem on Cartier modules.*

The generic vanishing theorem by Green and Lazarsfeld is the main tool in studying the geometry of varieties of maximal Albanese dimension. The theorem was generalized by Hacon, Pareschi and Popa using a derived category approach. Although the theorem is still valid in positive characteristic, one can not apply it to $R^i a_* \omega_X$ due to the failure of vanishing theorems. We will talk about a possible generalization of generic vanishing theorem in the context of Cartier modules, which is a joint work with A. Watson. (Received January 14, 2015)

1108-14-232 **Jack Huizenga*** (huizenga@uic.edu). *Interpolation problems and the birational geometry of moduli spaces of sheaves.*

Questions like the Nagata conjecture seek to determine when certain zero-dimensional schemes impose independent conditions on sections of a line bundle on a surface. Understanding analogous questions for vector bundles instead amounts to studying the birational geometry of moduli spaces of sheaves on a surface. We explain how to use higher-rank interpolation problems to compute the cone of effective divisors on any moduli space of sheaves on the plane. This is joint work with Izzet Coskun and Matthew Woolf. (Received January 14, 2015)

1108-14-244 **Thomas Lam**, **Changzheng Li**, **Leonardo Mihalcea** and **Mark Shimozono*** (mshimo@math.vt.edu), Department of Mathematics, MC 0123, 460 McBryde Hall, Virginia Tech, 225 Stanger Street, Blacksburg, VA 24061. *Quantum Equals Affine Conjecture for K-theory.*

A precise conjecture will be given which asserts (after harmless localization) the isomorphism of torus-equivariant quantum K-theory of flag manifolds, with the torus-equivariant K-homology of affine Grassmannians. This isomorphism is specified by an explicit bijection of Schubert classes. (Received January 15, 2015)

1108-14-280 **Casey J Machen*** (machenc@gmail.com), Department of Mathematics, MSU, C524 Wells Hall, 619 Red Cedar Road, East Lansing, MI 48824. *Abelian Varieties Associated to Certain Families of Complex Projective 4-folds.*

The Kuga-Satake construction associates an abelian variety to a polarized K3-surface X. This is done using the Clifford algebra corresponding to the quadratic from arising from the cohomology pairing on $H^2(X, \mathbb{Q})$. We investigate when this construction can be generalized. Specifically, we associate an abelian variety to certain families of complex projective 4-folds using the generalized Clifford algebra associated to the quartic form on H^2. This is a work in progress. (Received January 16, 2015)

1108-14-389 **Alexander Woo**, **Benjamin Wyser*** (bwyser@illinois.edu) and **Alexander Yong**. *Interval pattern avoidance and singularities of symmetric orbit closures in the flag variety.* Preliminary report.

We define interval pattern avoidance for combinatorial parameters of K-orbit closures on the flag variety G/B for the pair $(G, K) = (GL_n, GL_p \times GL_{n-p})$. We discuss how this combinatorial notion governs certain local properties of the orbit closures, including smoothness, lci-ness, and Gorensteinness. The key geometric result is an isomorphism between certain "attractive slices" of orbit closures. (Received January 19, 2015)

1108-14-428 **Christine Berkesch Zamaere** and **Laura Felicia Matusevich***, Department of Mathematics, Texas A&M University, Mailstop 3368, College Station, TX 77843-3368, and **Uli Walther**. *Torus equivariant D-modules and hypergeometric systems.*

Intuitively, the A-hypergeometric systems introduced by Gelfand, Graev, Kapranov and Zelevinsky in the late 1980s are torus equivariant versions of the classical hypergeometric differential equations whose study goes back to Euler and Gauss. Thus, equations of classical type are obtained from the equivariant ones by some kind of quotient procedure. The goal of this talk is to construct a quotient functor from a category of torus equivariant D-modules, in such a way that desirable properties are preserved upon passage to the quotient. (Received January 19, 2015)

1108-14-452 **Martha Precup*** (martha_precup@baylor.edu). *The geometry of semisimple Hessenberg varieties.*

In this talk, we consider certain closed subvarieties of the flag variety known as semisimple Hessenberg varieties. Like Schubert varieties, semisimple Hessenberg varieties are paved by affines and their structure can be studied using the combinatorics of the associated root system. We give a connectedness criterion for these varieties generalizing a criterion previously only known in the regular semisimple case due to Anderson and Tymoczko. Time permitting, we'll discuss other geometric properties of semisimple Hessenberg varieties and related open questions. (Received January 19, 2015)

1108-14-524 **Ian Shipman*** (ian.shipman@gmail.com). *Exceptional collections and rationality.* Preliminary report.

A classical theorem of Beilinson connects sheaves on projective spaces to representations of certain finite dimensional associative algebras. This is possible because projective space admits a full, strong, exceptional collection of sheaves. While rare, full strong exceptional collections show up on other varieties an well, all of which are rational. I will report on joint work with Morgan Brown concerning the rationality problem for varieties with a full, strong, exceptional collection of vector bundles. (Received January 20, 2015)

1108-14-530 **Daniel A Brake*** (danielthebrake@gmail.com). *Applications of Real Algebraic Varieties.*

Numerical Algebraic Geometry frequently uses methods which compute over the complex numbers, frequently using probability-one arguments as a mathematical foundation. Computation of the real part of a variety is challenging, but rewarding, as applications of numerical algebraic geometry coming from engineering, math, and science are frequently interested only in real solutions. This talk will discuss such applications. (Received January 20, 2015)

1108-14-541 **Christopher S Dodd*** (cdodd@math.toronto.edu), 44 Albany Ave., Toronto, ON M5R 3C3, Canada. *Quantization, reduction mod p, and automorphisms of the Weyl algebra.*

The Weyl algebra of polynomial differential operators is a basic object which appears in algebraic geometry, representation theory, and mathematical physics. In this talk, I will discuss some conjectures of A. Belov-Kanel and M. Kontsevich concerning the structure of the automorphism group of the Weyl algebra. The question turns out to be related to defining an appropriate notion of "support cycle" for a differential equation, which, in turn, involves techniques from positive characteristic. In particular, we shall explain a "quantization correspondence" which is based on reducing differential equations to finite characteristic. (Received January 20, 2015)

1108-14-585 **Caleb McKinley Shor*** (cshor@wne.edu), Department of Mathematics, Western New England University, 1215 Wilbraham Rd, Springfield, MA 01119. *Ordinary and higher-order Weierstrass points on superelliptic curves.*

Given an algebraic curve C of genus g defined over $\mathbb{C}$, we say a point P is a Weierstrass point if $\dim(\mathcal{L}(gP)) > 1$, where $\mathcal{L}(D)$ is the Riemann-Roch space associated to a divisor D. One can generalize this to define a higher-order Weierstrass point (which we call a q-Weierstrass point, for $q \geq 1$), and one can also talk about the weight of a Weierstrass point. For any curve of genus $g > 1$ and any $q \geq 1$, there are a finite number of q-Weierstrass points with bounded weights.

The subject of Weierstrass points is an interesting one with immediate applications. In particular, the set of Weierstrass points is an invariant of a curve which is useful in studying the automorphism group of a curve.

In this talk, we will consider Weierstrass points on superelliptic curves, which are curves of the form $y^n = f(x)$ for $f(x)$ a separable polynomial of degree d. Under a mild hypothesis, it is well known that the branch points of such curves are Weierstrass points. We will investigate the weights of these branch points for given values of n and d and use them to obtain some asymptotic results. We will also discuss arithmetic properties of these points. (Received January 20, 2015)

15 ► Linear and multilinear algebra; matrix theory

1108-15-269 **Yeonhyang Kim*** (kim4y@cmich.edu), 906 Southmoor Rd, Mt. Pleasant, MI 48858, and **Rachel Domagalski**, **Sivaram K. Narayan**, **Hong Suh** and **Xingyu Zhang**.
Structures of minimal scalings in R^n.

A tight frame in R^n is a redundant system which has a reconstruction formula similar to that of an orthonormal basis. Given a spanning set of vectors $\{f_i\}_{i=1}^k$ in R^n satisfying a certain property, one can manipulate the length of the vectors to obtain a tight frame. Such a spanning set is called a scalable frame. A scaling w is a minimal scaling if $\{w(i)f_i : w(i) > 0\}$ has no proper scalable subframes. In this talk, we present the uniqueness of the orthogonal partitioning property of any set of minimal scalings, and provide a construction of scalable frames by extending the standard orthonormal basis. (Received January 16, 2015)

1108-15-554 **Selin Aviyente*** (aviyente@egr.msu.edu), 428 S. Shaw Lane, 2210 Engineering Building, East Lansing, MI 48824, and **Alp Ozdemir** (ozdemira@msu.edu), 428 S. Shaw Lane, 2120 Engineering Building, East Lansing, MI 48824. *Compressive Sensing of Partially Symmetric Tensors.*

Conventional compressed sensing (CS) theory depends on vector type data representation. For higher order datasets such as tensors, applying CS framework requires vectorizing the data. However, using long vectors requires large measurement matrices which lead to high computational complexity. Recently, different methods have been proposed to address the issue of compressed sensing of tensors. For example, Friedland et al. presented serial and parallel recovery procedures for matrices and high order sparse tensors. In this paper, we present a procedure to recover a special case of three-way sparse tensors $\mathcal{X} \in R^{N_1 \times N_2 \times N_3}$ which are symmetric in modes 1 and 2, i.e. partially symmetric tensors with $N_1 = N_2$ from $\mathcal{Y} = \mathcal{X} \times_1 \mathbf{U}_1 \times_2 \mathbf{U}_2 \times_3 \mathbf{U}_3 + \mathcal{E}$, where $\mathcal{E}$ is the noise tensor and $\mathbf{U}_i$s are the measurement matrices. We propose a serial recovery algorithm and show that the approximation error is lower for this algorithm compared to standard sparse recovery for varying sparsity levels and compression rates. (Received January 20, 2015)

16 ► Associative rings and algebras

1108-16-55 **Adam Chapman*** (adchapman@math.msu.edu), Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48824. *Clifford algebras of binary cubic forms over fields of characteristic 3.*

The Clifford algebras of binary cubic forms have been studied extensively by several different people, focusing mainly on the nonsingular case over fields of characteristic not 2 or 3, where one can make use of algebraic geometry. In this talk, we discuss the situation when the base-field is of characteristic 3, in which case the associated cubic is always singular, and other methods are needed in order to describe the structure and the representations. This talk is based on a joint work with Jung-Miao Kuo. (Received December 16, 2014)

1108-16-197 **Semeon Arthamonov*** (semeon.artamonov@rutgers.edu), Department of Mathematics, Rutgers - The State University of New Jersey, 110 Frelinghuysen Rd., Piscataway, NJ 08854. *Noncommutative Inverse Scattering Method for the Kontsevich system.*

In my talk I will formulate an analog of Inverse Scattering Method for integrable systems on noncommutative associative algebras. In particular I will define Hamilton flows, Casimir elements and noncommutative analog of the Lax matrix. The noncommutative Lax element generates infinite family of commuting Hamilton flows on an associative algebra. The proposed approach to integrable systems on associative algebras satisfy certain universal property, in particular it incorporates both classical and quantum integrable systems as well as provides a basis for further generalization.

The motivation for definition will be given by explicit construction of noncommutative analog of Lax matrix for a system of differential equations on associative algebra recently proposed by Kontsevich. First these equations will be presented in the Hamilton form by defining a bracket of Loday type on the group algebra of the free group with two generators. To make the definition more constructive I will utilize (with certain generalizations) the Van den Bergh approach to Loday brackets via double Poisson brackets. Finally, it will be shown that there exists an infinite family of commuting flows generated by the noncommutative Lax element. (Received January 12, 2015)

1108-16-225 **Manuel L. Reyes*** (reyes@bowdoin.edu), Department of Mathematics, Bowdoin College, Brunswick, ME 04011-8486, and **Daniel Rogalski** and **James J. Zhang**. *Skew Calabi-Yau triangulated categories and Frobenius Ext-algebras.*

Modules over a graded Calabi-Yau algebra enjoy a kind of Serre duality, which has famously been encoded in the axioms of a Calabi-Yau triangulated category. Skew (or "twisted") Calabi-Yau algebras generalize Calabi-Yau algebras in such a way as to include many well-known algebras from noncommutative algebraic geometry, especially Artin-Schelter regular algebras. Do these algebras enjoy a "twisted" version of Serre duality? We answer this question affirmatively, introducing *skew Calabi-Yau triangulated categories* in order to axiomatize the appropriate duality. As an application, we show that the Nakayama automorphism of a noetherian Artin-Schelter regular algebra determines the Nakayama automorphism of its Ext-algebra. (Received January 14, 2015)

1108-16-276 **Pavel Etingof** and **Chelsea Walton***, Department of Mathematics, 77 Massachusetts Ave, Cambridge, MA 02139. *Semisimple Hopf actions on quantizations.* Preliminary report.

We study actions of semisimple Hopf algebras H on filtered deformations B of commutative domains such as algebras of differential operators on a smooth affine irreducible variety, universal enveloping algebras of a finite dimensional Lie algebra, symplectic reflection algebras, and quantized quiver varieties. We show that the action of H on B must factor through a group algebra, or in other words, if H acts inner faithfully on B, then H is cocommutative. The techniques used include reduction modulo p and the study of semisimple cosemisimple Hopf actions on division algebras.

(The title, authors, and abstract of the talk are subject to change.) (Received January 16, 2015)

1108-16-287 **Ryan Kinser*** (ryan-kinser@uiowa.edu) and **Chelsea Walton** (notlaw@math.mit.edu). *Hopf actions on path algebras.*

There is a notion of a Hopf algebra acting on another algebra which generalizes the classical notion of a group acting on an algebra by automorphisms. We classify (by explicit formulas) the Hopf actions of Taft algebras on path algebras of loopless, Schurian quivers. Then, we apply this to give some actions of the Frobenius-Lusztig kernel $u_q(\mathfrak{sl}_2)$ and Drinfeld doubles of Taft algebras on path algebras. (Received January 16, 2015)

1108-16-300 **Ellen E Kirkman*** (kirkman@wfu.edu), Box 7388 Reynolda Station, Wake Forest University, Winston-Salem, NC 27109, and **James J Kuzmanovich** and **James J Zhang**. *Reflection Hopf Algebras: The Dual of a Group Algebra.* Preliminary report.

The Shephard-Todd-Chevalley Theorem states that when a finite group G acts linearly on a commutative polynomial ring $A = k[x_1, \dots, x_n]$ over a field k of characteristic zero, the invariant subring A^G is a commutative polynomial ring if and only if G is generated by reflections. More generally, let H be a semi-simple Hopf algebra that acts on an Artin-Schelter regular algebra A so that A is an H-module algebra, the grading on A is preserved, and the action of H on A is inner faithful. When A^H is Artin-Schelter regular we call H a reflection Hopf algebra for A. We present some examples of such pairs (A, H) when $H = k^G$ is the dual of a group algebra, and consider when $H = k^G$ is not a Hopf reflection algebra for any AS regular algebra A. (Received January 16, 2015)

1108-16-455 **Charlotte Ure*** (urecharl@msu.edu), Department of Mathematics, MSU, C543 Wells Hall, 619 Red Cedar Road, East Lansing, MI 48824. *Maximal Dimension of Kummer Subspaces of Tensor Products of Cyclic Algebras of Degree Four.*

The maximal dimension of a Kummer subspace of tensor products of cyclic algebras can be used to bound the symbol length of any central simple algebra of a certain degree. Using graph theory, we show that in the special case of degree four, the maximal dimension of a Kummer subspace is $4n + 1$. This is a work in progress.
(Received January 19, 2015)

1108-16-457 **Marcelo Aguiar** (maguiar@math.cornell.edu) and **Aaron Lauve*** (lauve@math.luc.edu), Department of Mathematics and Statistics, Loyola University Chicago, 1032 W Sheridan Road, Chicago, IL 60660. *The characteristic polynomial of the antipode for combinatorial Hopf algebras.*

The Adams operators Ψ_n on a Hopf algebra H are the convolution powers of the identity of H. The antipode of H is the special case $n = -1$. We study the Adams operators when H is graded connected. The main result is a complete description of the characteristic polynomial—both eigenvalues and their multiplicities—for the action of the operator Ψ_n on each homogeneous component of H. The eigenvalues are powers of n. The multiplicities are independent of n, and in fact only depend on the dimension sequence of H. We look at some

combinatorial consequences of this result, and, time permitting, indicate extensions to Hopf monoids in species, q-Hopf algebras, and cofree graded connected Hopf algebras. (Received January 19, 2015)

1108-16-470 **Jason Gaddis*** (gaddisjd@wfu.edu) and **Daniel Rogalski**. *Blowups of 4-dimensional Sklyanin algebras.* Preliminary report.

We discuss ongoing work in our attempt to understand from a ring-theoretic point of view the blowups of 4-dimensional Sklyanin algebras. A key component in this construction is to determine the category of GK dimension one modules in A (modulo those of finite dimension over the ground field $\Bbbk$). Generalizing a result of Van den Bergh and Van Gastel from the 3-dimensional case, we show that this may be realized as the category of finite $\Bbbk$-dimension modules over a certain completed path algebra. (Received January 19, 2015)

1108-16-531 **Dylan Rupel*** (d.rupel@neu.edu), Department of Mathematics, 360 Huntington Ave., Boston, MA 02115. *Rank 2 Non-Commutative Laurent Phenomenon.*

In this talk I will discuss Laurentness and positivity properties of the generalized Kontsevich automorphisms acting on the skew-field of formal rational expressions in two non-commuting variables. (Received January 20, 2015)

1108-16-542 **Benjamin Antieau** and **Kenneth Chan*** (kenhchan@math.washington.edu). *Maximal orders in unramified central simple algebras.*

Using depth of coherent sheaves on noetherian algebraic stacks, we construct non-Azumaya maximal orders in unramified central simple algebras over schemes of dimension at least 3. (Received January 20, 2015)

1108-16-582 **Robert Won*** (rwon@ucsd.edu). *The category of graded modules of a generalized Weyl algebra.* Preliminary report.

The first Weyl algebra $A = k\langle x, y\rangle/(xy - yx - 1)$ is $\mathbb{Z}$-graded with $\deg x = 1$ and $\deg y = -1$. Sue Sierra studied its category of graded modules, $\mathrm{gr}-A$. Paul Smith showed that $\mathrm{gr}-A$ is equivalent to the category of graded modules over a commutative ring graded by finite subsets of $\mathbb{Z}$. Generalized Weyl algebras are a class of noncommutative rings introduced by Vladimir Bavula which generalize the Weyl algebra. In this talk, we investigate the category of graded modules over certain generalized Weyl algebras and in some cases construct commutative rings with equivalent graded module categories. (Received January 20, 2015)

17 ► Nonassociative rings and algebras

1108-17-324 **Robert Griess*** (rlg@umich.edu). *On integral forms in vertex operator algebras invariant under finite simple groups.*

We report on recent results obtained with coauthors Chongying Dong and Ching Hung Lam. Let V be a vertex operator algebra and G a finite subgroup of $Aut(V)$. Chongying Dong and the speaker proved existence of a G-invariant integral form for V under certain conditions. One application is an integral form for the Moonshine vertex operator algebra which is invariant under its automorphism group, isomorphic to the Monster finite simple group. Dong and the speaker give further conditions for the integral form to be integral as a lattice. Ching Hung Lam and the speaker prove that for every Chevalley group and every Steinberg variation over a finite field F is (up to diagonal and graph outer automorphisms) the full automorphism group of some vertex algebra of classical type over F. Thus, "most" finite groups occur (up to outer automorphisms) as the full automorphism group of vertex algebras. This theory combined with a covering Lie algebra theory of Frohardt and the speaker for certain modular Lie algebras is used to prove a modular moonshine conjecture of Borcherds and Ryba which implies a "theoretical" proof that the sporadic group F_3 of Thompson embeds in the Chevalley group $E_8(3)$. (Received January 17, 2015)

1108-17-422 **Gregory G. Simon*** (ggsimon@umich.edu). *Automorphism-invariant integral forms of the Norton-Sakuma algebras.*

Motivated by the existence of monster-invariant integral forms in the moonshine module, I will present a study of automorphism-invariant integral forms of the Norton-Sakuma algebras, which are certain distinguished small subalgebras of the monster Griess algebra and of other generalized Griess algebras. The major tools used in this talk will be 'integral form detector functions', the fusion rules of the algebras, and elementary number theory. In particular, I will give an overview of how the following theorem can be proven: each Norton-Sakuma algebra has a unique maximal automorphism-invariant integral form. This result gives a distinguished lattice in each Norton-Sakuma algebra, and it provides a collection of bases for each algebra for which the structure coefficients are particularly simple. (Received January 19, 2015)

1108-17-529 **Valery Lunts*** (vlunts@indiana.edu), Rawles Hall 251, Bloomington, IN 47405.
Exceptional collections and rationality questions.

We will discuss the connection between the following two properties of a smooth projective variety X: 1) X is "strongly rational" or "Tate", 2) The derived category D(cohX) has a full exceptional collection. Also we will report on some recent results (joint with A. Elagin) about strong exceptional collections of line bundles on Del Pezzo surfaces. (Received January 20, 2015)

20 ► Group theory and generalizations

1108-20-14 **Pham H. Tiep*** (tiep@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N. Santa Rita Ave., P.O. Box 210089, Tucson, AZ 85721-0089. *The non-commutative Waring problem.* Preliminary report.

The classical Waring problem deals with expressing every natural number as a sum of $g(k)$ kth powers. Recently there has been considerable interest in non-commutative variants of this problem for non-abelian groups, and simple groups in particular. Here the kth power word can be replaced by an arbitrary group word $w \neq 1$, and the goal is to express group elements as short products of values of w. It was shown by Larsen, Shalev, and the speaker in 2011 that, for (non-abelian) finite simple groups of sufficiently high order, a product of length two suffices to express all elements. In this talk we will report on more recent results on the non-commutative Waring problem, obtained in joint works with R. M. Guralnick, M. Larsen, M. Liebeck, E. O'Brien, and A. Shalev. (Received October 28, 2014)

1108-20-23 **Christopher M Drupieski*** (cdrupies@depaul.edu), Dept of Mathematical Sciences, DePaul University, 2320 N Kenmore Ave, Chicago, IL 60614. *Finite-generation for cohomology rings of finite supergroup schemes.*

It has been known since the publication of Maschke's Theorem in 1899 that, over a field of characteristic zero, every finite-dimensional representation V of a finite group G decomposes into a direct sum of irreducible representations. On the other hand, over a field k of prime characteristic p dividing the order of G (the modular situation), there can be non-split extensions between kG-modules. These non-split extensions are parameterized, up to equivalence, by certain cohomology spaces.

In the past 30 years, much progress has been made studying cohomology spaces for finite groups (and related structures) by way of certain associated geometric objects, called (cohomological) support varieties. The first step toward constructing these support varieties is proving that the associated cohomology ring $H^\bullet(G,k)$ is a finitely-generated k-algebra. For finite groups, this was established by Venkov (1959) and Evens (1961). For arbitrary finite group schemes, it was finally established by Friedlander and Suslin (1997). In this talk, I will discuss a generalization of Friedlander and Suslin's results (and methods) to a class of algebraic structures called finite supergroup schemes. Applications to cohomological support varieties will also be discussed. (Received November 13, 2014)

1108-20-46 **Daniel Frohardt*** (danf@math.wayne.edu). *The asymptotic genus of a family of groups.*

Let G be a transitive subgroup of S_n. Let g be the smallest positive integer g such that G is isomorphic to the action of Mon(f) on a generic fiber where f is a covering of the Riemann sphere by a surface of genus g and Mon(f) is the monodromy group of f. Set $\rho(G) = g/n$. We investigate the asymptotic behavior of $\rho(G)$ for G in various families of actions. For example, if $\mathcal{S}$ is the set of almost simple groups of type $L_2(p)$ acting on the points of the natural module then $\liminf_{G\in\mathcal{S}} \rho(G) = 1/84$ and $\limsup_{G\in\mathcal{S}} \rho(G) = 1/12$. This is joint work with Bob Guralnick and Kay Magaard. (Received December 12, 2014)

1108-20-72 **Adriana Nenciu*** (anenciu@otterbein.edu). *Nested GVZ–groups.*

In this talk we investigate the finite groups G for which $\chi(1)^2 = |G : Z(\chi)|$ for all $\chi \in \mathrm{Irr}(G)$ and $\{Z(\chi) \mid \chi \in \mathrm{Irr}(G)\}$ is a chain with respect to inclusion. We call these groups nested GVZ–groups. We will show that for every $n \geq 2$, there is a nested GVZ–group with nilpotency class n. (Received December 26, 2014)

1108-20-91 **Stephen D Smith*** (smiths@uic.edu), 728 Wisconsin Ave, Oak Park, IL 60304. *Some remarks on unitary posets.* Preliminary report.

For a prime $p \geq 7$, certain unitary groups $U_n(q)$ with $p|(q+1)$ are the obstacle to fully generalizing the 1993 Aschbacher-Smith work on Quillen's Conjecture.

That conjecture requires that when $O_p(G) = 1$, the poset $\mathcal{A}_p(G)$ of nontrivial elementary p-subgroups should have its order complex (i.e., of inclusion-chains) non-contractible. The Aschbacher-Smith work in effect reduces to a more specialized conjecture: of "Quillen dimension", for G given by the above unitary groups (perhaps with outer automorphisms)—namely that homology should be nonzero in the top dimension $m_p(G)-1$.

Indeed because $p|(q+1)$, elementary p-subgroups act diagonally on the underlying unitary space V; so it turns out to suffice for $U_n(q)$ just to exhibit suitable homology for the "unitary poset" of nonzero unitary subspaces of V (or indeed for any subposet $\mathcal{F}$ of the needed dimension).

Of course the number of unitary subspaces of V of each dimension is a polynomial in q; hence combinatorial invariants such as the Euler characteristic are also polynomials. The talk reports on a few features emerging from a preliminary study of such polynomials, such as divisibility by powers of $q \pm 1$. (Received January 02, 2015)

1108-20-103 **Mark L. Lewis*** (lewis@math.kent.edu), Department of Mathematical Sciences, Kent State University, Kent, OH 44242. *Camina p-groups of nilpotence class 3.*

A Camina group is a (finite) group where every element $g \in G \setminus G'$ has gG' for its conjugacy class. It is known that a finite Camina group is either a Frobenius group or a p-group for some prime p. Furthermore, it is known that if G is a Camina p-group for some prime p, then G has nilpotence class at most 3, and there exist Camina p-groups of nilpotence class 3 for every odd prime p.

In this talk, we determine which groups can occur as $G/Z(G)$ when G is a Camina p-group of nilpotence class 3. We will also present some results regarding $|Z(G)|$ when G is a Camina p-group of nilpotence class 3. (Received January 05, 2015)

1108-20-111 **Xiangdong Xie*** (xiex@bgsu.edu). *Quasiisometric rigidity of some solvable Lie groups.*

The n-th $(n \geq 2)$ model filiform algebra $\mathfrak{f}^n$ is a $(n+1)$ dimensional real Lie algebra. It has a basis $e_1, \cdots, e_{n+1}$ with the only non-trivial bracket relations:

$$[e_1, e_j] = e_{j+1},\ 2 \leq j \leq n.$$

The connected and simply connected Lie group F^n with Lie algebra $\mathfrak{f}^n$ is called the n-th model filiform group. The exponential map $\exp : \mathfrak{f}^n \to F^n$ is a diffeomorphism. We identify $\mathfrak{f}^n$ and F^n via the exponential map. The standard dilation action of $\mathbb{R}$ on $F^n = \mathfrak{f}^n$ is given by:

$$t \cdot (x_1 e_1 + x_2 e_2 + \sum_{j=2}^{n} x_{j+1} e_{j+1}) = e^t (x_1 e_1 + x_2 e_2) + \sum_{j=2}^{n} e^{jt} x_{j+1} e_{j+1}.$$

Let $S = F^n \rtimes \mathbb{R}$ be the associated semidirect product.

Theorem *Let G be a connected and simply connected solvable Lie group. If G and S are quasiisometric, then they are isomorphic.*

This is joint work with Tullia Dymarz. (Received January 05, 2015)

1108-20-121 **Bhama Srinivasan** and **C. Ryan Vinroot*** (vinroot@math.wm.edu). *Jordan decomposition of real-valued characters of finite reductive groups with connected center.*

Let $\mathbf{G}$ be a reductive group with connected center defined over a finite field $\mathbb{F}_q$ with q elements, and let $G = \mathbf{G}(\mathbb{F}_q)$ be the finite group of $\mathbb{F}_q$-points. We classify all irreducible complex characters of G which are real-valued through the Jordan decomposition of characters. The main tool is a uniqueness result of Digne and Michel for the Jordan decomposition of characters when the center is connected. (Received January 06, 2015)

1108-20-122 **James P Cossey*** (cossey@uakron.edu), Dept of Mathematics, University of Akron, Akron, OH 44325-4002. *Brauer graphs of blocks of finite groups.*

(Joint work with Mark Lewis and I.M. Isaacs) The p-blocks of the finite group G capture the interplay between the ordinary characters and the p-Brauer characters. In this talk we examine the Brauer graph of a block B, which is a graph with vertices labeled by the ordinary irreducible characters in B and with two vertices being adjacent if and only if they share a Brauer character in the restriction to p-regular elements. In particular, we will look at blocks of groups of odd order and blocks of symmetric groups, and give bounds on the diameters of the Brauer graphs in each case. (Received January 06, 2015)

1108-20-141 **John Hutchens*** (jdhutchens@saumag.edu). *symmetric spaces of $\mathfrak{p}$-adic exceptional groups.*

We discuss the symmetric spaces of exceptional algebraic groups defined over a $\mathfrak{p}$-adic field as they relate to the theory of symmetric k-varieties. We view exceptional groups of type G_2, F_4, and E_6 as automorphism groups of certain k-algebras, and also identify certain subalgebras of these k-algebras with the fixed point groups of k-involutions of algebraic groups of types G_2, F_4, and E_6. (Received January 08, 2015)

1108-20-169 **Joseph B Timmer*** (jtimme1@lsu.edu), 333 Lockett Hall, Louisiana State University, Baton Rouge, LA 70803-4918. *Exact Group Factorizations and Hopf Algebras.*

Given an exact factorization of a finite group $L = FG$, one may construct a bismash product of the "group" alge- bras $k^G\#kF = H$. These Hopf algebras have many interesting properties that are typically determined by the group, particularly the representations and Frobenius-Schur indicators.

In this talk, we discuss factorizations of the symmetric group S_n, based on our corrected version of a theorem of Wiegold and Williamson, and the resulting Hopf algebras H. We then discuss the theory of Frobenius-Schur indicators of Hopf algebras and how many of these Hopf algebras are "totally orthogonal". That is to say, all the second indicators are $+1$; which is analogous to the well-known result of the symmetric group for the classical Frobenius-Schur indicators of groups. (Received January 09, 2015)

1108-20-207 **Grant Lakeland*** (gslakeland@eiu.edu). *Equivalent trace sets for arithmetic Fuchsian groups.*

Let G be a Fuchsian group, and $M = H^2/G$ the associated Riemann surface. The length spectrum of M is the set of lengths of closed geodesics on M, counted with multiplicity, and the length set is the same set without multiplicities. Each is closely related to the traces of elements of G. While isospectral surfaces have the same area, results of Schmutz and Leininger-McReynolds-Neumann-Reid show that this does not hold for length sets. In this talk, I'll show that if G is the modular group, then G contains infinitely many finite index subgroups with the same trace set as G, and hence there exist infinitely many surfaces, each commensurable with the modular surface M, with the same length set. I will also show how to construct examples of such subgroups. Similar results hold when G is, for example, a principal congruence subgroup of the modular group. (Received January 13, 2015)

1108-20-210 **Paul Becker*** (peb8@psu.edu), **Sheridan Houghten**, **Jennifer Ulrich** and **Martin Derka**. *A natural two-generator construction of the sporadic Mathieu group M_{24}.*

The sporadic group M_{24} is known to be the full automorphism group of the extended binary Golay code. We discuss two very simple constructions for the Golay code; each admits a natural automorphism. We then correlate the two constructions, producing two permutations which are sufficient to generate M_{24}. (Received January 13, 2015)

1108-20-252 **Stephen J Trefethen*** (trefethen@math.arizona.edu), 617 N Santa Rite Ave, Tucson, AZ 85721. *Non-Abelian Composition Factors of Quadratic Rational Groups.* Preliminary report.

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. Recently, 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 possible non-abelian composition factors of (non-solvable) quadratic rational groups. (Received January 15, 2015)

1108-20-257 **C B Sass*** (sass@txstate.edu), San Marcos, TX 78666. *Character Degree Graphs of Finite Solvable Groups with Diameter three.*

Let G be a finite solvable group and $\mathrm{cd}(G)$ the set of character degrees of G. The character degree graph $\Delta(G)$ is the graph whose vertices, $\rho(G)$, are the primes dividing the degrees in $\mathrm{cd}(G)$ and there is an edge between two distinct primes p and q if their product pq divides some degree in $\mathrm{cd}(G)$. By Pálfy's Condition, we know that the diameter of a connected character degree graph is at most three for a connected graph. We will present the history on the character degree graphs of solvable groups with diameter three, and present some of the recent results. (Received January 15, 2015)

1108-20-305 **Spencer Dowdall**, **Ilya Kapovich** and **Christopher Leininger*** (clein@math.uiuc.edu). *Dynamics of splittings of free-by-cyclic groups.*

Associated to a splitting of a group G as a (finitely generated) free-by-cyclic group is a monodromy automorphism, which we view as a dynamical system on the free subgroup. In joint work with Dowdall and Kapovich, we show that on certain components of the BNS-invariant for G, all such associated dynamical systems are related in a beautiful and essential way. This comes from a geometric model for G, and a single dynamical system which encodes all of the dynamics associated to splittings coming from the given component of the BNS-invariant.

In this talk I will first describe the relevant background, terminology, and motivation, then I will explain our constructions and results. (Received January 17, 2015)

1108-20-414 **Rieuwert J Blok*** (rblok@bgsu.edu), Department of Mathematics and Statistics, Mathematical Sciences Building, Bowling Green, OH 43402, and **Corneliu G Hoffman** (c.g.hoffman@bham.ac.uk), School of Mathematics, Watson Building, University of Birmingham, Edgbaston, B152TT, United Kingdom. *Properties of Curtis-Tits Groups.*

The classification of Curtis-Tits amalgams with triangle free, simply-laced diagram over a field of size at least 4 was completed by the authors in an earlier paper. Orientable amalgams are those arising from applying the Curtis-Tits theorem to groups of Kac-Moody type, and indeed, their universal completions are central extensions of those groups of Kac-Moody type. In a different paper they exhibit concrete (matrix) groups as completions for all Curtis-Tits amalgams with diagram $\widetilde{A}_{n-1}$. For non-orientable amalgams these groups are symmetry groups of certain unitary forms over a ring of skew Laurent polynomials. We now generalize this to all amalgams arising from the classification above and, under some additional conditions, exhibit their universal completions as central extensions of twisted groups of Kac-Moody type. We also discuss some properties of these groups. (Received January 19, 2015)

1108-20-436 **Catherine A. Buell*** (cbuell1@fitchburgstate.edu). *On maximal quasi $\mathbb{R}$-split tori invariant under an involution.*

Symmetric k-varieties have been a topic of interest since the late 1980's. For any field k, a reductive group G defined over k and any k-involution of G, we define a symmetric k-variety as the homogeneous space G_k/H_k where H is the fixed point group of the k-involution and G_k and H_k are the k-rational points of G and H, respectively. These symmetric k-varieties are also known as generalized symmetric spaces and for $k = \mathbb{R}$ or $k = \mathbb{Q}_p$ they are also known as reductive symmetric spaces. The conjugacy classes of maximal k-split tori can be used to determine the orbit decomposition of minimal parabolic subgroups acting on a symmetric k-variety which is important to the representation theory of symmetric varieties. Commuting pairs and associated pairs of involutions classify the tori within the fixed point groups of the involutions. I'll discuss various characterizations for any k. For $k = \mathbb{R}$, I'll provide a classification of the representatives of maximal quasi $\mathbb{R}$-split tori. (Received January 19, 2015)

1108-20-448 **Sinead Lyle** and **Oliver Ruff*** (oruff@kent.edu). *Some graded decomposition numbers for Ariki-Koike algebras.*

The Ariki-Koike algebras $\mathcal{H}_{n,r}$ arise in many natural contexts, including as Hecke algebras of complex reflection groups of type $G(r, 1, n)$ and as a means of categorifying highest weight modules of certain Kac-Moody algebras. The most important open problem in their representation theory is to calculate their (graded) decomposition matrices. There is a combinatorial definition of *weight* for blocks of $\mathcal{H}_{n,r}$; blocks of weight at most 2 are now understood but higher weight blocks quickly become very complicated. We define a block-invariant graph called the *weight graph* associated to a core block of $\mathcal{H}_{n,r}$, and classify such blocks whose weight graphs are trees. (Received January 19, 2015)

1108-20-469 **George Glauberman** and **Justin Lynd*** (jlynd@math.rutgers.edu), Rutgers University, Department of Mathematics, 110 Frelinghuysen Rd, Piscataway, NJ 08854. *Centric linking systems and control of weak closure in finite groups.* Preliminary report.

A. Chermak has recently established that to each saturated fusion system over a finite p-group, there is a unique associated centric linking system. In particular, this result, and B. Oliver's reformulation of it, give new proofs of the Martino-Priddy conjecture, which says that two finite groups have homotopy equivalent p-completed classifying spaces if and only if they have the same fusion system at the prime p. Both Chermak's and Oliver's proofs depend on the classification of finite simple groups in an indirect way. I will discuss the homological obstruction theory developed by Broto, Levi, and Oliver to investigate this problem (which plays a central role in Oliver's proof), and explain how variations on classical results concerning control of weak closure in finite groups allow for a classification-free proof of Chermak's Theorem, at least when p is odd. (Received January 19, 2015)

22 ► Topological groups, Lie groups

1108-22-116 **William M. McGovern*** (mcgovern@math.washington.edu), Box 354350, University of Washington, Seattle, WA. *Rational singular loci of nilpotent varieties.*

We will give two methods for computing the rational singular loci of nilpotent varieties (closures of nilpotent orbits) in semisimple Lie algebras and give a number of interesting examples. (Received January 05, 2015)

1108-22-507 **Alex Furman*** (furman@uic.edu), Mathematics, Statistics, and Computer Science, (m/c 249), 851 S. Morgan Str, Chicago, IL 60607. *Rigidity for groups with hidden symmetries.*

In the 1970s G.A.Margulis proved that linear representations of certain discrete subgroups (lattices) in such Lie groups as SL(3,R) are essentially determined by the representations of the ambient Lie group. This phenomenon, known as superrigidity, has far reaching applications and has inspired a lot of research in such areas as geometry, dynamics, descriptive set theory, operator algebras etc.

We shall try to explain the superrigidity of lattices and related groups by looking at some hidden symmetries (Weyl group) that they inherit from the ambient group.

The talk is based on a joint work with Uri Bader. (Received January 20, 2015)

1108-22-528 **Thomas H. Lenagan** (t.lenagan@ed.ac.uk), Maxwell Institute for Mathematical Sciences, School of Mathematics, University of Edinburgh, Edinburgh, Scotland , United Kingdom, and **Milen T Yakimov*** (yakimov@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Cluster structures on quantum Richardson varieties.*

Richardson varieties play an important role in Schubert calculus and total positivity for flag varieties. Leclerc defined a cluster algebra inside the coordinate ring of each open Richardson variety for a symmetric Kac-Moody group, and Muller and Speyer studied these cluster algebras in the case of Richardson varieties in Grassmannnians. We will show how to realize the quantized coordinate ring of each open Richardson variety as a normal localization of a prime factor of a quantum Schubert cell algebra. Using a combination of ring theoretic and representation theoretic methods we produce large families of toric frames for all quantum Richardson varieties by constructing sequences of normal elements in chains of subalgebras. This gives a method to control the size of Leclerc's cluster algebras from below and ultimately to relate them to the coordinate rings of the Richardson varieties (for all symmetrizable Kac-Moody algebras). (Received January 20, 2015)

1108-22-562 **William Graham*** (wag@math.uga.edu) and **Victor Kreiman** (kreiman@uwp.edu). *Equivariant K-theory and cohomology for Schubert varieties in non-cominuscule flag varieties.* Preliminary report.

Let G be a complex semisimple algebraic group and X a generalized flag variety for G. If X is of cominuscule type, in previous work, we have obtained combinatorial formulas for pullbacks of classes of Schubert varieties in equivariant K-theory, with applications to multiplicities and Hilbert series. In this talk we will discuss extensions of this work beyond the setting of cominuscule flag varieties. (Received January 20, 2015)

1108-22-587 **Francisco Franco Munoz*** (francisco.munoz@yale.edu), New Haven, CT 06511. *Nilpotent orbits for classical groups and classification problems.*

I'll discuss in detail the combinatorics of the poset of nilpotent orbits for the group $Sp(p,q)$ and explain how this allows us to give a classification of associated varieties of certain generalized Harish-Chandra modules, as part of a program of Penkov and Zuckerman. I'll end with a similar classification for other classical groups like $U(p,q)$ and discuss the differences between both cases. (Received January 21, 2015)

26 ► Real functions

1108-26-496 **Stephane P Jaffard*** (jaffard@u-pec.fr). *New exponents for multifractal analysis.*

The purpose of the multifractal analysis of a function f is to determine the Hausdorff dimensions of the sets of points where a pointwise regularity exponent $h_f(x)$ takes a given value. The corresponding collection of dimensions is referred to as the multifractal spectrum. In applications, It is estimated through a Legendre transform of averaged quantities, computable on data. Multifractal analysis developed in the setting where the exponent is the Hölder exponent; this only applies to locally bounded functions, an a priori hypothesis which is seldom met in real-life.

We will present an alternative, where the pointwise Hölder regularity is the T^p_α regularity introduced by Calderón and Zygmund. The a priori assumption is that the data locally belong to L^p. We will set the mathematical framework supplied by this p-exponent based multifractal analysis, extend it to $p < 1$ and show that comparing the informations supplied by different values of p allows to infer additional knowledge on the nature of the singularities. We give applications to stochastic processes, random fields and real-life data.

This is joint work with Patrice Abry, Clotilde Melot, Roberto Leonarduzzi, Stéphane Roux, Maria Eugenia Torres and Herwig Wendt. (Received January 20, 2015)

28 ► Measure and integration

1108-28-127 **Machiel van Frankenhuijsen*** (vanframa@uvu.edu), Department of Mathematics, 800 West University Parkway, Orem, UT 84058. *Lacunarity of fractals.* Preliminary report.

We give an overview of the concept of lacunarity and discuss an idea of Michel Lapidus and the presenter to define it. (Received January 07, 2015)

1108-28-270 **Guotai Deng** (hilltower@163.com), School of Mathematics and Statistics, Central China Normal University, Wuhan, Hubei 430079, Peoples Rep of China, **Chuntai Liu** (lct984@163.com), School of Mathematics and Computer Science, Wuhan Polytechnic University, Wuhan, Hubei 430023, Peoples Rep of China, and **Sze-Man Ngai*** (smngai@georgiasouthern.edu), Department of Mathematical Sciences, Georgia Southern University, Statesboro, GA 30460-8093. *Topological properties of a class of self-affine tiles in* $\mathbb{R}^3$.

We construct a class of connected self-affine tiles in $\mathbb{R}^3$ and prove that it contains a subclass of tiles that are homeomorphic to the unit ball. Our construction is obtained by generalizing a two-dimensional one by Q. Deng and K.-S. Lau. (Received January 16, 2015)

1108-28-271 **Song-Gyong Ri**, Department of Applied Mathematics, Kim Chaek University of Technology, Pyongyang, North Korea, **Huo-Jun Ruan*** (ruanhj@zju.edu.cn), Department of Mathematics, Zhejiang University, Hangzhou, 310027, Peoples Rep of China, and **Qiang Xu** (xuqiangwang@jsnu.edu.cn), School of Mathematics and Statistics, Jiangsu Normal University, Xuzhou, 221116, Peoples Rep of China. *Fractal interpolation functions on rectangular grids and p.c.f. fractals.*

We will mainly talk about our recent results on fractal interpolation functions (FIFs), including: 1) Present a general method to construct FIFs on rectangular grids, and also introduce bilinear fractal interpolation surfaces which can be defined without any restriction on interpolation points and vertical scaling factors; 2) Construct FIFs on p.c.f. fractals, and discuss the energy, normal derivative and Laplacian of these functions. (Received January 16, 2015)

1108-28-277 **Bing Li*** (scbingli@scut.edu.cn), Department of Mathematics, South China University of Technology, Wushan Road 381, Tianhe District, Guangzhou, Guangdong 510640, Peoples Rep of China. *Hitting probabilities of random covering sets in high dimension.*

Let $E = \limsup_{n\to\infty}(g_n + \xi_n)$ be the random covering set on the torus $\mathbb{T}^d$, where $\{g_n\}$ is a sequence of ball-like sets and $\{\xi_n\}$ is a sequence of independent random variables uniformly distributed on $\mathbb{T}^d$. We prove that $E \cap F \neq \emptyset$ almost surely whenever $F \subset \mathbb{T}^d$ is an analytic set with Hausdorff dimension, $\dim_H(F) > d - \alpha$, where α is the almost sure Hausdorff dimension of E. Moreover, examples are given to show that the condition on $\dim_H(F)$ cannot be replaced by the packing dimension of F. This is a joint work with Ville Suomala. (Received January 16, 2015)

1108-28-400 **Hua Qiu*** (huaqiu@nju.edu.cn), Department of Mathematics, Nanjing University, Nanjing, Jiangsu 210093, Peoples Rep of China. *Two inequalities on the Hausdorff and packing measures of self-similar sets.*

In this talk, I would like to present two basic inequalities on the Hausdorff and packing measures of self-similar sets with or without satisfying the open set condition. Some applications related to these two inequalities will also be given. (Received January 20, 2015)

1108-28-521 **Yang Wang***, Department of Mathematics, Hong Kong University of Science and Technolog, Kowloon, Hong Kong. *Self-Similar Subsets of the Cantor Set.*

We study the following question proposed by Mattila in 1998: what are the self-similar subsets of the middle-third Cantor set C? For any non-trivial self-similar subset F of C, we show that any linear generating IFS of F should consist of similitudes whose contraction ratios are integer powers of 1/3. Furthermore, we provide necessary and sufficient conditions to characterize all self-similar subsets of C. A very simple criterion is formulated to characterize self-similar subsets of C with equal contraction ratio. For the general case a finite algorithm is provided to generate all self-similar subsets of C with pre-given contraction ratios. (Received January 20, 2015)

30 ► Functions of a complex variable

1108-30-218 **Kamran Sadiq**, Altenbergerstrasse 69, Linz, Austria, and **Alexandru Tamasan*** (tamasan@math.ucf.edu), 4000 Central Florida Blvd., Orlando, FL 32816. *Range Characterization of the attenuated X-ray transform of planar tensors.*

This talk concerns the characterization of the range of (non-attenuated and) Attenuated X-ray transform of symmetric tensors in the plane. We start with the forward model of the Radiative transport in attenuating media, and define the X-ray transform as traces of solutions of the transport model. We use the theory of A-analytic maps of A. Bukhgeim. The characterization is in terms of a Hilbert transform for A-analytic maps. (Received January 14, 2015)

1108-30-304 **Huy V. Tran*** (tvhuy@math.ucla.edu). *Convergence of an algorithm simulating SLE and Loewner curves.*

Together with the development of Schramm-Loewner evolution (SLE) which is scaling limits of many discrete models from statistical physics one want to see pictures of SLE directly from Loewner equation. The most standard method suggested by Marshall and Rohde is to sample Brownian motion at discrete times and interpolate appropriately between. This algorithm always produces piecewise smooth non self-intersecting curves whereas SLE_κ has been proven to be simple for $\kappa \in [0, 4]$, self-touching for $\kappa \in (4, 8)$ and space-filling for $\kappa \geq 8$. In the talk we show that this sequence of curves converges to SLE_κ for all $\kappa \neq 8$ by giving a condition of deterministic driving functions for having sup norm convergence of simulated curves when we use the same algorithm for these driving functions. (Received January 17, 2015)

1108-30-513 **Joan Lind*** (jlind@utk.edu) and **Huy Tran**. *Regularity of Loewner Curves.*

The Loewner equation encrypts a growing simple curve in the plane into a real-valued driving function. We show that if the driving function is in C^β with $\beta > 2$ then the Loewner curve is in $C^{\beta+\frac{1}{2}}$. This extends a result of Carto Wong who proved the statement for $1/2 < \beta \leq 2$. (Received January 20, 2015)

32 ► Several complex variables and analytic spaces

1108-32-36 **Xiaojun Huang** (huangx@math.rutgers.edu) and **Yuan Zhang*** (zhangyu@ipfw.edu). *CR transversality of holomorphic maps into hyperquadrics.*

Let M_ℓ and $\tilde{M}_\ell$ be smooth Levi-nondegenerate hypersurfaces of the same signature ℓ $(0 < \ell < \frac{n-1}{2})$ in $\mathbf{C}^n$ and $\mathbf{C}^N$ respectively with $3 \leq n \leq N$. In 2005, Baouendi and Huang conjectured that any holomorphic map F from M_ℓ into $\tilde{M}_\ell$ either sends an open neighborhood of M_ℓ in $\mathbf{C}^n$ into $\tilde{M}_\ell$, or is necessarily CR transversal everywhere. In this talk, we show the conjecture of Baouendi and Huang is true when $\tilde{M}_\ell$ is the standard hyperquadric H_ℓ^N of signature ℓ in $\mathbf{C}^N$ with $N - n < \frac{n-1}{2}$. Equivalently, we show that F is necessarily a local CR embedding from M_ℓ into H_ℓ^N. This is a joint work with Xiaojun Huang. (Received December 01, 2014)

1108-32-37 **Yang Liu** (liuyang@zjnu.edu.cn), Jinhua, Zhejiang , Peoples Rep of China, **Yifei Pan*** (pan@ipfw.edu), Fort Wayne, IN 46805, and **Zhihua Chen** (zzzhhc@tongji.edu.cn), Shanghai, Shanghai 200092, Peoples Rep of China. *Boundary rigidity result for holomorphic mappings between non-equidimensional unit balls.*

In [Burns and Krantz, JAMS, 1994], Burns and Krantz obtained the following rigidity result for holomorphic mappings on the unit ball. In this talk, we will give some new boundary rigidity of holomorphic mappings between non-equidimensional unit balls. (Received December 01, 2014)

1108-32-48 **Zhenghui Huo*** (huo3@illinois.edu), Urbana, IL 61801. *The Bergman kernel on Reinhardt domain.*

We provide a new method to compute the Bergman kernel on some Reinhardt domains. We express the kernel on this domain in $\mathbb{C}^{n+1}$ in terms of an already known kernel on a domain in $\mathbb{C}^n$ and a first order differential operator. We find, for example, an exact formula for the kernel on $\{(z, w) \in \mathbb{C}^{n+1}; \|z\|^2 < e^{-|w|^2}\}$. (Received December 15, 2014)

1108-32-68 **Mustafa Ayyürü**, Quantitative Finance Program, Rutgers Business School, Newark, NJ 07102, and **Emil J. Straube*** (straube@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843. *Compactness of the $\overline{\partial}$-Neumann operator on the intersection of two domains.*

Assume that Ω_1 and Ω_2 are two smooth bounded pseudoconvex domains in $\mathbb{C}^2$ that intersect (real) transversely, and that $\Omega_1 \cap \Omega_2$ is a domain (i.e. is connected). If the $\overline{\partial}$-Neumann operators on Ω_1 and on Ω_2 are compact, then so is the $\overline{\partial}$-Neumann operator on $\Omega_1 \cap \Omega_2$. The corresponding result holds for the $\overline{\partial}$-Neumann operators on $(0, n-1)$-forms on domains in $\mathbb{C}^n$. This is joint work with Mustafa Ayyürü. (Received December 22, 2014)

1108-32-70 **Samangi Munasinghe*** (samangi.munasinghe@wku.edu) and **Yunus E. Zeytuncu**. *On L^p-regularity of the Szegö projections.*

In this talk we will discuss the L^p-regularity of weighted Szegö projection operators in several complex variables. In particular, we will present a family of weights on the unit disc in $\mathbb{C}$ whose corresponding weighted Szegö projection operators are irregular on L^p spaces. This is joint work with Yunus E. Zeytuncu. (Received December 22, 2014)

1108-32-147 **Jeffery D McNeal*** (mcneal.28@osu.edu). *Percolation of closed range for $\bar{\partial}$.*

We will discuss the following result: if Ω is a domain in $\mathbb{C}^n$ and $\bar{\partial}$ has closed range (in L^2) at the level of $(0, q)$-forms, then it also has closed range at the level of $(0, q+1)$-forms. This fact holds in general, without assuming Ω is bounded, pseudoconvex, or has smooth boundary. The result is somewhat remarkable as stronger-than-closed range estimates on $\bar{\partial}$, e.g. subelliptic estimates, do not automatically flow up the $\bar{\partial}$-complex in this manner. (Received January 08, 2015)

1108-32-185 **Rasul Shafikov***, Department of Mathematics, Middlesex College, University of Western Ontario, London, Ontario N6A 5B7, Canada. *Polynomial and rational convexity of Lagrangian inclusions in $\mathbb{C}^2$.*

I will discuss recent progress concerning polynomial and rational convexity of Lagrangian inclusions of compact real surfaces in $\mathbb{C}^2$. (Received January 11, 2015)

1108-32-196 **Andrew Raich*** (araich@uark.edu) and **Michael Tinker**. *The Szegö kernel on a class of noncompact CR manifolds of high codimension.*

We generalize Nagel's formula for the Szegö kernel and use it to compute the Szegö kernel on a class of noncompact CR manifolds whose tangent space decomposes into one complex direction and several totally real directions. We also discuss the control metric on these manifolds and relate it to the size of the Szegö kernel. (Received January 12, 2015)

1108-32-215 **Laszlo Lempert*** (lempert@purdue.edu). *Representing analytic cohomology groups of complex manifolds.*

I will define a subcomplex of the usual Cech complex to compute cohomology groups of a complex manifold, with values in a holomorphic vector bundle. This has an application to holomorphic group actions on those vector bundles and to the representations induced on cohomology. (Received January 14, 2015)

1108-32-261 **John P D'Angelo** and **Jiri Lebl*** (lebl@math.okstate.edu), Department of Mathematics, Oklahoma State University, Stillwater, OK 74078. *Homotopy equivalence for proper holomorphic mappings.*

In the classification of proper homolorphic maps between balls or CR maps between spheres, the focus has been on spherical equivalence, and not much effort has been spent on the topology of the space of maps. We explore several natural notions of homotopy of such maps and their relation to spherical equivalence. (Received January 15, 2015)

1108-32-267 **Purvi Gupta*** (prvgupta@umich.edu). *Volume approximations of pseudoconvex domains.*

Several results in convex geometry establish asymptotic estimates for the gap between a convex domain and approximating polyhedra of increasing complexity. Is it possible to do the same for approximations of pseudoconvex domains by analytic polyhedra? We will see how this questions leads to alternate characterizations of Fefferman's hypersurface measure on smooth strongly pseudoconvex domains, which can help extend Fefferman's definition to more general settings. (Received January 18, 2015)

1108-32-307 **Luke D. Edholm*** (edholm.1@osu.edu). *L^p boundedness of the Bergman projection on fat Hartogs triangles.* Preliminary report.

The Bergman theory of domains $\Omega_k = \{|z_1|^k < |z_2| < 1\}$ in $\mathbb{C}^2$ is studied for positive integers k. For each k, we obtain an explicit formula for the Bergman kernel. Using these formulas, the L^p boundedness of the Bergman projection associated to these domains is established, for a restricted range of p depending on the value of k. This range of p is also shown to be sharp. (Received January 17, 2015)

1108-32-310 **Chia-chi Tung*** (chia.tung@mnsu.edu), Dept. of Mathematics and Statistics, Minnesota State University, Mankato, Mankato, MN 56001. *On Current Solutions to Schrödinger Type Equations.* Preliminary report.

The purpose of this work is to consider certain current solutions on a complex space to a Schrödinger type equation with a (possibly) complex parameter and/or a nonzero potential. Conditions under which such current solutions are distributionally induced by a C^∞, semismooth, respectively, semireal-analytic function, will be given in this talk. (Received January 17, 2015)

1108-32-347 **Janusz Adamus*** (jadamus@uwo.ca), Department of Mathematics, University of Western Ontario, London, ON N6A5B7, Canada. *CR-continuation of arc-analytic maps.*

Given a set E in $\mathbb{C}^m$ and a point $p \in E$, there is a unique smallest complex-analytic germ X_p containing E_p, called the holomorphic closure of E_p. We study the holomorphic closure of semialgebraic arc-symmetric sets. Our main application concerns CR-continuation of semialgebraic arc-analytic mappings: A mapping $f : M \to \mathbb{C}^n$ on a connected real-analytic CR manifold which is semialgebraic arc-analytic and CR on a non-empty open subset of M is CR on the whole M. (Received January 18, 2015)

1108-32-357 **Zeljko Cuckovic*** (zcuckovi@math.utoledo.edu), Department of Mathematics and Statistics, University of Toledo, 2801 W. Bancroft Street, Toledo, OH 43606, and **Yunus Zeytuncu**, University of Michigan - Dearborn, Department of Mathematics and Statistics, Dearborn, MI 48128. *Mapping properties of weighted Bergman projection operators on Reinhardt domains.*

We show that on smooth complete Reinhardt domains, weighted Bergman projection operators corresponding to exponentially decaying weights are unbounded on L^p spaces for all p different from 2. On the other hand, we show that the exponentially weighted projection operators are bounded on Sobolev spaces on the unit ball. (Joint work with Yunus Zeytuncu). (Received January 18, 2015)

1108-32-374 **Bingyuan Liu*** (liubingyuan@go.wustl.edu), One Brookings Dr., St. Louis, MO 63130. *Recent progresses in automorphism groups.*

Let $\Omega \Subset \mathbb{C}^n$ be a bounded domain. By a 1935 theorem of Cartan, all biholomorphisms from Ω onto Ω form a (real) finite dimensional Lie group, which is denoted by $\mathrm{Aut}(\Omega)$. When $\Omega \Subset \mathbb{C}$ is in complex space of one dimension, the study of $\mathrm{Aut}(\Omega)$ is classical. However, as one considers domains with higher dimensions, $\mathrm{Aut}(\Omega)$ shows both similarity and dissimilarity in terms of algebraic and topological properties comparing with those in one dimension. In this talk, I will give a short introduction and exhibit several recent progresses in the geometry of complex domains with non-compact automorphism groups. (Received January 18, 2015)

1108-32-412 **Phillip Harrington*** (psharrin@uark.edu) and **Andy Raich**. *The Cauchy-Riemann Complex on Unbounded Domains.*

Our goal is to estimate the solution operator for the Cauchy-Riemann Complex in L^2 Sobolev spaces on unbounded domains. On such domains, the weight function plays a critical role and this forces us to use great care when constructing our Sobolev spaces. With these tools developed, we will construct qualitatively new examples of domains where the Cauchy-Riemann equations can be studied. (Received January 19, 2015)

1108-32-453 **Sivaguru Ravisankar*** (sivagr@okstate.edu), Department of Mathematics, Oklahoma State University, Stillwater, OK 74078. *Tangential Lipschitz Gain for Holomorphic Functions on Domains of Finite Type.*

E. Stein discovered that Lipschitz holomorphic functions on a smoothly bounded domain enjoy a doubling in their order of Lipschitz regularity along complex tangential curves near the boundary. This gain by a factor of two is sharp only in strongly pseudoconvex domains and a better gain is expected otherwise. After a mild reformulation, we show that the order of tangential Lipschitz gain for holomorphic functions near a point of finite type is closely related to the type and we describe this explicitly in terms of the defining function. (Received January 19, 2015)

1108-32-481 **David E Barrett*** (barrett@umich.edu), Math Dept., 530 Church St., Ann Arbor, MI 48109-1043, and **Dusty Grundmeier**. *Characterization of a family of functions arising in the study of strongly $\mathbb{C}$-convex domains.* Preliminary report.

A smoothly bounded domain Ω in a complex projective space is called "strongly $\mathbb{C}$-convex" if each complex tangent hyperplane for $b\Omega$ is disjoint from Ω and has minimal order of contact with $b\Omega$. The collection of complex tangent hyperplanes to a the boundary of a strongly $\mathbb{C}$-convex domain forms the boundary of a smoothly bounded strongly $\mathbb{C}$-convex domain Ω^* in the dual projective space. There is a natural contact diffeomorphism between $b\Omega$ and $b\Omega^*$; using this diffeomorphism we may equip $b\Omega$ with two different Hardy spaces.

In complex dimension one an arbitrary function on $b\Omega$ decomposes (uniquely, up to constants) as a sum of functions in the two Hardy spaces.

In higher dimension, when Ω is the projective image of a ball, a function on $b\Omega$ is the sum of functions in the two Hardy spaces if and only if it extends to a pluriharmonic function on Ω.

The talk will consider the problem of characterizing the functions arising as sums of functions in the two Hardy spaces for general strongly $\mathbb{C}$-convex domains in two-dimensional projective space. Work of other authors on the characterization of pluriharmonic boundary values will also be reviewed. (Received January 19, 2015)

1108-32-533 **Liz Vivas*** (vivas.3@osu.edu), 231 West 18th Ave, Columbus, OH 43210.
Parametrization of unstable manifolds for parabolic skew-products.

Given a parabolic map in one dimension $f(z) = z + O(z^2)$, $f \neq \mathrm{Id}$, it is known that there exists the analogous of stable and unstable domains. That is, domains in which every point is attracted by f (or by the inverse f^{-1}) towards the fixed point. I will prove that there exists a natural parametrization for the unstable manifold in terms of iterates for some subset of parabolic maps and generalize this result for the case of skew-product maps that satisfy certain conditions. As time permits, I will give an application of this fact to construct Fatou disks for skew-product maps. (Received January 20, 2015)

1108-32-564 **Peter Ebenfelt*** (pebenfelt@ucsd.edu), Department of Mathematics, La Jolla, CA 92093.
Local Holomorphic Isometries of a Modified Projective Space into a Standard Projective Space. Preliminary report.

We consider local modifications $\omega_n + f^*\omega_d$ of the Fubini-Study metric (with associated $(1,1)$-form ω_n) on an open subset $\Omega \subset \mathbb{P}^n$ induced by a local holomorphic mapping $f\colon \Omega \to \mathbb{P}^d$. Our main result is that there are "gaps" in potential dimensions m such that the modification can be obtained as $h^*\omega_m$ for some local holomorphic mapping $h\colon \Omega \to \mathbb{P}^m$. We also consider the case of rational conformal factors. (Received January 20, 2015)

33 ► *Special functions*

1108-33-403 **Mohammad A AlQudah*** (alqudahm@northwood.edu), 4000 Whiting Dr, Midland, MI 48640. *Chebyshev and Bernstein polynomials change of bases.*

We construct multiple representations relative to different bases of Chebyshev polynomials. We provide a closed form for the matrix transformation of the generalized Chebyshev polynomial basis into Bernstein polynomial basis, and the matrix transformation of Bernstein polynomial basis into generalized Chebyshev polynomial basis. (Received January 19, 2015)

34 ► *Ordinary differential equations*

1108-34-137 **Shuguan Ji*** (jisg@jlu.edu.cn), 2699 Qianjin Street, Changchun, 130012, **Weishi Liu** (wsliu@ku.edu), 1460 Jayhawk Blvd., Lawrence, KS 66045, and **Mingji Zhang** (mzhang@math.msu.edu), 619 Red Cedar Road, East Lansing, MI 48823. *Effects of (small) permanent charge and channel geometry on ionic flows via classical Poisson-Nernst-Planck models.*

This talk is concerned with effects of permanent charges on ionic flows through ion channels via a quasi-one-dimensional classical Poisson-Nernst-Planck (PNP) model, which presents the geometry of the three-dimensional channel to a certain extent. Two ion species, one positively charged and one negatively charged, are considered with a simple profile of permanent charges: zeros at the two end regions and a constant Q_0 over the middle region. The classical PNP model can be viewed as a boundary value problem (BVP) of a singularly perturbed system. The singular orbit of the BVP depends on Q_0 in a regular way. Assuming $|Q_0|$ is small, a regular perturbation analysis is carried out for the singular orbit. Our analysis indicates that effects of permanent charges depend on a rich interplay between boundary conditions and the channel geometry. Furthermore, interesting common features are revealed: for $Q_0 = 0$, only an average quantity of the channel geometry plays a role; however, for $Q_0 \neq 0$, details of the channel geometry matter, in particular, to optimize effects of a permanent charge, the channel should have a short and narrow neck within which the permanent charge is confined. The latter is consistent with structures of typical ion channels. (Received January 07, 2015)

35 ► Partial differential equations

1108-35-15 **Peter Lindqvist** and **Juan J Manfredi*** (manfredi@pitt.edu), Department of Mathematics, University of Pittsburgh, Pittsburgh, PA 15260. *On the Mean Value Property for the p-Laplace equation in the plane.*

We study the p-Laplace equation in the plane and prove that the mean value property holds directly for the solutions themselves, at least for $1 < p < 9.5$. This removes the need to interpret the formula in the viscosity sense via test functions. The method is based on the hodograph representation (Received November 02, 2014)

1108-35-43 **Xin Yang*** (xinyangmath@gmail.com), C529, Wells Hall, 619 Red Cedar Road, East Lansing, MI 48824, and **Zhengfang Zhou**. *The blow up problem for the heat equation with piecewise continuous nonlinear Neumann boundary condition.* Preliminary report.

We will study the following heat equation with nonlinear piecewise boundary value problem:

$$\begin{cases} u_t(x,t) = \Delta u(x,t) & \text{in} \quad \Omega \times (0,T] \\ \frac{\partial u}{\partial n}(x,t) = u^p(x,t) & \text{on} \quad \Gamma \times (0,T] \\ \frac{\partial u}{\partial n}(x,t) = 0 & \text{on} \quad (\partial\Omega \setminus \Gamma) \times (0,T] \\ u(x,0) = u_0(x) & \text{in} \quad \Omega \end{cases} \tag{1}$$

where $p > 1$, $u_0(x) \geq 0$, Ω is a bounded open set in $\mathbb{R}^n$ with $\partial\Omega \in C^{1+\alpha}$, Γ is a connected part of $\partial\Omega$ with positive measure. The problem is motivated by partial damage to insulation of high speed flying subjects. We prove the local existence, uniqueness and comparison principle of the solutions in a suitable space. After that, we prove that the solution must blow up in finite time. And the blow up time is estimated by the measure of Γ and the size of initial data. (Received January 15, 2015)

1108-35-56 **Tao Huang*** (txh35@psu.edu), Department of Mathematics, Penn State University, State College, PA 16802, and **Chun Liu** and **Yoichiro Mori**. *Dynamics of Ionic Electrodiffusion.*

We consider a dynamic system of ionic electrodiffusion which can be considered as a special case of cardiac bidomain model. A global weak solution has been constructed by Galerkin argument and maximum principle. The electroneutral limit as capacitance tends to zero is also considered. (Received December 17, 2014)

1108-35-57 **Qiliang Wu***, 619 Red Cedar RD RM C212, East Lansing, MI 48824, and **Keith Promislow**. *Existence of pearled patterns in the planar Functionalized Cahn-Hilliard equation.*

The functionalized Cahn-Hilliard (FCH) equation supports planar and circular bilayer interfaces as equilibria which may lose their stability through the pearling bifurcation: a periodic, high-frequency, in-plane modulation of the bilayer thickness. In two spatial dimensions we employ spatial dynamics and a center manifold reduction to reduce the FCH equation to an 8th order ODE system. A normal form analysis and a fixed-point-theorem argument show that the reduced system admits a degenerate 1:1 resonant normal form, from which we deduce that the onset of the pearling bifurcation coincides with the creation of a two-parameter family of pearled equilibria which are periodic in the in-plane direction and exponentially localized in the transverse direction. (Received December 17, 2014)

1108-35-58 **Bjorn Sandstede*** (bjorn_sandstede@brown.edu), 182 George Street, Providence, RI 02912. *Nonlinear stability of source defects.*

Defects are interfaces that mediate between two wave trains with possibly different wave numbers. Of particular interest in applications are sources for which the group velocities of the wave trains to either side of the defect point away from the interface. While sources are ubiquitous in experiments and can be found easily in numerical simulations of appropriate models, their stability analysis still presents many challenges. One difficulty is that sources are not travelling waves but are time- periodic in an appropriate moving coordinate frame. A second difficulty is that perturbations are transported towards infinity, which makes it difficult to apply various commonly used approaches. In this talk, I will discuss nonlinear-stability results for sources that rely on pointwise estimates. (Received December 17, 2014)

1108-35-66 **Alex Misiats*** (omisiats@purdue.edu), 150 N University str., West Lafayette, IN 47907. *Ginzburg Landau superconductivity model with prescribed topological degrees on the boundary.*

Superconductivity is a complete loss of resistivity that occurs in most metals below a certain critical temperature. The key feature of this physical phenomenon is the vortices, or the points where the external magnetic field penetrates the bulk of a superconductor, thus destroying superconductivity. We model the superconducting vortices using the Ginzburg-Landau functional with a specific (degree) boundary condition that creates the same "quantized" vortices as the external magnetic field. In my talk, I will discuss the issue of well-posedness of such modelling, which reduces to the question of the existence of minimizers for a Ginzburg-Landau functional in certain functional classes. I will also describe the vortex structure of the Ginzburg-Landau minimizers, which may be useful in predicting the locations of the vortices depending on the geometry of a superconductor. (Received December 21, 2014)

1108-35-90 **Seckin Demirbas*** (demirba2@illinois.edu), 703 W. High St., Apt. 2, Urbana, IL 61801. *Construction of Gibbs measure and almost sure global well-posedness for one dimensional periodic fractional Schrodinger equation.*

In this talk we will give the intuition for and the explicit construction of a Gibbs measure for 1D periodic fractional Schrodinger equation. We will also give the proof of almost sure global wellposedness, which closes the gap between deterministic local and global wellposedness range in an almost sure sense. (Received January 02, 2015)

1108-35-99 **Qing Liu** (qingliu@pitt.edu), **Armin Schikorra** (armin.schikorra@unibas.ch) and **Xiaodan Zhou*** (xiz78@pitt.edu). *A game-theoretic proof of convexity preserving properties for motion by curvature.*

In this talk, we present new proofs of convexity preserving properties for the p-Laplace equation and the level set mean curvature flow equation by using game-theoretic approximations. Our new proofs are based on selecting appropriate game strategies and iterating the corresponding dynamic programming principles. (Received January 04, 2015)

1108-35-100 **Bob Eisenberg*** (beisenbe@rush.edu), Dept of Molecular Biophysics, Rush University, 1653 West Congress Parkway, Chicago, IL 60305. *Ions in Solutions and Channels: Local Structure and Global Controls.*

Electronic technology is possible because mathematics describes atomic scale electrical structure of semiconductor devices and links them accurately and robustly to power supplies, inputs and outputs. Biology is possible because evolution links ionic structure of proteins robustly to power supplies (ion gradients), inputs (voltages), and outputs (currents). Nanosystems of great technological interest are difficult to design robustly by trial and error. Efficient design and robust function needs mathematics to link atomic scale ionic structure accurately and robustly to power supplies (Dirichlet boundary conditions for electrical and chemical potential), inputs and outputs. Chemical tradition analyzes isolated systems without inputs or outputs. Indeed, its law of mass action does not conserve charge. Crucial mathematical issues are (1) accurate description of Dirichlet boundary conditions far from atomic structures controlling ions. (2) adequate description of NON-ideal properties of ions that link 'everything with everything else'. Several approaches successfully describe properties of calcium channels over a 10^7 range of concentrations. A new approach uses a Fermi like distribution to compute nonideal properties from properties of mixtures of spheres of any diameter. (Received January 04, 2015)

1108-35-102 **Marius Beceanu*** (mbeceanu@berkeley.edu), 970 Evans Hall, UC Berkeley Math. Dept., Berkeley, CA 94720. *A semilinear Schrödinger equation with random potential.*

We study Schrödinger's equation with a random time-dependent potential. We prove that energy remains bounded and solutions scatter in the presence of small nonlinear perturbations. (Received January 05, 2015)

1108-35-104 **Brian Pigott** (raynorsg@wfu.edu), Winston Salem, NC 27109, and **Sarah Raynor*** (raynorsg@wfu.edu). *Asymptotic Stability of KdV Solitons in Weighted H^s spaces.*

In this work, we consider the stability of solitons for the KdV equation below the energy space, using spatially-exponentially-weighted norms. Using a combination of the I-method and spectral analysis following Pego and Weinstein, we are able to show that, in the exponentially weighted space, the perturbation of a soliton decays exponentially for arbitrarily long times. The finite time restriction is due to a lack of global control of the unweighted perturbation. (Received January 05, 2015)

1108-35-123 **Chenchen Mou** and **Andrzej Swiech*** (swiech@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30030. *Uniqueness of viscosity solutions for a class of integro-differential equations.*

We will present comparison theorems and uniqueness results for viscosity solutions for a class of nonlocal equations. This class of equations includes Bellman-Isaacs equations containing operators of Lévy type with measures depending on x and control parameters, as well as elliptic nonlocal equations that are not strictly monotone in the u variable. The proofs of the theorems use apriori knowledge about regularity of viscosity solutions of such equations. (Received January 06, 2015)

1108-35-125 **Anna Ghazaryan*** (ghazarar@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056, and **Stephane Lafortune** and **Peter McLarnan**. *Stability analysis for combustion fronts traveling 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 absence of unstable eigenvalues the fronts are convectively unstable. (Received January 06, 2015)

1108-35-133 **Ryan N. Goh*** (gohxx037@umn.edu) and **Arnd Scheel**. *Hopf Bifurcation from Fronts in the Cahn-Hilliard Equation.*

We study Hopf bifurcation from traveling-front solutions in the Cahn-Hilliard equation. Models of this form have been used to study numerous physical phenomena, including pattern formation in chemical deposition and precipitation processes. Technically we contribute a simple and direct functional analytic method to study bifurcation in the presence of essential spectrum. Our approach uses exponential weights to recover Fredholm properties, spectral flow ideas to compute Fredholm indices, and mass conservation to account for negative index. We also construct an explicit, prototypical example, for which we prove the existence of a bifurcating front, and determine the direction of bifurcation. (Received January 07, 2015)

1108-35-136 **Seonghak Kim*** (kimseo14@msu.edu), 619 Red Cedar Road, East Lansing, MI 48824, and **Baisheng Yan**. *Convex integration and infinitely many weak solutions to the Perona-Malik equation in all dimensions.*

We study the forward-backward parabolic Perona-Malik equation in image processing with the homogeneous Neumann boundary condition on an n-dimensional smooth bounded convex domain. Our approach is motivated by a reformulation of the n-dimensional Perona-Malik equation as a nonhomogeneous partial differential inclusion with linear constraint. Based on a functional setup appropriate for the Baire category method, an explicit formula of the lamination convex hull of the matrix set involved, and a new convex integration method overcoming the difficulty due to some uncontrollable components of gradient in the differential inclusion when dimension $n \geq 2$, we establish the main result that for suitable nonconstant smooth initial data the initial-boundary value problem possesses infinitely many Lipschitz continuous weak solutions. We also introduce some recent generalized results. (Received January 07, 2015)

1108-35-138 **Henri Berestycki**, **Tianling Jin*** (tj@math.uchicago.edu) and **Luis Silvestre**. *Propagation in a non local reaction diffusion equation with spatial and genetic trait structure.*

We study existence and uniqueness of traveling fronts, and asymptotic speed of propagation for a non local reaction diffusion equation with spatial and genetic trait structure. (Received January 07, 2015)

1108-35-139 **Xavier Ros-Oton*** (ros.oton@math.utexas.edu), Austin, TX 78751. *Regularity theory for stable operators.*

We establish sharp regularity estimates for solutions to $Lu = f$ in $\Omega \subset \mathbb{R}^n$, being L the generator of any stable and symmetric Lévy process. Such nonlocal operators L depend on a finite measure on S^{n-1}, called the spectral measure.

We study both the interior and the boundary regularity of solutions.

Even for linear and translation invariant equations, the regularity properties of solutions depend strongly on the regularity of the spectral measure. (Received January 08, 2015)

1108-35-144 **Mark M Meerschaert*** (mcubed@stt.msu.edu), Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824. *Fractional diffusion on bounded domains.*

Fractional derivatives were invented in the 17th century, soon after their integer order cousins. In the past decade, an explosion of practical applications has intensified interest in the subject. Fractional differential equations are now being used in cell biology, ecology, electronics, hydrology, and medical imaging to model anomalous diffusion, where a plume of particles spreads faster than the traditional integer-order diffusion equation predicts. There now exist a variety of effective numerical methods to solve fractional diffusion equations. However, the mathematically correct specification of a well-posed fractional diffusion on a bounded domain remains an open problem. The main issue is to write appropriate boundary conditions, or their fractional analogues. In this talk, we will discuss this open problem, and one possible approach using the newly developed theory of nonlocal diffusion. (Received January 08, 2015)

1108-35-150 **Mark Hubenthal*** (hubenjm@math.uh.edu), University of Houston, Department of Mathematics, 641 PGH, Houston, TX 77204-3008, and **Daniel Onofrei** (onofrei@math.uh.edu), University of Houston, Department of Mathematics, 641 PGH, Houston, TX 77204-3008. *Sensitivity analysis for active control of the Helmholtz equation.*

We consider the problem of active exterior cloaking for the Helmholtz equation. The previous work of Onofrei implies the following: Suppose we have a source region $D_a \subset \mathbb{R}^d$ ($d = \overline{2,3}$) and a solution u_0 to the homogeneous scalar Helmholtz equation in a set containing the control region $D_c \subset \mathbb{R}^d$. Then there exists an infinite class of boundary data on ∂D_a such that the radiating solution to the corresponding exterior scalar Helmholtz problem in $\mathbb{R}^d \setminus D_a$ will closely approximate u_0 in D_c, while having vanishingly small values beyond a sufficiently large "far-field" radius R.

In this work we study the minimal energy solution to the above problem, which is obtained using Tikhonov regularization and the Morozov discrepancy principle, and we perform a detailed sensitivity analysis. That is, we analyze the stability of the the minimal energy solution with respect to measurement errors as well as the feasibility of the active scheme (power budget, accuracy, stability) depending on: mutual distances between the antenna, control region and far field radius R, regularization parameter, frequency, location of the source, etc. (Received January 08, 2015)

1108-35-160 **Kam C Ng*** (kam.ng@kodak.com), Kodak Technology Center, Materials Deposition Interaction Department, Eastman Kodak Company, Rochester, NY 14650-2109. *Liquid Transfer in Flexographic Printing.*

We will use liquid bridge to study the liquid transfer between parallel plates. The liquid bridge is assumed to be axis symmetric and can be modeled by one-dimensional dynamical equations. The contact line movement on the plates is modeled by the dynamic contact angles of Dussan. Discussion of the dependence on viscosity, contact angles and pulling speed will be presented. (Received January 09, 2015)

1108-35-164 **Margaret Beck**, **Osman Chaudhary** and **C. Eugene Wayne*** (cew@math.bu.edu). *Analysis of enhanced diffusion in Taylor dispersion.* Preliminary report.

We consider a simple model of the evolution of the concentration of a tracer, subject to a background shear flow by a fluid with viscosity $\nu << 1$ in an infinite channel. Taylor observed in the 1950's that, in such a setting, the tracer diffuses at a rate proportional to $1/\nu$, rather than the expected rate proportional to ν. We provide a mathematical explanation for this enhanced diffusion using a combination of Fourier analysis and center manifold theory. More precisely, we show that, while the high modes of the concentration decay exponentially, the low modes decay algebraically, but at an enhanced rate. Moreover, the behavior of the low modes is governed by finite-dimensional dynamics on an appropriate center manifold, which corresponds exactly to diffusion by a fluid with viscosity proportional to $1/\nu$. (Received January 09, 2015)

1108-35-168 **Biao Brian Ou*** (bou@math.utoledo.edu), Department of Mathematics and Statistics, University of Toledo, Toledo, OH 43606. *An equality for the geodesic curvature of certain curves on a two-dimensional Riemannian surface.*

We prove an equality for the geodesic curvature function of certain closed curves in a local domain of a two-dimensional Riemannian surface. We address its connection to the local Gauss-Bonnet theorem. We also show that the equality leads to a four-vertex theorem for simple and closed curves on a two-dimensional Riemannian surface with a constant Gauss curvature. (Received January 09, 2015)

1108-35-178 **Alexander Kiselev**, **Lenya Ryzhik**, **Yao Yao*** (yaoyao@math.wisc.edu) and **Andrej Zlatos**. *Finite time singularity of a vortex patch model in the half plane.*

The question of global regularity vs. finite time blow-up remains open for many fluid equations. In this talk, I will discuss an active scalar equation which is an interpolation between the 2D Euler equation and the surface quasi-geostrophic equation. We study the patch dynamics for this equation in the half-plane, and prove that the solutions can develop a finite-time singularity. (Received January 10, 2015)

1108-35-202 **Xumin Jiang*** (xjiang1@nd.edu) and **Qing Han**. *Boundary expansions for minimal graphs in the hyperbolic space.*

We study expansions near the boundary of solutions to the Dirichlet problem for minimal graphs in the hyperbolic space and characterize the remainders of the expansion by multiple integrals. With such a characterization, we establish optimal asymptotic expansions of solutions with boundary values of finite regularity and demonstrate a slight loss of regularity for nonlocal coefficients. (Received January 13, 2015)

1108-35-216 **Bei Hu*** (b1hu@nd.edu), University of Notre Dame, Dept of Applied Computaional Math and Stat, 153 Hurley Hall, Notre Dame, IN 46556, **Jin Liang**, Shanghai, 200092, Peoples Rep of China, and **Yuan Wu**, Shanghai, 200092, Peoples Rep of China. *A PDE Free Boundary Problem for Corporate Bond with Credit Rating Migration.*

A free boundary model for pricing a corporate bond with credit rating migration is studied. Some interesting properties as well as numerical examples will be presented. (Received January 14, 2015)

1108-35-220 **Liliana Borcea*** (borcea@umich.edu), Department of Mathematics, 2074 East Hall, 530 Church St, Ann Arbor, MI 48109-1043. *A model reduction approach to inversion for a parabolic partial differential equation.*

I will describe a novel numerical inversion method for a parabolic partial differential equation arising in applications of control source electromagnetic exploration. The unknown is the electrical resistivity in the earth and the data are time resolved measurements of the magnetic field. The method described uses model reduction ideas and has been implemented in one and two dimensions. (Received January 14, 2015)

1108-35-223 **Paul A Carter*** (pacarter@math.brown.edu), Brown University, Department of Mathematics, 151 Thayer St., Providence, RI 02912, and **Bjorn Sandstede** (bjorn_sandstede@brown.edu), Brown University, Division of Applied Mathematics, 182 George St., Providence, RI 02912. *Pulses with oscillatory tails in the FitzHugh-Nagumo system.*

The FitzHugh-Nagumo equations are a simplified version of the Hodgkin-Huxley equations of mathematical biology describing the propagation of signals along nerve fibers. Numerical studies indicate that the FitzHugh-Nagumo system exhibits stable traveling pulse solutions with oscillatory tails. We discuss an analytical result regarding the existence of such pulses using geometric blow up techniques and singular perturbation theory. We also describe numerical results regarding the stability of the pulses, and we propose a mechanism that explains the transition from single to double pulses that was observed in earlier numerical studies. (Received January 14, 2015)

1108-35-224 **Benjamin R Holman*** (bholman@math.arizona.edu). *Gradual time reversal in thermo- and photo- acoustic tomography within a resonant cavity.*

Thermo-acoustic tomography (TAT) is a hybrid form of medical imaging in which biological tissues are radiated with microwaves to illicit a thermal expansion which produces acoustic pressure waves. These waves are measured outside of the tissue. Traditional reconstruction algorithms for TAT assume that acoustic pressure waves eventually leave a region of interest. We consider a non-standard data acquisition scheme with acoustically reflecting walls that cause pressure waves to reverberate within the region of interest. This type of boundary condition requires a new reconstruction procedure. We investigate convergence of a modified time reversal technique and show that, under certain conditions on the shape of the cavity, this method converges as measurement time increases. This is joint work with Leonid Kunyansky. (Received January 14, 2015)

1108-35-239 **Thomas E Carty*** (tcarty@bradley.edu), 1501 W Bradley Ave, Bradley Hall 445, Peoria, IL 61625. *Grossly Determined Solutions for a Boltzmann-like Equation.* Preliminary report.

In gas dynamics, the connection between the continuum physics model offered by the Navier-Stokes equations and the molecular theory of gases governed by the Boltzmann equation are not always transparent in the known solutions of these different models. In this talk, I attempt to bridge the gap between the two models by deriving a subclass of solutions to a Boltzmann-like equation and demonstrate that they are akin to the classical equilibrium solutions of gas dynamics offered by Hilbert, and Chapman and Enskog. (Received January 14, 2015)

1108-35-240 **Alexandre Girouard**, **Richard S Laugesen*** (laugesen@illinois.edu) and **Bartlomiej A. Siudeja**. *Steklov spectral estimation through quasiconformal mapping.*
Eigenvalues of the Steklov or Dirichlet-to-Neumann operator represent frequencies of vibration of a free membrane whose mass is concentrated at the boundary, and they arise also in sloshing problems.

We show the disk maximizes functionals of the Steklov eigenvalues, under normalization of the perimeter and a kind of boundary moment. The results cover the first eigenvalue, spectral zeta function and partition function. Interestingly, the method employs quasiconformal mapping to estimate the distortion of the energy functional (Dirichlet integral). (Received January 14, 2015)

1108-35-245 **Russell Brown**, **Seick Kim** and **Katharine Ott*** (kott@bates.edu). *The mixed problem for the linear Stokes system in domains in the plane.*
In this talk I will discuss recent work on the mixed boundary value problem for the linear Stokes system in a Lipschitz domain in two dimensions. The first step is to construct a Green function for the linear Stokes system in this setting. The construction of the Green function will impose conditions on the decomposition of the boundary of the domain into Dirichlet and Neumann sets. (Received January 15, 2015)

1108-35-248 **Kiril Datchev*** (kdatchev@purdue.edu). *Resolvent estimates for manifolds with large infinite ends.* Preliminary report.
We prove high energy resolvent bounds for second order differential operators on manifolds with large infinite ends, with applications to Schrodinger and wave evolution. This generalizes previous work of Burq, Cardoso, and Vodev, and provides simpler proofs. The key tool in the proof is a global Carleman estimate. (Received January 15, 2015)

1108-35-256 **E. Compaan*** (compaan2@illinois.edu). *Smoothing and global attractors for the periodic Majda-Biello system.*
This talk will discuss smoothing and dynamical properties of the periodic Majda-Biello system, a coupled KdV-type system. First, given initial data in a Sobolev space, we show that the difference between the linear and the nonlinear evolution almost always lives in a smoother space. The smoothing depends on arithmetic properties of coupling parameter in the system, which controls the resonant sets. Similar smoothing results hold for the forced and damped version of the system; these results imply the existence of a global attractor in the energy space. Finally, when the damping is large in relation to the forcing term, the attractor is trivial. (Received January 15, 2015)

1108-35-266 **Dustin Steinhauer*** (dsteinha@math.tamu.edu) and **Peter Kuchment**. *Stabilizing inverse problems by internal data.*
I will discuss various inverse problems that arise from hybrid methods in medical imaging. Some of these methods provide internal data, that is, certain functionals that give pointwise information from inside the object of interest. I will show how internal data can stabilize exponentially unstable inverse problems, and I will present uniqueness and stability results for various applications. Joint work with Peter Kuchment. (Received January 15, 2015)

1108-35-275 **Todd Kapitula*** (tmk5@calvin.edu), Department of Mathematics and Statistics, Calvin College, Grand Rapids, MI 49546. *Reformulating spectral problems with the Krein matrix.*
Successful resolution of spectral problems in Hamiltonian systems require that we locate not only the eigenvalues, but we also determine the Krein signature of those which are purely imaginary. The well-known Evans function determines the location and multiplicity of the eigenvalues, but in its classical form it does not allow a determination of the signature. On the other hand, the Krein matrix, and the accompanying Krein eigenvalues, allow us to not only find the eigenvalues, but the graphs can be used to determine the signature. We will briefly consider the construction of the matrix, and discuss its role in applications. (Received January 16, 2015)

1108-35-282 **Mingji Zhang***, 619 Rred Cedar Road, East Lansing, MI 48824, and **Peter Bates**, **Guojian Lin**, **Weishi Liu**, **Hong Lu** and **Yingfei Yi**. *Effects of ion size and ion valence on ionic flows via Poisson-Nernst-Planck models with a local hard-sphere potential.*
We analyze a one-dimensional Poisson-Nernst-Planck model for ionic flows. We consider two ion species, one positively charged and one negatively charged, and assume zero permanent charge. A local hard-sphere potential that depends pointwise on ion concentrations is included in the model to account for ion size effects on the ionic

flow. The model problem is treated as a boundary value problem (BVP) of a singularly perturbed differential system. Our analysis is based on the geometric singular perturbation theory but, most importantly, on specific structures of this concrete model. The existence of solutions to the BVP for small ion sizes is established and, treating the ion sizes as small parameters, we also derive an approximation of the I-V (current-voltage) relation. Based on that, critical potentials or voltages for ion size and valence effects are identified and their roles in characterizing the effects on ionic flows are discussed. Important scaling laws of I-V relations and critical potentials in boundary concentrations are obtained. Similar analysis is applied for individual flux of charge, which provides detailed information on the interaction among different ions. This is related to the selectivity phenomena of ion channels. (Received January 16, 2015)

1108-35-291 **Chi Shing Sidney Tsang*** (tsangcs@uci.edu). *Bounds on the density of states for Schrödinger operators with singular potentials.*

We extend Bourgain and Klein's results for bounds on the density of states measure for Schrödinger operators to the case of singular potentials, i.e., to potentials satisfying appropriate L^p conditions. (Joint work with A. Klein) (Received January 16, 2015)

1108-35-308 **Cristian E. Gutierrez** (gutierre@temple.edu) and **Ahmad Sabra*** (ahmad.sabra@temple.edu). *Nonconvex solutions of the near field reflector problem.*

In recent decades, new techniques in nonlinear pde were introduced to solve problems in Geometric Optics. This work considers the near field reflector problem, that is, to find a surface that reflects rays emitted from a point source O into a target set D and satisfying some energy and luminance conditions at the target, taking into account the inverse square law of irradiance. The surface solving this problem is a weak solution of a Monge Ampère type differential equation. Similar problems have been already addressed mathematically and only convex or concave solutions were constructed. Using a covering theorem, we prove the existence of non convex nor concave solutions of the near field reflector problem, which provides a new class of solutions to the corresponding pde. (Received January 17, 2015)

1108-35-309 **Nguyen Lam*** (nhlam@pitt.edu), Department of Mathematics, 301 Thackeray Hall, Pittsburgh, PA 15260. *Sharp Moser-Trudinger and Adams inequalities.*

Moser-Trudinger and Adams inequalities have received important attention in recent years. In this talk, we present some recent development on sharp Moser-Trudinger type inequalities on first order Sobolev spaces and sharp Adams type inequalities on high order Sobolev spaces on both Euclidean spaces and Heisenberg groups. Since the symmetrization argument is not available on these settings, we propose a rearrangement-free method to study these sharp inequalities. This talk is based on joint works with Guozhen Lu and Hanli Tang. (Received January 17, 2015)

1108-35-316 **M Burak Erdogan*** (berdogan@illinois.edu), 1409 W. Green Street (MC-382), Urbana, IL 61801. *Dispersive estimates for Schrodinger operators with obstructions at zero energy.*

We will discuss recent results (joint with W. Green, and with W. Green and M. Goldberg) on $L^1(\mathbb{R}^n) \to L^\infty(\mathbb{R}^n)$ dispersive estimates for Schrodinger operators with real and decaying potentials in the case when there are resonances and/or an eigenvalue at the zero energy. (Received January 17, 2015)

1108-35-318 **Dinh-Liem Nguyen*** (dlnguyen@umich.edu), Dinh-Liem Nguyen, Department of Mathematics, University of Michigan, 4863 East Hall, 530 Church Street, Ann Arbor, MI 48109. *An inverse electromagnetic scattering problem for the Drude-Born-Fedorov model for chiral gratings.*

We consider the electromagnetic inverse scattering problem for the Drude-Born-Fedorov model for periodic chiral structures known as chiral gratings both in R2 and R3. The Factorization method is studied as an analytical as well as a numerical tool for solving this inverse problem. The method constructs a simple criterion for completely characterizing shape of the periodic scatterer which leads to a uniqueness result and a fast imaging algorithm. The required data consists of certain components of Rayleigh sequences of (measured) scattered fields caused by plane incident electromagnetic waves. We propose in this electromagnetic plane wave setting a rigorous analysis for the Factorization method. Numerical examples in two and three dimensions are also presented for showing the efficiency of the method. (Received January 17, 2015)

1108-35-322 **Nathan Pennington*** (nathanpennington@creighton.edu), NE 68102. *Low regularity global solutions to a generalized Leray-alpha equation.*

It has recently become common to study many different approximating equations of the Navier-Stokes equation. One of these is the Leray-α equation, which regularizes the Navier-Stokes equation by replacing (in most locations) the solution u with $(1-\alpha^2\triangle)u$. Another is the generalized Navier-Stokes equation, which replaces the Laplacian with a Fourier multiplier with symbol of the form $-|\xi|^\gamma$ ($\gamma = 2$ is the standard Navier-Stokes equation), and recently in [**?**] Tao also considered multipliers of the form $-|\xi|^\gamma/g(|\xi|)$, where g is (essentially) a logarithm. The generalized Leray-α equation combines these two modifications by incorporating the regularizing term and replacing the Laplacians with more general Fourier multipliers, including allowing for g terms similar to those used in [**?**]. Here we prove the existence of unique, low regularity solutions to the generalized Leray-alpha equation with non-L^2 initial data. (Received January 17, 2015)

1108-35-326 **Tao Huang**, **Chun Liu**, **Fanghua Lin** and **Changyou Wang***, 150 N. University Street, West Lafayette, IN 47907. *Existence of finite time singularity of nematic liquid crystal flow in dimension three.* Preliminary report.

In this talk, I will present two constructions of finite time singularity for the hydrodynamic flow of nematic liquid crystals, which is a simplified version of Ericksen-Leslie system modeling the macroscopic motion of the orientation director of nematic liquid crystal molecules and the fluid velocity field. This is a joint paper with Tao Huang, Chun Liu, and Fanghua Lin. (Received January 17, 2015)

1108-35-336 **Jason Metcalfe*** (`metcalfe@email.unc.edu`), Department of Mathematics, University of North Carolina, Chapel Hill, NC 27599-3250. *Local well-posedness for quasilinear Schrodinger equations.*

We will discuss ongoing joint work with J. Marzuola and D. Tataru concerning low regularity local well-posedness results for quasilinear Schrodinger equations. Our results establish new benchmarks in terms of the required regularity for such equations to be well-posed. The function spaces in which we work incorporate a summability over cubes in order to deal with issues arising from the Mizohata integrability condition / the infinite speed of propagation. (Received January 18, 2015)

1108-35-343 **Gurgen Hayrapetyan***, hayrapet@ohio.edu, and **Keith Promislow**. *Stability and evolution of bilayer interfaces in amphiphilic systems.*

Functionalized energies, such as the Functionalized Cahn-Hilliard, model phase separation in amphiphilic systems, in which interface production is energetically favorable, but is limited by competition for surfactant phase, which wets the interface. This is in contrast to classical phase-separating energies, such as the Cahn-Hilliard, in which interfacial area is energetically penalized. Gradient flows of the Functionalized Cahn-Hilliard free energy produce network morphologies which have significant applications to biomembranes, as well as to membrane separators in energy conversion devices such as fuel cells and Lithium ion batteries. We discuss the stability and evolution of bilayer interfaces, including the onset of pearling bifurcations which lead to development of pore dominated network morphologies. (Received January 18, 2015)

1108-35-348 **Adam Coffman*** (`coffmana@ipfw.edu`), Dept of Mathematical Sciences, IPFW, 2101 E. Coliseum Blvd., Fort Wayne, IN 46805-1499, and **Yifei Pan** and **Yuan Zhang**. *Continuous solutions of nonlinear Cauchy-Riemann equations and pseudoholomorphic curves in normal coordinates.*

Elliptic regularity holds for the single-variable nonlinear Cauchy-Riemann equation $\partial u/\partial\bar{z} = E(z,u)$, under some weak assumptions. In some cases where the inhomogeneous term has a separable factorization, $E = g(z)f(u)$, the set of continuous solutions can be explicitly calculated. As an application, we find local parametric formulas for pseudoholomorphic curves with respect to some continuous almost complex structures. (Received January 18, 2015)

1108-35-350 **Jennifer Beichman*** (`beichman@math.wisc.edu`). *Nonstandard dispersive estimates and linearized water waves.*

In this talk, we focus on understanding the relationship between the decay of a solution to the linearized water wave problem and its initial data. We obtain decay bounds for a class of 1D dispersive equations that includes the linearized water wave. These decay bounds display a surprising growth factor, which we show is sharp. A further exploration leads to a result relating singularities of the initial data at the origin in Fourier frequency to the regularity of the solution. (Received January 18, 2015)

1108-35-351 **Deniz Bilman*** (`dbilma2@uic.edu`), Department of Mathematics, University of Illinois at Chicago, 851 S Morgan St, Chicago, IL 60607, and **Irina Nenciu**. *On the evolution of scattering data under perturbations of the Toda lattice.*

We present the results of an analytical and numerical study of the long-time behavior for certain Fermi-Pasta-Ulam (FPU) lattices viewed as perturbations of the completely integrable Toda lattice. Our main tools are the direct and inverse scattering transforms for doubly-infinite Jacobi matrices, which are well-known to linearize the Toda flow. We focus in particular on the evolution of the associated scattering data under the perturbed vs. the unperturbed equations. (Received January 19, 2015)

1108-35-352 **Khaldoun Al-Yasiri*** (alyasiri@msu.edu), 619 Red ceder Rd., C 537 Wells Hall, E. Lansing, MI 48824, and **Zhengfang Zhou**. *Elliptic estimates for solutions to divergence form elliptic equations with piecewise constant coefficients in dimension n by using integral equation method.*

In a bounded C^{1,α_0} domain $\Omega \subset \mathbb{R}^n$ that contains two C^{1,α_0} subdomains, $0 < \alpha_0 \le 1$, where the subdomains are separated from the boundary of Ω, we consider an elliptic equation in divergence form with piecewise constant coefficients. The solution of the elliptic equation has an integral representation in terms of potential functions defined on the boundary of each subdomain when the subdomains are separated from each other. We derive a uniform piecewise $C^{1,\alpha}$, $0 < \alpha < \alpha_0$, estimates for this solution which are independent of the distances between the subdomains. This extends the earlier results for $n = 2$. (Received January 18, 2015)

1108-35-371 **Keith Promislow*** (kpromisl@math.msu.edu), Department of Mathematics, East Lansing, MI 48824. *Continuum Models for High Molarity Electrolyte Solutions.*

Differential capacitance data is one of the most widely used experimental quantities for characterizing the structure of electrolyte solutions near charged interfaces. Many studies have attempted to fit differential capacitance data to generalized Poisson-Boltzmann models, particularly to account for finite-volume, ion-crowding effects. We consider the inverse problem: the derivation of generalized Poisson-Boltzmann type free energies from prescribed differential capacitance data. The method is applied to differential capacitance data obtained from experiments and from theoretical models typically found in the literature. In particular, we show that differential capacitance data can not uniquely determine finite volume effects, and provide examples for models which give rise to the same differential capacitance data but characterize solutions with very different qualitative features. Further, we show that uniqueness within the class of generalized Poisson-Boltzmann free energies requires knowledge of the excess chemical potential of the system in the bulk (spatially uniform) state. We discuss applications of the derived free energies to models of pore formation within ionomer membranes. (Received January 18, 2015)

1108-35-381 **Nung Kwan Yip*** (yip@math.purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907, and **Chaoqun Huang** (cqhuang@hnu.edu.cn), Hunan University, 2 Lushan South Road, Yuelu, Changsha, Hunan , Peoples Rep of China. *Bifurcation of Singularly Perturbed Transition Layer Problem in Inhomogeneous Medium.*

We present results of a one-dimensional singularly perturbed transition layer problem (such as Allen-Cahn equation) in inhomogeneous media that undergo some bifurcation phenomena. The quantitative connection (similarities and differences) between the diffuse layer and reduced problems are demonstrated. It is the first result that simultaneously takes into account the presence of singular perturbation, spatial inhomogeneity and bifurcation. (Received January 19, 2015)

1108-35-406 **Patricia Bauman** and **Guanying Peng*** (pengggg@ucmail.uc.edu). *Analysis of the Lawrence-Doniach model for layered superconductors in magnetic fields.* Preliminary report.

We analyze minimizers of the Lawrence-Doniach energy for layered superconductors occupying a bounded generalized cylinder. For an applied magnetic field $\vec{H}_{ex} = h_{ex}\vec{e}_3$ that is perpendicular to the layers with $|\ln\epsilon| \ll h_{ex} \ll \epsilon^{-2}$ as $\epsilon \to 0$, where ϵ is the reciprocal of the Ginzburg-Landau parameter, we prove an asymptotic formula for the minimum Lawrence-Doniach energy as ϵ and the interlayer distance s tend to zero. We establish comparison results between the minimum Lawrence-Doniach energy and the minimum $3D$ anisotropic Ginzburg-Landau energy. We also discuss some results on the minimum Lawrence-Doniach energy with the applied magnetic field in the regime $h_{ex} = O(|\ln\epsilon|)$. (Received January 19, 2015)

1108-35-407 **L Korobenko**, Hamilton, Ontario , Canada, **C Rios**, Calgary, Alberta , Canada, **E Sawyer***, 1280 Main St. W., Hamilton, Ontario , Canada, and **R Shen**, Hamilton, Ontario , Canada. *Local boundedness and continuity of weak solutions to certain infinitely degenerate elliptic equations with rough coefficients.* Preliminary report.

We report on work in progress on establishing local boundedness and continuity of weak solutions to L = (d/dx)2 + f(x)(d/dy)2 where f is rough and vanishes to infinite order at 0. The corresponding case when f is smooth in known to be hypoelliptic from work of Fedii. (Received January 19, 2015)

1108-35-424 **Mathew Johnson*** (matjohn@ku.edu). *Stability of Viscous Roll Waves.*
Roll-waves are a well observed hydrodynamic instability occurring in inclined thin film flow, mathematically described as periodic traveling wave solutions of the St. Venant system. In this talk, I will discuss recent progress concerning the stability of viscous roll-waves in a variety of asymptotic regimes, including near the onset of hydrodynamic instability and in the inviscid limit.

This is joint work with Blake Barker (Brown), Pascal Noble (University of Toulouse), L. Miguel Rodrigues (University of Lyon), and Kevin Zumbrun (Indiana University). (Received January 19, 2015)

1108-35-431 **Hans Christianson*** (hans@math.unc.edu), CB #3250 Dept. of Mathematics, UNC, Chapel Hill, NC 27599, and **Dylan Muckerman**. *Local Smoothing Estimates near a Trapped Set with Infinitely Many Connected Components.*
We prove a local smoothing result for the Schrodinger equation on a class of surfaces of revolution which have infinitely many trapped geodesics. Our main result is a local smoothing estimate with loss depending on the accumulation rate of the critical points of the profile curve. The proof uses an h-dependent version of semiclassical propagation of singularities, and a result on gluing an h-dependent number of cutoff resolvent estimates. (Received January 19, 2015)

1108-35-442 **Peng Feng*** (pfeng@fgcu.edu), 11501 FGCU Blvd. S., Fort Myers, FL 33965. *Dynamics and pattern formation in a modified Leslie-Gower model with Allee effect and Bazykin functional response.*
In this talk, we study the dynamics of a modified Leslie Gower model with Allee effect. We give detailed study on the stability of equilibria. Nonexistence of nonconstant positive steady state solutions are shown to identify the rage of parameters of spatial pattern formation. We also give the conditions of Turing instability and perform a series of numerical simulations and find that the model exhibits complex patterns. (Received January 19, 2015)

1108-35-445 **William Rundell***, Department of Mathematics, Texas A&M University, College Station, TX 77843-3368, and **Bangti Jin**, Department of Computer Science, University College London, Gower Street, London, UK WC1E 6BT, United Kingdom. *A tail of two distributions; case studies for two classical inverse problems for fractional derivatives.*
Two classical inverse problems that exhibit extreme ill-conditioning are the backwards heat problem and the sideways heat problem. This talk looks at these when the heat operator is changed to one involving fractional derivatives. The results obtained are surprising and show that the physics involved gives rise to quite different outcomes. (Received January 19, 2015)

1108-35-464 **Matthew D Blair*** (blair@math.unm.edu). *L^p norms of eigenfunctions and Kakeya-Nikodym averages.*
We consider the problem of determining optimal upper bounds on the growth of L^p norms of eigenfunctions of the Laplacian on a compact Riemannian manifold in the high frequency limit. After an introduction to the problem, we will discuss recent works relating such upper bounds to mass concentration in frequency dependent tubes about geodesic segments. When the manifold has nonpositive sectional curvatures, it can be shown that the criteria developed here yields improved L^p bounds on the eigenfunctions. These are results in joint works with C. Sogge and S. Zelditch. (Received January 19, 2015)

1108-35-483 **Nestor Guillen** and **Russell W. Schwab*** (rschwab@math.msu.edu). *Neumann Homogenization via Integro-Differential Operators.*
We use a recent result about the representation of the Dirichlet-to-Neumann operator for fully nonlinear equations as an integro-differential operator on the boundary of the domain to guide the analysis of the homogenization problem with oscillatory Neumann data. This allows us to attack the homogenization problem as a nonlocal homogenization on the boundary, which is amenable to methods already established for integro-differential equations. We will present the case of a infinite strip domain with almost periodic Neumann data. The emphasis will be on the method of converting the Neumann analysis into an auxiliary nonlocal problem which lives only on the boundary. This is joint work with Nestor Guillen. (Received January 19, 2015)

1108-35-484 **Nestor D Guillen*** (nguillen@math.umass.edu), University of Massachusetts, Amherst, MA 01002, and **Maria Gualdani**. *Remarks on radial solutions to the homogeneous Landau equation with Coulomb potential.*
We obtain pointwise upper bounds for radially symmetric and monotone solutions to the homogeneous Landau equation with Coulomb potential. Roughly speaking, the estimates say that blow up in the L^∞-norm at time T can occur only if the local $L^{3/2}$-norm of the solution divided by its Newtonian potential blows up. The bounds

are obtained using the comparison principle for the Landau equation and for the associated mass function. This method does not go as far as preventing blow for the Landau equation, but it does achieve this much for the isotropic version of the Landau equation with Coulomb potential, recently introduced by Krieger and Strain. (Received January 19, 2015)

1108-35-489 **Vera Mikyoung Hur***, Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W Green Street, Urbana, IL 60801. *Breaking the Waves.*

It is a matter of experience that the surface of an ocean wave, after some time, may become vertical and accelerate infinitely rapidly; thereafter a portion of the surface overturns, projects forward and forms a jet of water. Think of the stunning Hokusai wave. I will begin by going over laboratory experiments and numerical simulations which support "breaking" of water waves. I will talk about recent analytical proofs of splash singularity in *exact* water waves. The complexity of the governing equations habitually prevents a detailed account, though. I will then discuss various approximate models of water waves, blowup of their solutions and ill-posedness. (Received January 19, 2015)

1108-35-504 **Jonathan Bohn*** (bohnjona@msu.edu), Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48824. *Global Carleman Estimates for Waves with Variable Coefficients.*

In this talk, we consider global Carleman estimates for the wave equation with variable coefficients. We derive improvements on the admissible class of functions for which such inequalities hold in the one dimensional case. In turn, this allows for the formation of control functions by constructive methods. For the Carleman estimate, the main idea is to introduce an appropriate weight function that satisfies a certain set of inequalities to give bounds on energy terms for a sufficiently large enough time. From there, a modified approach to a known duality method ensures the existence of suitable controls. Some progress on higher dimensions will also be reported. (Received January 20, 2015)

1108-35-505 **Giles Auchmuty** and **Manki Cho*** (realmann@math.uh.edu). *Boundary Integrals and Approximation of Harmonic Functions.*

Steklov expansions for a harmonic function on a rectangle are analyzed. The value of a harmonic function at the center of a rectangle is shown to be well approximated by the mean value of the function on the boundary plus a very small number (often 3 or fewer) of additional boundary integrals. Similar approximations are found for the central values of solutions of Robin and Neumann boundary value problems. These results are based on finding explicit expressions for the Steklov eigenvalues and eignfunctions. This is joint work with Professor Giles Auchmuty. (Received January 20, 2015)

1108-35-509 **Michael Hinz*** (mhinz@math.uni-bielefeld.de), University of Bielefeld, Department of Mathematics, P.O. Box 100131, 33501 Bielefeld, Germany. *Some remarks on nonlinear PDE on fractals.*

In this talk we deal with some recent results for PDE on fractals. The equations we consider may have nonlinear terms that involve gradients. We discuss how classical methods transfer to fractals that carry a suitable energy (Dirichlet or resistance) form. As examples we discuss (1) weak solutions to a fractal analog of Burger's equation and (2) some items of the calculus of variations. (Received January 20, 2015)

1108-35-534 **Chi Hin Chan** and **Magdalena Czubak*** (czubak@math.binghamton.edu). *Liouville theorems for the Navier-Stokes equation on the hyperbolic space.*

The problem for the stationary Navier-Stokes equation in 3D under finite Dirichlet norm is open. In this talk we answer the analogous question on the 3D hyperbolic space. This is joint work with Chi Hin Chan. (Received January 20, 2015)

1108-35-555 **Khaldoun Al-Yasiri*** (alyasiri@msu.edu), 619 Red ceder Rd., C 537 Wells Hall, E. Lansing, MI 48824, and **Zhengfang Zhou**. *Elliptic estimates for solutions to divergence form elliptic equations with piecewise constant coefficients in dimension n by using integral equation method.*

In a bounded C^{1,α_0} domain $\Omega \subset \mathbb{R}^n$ that contains two C^{1,α_0} subdomains, $0 < \alpha_0 \leq 1$, where the subdomains are separated from the boundary of Ω, we consider an elliptic equation in divergence form with piecewise constant coefficients. The solution of the elliptic equation has an integral representation in terms of potential functions defined on the boundary of each subdomain when the subdomains are separated from each other. We derive a uniform piecewise $C^{1,\alpha}$, $0 < \alpha < \alpha_0$, estimates for this solution which are independent of the distances between the subdomains. This extends the earlier results for $n = 2$. (Received January 20, 2015)

1108-35-557 **Alin Pogan*** (pogana@miamioh.edu), Miami university, Department of Mathematics, Oxford, OH 45056. *O(2) Hopf bifurcation of viscous shock waves in a channel.*

We study $O(2)$ transverse Hopf bifurcation, or "cellular instability", of viscous shock waves in an infinite channel, with periodic boundary conditions, for a class of hyperbolic-parabolic systems including the equations of thermoviscoelasticity. Due to the refection symmetry property of our model, the underlying bifurcation is not of planar Hopf type, but, rather, a four-dimensional $O(2)$ Hopf bifurcation: roughly speaking, a "doubled" Hopf bifurcation coupled by nonlinear terms. Since the linearized operator about the wave has no spectral gap, the standard center manifold theorems do not apply; indeed, existence of a center manifold is unclear. To prove the result, we use the Lyapunov–Schmidt reduction method applied to the time-T evolution map of the underlying perturbation equations, resulting in a 4-dimensional stationary bifurcation problem with $O(2)$ symmetry plus an additional "approximate S^1 symmetry" induced by the underlying rotational linearized flow. (Received January 20, 2015)

1108-35-578 **Michael G Dabkowski*** (mgdabkow@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, and **Joseph Conlon** and **Jingchen Wu**. *Fractional Differentiation Operators as Models of Diffusion.*

We study of a diffusive perturbation of the linear Lifschitz-Slyozov-Wagner model introduced by Carr and Penrose. A main subject of interest is to understand how the presence of diffusion acts as a selection principle, which singles out a particular self-similar solution of the linear Lifschitz-Slyozov- Wagner model as determining the large time behavior of the diffusive model. A selection principle is rigorously proven for a model which is a semi-classical approximation to the diffusive model. Upper bounds on the rate of coarsening are also obtained for the full diffusive model. (Received January 20, 2015)

1108-35-589 **Peiyong Wang*** (pywang@math.wayne.edu), 656 W.Kirby, 1150 FAB, WSU, Detroit, MI 48202. *A Free Boundary Problem Associated With The p-Laplacian.*

A free boundary problem associated with the p-Laplacian will be introduced, with the existence of a minimizer and a free boundary condition being proved. In addition, non-uniqueness and non-degeneracy of a minimizer is going to be shown. At last, some partial regularity of the free boundary will be presented. The proof of the well-posedness of the problem with the p-Laplacian in general differs substantially from that of the classical problem for the Laplacian in that many nice and useful properties are absent in the general case. In particular, a counterpart of a monotonicity formula for the Laplacian is missing in the general situation. So one needs to find alternatives to secure the above-mentioned results. (Received January 21, 2015)

37 ► Dynamical systems and ergodic theory

1108-37-10 **Michel L. Lapidus** (lapidus@math.ucr.edu), 900 Big Springs Rd., Surge Building, Department of Mathematics, Riverside, CA 92521, **Robyn L. Miller** (rmiller@mrn.org), The MIND Research Network, Albuquerque, NM 87131, and **Robert G. Niemeyer*** (niemeyer@math.unm.edu), University of New Mexico, 311 Terrace NE MSC01 1115, Science and Math Learning Center, Albuquerque, NM 87131. *Result results on the T-fractal billiard.*

We present our latest results on orbits of the T-fractal billiard table. We survey some known results on the T-fractal billiard before presenting an example of an orbit with an irrational slope that 1) converges to a rational elusive point and 2) does so in a way that is consistent with how a nontrivial path in a rational direction is constructed. Other recent results will be presented. (Received October 18, 2014)

1108-37-142 **Boris Kalinin*** (kalinin@psu.edu) and **Victoria Sadovskaya** (sadovskaya@psu.edu). *Holonomies and cohomology for cocycles over partially hyperbolic diffeomorphisms.*

We consider group-valued cocycles over a partially hyperbolic diffeomorphism which is accessible volume-preserving and center bunched. We study cocycles with values in the group of invertible continuous linear operators on a Banach space. We describe properties of holonomies for fiber bunched cocycles and establish their Holder regularity. We also study cohomology of cocycles and its connection with holonomies. We obtain a result on regularity of a measurable conjugacy, as well as a necessary and sufficient condition for existence of a contionuous conjugacy between two cocycles. (Received January 08, 2015)

1108-37-146 **Hongkun Zhang*** (hongkunz@gmail.com), Department of Mathematics, University of Houston, Houston, TX 77004, and **Luke Mohr**. *Superdiffusion constants for certain nonuniformly hyperbolic systems.* Preliminary report.

We investigate deterministic superdiffusion in nonuniformly hyperbolic system models, which following the abnormal central limit theorem. We construct a martingale approximation, following the idea of Doob's decomposition theorem; and we obtain a pronounced formula for the superdiffusion constant, in terms of fine structure that originated in the phase transitions as well as the geometry of the configuration domains of the systems. The main models satisfying our main assumptions including chaotic Lorentz gas, Bunimovich stadia, billiard with cusps and other nonuniformly hyperbolic systems with slow decay rates of correlations of order O(1/n). This is a joint work with Luke Mohr. (Received January 08, 2015)

1108-37-153 **Yunping Jiang*** (yunping.jiang@qc.cuny.edu), Department of Mathematics, Queens College of CUNY, 65-30 Kissena Blvd, Flushing, NY 11367. *The Ruelle Operator Theorem for Expansive and Non-Expansive Systems.*

The Ruelle operator theorem studies the existence and the uniqueness of an equilibrium state and the decay rate of correlation for a given dynamical system. In this talk, I will give a review about my work, partly with Aihua Fan and partly with Yuan-Ling Ye on the Ruelle operator theorem for expansive and non-expansive dynamical systems and iterated function systems (Received January 08, 2015)

1108-37-155 **Zhihong Jeff Xia** (xia@math.northwestern.edu) and **Pengfei Zhang*** (pzhang@math.uh.edu). *Homoclinic points for generic convex billiards.*

Kupka-Smale Theorem implies that, C^r-generically, each homoclinic orbit, if exists, is the transversal intersection of invariant manifolds. It is unknown that whether the homoclinic orbits exist C^r-generically. In this talk I will give a brief introduction of some recent progresses for surface diffeomorohisms, and describe the dynamical billiards on convex domains. Then we prove that C^r generically, there exists some homoclinic orbit for every hyperbolic periodic point of the billiard system. This is a joint work with Zhihong Jeff Xia. (Received January 08, 2015)

1108-37-181 **Kelly McQuighan*** (kmcquigh@bu.edu), 111 Cummington Mall, Boston, MA 02215, and **Bjorn Sandstede** (bjorn_sandstede@brown.edu), 182 George St, Providence, RI 02912. *Oscillons Near Hopf Bifurcations of Planar Reaction Diffusion Equations.* Preliminary report.

Oscillons are planar, spatially localized, temporally oscillating, radially symmetric structures often arising near forced Hopf bifurcations. Using spatial dynamics, we show that the dynamics on the center manifold of a periodically forced reaction diffusion equation (fRD) near a Hopf bifurcation can be captured by the forced complex Ginzburg—Landau equation (fCGL). Thus, oscillon solutions to the fRD can be thought of as a foliation over localized solutions to the fCGL. (Received January 11, 2015)

1108-37-190 **Noa Kraitzman*** (kraitzm1@msu.edu), 619 Red Cedar Road, East Lansing, MI 48824. *Bifurcation and competitive evolution of network morphologies in the strong Functionalized Cahn-Hilliard equation.*

The FCH is a higher-order free energy for blends of amphiphillic polymers and solvent which balances solvation energy of ionic groups against elastic energy of the underlying polymer backbone. Its gradient flows describe the formation of solvent network structures which are essential to ionic conduction in polymer membranes. The FCH possesses stable, coexisting network morphologies and we characterize their geometric evolution, bifurcation and competition through a center-stable manifold reduction which encompasses a broad class of coexisting network morphologies. The stability of the different networks is characterized by the meandering and pearling modes associated to the linearized system. For the H^{-1} gradient flow of the FCH energy, using functional analysis and asymptotic methods, we drive a sharp-interface geometric motion which couples the flow of co-dimension 1 and 2 network morphologies, through the far-field chemical potential. In particular, we derive expressions for the pearling and meandering eigenvalues for a class of far-from-self-intersection co-dimension 1 and 2 networks, and show that the linearization is uniformly elliptic off of the associated center stable space. (Received January 12, 2015)

1108-37-241 **Nicolai Haydn** and **Fan Yang*** (yang617@usc.edu), 3620 S. Vermont Ave, KAP 104, Los Angeles, CA 90089. *Hitting Time Distribution for Dynamical Balls.*

For measure preserving systems with α-mixing property, we prove that the first hitting times of Bowen-balls have approximately exponential law if the measure has certain regularity. We also look at higher order return times of both cylinders and Bowen-balls and prove that the limiting distributions are Poissonian under proper mixing conditions. Finally, we show that the Poincaré return time of a typical n Bowen-ball is at least n. (Received January 15, 2015)

1108-37-278 **Elizabeth J Makrides*** (elizabeth_makrides@brown.edu), Division of Applied Mathematics, Brown University, 182 George St, Box F, Providence, RI 02912, and **Bjorn Sandstede** (bjorn_sandstede@brown.edu), Division of Applied Mathematics, Brown University, 182 George St, Box F, Providence, RI 02912. *Stability in Spatially Localized Patterns.*

Motivated by numerical stability results on spatially localized patterns in spatially extended systems, we show how the stability of patterns that are formed of nonlocalized fronts can be understood from the spectra of the underlying fronts. We use extended Evans functions to understand the spectral properties of these patterns on the original unbounded domain and on large but bounded domains, and we compare our results to previous findings on resonance poles and edge bifurcations. (Received January 16, 2015)

1108-37-311 **Vaughn Climenhaga**, **Todd Fisher** and **Daniel J Thompson*** (thompson@math.osu.edu). *Equilibrium States for robustly transitive systems II.*

We establish results on uniqueness of equilibrium states for the well-known Mañé and Bonatti-Viana classes of robustly transitive diffeomorphisms. This is an application of machinery developed by Vaughn Climenhaga and myself, which applies when systems satisfy suitably weakened versions of expansivity and the specification property. This talk is a sequel to Todd Fisher's talk, and will focus on the general methods and ideas which drive all these results. This is joint work with Vaughn Climenhaga (Houston) and Todd Fisher (Brigham Young). (Received January 17, 2015)

1108-37-314 **Vaughn Climenhaga** and **Todd Fisher*** (tfisher@mathematics.byu.edu), Department of Mathematics, 274 TMCB, Provo, UT 84602, and **Dan Thompson**. *Equilibrium states for robustly transitive systems.*

We will prove existence and uniqueness of equilibrium states for a large class of potential functions associated with certain robustly transitive diffeomorphisms. (Received January 17, 2015)

1108-37-320 **Eriko Hironaka***, hironaka@math.fsu.edu. *Mixed-sign Coxeter mapping classes.* Preliminary report.

In this talk I will describe mixed-sign Coxeter systems, and their associated mapping classes. Unlike in the case of classical Coxeter mapping classes, there are associated pseudo-Anosov mapping classes with arbitrarily small dilatation. I will also discuss the relation between families of graphs, and corresponding mapping classes that give rise to convergent sequences on the fibered face of a single 3-manifold. (Received January 17, 2015)

1108-37-334 **Samuel J. Roth*** (sjroth@iupui.edu) and **Michal Misiurewicz**. *Degree One Liftings in Dimension Zero.*

We study countable state Markov chains. We define a notion of "degree one lifting," mimicking ideas from circle maps in one-dimensional dynamics. We analyze our chains from the point of view of entropy and conformal measures. (Received January 18, 2015)

1108-37-380 **Jerome Rousseau*** (jerome.rousseau@ufba.br). *Hitting time statistics for random dynamical systems.*

In this talk, we will give a quick overview of recent results on law of rare events for random dynamical systems.

For super-polynomially mixing random dynamical systems, we obtain an exponential law (with respect to the invariant measure of the skew-product).

For random subshifts of finite type, we analyze the distribution of hitting times with respect to the sample measures. We prove that with a superpolynomial decay of correlations one can get an exponential law for almost every point and with stronger mixing assumptions one can get a law of rare events depending on the extremal index for every point. (These are joint works with Benoit Saussol and Paulo Varandas, and Mike Todd). (Received January 19, 2015)

1108-37-392 **Yao Li*** (yaoli@cims.nyu.edu), 251 Mercer Street, New York, NY 10003, and **Lai-Sang Young**. *Nonequilibrium steady-states for some interacting particle systems.*

In this talk I will present our recent results on non-equilibrium steady states (NESS) for a class of microscopic heat conduction models, in which energy exchange among particles is mediated by a lattice of "energy tanks". Those heat conduction models are derived from billiards-like mechanical chain models (Eckmann & Young 2006) by randomizing certain chaotic quantities. We proved various rigorous results including the existence and uniqueness of NESS, the exponential convergence towards NESS, and the slow (polynomial) mixing phenomenon under some relaxed conditions. (Received January 19, 2015)

1108-37-405 **Yanxia Deng*** (dengyx@math.northwestern.edu), 2033 sheridan road, Mathematics Department, Evanston, IL 60208. *Instability of Periodic Extremals by Conley-Zehnder Index Theory.* Preliminary report.

We study the connections between the stability properties, the Morse index and the Conley-Zehnder index of a periodic extremal in Lagrangian systems. One consequence of our result is that an isolated minimizing closed geodesic in an even dimensional space is always unstable. (Received January 19, 2015)

1108-37-417 **Yun Yang*** (summeryangyun@gmail.com), 1133 E 61 st street, Apt 3, Chicago, IL 60637. *Livšic measurable rigidity theorem for $\mathcal{C}^1$ generic volume-preserving Anosov systems.*

Let $T : M \to M$ be a diffeomorphism on a compact Riemannian manifold M. We consider a **cocycle** $\mathcal{A} : \mathbb{Z}\times M \to \mathbb{R}$; that is, a map satisfying the cocycle relation $\mathcal{A}(n_1 + n_2, x) = \mathcal{A}(n_1, T^{n_2}(x)) + \mathcal{A}(n_2, x)$, for every $n_1, n_2 \in \mathbb{Z}$ and every $x \in M$. If a cocycle $\mathcal{A} : \mathbb{Z} \times M \to \mathbb{R}$ is Hölder continuous, can we get a Hölder continuous solution Φ to equation $\mathcal{A}(n, x) = \Phi(T^n(x)) - \Phi(x)$ from a measurable solution? We call results answering this question Livšic measurable rigidity theorem. We will show that for $\mathcal{C}^1$ generic volume-preserving Anosov diffeomorphisms of a compact Riemannian manifold, Livšic measurable rigidity theorem holds. (Received January 19, 2015)

1108-37-430 **Vaughn Climenhaga*** (climenha@math.uh.edu), **Dmitry Dolgopyat** and **Yakov Pesin**. *Effective hyperbolicity and SRB measures.*

We describe a notion of "effective hyperbolicity" that can be used to prove Hadamard-Perron theorems and establish existence of SRB measures for non-uniformly hyperbolic systems, even in the absence of the usual tools such as a dominated splitting or countable Markov structure. (Received January 19, 2015)

1108-37-439 **Viorel Nitica*** (vnitica@wcupa.edu). *Invariant distributions for parabolic flows in SL(2,C).* Preliminary report.

We will show how to find invariant distributions for certain parabolic flows in SL(2,C). (Received January 19, 2015)

1108-37-467 **Tracy Lin Payne*** (payntrac@isu.edu), Mathematics Department, Idaho State University, 921 S. 8th St., Pocatello, ID 83209-8085. *Applying evolutionary game theory to geometric flows.* Preliminary report.

In the presence of symmetry, the Ricci flow for a manifold may be expressed as a system of ordinary differential equations. Geometric flows for discrete geometries may be expressed as systems of ordinary differential equations as well; one such example is the combinatorial Ricci flow for a triangulated surface.

The equations for the Ricci flow for homogeneous spaces are of the same form as the generalized Lotka-Volterra equations which arise in population biology. Inspired by this, we view geometric flows which can be encoded as a system of ODEs from the point of view of evolutionary game theory. We find that the many familiar geometric flows arise as replicator equations. We propose new geometric evolution laws taken from standard models in evolutionary game theory. One example is the best response flow, a differential inclusion whose trajectories are almost everywhere lines.

We interpret game-theoretic notions such as the Nash equilibrium geometrically, and we apply results from evolutionary game theory to geometric flows. We give phase plane portraits for a variety of geometries and flows. (Received January 19, 2015)

1108-37-506 **Xu Zhang*** (zhangx94@math.msu.edu), Dept. of Math., Michigan State Univ., 619 Red Cedar Rd., East Lansing, MI 48824. *Subexponential decay of correlations for "almost Anosov" diffeomorphisms.*

The correlation function of a system is used to describe how fast the state of the system becomes uncorrelated with its future status, and to estimate this function is a very interesting problem in dynamical systems. In this talk, we will investigate the subexponential lower and upper bounds for the correlation functions of a class of two-dimensional "almost Anosov" diffeomorphisms by using the renewal theory, where the "almost Anosov" system is a system which is hyperbolic everywhere except for one point. This is a joint work with Prof. Huyi Hu. (Received January 20, 2015)

1108-37-525 **Jianyu Chen*** (jychen@math.msu.edu), C236 Wells Hall, Department of Mathematics, Michigan State University, East Lansing, MI 48823, and **Huyi Hu**. *Exponential mixing of torus extension over expanding maps.*

We study the mixing property for the skew product $F : T^d \times T^l \to T^d \times T^l$ given by $(x, y) \to (Tx, y + \tau(x))$, where $T : T^d \to T^d$ is a C^∞ uniformly expanding endomorphism, and the fiber map $\tau : T^d \to T^l$ is a C^∞ map. We apply the semiclassical approach to show the dichotomy: either F mixes exponentially fast or τ is an essential coboundary. This is a joint work with Huyi Hu. (Received January 20, 2015)

1108-37-526 **Jianyu Chen*** (jychen@math.msu.edu), C236 Wells Hall, Department of Mathematics, Michigan State University, East Lansing, MI 48823, and **Huyi Hu**. *Exponential mixing of torus extension over expanding maps.*

We study the mixing property for the skew product $F : T^d \times T^l \to T^d \times T^l$ given by $(x, y) \to (Tx, y + \tau(x))$, where $T : T^d \to T^d$ is a C^∞ uniformly expanding endomorphism, and the fiber map $\tau : T^d \to T^l$ is a C^∞ map. We apply the semiclassical approach to show the dichotomy: either F mixes exponentially fast or τ is an essential coboundary. This is a joint work with Huyi Hu. (Received January 20, 2015)

39 ► Difference and functional equations

1108-39-191 **Taylor Anderson**, **Gregory Faye** and **Arnd Scheel*** (scheel@umn.edu), School of Mathematics, 206 Church St SE, Minneapolis, MN 55455, and **David Stauffer**. *Pinning and unpinning in nonlocal systems.*

We investigate pinning regions and unpinning asymptotics in nonlocal equations. We show that phenomena are related to but different from pinning in discrete and inhomogeneous media. We establish unpinning asymptotics using geometric singular perturbation theory in several examples. We also present numerical evidence for the dependence of unpinning asymptotics on regularity of the nonlocal convolution kernel. (Received January 12, 2015)

41 ► Approximations and expansions

1108-41-25 **Radu Balan*** (rvbalan@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742, and **Dongmian Zou** (zou@math.umd.edu), AMSC Program, University of Maryland, College Park, MD 20742. *Phase Retrieval using Lipschitz Continuous Maps.* Preliminary report.

In this note we prove that reconstruction from magnitudes of frame coefficients (the so called "phase retrieval problem") can be performed using Lipschitz continuous maps. Specifically we show that when the nonlinear analysis map $\alpha : H \to R^m$ is injective, with $(\alpha(x))_k = | < x, f_k > |$, where $\{f_1, ..., f_m\}$ is a frame for the Hilbert space H, then it is bi-Lipschitz on $\hat{H}$ endowed with the natural metric $D_2(x, y) = \min_\varphi ||x - e^{i\varphi} y||_2$. (Received November 14, 2014)

1108-41-32 **Somayeh Mashayekhi*** (sm2395@msstate.edu), 21 Ace Ave, Starkville, MS 39759. *New numerical method for Fractional calculus.*

Due to the extensive applications of dynamical systems with fractional order (DSFOs) in engineering and science, research in this area has grown significantly, and there has been considerable interest in developing numerical schemes for their solution. Spectral method is one of the numerical methods that is used to find the solution of DSFOs. Two different attempts were performed in this area. In the first attempt, mathematicians tried to introduce a new base that usually was called Jacobi polyfractonomials. Jacobi polyfractonomials were used as a trail function to find the approximation of solution for dynamical systems with fractional order. However, this new trail function has some limitation.In the other attempt, authors tried to use classical orthogonal functions or wavelet of orthogonal functions as a trail function. Furthermore, for solving DSFOs by these wavelet functions, the operational matrices for fractional order (OMFO) of these wavelets were calculated. But they did not find OMFO directly. In this area we had two important questions. First, Do we need to introduce new base to use as a trial function as they did in the first attempt? Second, can we find OMFO directly without using block-pulse functions. In this work I want to talk about these two question. (Received November 22, 2014)

1108-41-61 **Weihong Guo*** (wxg49@case.edu), 10900 Euclid Avenue, Cleveland, OH 44106, and **Liangjian Deng** (liangjian1987112@126.com) and **Ting-Zhu Huang** (tingzhuhuang@126.com). *Single image super-resolution via an iterative reproducing kernel Hilbert space method.* Preliminary report.

Image super-resolution, a process to enhance image resolution, has important applications in satellite imaging, high definition television, medical imaging, etc. Many existing approaches use multiple lowresolution images to recover one high-resolution image. In this paper, we present an iterative scheme to solve single image super-resolution problems. It recovers a high quality high-resolution image from solely one low-resolution image without using a training data set. We solve the problem from image intensity function estimation perspective and assume the image contains smooth and edge components. We model the smooth components of an image using a thin-plate reproducing kernel Hilbert space (RKHS) and the edges using approximated Heaviside functions. The proposed method is applied to image patches, aiming to reduce computation and storage. Visual and quantitative comparisons with some competitive approaches show the effectiveness of the proposed method. (Received December 18, 2014)

1108-41-89 **Xianfeng (Janice) Hu*** (hxf0204@gmail.com), **Mark Iwen** and **Hyejin Kim**. *Rapidly Computing Sparse Legendre Coefficient Expansions via Sparse Fourier Transforms.*

Algorithms for recovering functions with sparse Chebyshev or Legendre expansions will be discussed. In both situations, SFT techniques can be used to "automatically" generate new sublinear-time interpolation methods for these Fourier-related orthonormal bases by sampling with respect to a relatively simple change of variables (as opposed to subsampling from a uniform grid). We will present these sampling transformations as well as some initial theoretical and numerical results. (Received January 02, 2015)

1108-41-94 **Jean Bourgain**, **Stephen Dilworth**, **Kevin Ford**, **Sergei Konyagin** and **Denka Kutzarova*** (denka@math.uiuc.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, Urbana, IL 61801. *Explicit constructions of RIP matrices.*

We give a new explicit construction of $n \times N$ matrices satisfying the Restricted Isometry Property (RIP). Namely, for some $\epsilon > 0$, large N and any n satisfying $N^{1-\epsilon} \leq n \leq N$, we construct RIP matrices of order $k \geq n^{1/2+\epsilon}$ and constant $\delta = n^{-\epsilon}$. This overcomes the natural barrier $k = O(n^{1/2})$ for proofs based on small coherence, which are used in all previous explicit constructions of RIP matrices. Key ingredients in our proof are new estimates for sumsets in product sets and for exponential sums with the products of sets possessing special additive structure. The paper was published in 2011, but it is still the only proof which breaks the square-root bottleneck. (Received January 03, 2015)

1108-41-95 **Simon Foucart*** (foucart@math.uga.edu). *Semidefinite Programming for Constrained Approximation.*

In this talk, I will detail the theoretical grounds for a semidefinite-programming-based method that computes best approximants by splines under some general constraints and relative to several function norms, notably the max-norm. The method has been implemented as a MATLAB package called Basc, which relies on the two external packages Chebfun and CVX. (Received January 04, 2015)

1108-41-167 **Deguang Han*** (deguang.han@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Frames and erasure recovering from known and unknown locations.* Preliminary report.

We discuss a simple frame based kernel analysis approach to the problem of erasure recovering from either known or unknown locations. This is a joint work with Wenchang Sun. (Received January 09, 2015)

1108-41-189 **Palle E.T. Jorgensen***, Palle Jorgensen, dept of Math MLH, University of Iowa, Iowa City, IA 52242. *Some fractals arising as metric completions of infinite weighted graphs.*

We study a class of fractals arising as metric completions of infinite weighted graphs. The weighted graphs in turn are defined by their vertex set V , their set of edges E , and a conductance function is prescribed on E ; conductance = 1/resistance. From this we get a natural reproducing kernel Hilbert space, which in turn comes with a canonical Parseval-frame, and a resistance metric on V. The associated metric completions are the fractals under consideration; as well as their analysis. (Received January 12, 2015)

1108-41-295 **Somantika Datta*** (sdatta@uidaho.edu) and **Jesse Oldroyd** (jesseo@uidaho.edu). *Approximating Equiangular Tight Frames.*

An equiangular tight frame (ETF) is a set of unit vectors in a Hilbert space such that the modulus of the inner products between pairs of vectors are identical and as small as possible. ETFs have found applications in communications, coding theory, and sparse approximation. It has been shown that ETFs are optimal for signal representation in erasure channels. Therefore, it is highly desirable to construct ETFs. However, in most cases ETFs do not exist and can be very hard to construct when they do exist. This leads to the problem of constructing objects that are in some sense close to ETFs and will be referred to as approximate ETFs.

Two different approaches to obtaining approximate ETFs will be explored. First, instead of requiring the modulus of the inner products between pairs of vectors to be identical, the moduli of these inner products will take values from a set of k values, where k is small. Tight frames having this property will be called k-distance tight frames. Another approach is to construct frames such that (i) all eigenvalues of the frame operator lie in a small interval, and (ii) the modulus of the inner products of the frame vectors also lie in a small interval. These frames are nearly tight and nearly equiangular and offer another way to approximate ETFs. (Received January 16, 2015)

1108-41-515 **Zhihui Zhu** (zzhu@mines.edu) and **Michael B. Wakin*** (mwakin@mines.edu). *New analysis of multiband modulated DPSS dictionaries.*

Discrete Prolate Spheroidal Sequences (DPSS's) form an efficient basis for sampled bandlimited signals. By modulating and merging the DPSS vectors, one can obtain an efficient dictionary for sampled multiband signals. We show that this dictionary provides a very high approximation not only in an MSE sense for random multiband signals, but also for all sampled sinusoids in the targeted bands. We investigate the spectrum of the corresponding time- and multiband- limiting operator. By analyzing the relationship between the subspaces spanned by the true eigenvectors and by the modulated DPSS vectors, we argue that this multiband modulated DPSS dictionary is indeed approximately the optimal one for representing sampled multiband signals. (Received January 20, 2015)

42 ► Fourier analysis

1108-42-12 **Palle E Jorgensen***, Palle Jorgensen, Math MLH, University of Iowa, Iowa City, IA. *New approached to spectral-to tile correspondences.*

In the talk, we will introduce an operator algebraic setting for computing and encoding orthonormal bases, with examples drawn from wavelets and fractal measures. The framework will be Hilbert spaces that arise naturally in iterated function systems, and in signal and image processing. The operator algebras involved will include Cuntz as well as a special family of irreducible representations. Some advantages of these tools are that they offer a new set of effective algorithms. (Received October 21, 2014)

1108-42-22 **Richard G Lynch*** (rglz82@mail.missouri.edu), 202 Mathematical Sciences Bldg, University of Missouri, Columbia, MO 65211. *Weaving Hilbert Space Frames.* Preliminary report.

A new area of research called *Weaving Frames* is introduced. Two frames $\{\varphi_i\}_{i\in I}$ and $\{\psi_i\}_{i\in I}$ for a Hilbert space $\mathbb{H}$ are *weaved* if there are constants $0 < A \leq B$ so that for every subset $\sigma \subset I$, the family $\{\varphi_i\}_{i\in\sigma} \cup \{\psi_i\}_{i\in\sigma^c}$ is a frame for $\mathbb{H}$ with frame bounds A, B. Fundamental properties of weaved frames are developed and key differences between weaving Riesz bases and weaving frames are considered. In particular, it is shown that you cannot weave a Riesz basis with a redundant frame. We also introduce an apparently weaker form of *weaving* but show that it is equivalent to weaving. Weaving frames have potential applications in wireless sensor networks that require distributed processing under different frames, as well as preprocessing of signals using Gabor frames. (Received November 12, 2014)

1108-42-53 **Alexander M. Powell*** (alexander.m.powell@vanderbilt.edu) and **Xuemei Chen** (chenxuem@missouri.edu). *Randomized subspace actions for fusion frames.*

We investigate a version of the randomized Kaczmarz algorithm for recovering a signal from a collection of projection-valued fusion-frame measurements. We prove error bounds on the rates of almost sure convergence for this algorithm, and address the question of which probability distributions on a randomized fusion frame lead to fast convergence. (Received December 16, 2014)

1108-42-151 **Betsy Stovall*** (stovall@math.wisc.edu). *Uniform restriction estimates for certain hypersurfaces of revolution.*

Conditional on restriction theorems for elliptic hypersurfaces, we prove optimal, uniform restriction estimates for polynomial hypersurfaces of revolution for which the defining polynomial has non-negative coefficients. In particular, we obtain unconditional results slightly beyond the bilinear range. (Received January 08, 2015)

1108-42-165 **Christopher Heil*** (heil@math.gatech.edu), School of Mathematics, Georgia Tech, Atlanta, GA 30332, and **Darrin Speegle** (speegled@slu.edu), Department of Mathematics, Saint Louis University, St. Louis, MO 63103. *HRT versus the Zero Divisor Conjecture.*

The Linear Independence of Time-Frequency Translates Conjecture, also known as the HRT conjecture, states that any finite set of time-frequency translates of a given L^2 function must be linearly independent. This conjecture, which was first stated in print in 1996, remains open today. We will discuss this conjecture, its relation to the Zero Divisor Conjecture in abstract algebra, and the (frustratingly few) partial results that are currently available. (Received January 09, 2015)

1108-42-171 **Yumeng Ou*** (yumeng_ou@brown.edu), 151 Thayer Street, Providence, RI 02912, and **Laurent Dalenc**. *Upper bound for iterated commutators of Calderon-Zygmund operators.*

We show that the product BMO space can be characterized by iterated commutators of a large class of Calderon-Zygmund operators. This result follows from a proof of boundedness of iterated commutators of arbitrary Calderon-Zygmund operators in terms of the BMO norm of their symbol functions, using Hytonen's representation theorem of Calderon-Zygmund operators as averages of dyadic shifts. As a key element of the proof, we introduce some new dyadic paraproducts which have BMO estimates. And the main idea of the proof is to show that commutator of any dyadic shift operators can be represented as a finite linear combination of those paraproducts. (Received January 10, 2015)

1108-42-179 **Dorin Dutkay*** (ddutkay@gmail.com), Oviedo, FL 32765, and **John Haussermann**. *Tiling and scaling properties of spectra of fractals.*

We present some recent results on the tiling properties of the Fourier frequencies associated to a Fourier basis for a fractal measure and some number theoretic questions related to the spectra of the Jorgensen-Pedersen Cantor set. (Received January 11, 2015)

1108-42-184 **Raluca Felea***, Rochester Institute of Technology, School of Mathematical Sciences, Rochester, NY 14623. *Microlocal analysis in seismic imaging.*

We consider two standard ways of collecting data in seismic imaging: the common midpoint acquisition geometry and the common offset acquisition geometry. We study the linearized operator F, which maps singularities in the velocity field to singularities in the resulting pressure field at the surface. We use the microlocal properties of F and F^*F to determine which geometry shows more features of the subsurface and adds fewer artifacts. This is joint work with V. Krishnan, C. Nolan, T. Quinto. (Received January 11, 2015)

1108-42-268 **Chun-Kit Lai*** (cklai@sfsu.edu), San Francisco, CA 94132, and **Dorin Ervin Dutkay**, Orlando, FL. *Self-affine spectral measures and frame spectral measures on $\mathbb{R}^d$.*

Given an expansive matrix R, and two digit sets B and L. (R, B, L) is called a Hadamard triple if the matrix $[\frac{1}{\sqrt{N}}e^{2\pi i<R^{-1}b,l>}]$ is a unitary matrix. There has been conjecture that Hadamard triples generate self-affine spectral measures. We show that under a natural geometric condition, the Hadamard triples (R, B, L) will generate a self-affine spectral measure.

We also relax the Hadamard triple condition to an almost Parseval frame condition. This condition, if satsified, is sufficient to generate a Fourier frame for a self-affine measure.

This is a joint work with Dorin Dutkay. (Received January 16, 2015)

1108-42-294 **Sivaram K Narayan*** (sivaram.narayan@cmich.edu), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859. *Inverse Factor Poset Problem for Finite Frames.*

A *frame* in an n-dimensional Hilbert space H_n is a possibly redundant collection of vectors $\{f_i\}_{i\in I}$ that span the space. A *tight* frame is a generalization of an orthonormal basis. We define the *factor poset* of a frame $\{f_i\}_{i\in I}$ to be a collection of subsets of I ordered by inclusion so that nonempty $J \subseteq I$ is in the factor poset if and only if $\{f_j\}_{j\in J}$ is a tight frame for H_n. The *inverse factor poset problem* inquires when there exists a frame whose factor poset is some given poset P. We determine a necessary condition for solving the inverse factor poset problem in H_n which is shown to be sufficient for H_2. We address how factor poset structure is preserved under orthogonal projections. Furthermore, we discuss how many non-isomorphic factor posets are there for a fixed dimension n and number of vectors k and how large can these factor posets be. This is a joint work with Alice Chan, Martin Copenhaver, Logan Stokols and Allison Theobold. (Received January 16, 2015)

1108-42-298 **Michael Greenblatt***, 322 Science and Engineering Offices (M/C 249), 851 S Morgan Drive, Chicago, IL 60607. *Van der Corput lemmas, Fourier transforms of irregular hypersurface measures, and some PDE consequences.*

Using one-dimensional Van der Corput lemmas on functions that are either mixed homogeneous in several variables, or are arbitrary real-analytic functions in two variables, we provide local estimates on the Fourier transforms of hypersurfaces with various types of singularities. Applications to associated PDE problems are then described.

The two-dimensional results in addition use a local resolution of singularities theorem dimensions which provides appropriate coordinate systems to effectively use such one-dimensional Van der Corput lemmas. (Received January 16, 2015)

1108-42-313 **Lucas Chaffee*** (chaffel@ku.edu) and **Rodolfo H. Torres**. *Commutators of Bilinear Singular Integrals With Pointwise Multiplication.*

In this talk we will discuss commutators of certain singular integral operators with functions in BMO and CMO. In particular, we will expand on recent results to obtain full characterizations of BMO and CMO in terms of the boundedness and compactness of said commutators. (Received January 17, 2015)

1108-42-315 **David V Cruz-Uribe*** (david.cruzuribe@trincoll.edu), **Kabe Moen** and **Scott Rodney**. *$H = W$ in matrix weighted spaces, with applications to mappings of finite distortion.*

Let W be a matrix weight in the matrix A_p class, and let $v = |W|_{op}$. Define the matrix Sobolev space $\mathcal{W}^{1,p}_W$ to be the set of functions $f \in W^{1,1}_{loc}$ such that $f \in L^p(v)$ and $\nabla f \in L^p(W)$. We prove that the classical $H = W$ theorem of Meyers and Serrin, that smooth functions are dense, is true in this setting. As an application we prove partial regularity results for mappings of finite distortion. (Received January 17, 2015)

1108-42-330 **Árpád Bényi**, **José María Martell**, **Kabe Moen**, **Eric Stachura** and **Rodolfo H. Torres*** (torres@ku.edu). *Commutators vs. weighted estimates.* Preliminary report.

We revisit the relation between commutator of linear or multilinear operators with pointwise multiplication by BMO functions and weighted norm inequalities. We consider a unified approach to several different operators and contexts. (Received January 18, 2015)

1108-42-346 **Akram Aldroubi** and **Keri Kornelson*** (kkornelson@ou.edu). *Forced dynamical sampling systems in finite and infinite dimensions.* Preliminary report.

In a dynamical sampling system, an initial signal is evolving over time. If the evolution can be modeled by an operator A, it is, under some conditions, possible to determine the signal from samples that are taken at few points, but are repeated at regular time increments. There is a growing body of research into the conditions under which this notion of increasing time but reducing space samples can be effective. In this talk, we give results when the signal is influenced by an additive forcing term. We give stable reconstruction conditions in both the finite- and infinite-dimensional cases. (Received January 18, 2015)

1108-42-359 **Phi L Le*** (llc33@mail.missouri.edu), **Steve Hofmann** (hofmanns@missouri.edu) and **Andrew Morris** (morris@maths.ox.ac.uk). *L^p bounds for Riesz transforms, square root functions associated to degenerate elliptic operators.*

In this talk, we give some new results related to Kato problem for degenerate elliptic operators. More precisely, we show that if $L = -\mathrm{div} A\nabla$ is a degenerate elliptic operate satisfying weighted elliptic conditions, i.e. $\lambda\mu(x)|\xi|^2 \leq \langle A(x)\xi, \xi\rangle \leq \Lambda\mu(x)|\xi||^2$ where A is a n by n real matrix defined on $\mathbb{R}^n$, $A \in L^\infty$ and μ belongs Muckenhoupt A_2 class, then we prove that we have the L^p bound for square root function $\sqrt{L}$, for Riesz transform associated to operator L and also L^p bounds for semigroups, gradient of semigroups and their related functions. (Received January 18, 2015)

1108-42-363 **Guozhen Lu** and **Lu Zhang*** (eu4347@wayne.edu), Department of Mathematics, Wayne State University, Detroit, MI 48201. *L^p estimate for a trilinear pseudo-differential operator.*

We study the L^p estimate for a trilinear pseudo-differential operator with flag symbols. That is, the symbols are in the form of the product of two standard symbols from the Hömander class $BS^0_{1,0}$. This operator is an extension from the trilinear operator with flag singularities, with the symbols in the form of product of two Marcinkiewcz-Mikhlin-Hörmander symbols. This extends the work of C. Muscalu on L^p estimates for a trilinear operator of Fourier multipliers of flag singularity to the case of pseudo-differential operator setting. Our work is based on the use of paraproducts and some careful decay estimates. (Received January 18, 2015)

1108-42-378 **Leonid Slavin*** (leonid.slavin@uc.edu) and **Vasily Vasyunin**. *Inequalities for BMO on α-trees.*

We develop technical tools that enable the use of Bellman functions for BMO defined on α-trees, which are structures that generalize dyadic lattices. As applications, we prove the integral John–Nirenberg inequality and an inequality relating L^1- and L^2-oscillations for BMO on α-trees, with explicit constants. When the tree in question is the collection of all dyadic cubes in $\mathbb{R}^n$, the inequalities proved are sharp. We also reformulate the John–Nirenberg inequality for the continuous BMO in terms of special martingales generated by BMO functions. The tools presented can be used for any function class that corresponds to a non-convex Bellman domain. (Received January 19, 2015)

1108-42-384 **Anna C Gilbert***, 2074 East Hall, 530 S. Church Street, Ann Arbor, MI 48109, and **Piotr Indyk**, **Mark Iwen** and **Ludwig Schmidt**. *A Survey of Fourier Sampling Problems.*

The Discrete Fourier Transform (DFT) is a fundamental component of numerous computational techniques in signal processing and scientific computing. The most popular means of computing the DFT is the Fast Fourier Transform (FFT). However, with the emergence of big data problems, in which the size of the processed data sets can easily exceed terabytes, the “Fast” in Fast Fourier Transform is often no longer fast enough. In addition, in many big data applications it is hard to acquire a sufficient amount of data in order to compute the desired Fourier transform in the first place. The Sparse Fourier Transform (SFT) addresses the big data setting by computing a compressed Fourier transform using only a subset of the input data, in time *sub-linear* in the data set size. The goal of this article is to survey these recent developments, to explain the basic techniques with examples and applications in big data, to demonstrate trade-offs in empirical performance of the algorithms, and to discuss the connection between the SFT and other techniques for massive data analysis such as streaming algorithms and compressive sensing. (Received January 19, 2015)

1108-42-395 **Jincheng Jiang**, Hsinchu, Taiwan 30013, Taiwan, **Shuanglin Shao***, 1460 Jayhawk Blvd, Lawrence, KS 66045, and **Betsy Stovall**, Madison, WI. *Linear profile decompositions for a family of fourth order Schrödinger equations.*

We establish a linear profile decomposition for the fourth order Schrodinger equations. The proof relines on a refined Strichartz inequality. We also give an application establishing a dichotomy result on the extremal problem of the Strichartz inequality for the fourth order Schrodinger equation. (Received January 19, 2015)

1108-42-425 **Jiawei Shen*** (fd8315@wayne.edu), 940 West Forest Avenue, Apt. 5, Detroit, MI 48201.
The Characterization of Sobolev spaces in the metric spaces. Preliminary report.

This paper mainly aims to characterize the Sobolev space for $p = 1$ (i.e. $W^{1,1}$) in the general metric space. Such characterization in the Euclidean space was given by Hajlasz. Fortunately, if we assume the metric space is equipped with the doubling measure and satisfies the s-regular property, for example the Heisenberg group, we can also obtain the Poincaré inequality in the metric space for $p = 1$. Hence, the characteriztion of $W^{1,1}$ follows. (Received January 19, 2015)

1108-42-479 **Eric T. Sawyer** (sawyer@mcmaster.ca), Department of Mathematics and Statistics, McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4K1, Canada, **Chun-Yen Shen**, National Central University, Dept of Math, No.300, Jhongda Rd., Jhongli City, Taoyuan County 32001, Taiwan, and **Ignacio Uriarte-Tuero*** (ignacio@math.msu.edu), Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48824. *Two weight norm inequalities for singular and fractional integral operators in R^n.*

I will report on recent advances on the topic, related to proofs of T1 type theorems in the two weight setting for Calderón-Zygmund singular and fractional integral operators, with side conditions, and related counterexamples. Joint work with Eric Sawyer and Chun-Yen Shen. (Received January 19, 2015)

1108-42-569 **Shahaf Nitzan*** (shahaf.n.h@gmail.com), **Alexander Olevskii** and **Alexander Ulanovskii**. *Exponential frames on unbounded sets.*

In contrast to orthonormal and Riesz bases, exponential frames are in many cases easy to come by. In particular, it is not difficult to show that every bounded set of positive measure admits an exponential frame.

When unbounded sets (of finite measure) are considered, the problem becomes more delicate. In this talk I will discuss a joint work with A. Olevskii and A. Ulanovskii, where we prove that every such set admits an exponential frame. To obtain this result we apply one of the outcomes of Marcus, Spielman and Srivastava's recent solution of the Kadison-Singer conjecture. (Received January 20, 2015)

43 ► Abstract harmonic analysis

1108-43-30 **Vignon S Oussa*** (voussa@bridgew.edu), Bridgewater, MA 02325. *Sampling and Interpolation on nilpotent Lie groups.*

A relatively novel problem in harmonic analysis has been to find analogues of the well-known Shannon-Whittaker-Kotel'nikov theorem for non-commutative groups. Using results from frame theory and Gabor analysis, we establish the existence of sampling subspaces of square-integrable functions over some non-commutative nilpotent Lie groups. We will also present recent results on the existence of sampling spaces over non-commutative nilpotent Lie groups which enjoy the interpolation property. (Received November 20, 2014)

1108-43-288 **Palle E.T. Jorgensen*** (palle-jorgensen@uiowa.edu), Dept Math, MLH, University of Iowa, Iowa City, IA. *Fractals from representations of Cuntz-algebras.*

Among the many approaches to analysis of fractals, we study here a representation theoretic framework; i.e., realizations of certain representations on Hilbert spaces H having associated families of closed subspaces in such a way that "non-overlapping frequency bands" correspond to orthogonal subspaces in H; or equivalently to systems of orthogonal projections. Our analysis is based on Iterated Function Systems (IFS), and we outline the role of frequency bands for IFSs. Since the different frequency bands must exhaust the range for the entire IFS, in constructing representations, one must look for orthogonal projections which add to the identity operator in H. (Received January 16, 2015)

1108-43-355 **Xiaoyue Cui*** (xiaoyue@wayne.edu), 4417 2nd Avenue, Apt. 101, Detroit, MI 48201. *New characterizations of the second order Sobolev spaces in Euclidean spaces.*

The theory of Sobolev spaces plays an important role in applications to partial differential equations, geometric analysis, harmonic analysis, complex analysis, etc. The main purpose of this talk is to establish some new characterizations of the second order Sobolev spaces in Euclidean spaces. I will present the characterizations by two different types: by the second order difference, by the Taylor remainder of first order and by the differences of the first order gradient. Such characterizations are inspired by the works of H.M. Nguyen and Bourgain, Brezis and Mironescu on characterizations of first order Sobolev spaces in the Euclidean space. (Received January 18, 2015)

1108-43-556 **Alex Cloninger** and **Wojciech Czaja***, Department of Mathematics, University of Maryland, College Park, MD 20742, and **Ariel Hafftka**. *Solving Fredholm integrals from incomplete measurements.*

We present an algorithm to solve Fredholm integrals of the first kind with tensor product structures, from a limited number of measurements with the goal of using this method to accelerate nuclear magnetic resonance (NMR) measurements. This is done by incorporating compressive sampling type arguments to fill in the missing measurements using a priori knowledge of the structure of the data. In the first step, we recover a compressed data matrix from measurements that form a tight frame, and establish that these measurements satisfy the restricted isometry property (RIP). In the second step, we solve the zeroth-order regularization minimization problem using the Venkataramanan-Song-Huerlimann algorithm. We demonstrate the performance of this algorithm on simulated data and compare it with other sampling techniques. (Received January 20, 2015)

44 ► Integral transforms, operational calculus

1108-44-51 **Alexander Katsevich*** (alexander.katsevich@ucf.edu), Mathematics Department, University of Central Florida, Orlando, FL 32816, and **Roman Krylov**. *Inversion of the broken ray transform in the case of energy-dependent attenuation.*

Broken Ray transform (BRT) arises when one considers a narrow x-ray beam propagating through medium under the assumption of single scattering. Previous algorithms for inverting the BRT assumed that the medium is characterized by a single attenuation coefficient μ. However x-rays lose their energy after Compton scattering, and the energy loss depends on the scattering angle. Since the attenuation coefficient depends on energy, the μ's before and after scattering are different.

The main thrust of this paper is inversion of the BRT with $N \geq 3$ detectors under the assumption that the attenuation coefficient is a linear function of energy. When the number of detectors is four or greater, we derive a family of inversion formulas. If $N > 4$, we find the optimal formula, which provides the best stability with respect to noise in the data. If $N = 4$, the family collapses into a single formula and no optimization is possible. If μ is independent of energy, $N = 3$ is sufficient for inversion. We also develop iterative reconstruction algorithms that can use global and local data. The results of testing the algorithms are presented. (Received December 16, 2014)

1108-44-152 **Michael Perlmutter*** (mperlmut@math.purdue.edu). *Calderón-Zygmund Operators Arising from Projections of Martingale Transforms.*

Probabilistic methods provide a powerful tool for studying the L^p boundedness of classical Calderón-Zygmund operators such as the Riesz and Beurling-Ahlfors transforms. These classical operators may be interpreted as particular cases of the projections of the martingale transforms of stochastic integrals with respect to Brownian motion. An advantage of this approach is that it gives very good information on the size of these L^p bounds and, in particular, provides constants that are independent of the dimension. We show that a large class of these probabilistic operators, as well as other closely related operators, are in fact Calderón–Zygmund operators. Consequently, such operators are not only bounded on L^p, $1 < p < \infty$, but also satisfy weak-type inequalities. Unlike the boundedness on L^p, which can be obtained directly from the Burkholder martingale transform inequalities, the weak-type estimates do not follow from the corresponding martingale results. (Received January 08, 2015)

1108-44-174 **Fatma Terzioglu*** (fatma@math.tamu.edu). *An Inversion Formula for the Cone Transform.*

Compton cameras arise in medical imaging, astronomy, and lately in homeland security applications. It naturally leads to a variety of Radon type transforms where integration is done over conical surfaces. In this talk, we present integral relations between cone and Radon transforms in $\mathbb{R}^n$, and give filtered back-projection type inversion formulas for the overdetermined cone transform. (Received January 10, 2015)

1108-44-340 **Jarod Hart*** (jarod.hart@wayne.edu) and **Guozhen Lu**. *Hardy Space Estimates for Bilinear Calderón-Zygmund Operators.*

In this joint work with Guozhen Lu, we find sufficient conditions for bilinear Calderón-Zygmund operators to be bounded on Hardy spaces. For a bilinear operator $T(f_1, f_2)$, we give sufficient regularity and cancellation conditions for T to be bounded from $H^{p_1} \times H^{p_2}$ into H^p for $0 < p_1, p_2, p \leq 1$. The fundamental difficulty that arises in the bilinear Hardy spaces estimates, which is not present in the linear setting, can be observed in the fact that $f_1, f_2 \in H^1$ does not imply $f_1 \cdot f_2 \in H^{1/2}$, i.e. the pointwise product operator $(f_1, f_2) \mapsto f_1(x)f_2(x)$ is not bounded from $H^1 \times H^1$ into $H^{1/2}$. The product structure of bilinear Calderón-Zygmund operators severely complicates analysis of operators on H^p when $0 < p \leq 1$, which stems from difficulties in understanding the oscillatory behavior of products of functions. Some Hardy space paraproduct boundedness properties for bilinear operators will also be discussed. In particular, we will introduce a paraproduct $\Pi(f_1, f_2)$ that maps (and is bounded) from $H^{p_1} \times H^{p_2}$ into H^p and resembles the product operator, $\Pi(f_1, f_2)(x) \approx f_1(x)f_2(x)$, in the appropriate sense. (Received January 18, 2015)

1108-44-552 **Eric L Grinberg*** (eric.grinberg@umb.edu), Department of Mathematics, UMass Boston, Boston, MA 02125. *Integral Geometric Transforms on Symmetric Spaces of Compact Type.* Preliminary report.

We discuss integral transforms in the context of symmetric spaces of compact type, such as projective spaces and grassmannians, typically involving integration along distinguished submanifolds; some of these may be viewed as extensions of the X-Ray transform that integrates along closed geodesics, and are of interest in applications. We'll consider questions of injectivity that are amenable to harmonic analysis methods on homogeneous spaces. For some transforms only injectivity is considered while for others, especially those related to complex structure, inversion formulas can be considered as well. (Received January 20, 2015)

45 ► Integral equations

1108-45-93 **Burak Aksoylu**, **Horst R Beyer** and **Fatih Celiker*** (celiker@wayne.edu), Department of Mathematics 1150 FAB, Detroit, MI 48202. *Incorporating local boundary conditions into nonlocal theories.*

We study nonlocal equations from the area of peridynamics on bounded domains. In our companion paper, we discover that, on $\mathbb{R}^n$, the governing operator in peridynamics, which involves a convolution, is a bounded function of the classical (local) governing operator. Building on this, we define an abstract convolution operator on bounded domains which is a generalization of the standard convolution based on integrals. The abstract convolution operator is a function of the classical operator, defined by a Hilbert basis available due to the purely discrete spectrum of the latter. As governing operator of the nonlocal equation we use a function of the classical operator, this allows us to incorporate local boundary conditions into nonlocal theories.

We present a numerical study of the solutions of the wave equation. For discretization, we employ a weak formulation based on a Galerkin projection and use piecewise polynomials on each element which allows discontinuities of the approximate solution at the element borders. We study convergence order of solutions with respect to polynomial order and observe optimal convergence. We depict the solutions for each boundary condition. (Received January 03, 2015)

1108-45-161 **Kam C Ng*** (kam.ng@kodak.com), Kodak Technology Center, Materials Deposition Interaction Department, Eastman Kodak Company, Rochester, NY 14650-2109. *A Mathematical Model for the Capacitive Touch Sensor.* Preliminary report.

We have developed a mathematical model of simulating a finger approaching a touch screen sensor. The simulating results have been shown to be consistent with experiments. The model includes electrode conductors and floating conductors in which potentials or the sum of the charges is specified. Boundary element or method of moments is used to compute the charges on the sensor. The model has been applied to the 2D touch screen sensors. (Received January 09, 2015)

46 ► Functional analysis

1108-46-24 **Peter G Casazza**, **Eric Pinkham** and **Brian Tuomanen*** (bpt6gc@missouri.edu). *Riesz Outer Product Hilbert Space Frames: Quantitative Bounds, Topological Properties, and Full Geometric Characterization.* Preliminary report.

In this paper, we make the first detailed study of the family of outer product frames induced directly by vector sequences. We are interested in both the quantitative frame attributes of these outer product sequences, as well as their independence and spanning properties. We show that Riesz sequences of vectors yield Riesz sequences of outer products with the same (or better) Riesz bounds. Equiangular tight frames are shown to produce Riesz sequences with optimal Riesz bounds for outer products. We provide constructions of frames which produce Riesz outer product bases with "good" Riesz bounds. We show that the family of unit norm frames which yield independent outer product sequences is open and dense within the topological space $\otimes_{i=1}^{M} S_{N-1}$ where M is less than or equal to the dimension of the space of symmetric operators on $\mathbb{H}^N$; that is to say, almost every frame with such a bound on its cardinality will induce a set of independent outer products. Thus, this would mean that finding the necessary and sufficient conditions such that the induced outer products are dependent is a more interesting question. Finally we give a full analytic and geometric classification of such sequences which produce dependent outer products. (Received November 13, 2014)

1108-46-64 **Peter G Casazza*** (casazzap@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Phase Retrieval by Projections.*

Over the 100 year history of phase retrieval, it has had broad application to x-ray crystallography, electron microscopy, diffractive imaging, DNA, x-ray tomography and much more. Phase retrieval will even be needed to align the mirrors of the new James Webb Space Telescope scheduled for launch in 2018. We will start with the fundamentals of phase retrieval and its applications which have garnered a dozen Nobel Prizes over the years. Only recently have mathematicians entered this area to give a solid mathematical foundation to phase retrieval. In the second half of this talk we will look at recent advances in the mathematics of phase retrieval – especially recent advances in phase retrieval by projections. (Received December 19, 2014)

1108-46-117 **Marius V Ionescu*** (ionescu@usna.edu), Department of Mathematics, Chauvenet Hall, United States Naval Academy, 572C Holloway Road, Annapolis, MD 21402, and **Kasso Okoudjou** and **Luke G Rogers**. *Asymptotics of eigenvalue clusters for generalized Schrödinger operators.*

A generalized Schrödinger operator with continuous potential χ on the Sierpinksi gasket is an operator of the form $H = p(-\Delta) + [\chi]$, where $p : (0, \infty) \to \mathbb{R}$ is a measurable function. In this talk we present some results on the asymptotic behavior of spectra of generalized Schrödinger operators with continuous potentials and continuous p, generalizing some results of Okoudjou and Strichartz. Our proof is based on the the study of the asymptotics of the trace of continuous functions of pseudo-differential operators. Our results are the fractal analogue of results first observed by Weinstein and Guillemin for Schrödinger operators on compact Riemannian manifolds. This talk is based on joint work with Kasso Okoudjou and Luke Rogers. (Received January 06, 2015)

1108-46-166 **Richard H Rochberg*** (rr@math.wustl.edu). *Representing the Dirichlet Space as a Quotient.* Preliminary report.

The general theory of reproducing kernel Hilbert spaces with complete Pick kernels insures that by mapping the disk into the $n-$ball, the Dirichlet space can be realized as a quotient space of the Drury-Arveson space of the $n-$ball. I will describe a geometric obstrucion to having such a map if n is finite. (Received January 09, 2015)

1108-46-211 **Daniel Freeman*** (dfreema7@slu.edu). *An unconditional FDD of translations of a single function in L_p for $p > 2$.* Preliminary report.

Wavelet coordinate systems are constructed by translating and dilating a single function in L_2 to form a basis or a frame for L_2. We are interested in what possible coordinate systems can be formed by just translations of a single function. It has previously been shown that for all $1 \leq p < \infty$, L_p does not have an unconditional basis of translations of a single function. In contrast to this, we prove that for all $2 < p < \infty$ there exists a sequence of translations of a single function in L_p which may be blocked to be an unconditional FDD for L_p. That is, there exists a function $F \in L_p$, a sequence of real numbers $(\lambda_j)_{j=1}^\infty$, and an increasing sequence of natural numbers $(n_j)_{j=1}^\infty$ with $n_1 = 1$ such that $(span_{n_j \leq i < n_{j+1}} T_{\lambda_i} F)_{j=1}^\infty$ is an unconditional FDD for L_p. In particular, for all $f \in L_p$ there exists a unique sequence of scalars $(a_i)_{i=1}^\infty$ such that

$$f = \sum_{j=1}^{\infty} \sum_{i=n_j}^{n_{j+1}-1} a_i T_{\lambda_i} F,$$

and the outside sum converges unconditionally. (Received January 13, 2015)

1108-46-517 **Jameson Cahill*** (jcahill@math.duke.edu), 2018 JERSEY AVE, Durham, NC 27707. *Stability in phase retrieval.*

One of the key issues in phase retrieval is stability of reconstruction in the presence of noise. This problem has been approached from a variety of angles by many different researchers in both the finite and infinite dimensional settings. In this talk we will survey what has been done up to this point, and present some some new results about stability for general algorithms. (Received January 20, 2015)

1108-46-544 **Daniel J Kelleher*** (dkellehe@purdue.edu), Dept Of Mathematics, Purdue Univ., 150 N. University St, West Lafayette, IN 47907-2067. *Differential forms on Dirichlet spaces and analysis on fractals.*

We will discuss the possibility of defining intrinsic metrics and vector analysis for measurable Dirichlet forms (quadratic forms on scalar functions) and resistance forms. This vector analysis has applications in constructing a Dirac operator and intrinsic metrics. This construction combines ideas from classical and non-commutative functional analysis. We will discuss the spectral properties of these ideas, as well as how they relate to analytic ideas such as heat kernel estimates. If time permits we shall discuss how this leads to the definition of spectral triples on fractal spaces. (Received January 20, 2015)

1108-46-577 **Matthew Fickus** (matthew.fickus@gmail.com), **John D Jasper*** (jjasper@uoregon.edu), **Dustin G Mixon** (dustin.mixon@gmail.com) and **Jesse D Peterson** (peterson.jesse.d@gmail.com). *Generalized Steiner Equiangular Tight Frames.*

We will present a new construction of complex equiangular tight frames (ETFs), which combines Steiner ETFs and harmonic ETFs. The construction not only gives a new infinite class of complex ETFs but also a new infinite class of real ETFs. Through the well known correspondence between real equiangular line sets and strongly regular graphs our construction gives a new infinite class of strongly regular graphs. By modifying our construction slightly, we are also able to demonstrate the nonexistence of some combinatorial designs whose existence was previously an open problem. (Received January 20, 2015)

47 ► Operator theory

1108-47-47 **Horst R Beyer**, **Burak Aksoylu** and **Fatih Celiker*** (celiker@wayne.edu), 656 W. Kirby, Detroit, MI 48202. *On a Class of Nonlocal Wave Equations from Applications.*

We study equations from the area of peridynamics, which is an extension of elasticity. The governing equations form a system of nonlocal wave equations. Its governing operator is found to be a bounded, linear and self-adjoint operator on a Hilbert space. We study the well-posedness and stability of the associated initial value problem. We solve the initial value problem by applying the functional calculus of the governing operator. In addition, we give a series representation of the solution in terms of spherical Bessel functions. For the case of scalar valued functions, the governing operator turns out as functions of the Laplace operator. This result enables the comparison of peridynamic solutions to those of classical elasticity as well as the introduction of local boundary conditions into the nonlocal theory. The latter is studied in a companion paper. (Received December 12, 2014)

1108-47-59 **Darren C. Ong*** (darrenong@math.ou.edu), Mathematics Department, University of Oklahoma, Norman, OK 73019-3103. *Decaying oscillatory perturbations of periodic Schrödinger operators.*

We consider decaying oscillatory perturbations of periodic Schrödinger operators on the half line. More precisely, the perturbations we study satisfy a generalized bounded variation condition at infinity and an L^p decay condition. We show that the absolutely continuous spectrum is preserved, and give bounds on the Hausdorff dimension of the singular part of the resulting perturbed measure. Under additional assumptions, we instead show that the singular part embedded in the essential spectrum is contained in an explicit countable set. Finally, we demonstrate that this explicit countable set is optimal. That is, for every point in this set there is an open and dense class of periodic Schrödinger operators for which an appropriate perturbation will result in the spectrum having an embedded eigenvalue at that point. (Received December 17, 2014)

1108-47-69 **Zeljko Cuckovic** (zcuckovi@math.utoledo.edu), Toledo, OH 43606, and **Sonmez Sahutoglu*** (sonmez.sahutoglu@utoledo.edu), Toledo, OH 43606. *Essential norm estimates for Hankel operators on convex domains in $\mathbb{C}^2$.*

Let Ω be a bounded convex domain in $\mathbb{C}^2$ with C^1-smooth boundary and $\varphi \in C^1(\overline{\Omega})$ such that φ is harmonic on the nontrivial analytic disks in the boundary. We estimate the essential norm of the Hankel operator H_φ in terms of the $\overline{\partial}$ derivatives of φ "along" the nontrivial disks in the boundary. This is joint work with Zeljko Cuckovic. (Received December 22, 2014)

1108-47-84 **Injo Hur*** (ihur@math.ou.edu), Department of mathematics, University of Oklahoma, Norman, OK 73019. *Density of Schrödinger Titchmarsh-Weyl m functions on Herglotz functions.*

We will show that all Titchmarsh-Weyl m functions corresponding to Schrödinger operators are dense in all Herglotz functions. To show this, we first discuss a topology on canonical systems which interacts with the uniform convergence of Herglotz functions on compact subsets of the upper half plane. We then characterize canonical systems which can be written in a Schrödinger (eigenvalue) equation and vice versa, which gives us an easy way to construct m functions corresponding to Schrödinger equations in terms of canonical systems. Finally we approximate the canonical system whose m function is a given Herglotz function by canonical systems which can be written in Schrödinger equations such that their m functions converges to a given Herglotz function. (Received December 31, 2014)

1108-47-222 **Svetlana Jitomirskaya** (szhitomi@math.uci.edu), Department of Mathematics, University of California, Irvine, Irvine, CA 92697, and **Ilya Kachkovskiy*** (ikachkov@uci.edu), 340 Rowland Hall, Department of Mathematics, University of California, Irvine, Irvine, CA 92697. *Anderson localization for one-dimensional ergodic Schrodinger operators with piecewise monotonic sampling functions.* Preliminary report.

We consider the one-dimensional ergodic operator family

$$(H_{\alpha,\lambda}(x)\Psi)_m = \Psi_{m+1} + \Psi_{m-1} + \lambda v(x+\alpha m)\Psi_m, \quad m \in \mathbb{Z}, \tag{1}$$

in $l^2(\mathbb{Z})$. Such operators are well studied for analytic v where a metal-insulator transition (from absolutely continuous to pure point spectra) occurs for almost every alpha.

We are mainly interested in the case $v(x) = \{x\}$ but the results remain true under a general bi-Lipshitz condition on v. For every λ, for almost every α and almost every x, we show that the spectrum of $H_{\alpha,\lambda}(x)$ is pure point. This model is the first example of pure point spectrum at small coupling for bounded quasiperiodic-type operators, or more generally for ergodic operators with underlying systems of low disorder.

We also show continuity of the Lyapunov exponent in energy for all λ, and uniform positivity for (nonperturbatively) large λ. Finally, in the regime of uniformly positive Lyapunov exponent we establish uniform Anderson localization, thus providing the first natural example of an operator with this property. (Received January 14, 2015)

1108-47-281 **Chris Marx*** (cmarx@oberlin.eud), Oberlin College, Department of Mathematics, 10 N. Professor St/King 205, Oberlin, OH 44074. *Subcritical behavior for quasi-periodic Schrödinger operators with trigonometric polynomials.*

We give a criterion implying subcritical behavior for quasi-periodic Schrödinger operators where the potential sampling function is given by a trigonometric polynomial. Subcritical behavior, in the sense of Avila's global theory, is known to imply purely absolutely continuous spectrum for all irrational frequencies and all phases. The work is joint with Laura Shou and Jake Wellens. (Received January 16, 2015)

1108-47-285 **Oleksandra Beznosova**, **Daewon Chung**, **Jean Carlo Moraes** and **Maria Cristina Pereyra*** (crisp@math.unm.edu), Department of Mathematics and Statistics, MSC01 1115, 1 University of New Mexico, Albuquerque, NM 87131. *Quantitative two weight inequalities for dyadic operators.* Preliminary report.

We discuss quantitative two weight inequalities for some dyadic operators including the dyadic square function and the dyadic paraproduct. (Received January 16, 2015)

1108-47-361 **Mihai Stoiciu*** (mstoiciu@williams.edu), Department of Mathematics and Statistics, Williams College, Williamstown, MA 01267. *Bounds for the Pseudospectra of Various Classes of Matrices and Operators.* Preliminary report.

We investigate the ε-pseudospectra of various classes of non-normal matrices and operators. In particular, we are interested in the shape of the pseudospectrum, regarded as a subset of the complex plane. We provide explicit lower and upper bounds for the ε-pseudospectra of bi-diagonal and tri-diagonal matrices and operators.
(Received January 18, 2015)

1108-47-410 **Roger Nichols*** (roger-nichols@utc.edu), 415 EMCS Building Dept. 6956, 615 McCallie Ave, Chattanooga, TN 37403, and **Fritz Gesztesy** and **Sergey Naboko**. *On a Problem in Eigenvalue Perturbation Theory.*

We consider additive perturbations of the type $H_t = H_0 + tV$, $t \in [0,1]$, where H_0 and V are self-adjoint operators in a separable Hilbert space $\mathcal{H}$ and V is bounded. In addition, we assume that the range of V is a generating (i.e., cyclic) subspace for H_0. If λ_0 is an eigenvalue of H_0, then under the additional assumption that V is nonnegative, the Lebesgue measure of the set of all $t \in [0,1]$ for which λ_0 is an eigenvalue of H_t is known to be zero. We recall this result, discuss its connection with operator pencils, and show by explicit counterexample that the nonnegativity assumption $V \geq 0$ cannot be removed. (Received January 19, 2015)

49 ► *Calculus of variations and optimal control; optimization*

1108-49-20 **Nicolas Garcia Trillos*** (ngarciat@andrew.cmu.edu), Department of Mathematical Sciences, Wean Hall 6113, Carnegie Mellon University, Pittsburgh, PA 15213. *Continuum limit of total variation on point clouds.*

We consider point clouds obtained as random samples of a measure on a Euclidean domain. A graph representing the point cloud is obtained by assigning weights to edges based on the distance between the points they connect. We study when is the cut capacity, and more generally total variation, on these graphs a good approximation of the perimeter (total variation) in the continuum setting. We address this question in the setting of Γ-convergence. Applications to the study of consistency of cut based clustering procedures will be discussed.
(Received November 11, 2014)

1108-49-52 **Xiang Xu*** (xu719@purdue.edu), 150 N University St, West Lafayette, IN 47907, and **David Kinderlehrer** and **Leonard Monsaingeon**. *A variational approach to Poisson-Nernst-Planck equations.*

The Poisson-Nernst-Planck system of equations used to model ionic transport is interpreted as a gradient flow for the Wasserstein distance and a free energy in the space of probability measures with finite second moment. A variational scheme is then set up and is the starting point of the construction of global weak solutions in a unified framework for the cases of both linear and nonlinear diffusion. The proof of the main results relies on the derivation of extra estimates based on the flow interchange techniques (Received December 16, 2014)

1108-49-71 **Marian Bocea*** (mbocea@luc.edu), Department of Mathematics & Statistics, Loyola University Chicago, 1032 W. Sheridan Road, Chicago, IL 60660. *Relaxation and Duality for the L^∞ Mass Transport Problem.*

The original mass transport problem, formulated by Gaspard Monge in 1781, asks to find the optimal volume preserving map between two given sets of equal volume, where optimality is measured against a cost functional given by the integral of a cost density. After reviewing some aspects of this classical problem, I will describe recent joint work with E. N. Barron and R. R. Jensen (Loyola University Chicago) leading to a duality theory for

the case of relaxed L^∞ cost functionals acting on probability measures with prescribed marginals. (Received December 22, 2014)

1108-49-134 **Tai-Ho Wang*** (tai-ho.wang@baruch.cuny.edu), 1 Bernard Baruch Way, New York, NY 10010, and **Xue Cheng** (chengxue@pku.edu.cn), Beijing, Peoples Rep of China. *Optimal execution with uncertain order fills.*

In this talk we present an extension of the classical price impact model of Almgren and Chriss to incorporate the uncertainty of order fills. The extended model can be recast as alternatives to uncertain impact models, stochastic liquidity models, and an approximation of models for liquidation with limit orders. Optimal strategies are determined by maximizing the expected final P&L and various P&L-risk tradeoffs including utility maximization. Closed form expressions for optimal strategies are obtained in linear cases. The results suggest a type of adaptive volume weighted average price (VWAP) and adaptive Almgren-Chriss strategies. Possible generalizations to transient impact models are also discussed. (Received January 07, 2015)

1108-49-571 **Katy Craig*** (kcraig@math.ucla.edu) and **Ihsan Topaloglu**. *Regularization and convergence of nonlocal interaction energies.*

A variety of physical and biological processes—from self-assembly of nano particles to biological swarming—can be modeled as particles moving to minimize a nonlocal interaction energy. Often, the interaction between particles is chosen to scale according to a repulsive-attractive power-law potential, which causes rich patterns to develop. However, in general, these energies are neither convex nor differentiable, placing them outside the scope of most existing results on energy minimization and gradient flow.

In this talk, I will present recent work with Ihsan Topaloglu, in which we restore convexity and differentiability by regularization and prove that the regularized energies Gamma converge to the original energy. This provides further theoretical justification for the success of the numerical blob method, developed in previous work with Andrea Bertozzi. It also links the well-understood case of convex minimization and gradient flow with emerging results in the non-convex case, including ongoing work with Inwon Kim and Yao Yao. (Received January 20, 2015)

51 ► Geometry

1108-51-321 **David Constantine*** (dconstantine@wesleyan.edu), Department of Math and Computer Science, Welseyan University, 265 Church St, Middletown, CT 06459. *Marked length spectrum and volume rigidity for Fuchsian buildings.*

Let X_1 and X_2 be compact quotients of thick Fuchsian buildings with $CAT(-1)$ metrics. We prove that if the marked length spectra of these spaces are the same, then they have the same volume. This is joint work with Jean-François Lafont, and is one part of the proof of marked length spectrum rigidity for Fuchsian buildings presented in his talk in this session. (Received January 17, 2015)

1108-51-404 **J.-F. Lafont*** (jlafont@math.ohio-state.edu), Dept. of Mathematics, Ohio State University, 231 West 18th Avenue, Columbus, OH 43210-1174, and **D. B. McReynolds** (dmcreyno@purdue.edu), Purdue University, Department of Mathematics, 150 North University, Math 704, West Lafayette, IN 47907-2067. *Primitive geodesic lengths and (almost) arithmetic progressions.*

We are interested in looking for arithmetic progressions in the primitive length spectrum of a negatively (or non-positively) curved manifold. The primitive length spectrum is the (multi)-set of lengths of primitive closed geodesics. We first show that generically, the primitive length spectrum does not contain any arithmetic progressions. We show that they always contain almost arithmetic progressions. We also show that all non-compact arithmetic hyperbolic 2- or 3-manifolds have primitive length spectrums which contain arbitrarily long arithmetic progressions. This is joint work with Ben McReynolds (Purdue). (Received January 19, 2015)

1108-51-408 **J.-F. Lafont*** (jlafont@math.ohio-state.edu), Dept. of Mathematics, Ohio State University, 231 West 18th Ave., Columbus, OH 43210-1174, and **D. Constantine** (dconstantine@wesleyan.edu), Wesleyan University, Mathematics and Computer Science Department, 265 Church Street, Middletown, CT 06459. *Marked length spectrum rigidity for Fuchsian buildings.* Preliminary report.

We consider certain compact quotients of Fuchsian buildings. If the quotients are equipped with piecewise hyperbolic locally CAT(-1) metrics, and have no vertex links which are generalized 3-gons, we show that these spaces are marked length spectrum rigid. That is to say, if there is an isomorphism of fundamental groups that preserves the minimal length of geodesics in free homotopy classes of loops, then there is in fact an isometry realizing the isomorphism of fundamental groups. Next we show that, amongst the piecewise negatively curved locally CAT(-1) metrics, the piecewise hyperbolic ones maximize the volume. This is joint work with Dave Constantine, who will present some related results in his talk in this session. (Received January 19, 2015)

1108-51-435 **Grace Work*** (work2@illinois.edu). *Distribution of gaps for slopes of saddle connections on the octagon.*

Finding the distribution of the gaps in a sequence gives us a way of understanding how much it resembles a random sequence. In joint work with Caglar Uyanik, we apply this notion to the sequence of slopes of saddle connections on the translation surface associated to the regular octagon. By reducing the problem to a question of return times of the horocycle flow on the moduli space of translation surfaces to a Poincare section, we are able to use the ergodic properties of the horocycle flow to explicitly compute the gap distribution. This is the first example where the gap distribution has been computed for a Veech surface where the associated Teichmuller curve has multiple cusps. (Received January 19, 2015)

1108-51-438 **Wouter Van Limbeek***, Dept of Math, Univ of Chicago, 5734 S University Ave, Chicago, IL 60615. *Symmetry gaps in Riemannian geometry and minimal orbifolds.*

In 1893 Hurwitz showed that a hyperbolic surface of genus at least 2 has isometry group of order at most 84(g-1). Do such bounds on the order of isometry groups exist more generally? It was conjectured by Farb-Weinberger that this is the case for certain aspherical manifolds. In this spirit we prove that the size of the isometry group of an arbitrary closed manifold is bounded in terms of certain geometric quantities (such as curvature and volume), unless the manifold admits an action by a compact connected Lie group. We give two applications of this result: First we characterize locally symmetric spaces among all Riemannian manifolds, and secondly, we generalize results of Kazhdan-Margulis and Gromov on the existence of minimal quotients of locally symmetric spaces and negatively curved manifolds. (Received January 19, 2015)

1108-51-446 **Andrew Zimmer*** (aazimmer@uchicago.edu). *Gromov hyperbolicity and the Kobayashi metric.*

The Kobayashi metric is a (possibly degenerate) metric defined for any complex manifold. It has the remarkable property that every holomorphic map is non-expansive with respect to this metric. This metric also appears frequently in differential geometry, for instance the Kobayashi metric on the unit ball is a model of complex hyperbolic space. In this talk I will discuss the geometry of the Kobayashi metric on open domains in $\mathbb{C}^n$ and in particular when the metric is Gromov hyperbolic. (Received January 19, 2015)

1108-51-495 **Richard K Hind*** (hind.1@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Symplectic embeddings in dimension greater than four.* Preliminary report.

In their 2012 paper McDuff and Schlenk completely solved the existence problem for symplectic embeddings of 4-dimensional ellipsoids into balls. In other words, they calculated the function

$$c(x) = \inf\{R|E(1,x) \hookrightarrow B^4(R)\}.$$

Here an ellipsoid inside the standard symplectic Euclidean space is written as $E(a,b) = \{\frac{\pi}{a}(p_1^2+q_1^2)+\frac{\pi}{b}(p_2^2+q_2^2) < 1\}$ and $B^4(R) = E(R,R)$ is a ball.

For a fixed $n \geq 3$ we can define the function

$$f(x) = \inf\{R|E(1,x) \times \mathbb{R}^{2(n-2)} \hookrightarrow B^4(R) \times \mathbb{R}^{2(n-2)}\}.$$

I will talk about some constructions and obstructions which give upper and lower bounds respectively for $f(x)$. It is clear that $f(x) \leq c(x)$ but it turns out we have equality precisely when $x \leq \tau^4$, the fourth power of the golden ratio. This is work in progress with Daniel Cristofaro-Gardiner. (Received January 20, 2015)

52 ► Convex and discrete geometry

1108-52-54 **Wei-Hsuan Yu*** (u690604@gmail.com), **Alexander Barg** and **Takayuki Okuda**. *New upper bounds for equiangular line sets.*

The maximum size of equiangular line sets had been studied in the 1940s. We use the semidefinite programming method to extend the known results of the maximum size of equiangular line sets in R^n when 24 <=n <= 41 and n=43. This provides a partial resolution of the conjecture set forth by Lemmens and Seidel (1973). We also derive new relative bounds for the equiangular line sets and prove the non-existence of tight spherical designs of harmonic index 4 in R^n for n >= 3. (Received December 16, 2014)

1108-52-393 **Gloria Mari Beffa*** (maribeff@math.wisc.edu), Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706. *A Lax representation for the Shift map on pentagram spirals.*

In this talk we will describe the definition of pentagram spirals of class (N,K) and study the case K=1. Pentagram spirals were introduced by Richard Schwartz, and they are formed by choosing a distinguished point on the side of a polygon starting at which the polygon starts spiraling inwards using a pentagram map construction. Schwartz interpreted the shift map (the map that takes a spiral to the one obtained by shifting the vertices once) as the N+1 root of the pentagram map, he also conjectured that the map was also integrable. We will describe a coordinate system on the moduli space of twisted spirals, a system that can be used to create a parameter-free Lax representation for the shift map. We will then show that in our coordinates the shift map is invariant under the action of a one parameter group, hence introducing the spectral parameter in a representation that can then be used for integration. (Received January 19, 2015)

1108-52-590 **Casey Mann*** (cemann@uw.edu), University of Washington Bothell, 18115 Campus Way NE, Box 358538, Bothell, WA 98011, and **Jennifer McLoud**. *Convex pentagons that admit i-block transitive tilings.* Preliminary report.

The problem of classifying the convex pentagons that admit tilings of the plane is a long-standing unsolved problem. There are 14 known distinct kinds of pentagons that admit tilings of the plane. Five of these known types admit tile-transitive tilings (i.e. there is a single transitivity class with respect to the symmetry group of the tiling). The remaining 9 known types admit either 2-block transitive tilings or 3-block transitive tilings; these are tilings comprised of clusters of 2 or 3 pentagons such that these clusters form a tile-transitive tiling. In this talk, we present some combinatorial results concerning pentagons that admit i-block transitive tilings for $i \in \mathbb{N}$. These results form the basis for an automated approach to finding all pentagons that admit i-block transitive tilings for each $i \in \mathbb{N}$. We will present the methods of this algorithm and the results of the computer searches so far. (Received January 21, 2015)

53 ► Differential geometry

1108-53-85 **Luc Vrancken*** (luc.vrancken@univ-valenciennes.fr), LAMAV, Campus du Mont Houy, 59313 Valenciennes Cedex 9, 59313 Valenciennes, Nord, France. *Isotropic Lagrangian and affine immersions.*

The notion of a submanifold with isotropic second fundamental form was first introduced by O'Neill. Namely, if

$$< h(X(p), X(p)), h(X(p), X(p)) >= \lambda(p) < X(p), X(p) >^2,$$

for any $X(p) \in T_pM$, we say that M has isotropic second fundamental form. If λ is independent of the point p, the submanifold is called constant isotropic.

For Lagrangian submanifolds, the first result about isotropic submanifolds was obtained by Naitoh, in his study of submanifolds with parallel second fundamental form. Later such submanifolds were studied and classified by Montiel and Urbano (1988).

In this talk we will deal with several posible generalisations of these results, i.e. we will discuss

(1) Lagrangian submanifolds for which
$$T(X,Y,Z,W) =< \nabla h)(X,Y,Z), JW >$$
is isotropic

(2) Lagrangian submanifolds for which
$$T(X,Y,Z,W,U,V) =< \nabla h)(X,Y,Z), (\nabla h)(W,U,V) >$$
is isotropic

(3) Affine hypersurfaces with parallel difference tensor in affine differential geometry

(4) Indefinite Lagrangian submanifolds with isotropic second fundamental form

(Received January 01, 2015)

1108-53-86 **Zhiqin Lu*** (zlu@uci.edu), Department of Mathematics, UC Irvine, Irvine, CA 92697. *On a common generalization of the Bottcher-Wenzel Inequality and the Normal Scalar Curvature Inequality.* Preliminary report.

In this talk, I will go over the Bottcher-Wenzel Inequality and the Normal Scalar Curvature Inequality. I will discuss a conjecture which gives a common generalization of the above two inequalities. This is a working project with David Wenzel. (Received January 01, 2015)

1108-53-87 **Young Ho Kim*** (yhkim@knu.ac.kr), Daehak-Ro 80, Daegu, 702-701, South Korea. *Submanifolds related to Gauss map and some differential operators.* Preliminary report.

Gauss map is one of interesting smooth maps on a submanifolds of Euclidean and pseudo-Euclidean space, which describes how the immersion behaves in the ambient space. In this talk, we introduce how the Gauss map plays a role to classify or characterize ruled submanifolds in Euclidean space or Minkowski space related to the Laplace operator and the Cheng-Yau operator. In particular, we characterize ruled submanifolds in Minkowski space with the Gauss map and such operators. (Received January 02, 2015)

1108-53-98 **Benjamin Linowitz*** (linowitz@umich.edu), Ann Arbor, MI 48103, and **Jeffrey S Meyer**, Norman, OK 73019. *Can an orbifold be isospectral to a manifold?*

An old problem asks whether a Riemannian manifold can be isospectral to a Riemannian orbifold with nontrivial singular set. We show that under the assumption of Schanuel's conjecture in transcendental number theory, this is impossible whenever the orbifold and manifold in question are compact locally symmetric spaces of nonpositive curvature associated to simple Lie groups. (Received January 04, 2015)

1108-53-109 **Ye-Lin Ou*** (yelin.ou@tamuc.edu). *Some recent work on biharmonic submanifolds and biharmonic maps.*

Biharmonic maps are generalizations of biharmonic functions and harmonic maps. Biharmonic sumanifolds are submanifolds whose defining isometric immersions are biharmonic maps. Biharmonic submanifolds generalize the notion of geodesic and minimal submanifolds. In this talk we will start with a review on some basic concept, examples and fundamental problems in the study of biharmonic maps, and then we will talk about some recent work on Chen's conjecture and the generalized Chen's conjecture on biharmonic submanifolds, and the classifications and constructions of proper biharmonic maps from a 2-sphere. (Received January 05, 2015)

1108-53-112 **Bang-Yen Chen***, Department of Mathematics, Michigan State University, East Lansing, MI 48864. *Ricci solitons on Riemannian submanifolds.* Preliminary report.

A smooth vector field ξ on a Riemannian manifold (M, g) is said to define a *Ricci soliton* if it satisfies

$$\frac{1}{2}\pounds_\xi g + Ric = \lambda g,$$

where $\pounds_\xi g$ is the Lie-derivative of the metric tensor g with respect to ξ, Ric is the Ricci tensor of (M, g) and λ is a constant. During the last two decades, the geometry of Ricci solitons has been the focus of attention of many mathematicians. It has become more important after G. Perelman applied Ricci solitons to solve the long standing Poincaré conjecture posed in 1904.

In this article we survey important results on Ricci solitons which occur naturally on certain Riemannian submanifolds. (Received January 05, 2015)

1108-53-119 **Joeri Van der Veken*** (joeri.vanderveken@wis.kuleuven.be), KU Leuven, Department of Mathematics, Celestijnenlaan 200B - Box 2400, 3001 Leuven, Belgium. *Curvature inequalities for Lagrangian submanifolds.*

This talk is based on joint work with Bang-Yen Chen, Franki Dillen and Luc Vrancken on curvature inequalities for Lagrangian submanifolds of complex space forms. In particular, if M^n is an n-dimensional Lagrangian submanifold of a complex space form $\tilde{M}^n(c)$ of constant holomorphic sectional curvature c, then one can prove pointwise inequalities of the following type:

$$\delta(n_1, \ldots, n_k) \leq a(n, k, n_1, \ldots, n_k)\|H\|^2 + b(n, k, n_1, \ldots, n_k)c.$$

Here, H is the mean curvature vector and $\delta(n_1, \ldots, n_k)$ is any delta-curvature of M^n. Recall that on an n-dimensional Riemannian manifold, one can define a delta-curvature for any k-tuple $(n_1, \ldots, n_k)$ of integers, satisfying $2 \leq n_1 \leq \ldots \leq n_k \leq n-1$ and $n_1 + \ldots + n_k \leq n$. The strength of the inequalities lies in the fact that they give information about intrinsic invariants (the delta-curvatures) by knowing an extrinsic invariant (the mean curvature) and vice versa.

In this talk, I will give an overview of the search for the optimal constants a and b in the above inequality. Franki Dillen was involved in all major steps, from the first proposal in 1994 until our final solution in 2013. (Received January 06, 2015)

1108-53-156 **Handan Yildirim*** (handanyildirim@istanbul.edu.tr), Istanbul University Mathematics Department, (Current address: Michigan State University), Wells Hall 619 Red Cedar Road, East Lansing, MI 48824-1027. *On conformally flat almost $C(\alpha)$-manifolds.* Preliminary report.

In this talk which is based on a joint work with David E. Blair, we focus on conformally flat almost $C(\alpha)$-manifolds, and we prove that there exist 3-dimensional conformally flat almost α-Kenmotsu manifolds which are of nonconstant sectional curvature. Then, we conclude that there exist 3-dimensional conformally flat almost Kenmotsu manifolds which not only contrast with both $H^3(-1)$ and $H^2(-4)\times\mathbb{R}$ and but also are of nonconstant sectional curvature.

(The speaker expresses her appreciation to TUBITAK-BAYG for the financial support during her researches at Mathematics Department of Michigan State University.) (Received January 09, 2015)

1108-53-221 **Nathaniel Bottman*** (bottman@math.mit.edu) and **Katrin Wehrheim** (katrin@math.berkeley.edu). *A way to build maps between Fukaya categories.*

I will explain work-in-progress with Katrin Wehrheim in which we aim to bind together the Fukaya categories of many different symplectic manifolds into a single algebraic object. This object is the "symplectic A_∞-2-category", whose objects are symplectic manifolds, and where $\hom(M,N) := \mathrm{Fuk}(M^- \times N)$. In particular, a Lagrangian correspondence $\Lambda \subset M^- \times N$ will induce an A_∞-functor $F_\Lambda \colon \mathrm{Fuk}(M) \to \mathrm{Fuk}(N)$, improving on a result of Ma'u–Wehrheim–Woodward. At the core of our project are pseudoholomorphic quilts with figure eight singularity, and I will discuss several analytical results related to these objects, including a removal of singularity and a Gromov compactness theorem. (Received January 14, 2015)

1108-53-233 **Martha P. Dussan**, **Nikos Georgiou** and **Martin Magid*** (mmagid@wellesley.edu). *Minimal surfaces in the product of two dimensional space forms with the neutral Kähler structure.* Preliminary report.

Our ambient space is the product of two of the following surfaces: the sphere $\mathbb{S}^2$, hyperbolic space $\mathbb{H}^2$, the deSitter space $d\mathbb{S}^2$ or the anti-deSitter space $Ad\mathbb{S}^2$. Our metric is $(g,-g)$, where g is the standard metric on the surface. This is a neutral metric, i.e., with signature (+,+,-,-).

We consider either Riemannian or Lorentzian surfaces immersed in these ambient spaces. We find the structure equations for minimally immersed surfaces and prove some results about these minimal immersions. One example is the following theorem:

Let $F : \Sigma \to M^2 \times M^2$ be a minimal immersion of a compact surface Σ such that the induced metric is Riemannian. Assume that $K(x) + (-1)^m K^\perp(x) \geq 0$, for every $x \in \Sigma$ and $m = 0$ or 1. If M is a Riemannian space form then the immersion F is a complex curve and if M is deSitter space, the immersion F is locally the product of circles. (Here K is the Gaussian curvature and $K^\perp$ is the normal curvature.) (Received January 14, 2015)

1108-53-259 **Michael Jablonski*** (mjablonski@math.ou.edu). *Non-compact, homogeneous Einstein spaces.*

In the 1970s, D. Alekseevskii conjectured that if G/K is a non-compact, homogeneous Einstein space with negative scalar curvature, then K is a maximal compact subgroup of G. In this talk, we will present the current state of knowledge, with evidence both for and against the conjecture. (Received January 15, 2015)

1108-53-283 **Rachelle C DeCoste** and **Lisa A DeMeyer*** (demey1la@cmich.edu), Mathematics Department, Pearce 214, Central Michigan University, Mount Pleasant, MI 48858. *Totally geodesic submanifolds in 2-step nilpotent Lie groups.*

Let N be a 2-step nilpotent Lie group with left invariant metric. We give conditions under which a totally geodesic submanifold is also a subgroup, generalizing results of P. Eberlein (1994) and will present results on properties of the associated totally geodesic subalgebra. (Received January 16, 2015)

1108-53-284 **Allie Ray*** (allie.ray@mavs.uta.edu). *The Geometry of Two-Step and Three-Step Nilpotent Lie Algebras and Nilmanifolds Constructed from Schreier Graphs.*

I will present necessary and sufficient conditions for extending a certain two-step nilpotent Lie algebra constructed from a colored, directed graph to a three-step nilpotent Lie algebra. The two-step construction is a generalization of a method used by S.G. Dani and M.G. Mainkar. Three-step nilpotent Lie algebras are more delicate to construct since the Jacobi equation becomes a consideration. In addition, starting with pairs of Schreier graphs of a Gassmann-Sunada triple, I will consider the geometry (in particular issues of isospectrality and isometry) of the associated nilmanifolds. (Received January 16, 2015)

1108-53-292 **Renato G. Bettiol*** (rbettiol@nd.edu), University of Notre Dame, Department of Mathematics, 255 Hurley Building, Notre Dame, IN 46617. *On 4-manifolds with positive biorthogonal curvature.*

A 4-manifold is said to have positive biorthogonal curvature if the average of the sectional curvatures of orthogonal planes is positive. In this talk, I will describe a construction of metrics with positive biorthogonal curvature on the product of spheres, and apply surgery techniques due to Hoelzel to classify (up to homeomorphism) the closed simply-connected 4-manifolds that admit a metric with positive biorthogonal curvature. (Received January 16, 2015)

1108-53-293 **Caitlin Leverson*** (cleverso@math.duke.edu). *Legendrian Knots, Augmentations, and Rulings.*

A Legendrian knot in $\mathbb{R}^3$ with the standard contact structure is a knot for which $dz - ydx = 0$. Given a Legendrian knot, one can associate the Chekanov- Eliashberg differential graded algebra (DGA) over $\mathbb{Z}/2$. Fuchs and Sabloff showed there is a correspondence between augmentations to $\mathbb{Z}/2$ of the DGA and rulings of the knot diagram. Etnyre, Ng, and Sabloff showed that one can define a lift of the Chekanov-Eliashberg DGA over $\mathbb{Z}/2$ to a DGA over $\mathbb{Z}[t, t^{-1}]$. This talk will give an extension of the relationship between rulings and augmentations to $\mathbb{Z}/2$ for the DGA over $\mathbb{Z}/2$, to a relationship between rulings and augmentations to a field of the DGA over $\mathbb{Z}[t, t^{-1}]$. No knowledge of the Chekanov-Eliashberg DGA will be assumed. (Received January 16, 2015)

1108-53-296 **Tommy Murphy*** (tmurphy@fullerton.edu), 800 N State College Blvd., Fullerton, CA 92831. *Totally geodesic submanifolds in Riemannian geometry.* Preliminary report.

A natural and fundamental question in submanifold geometry is to classify all the totally geodesic submanifolds of dimension > 1 for a given Riemannian manifold. Little is known aside from Riemannian symmetric spaces, where one has (in theory) complete control of the curvature tensor. For example, whilst it is widely believed that such submanifolds do not exist for a generic metric, there is only one explicitly known example of this (certain Berger spheres). In this preliminary report, I will outline some progress on this problem. (Received January 16, 2015)

1108-53-317 **Megan M Kerr*** (mkerr@wellesley.edu), Department of Mathematics, Wellesley College, 106 Central St, Wellesley, MA 02482, and **Tracy L Payne**, Department of Mathematics, Idaho State University, Pocatello, ID 83209-8085. *Submanifolds of solvmanifolds: a generalization to nilsolitons.* Preliminary report.

In a 2011 paper, H. Tamaru obtained new examples of Einstein solvmanifolds via parabolic subalgebras of semisimple Lie algebras, to build solvable subalgebras by restricting to a subset Λ' of the set Λ of simple roots, using this subset to generate a subalgebra. The corresponding submanifold, given a natural inner product, is called an *attached* solvmanifold. Tamaru proves that when the original solvmanifold is Einstein, then the attached subspace is also Einstein. That is, the constant Ricci curvature is inherited, unchanged.

We explore when Tamaru's method can be extended beyond the setting of a solvmanifold corresponding to a symmetric space, to an arbitrary nilsoliton with Einstein solvable extension, so that the same results carry over. (Received January 17, 2015)

1108-53-332 **Ion Mihai*** (imihai@fmi.unibuc.ro), Faculty of Mathematics and Computer Science, Str. Academiei 14, 010014 Bucharest, Romania. *On the Generalized Wintgen Inequality for Submanifolds in Complex and Sasakian Space Forms.* Preliminary report.

The generalized Wintgen inequality was conjectured by De Smet, Dillen, Verstraelen and Vrancken in 1999 for submanifolds in real space forms. It is also known as the DDVV conjecture. It was proven recently by Lu (2011) and by Ge and Tang (2008), independently.

The present author established a generalized Wintgen inequality for Lagrangian submanifolds and Kählerian slant submanifolds, respectively, in complex space forms in 2014.

We investigate corresponding inequalities for submanifolds in Sasakian space forms. Dillen et al. (2007) proved such inequalities for Sasakian submanifolds in Sasakian space forms. We state the generalized Wintgen inequality for Legendrian submanifolds and contact slant submanifolds in Sasakian space forms. Some geometric applications are derived.

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3. I. Mihai, *On the generalized Wintgen inequality for Lagrangian submanifolds in complex space forms*, Nonlinear Anal. **95** (2014), 714-720. (Received January 18, 2015)

1108-53-338 **Alfonso Carriazo*** (carriazo@us.es), Dept. Geometry and Topology. Fac. Mathematics, University of Seville, c/ Tarfia s/n, 41012 Seville, Spain. *Semi-Riemannian generalized Sasakian-space-forms.*

In this talk we will review the main facts about generalized Sasakian-space-forms, as well as their possible extensions to semi-Riemannian geometry. (Received January 18, 2015)

1108-53-358 **Wendy Goemans*** (wendy.goemans@kuleuven.be), KU Leuven, Campus Brussel, Warmoesberg 26, 1000 Brussels, Belgium. *Clelia curves in Euclidean and Minkowski 3-space.* Preliminary report.

In the 18th century, Clelia Grillo Borromeo Arese studied special spherical curves for which the angle coordinates, when the curve is parametrized using spherical coordinates, are linearly dependent. These curves were named after her by Luigi Guido Grandi. Two well-known examples of a Clelia are Pappus' spiral and Viviani's curve. Clelias are also called spherical spirals by some authors.

In this presentation, I draw the attention to Clelias from two viewpoints. On the one hand, Clelias are the links of the cones which are flat twisted surfaces. On the other hand, the intersection of a sphere and Plücker's conoid, is a Clelia.

A twisted surface is traced out by a planar curve that rotates in its supporting plane while simultaneously this supporting plane is rotated about an axis in the plane, possibly at different speeds. Because of the different causal characters of the rotation axis, different parametrizations of twisted surfaces have to be considered in Minkowski 3-space. However, in all cases, a cone over a Clelia is a flat twisted surface.

The construction of Plücker's conoid is translated to Minkowski 3-space. Then, it is shown that a Clelia in Minkowski 3-space is the intersection of a pseudosphere or a pseudohyperbolic space and a kind of Plücker's conoid. (Received January 18, 2015)

1108-53-386 **Brendan J Foreman*** (bforeman@jcu.edu), John Carroll University, Department of Math/CS, 20700 N. Park Boulevard, University Heights, OH 44118. *A vertex-type theorem on the projective plane and its applications to curve theory on* $\mathbb{H}^2 \times \mathbb{R}$. Preliminary report.

In this talk, we will present a vertex-type theorem to curves in the projective plane. Namely, we will prove that, if Γ is a strictly convex curve in $\mathbb{R}^2$ whose image is closed in the projective plane and if l_1 and l_2 are distinct lines tangent to Γ, then there are at least four conics that are tangent to both l_1 and l_2 and have contact order of at least three with Γ.

We will then show how this theorem has been recently refined by M. Umehara and G. Thorbergsson in such a way that we can develop vertex-type theorems for closed curves in $\mathbb{H}^2 \times \mathbb{R}$ with respect to constant angle surfaces. (Received January 19, 2015)

1108-53-401 **Timothy Nguyen*** (timothyn@math.msu.edu), 619 Red Cedar Road, Room C207, East Lansing, MI 48824. *2D Quantum Yang-Mills Theory and Stochastic Analysis.* Preliminary report.

Quantum Yang-Mills theory in two dimensions is special in that it is exactly soluble. More precisely, expectation values of Wilson loop observables can be evaluated exactly in terms of Brownian motion on the given gauge group. On the other hand, most quantum field theories can only be analyzed perturbatively via Wick's Lemma applied to Gaussian measures. In this talk, we show how perturbation theory and the exact solution to 2D Yang-Mills are related through the appropriate stochastic analysis. (Received January 19, 2015)

1108-53-427 **Sushmita Venugopalan**, H1, SIPCOT IT Park, Siruseri Kelambakk, 603103, India, and **Chris Woodward*** (ctw@math.rutgers.edu), 110 Frelinghuysen Rd, Piscataway, NJ 08854. *Vortex counting.*

We classify vortices on the affine line. This allows several "vortex-counting" invariants to be rigorously defined.
(Received January 19, 2015)

1108-53-482 **Shihshu Walter Wei*** (wwei@ou.edu), Department of Mathematics, The University of Oklahoma, Norman, OK 73019. *Multiply warp product manifolds and slant submanifolds.*

We'll discuss multiply warp product manifolds and their warped functions. Some study on slant submanifolds of Kähler manifolds via p-harmonic morphisms will also be made. (Received January 19, 2015)

1108-53-498 **Boris Mordukhovich**, 656 W Kirby, Detroit, MI 48201, and **Yuan Tian***, 656 W Kirby, Detroit, MI 48201. *Implicit Euler Approximation and Optimization of One-Sided Lipschitzian Differential Inclusions.*

This paper concerns the study of the generalized Bolza problem governed by differential inclusions satisfying the so-called "relaxed one-sided Lipschitzian" (ROSL) condition with respect to the state variables subject to various types of nonsmooth endpoint constraints. We construct discrete approximations of differential inclusions with ROSL right-hand sides by using the implicit Euler scheme for approximating time derivatives, and then we justify an appropriate well-posedness of such approximations. Our principal result establishes the strong approximation (in the sense of the $W^{1,2}$ norm convergence) of an "intermediate" local optimal solution of the continuous-time Bolza problem under the ROSL assumption by optimal solutions of the implicitly discretized finite-difference systems. Finally, we derive necessary optimality conditions for the discretized Bolza problems via suitable generalized differential constructions of variational analysis. The obtained results on the well-posedness of discrete approximations and necessary optimality conditions allow us to justify a numerical approach to solve the generalized Bolza problem for one-sided Lipschitzian differential inclusions by using discrete approximations constructed via the implicit Euler scheme. (Received January 20, 2015)

1108-53-536 **Sheel C Ganatra*** (ganatra@math.stanford.edu), Stanford Department of Mathematics, Building 380, 450 Serra Mall, Stanford, CA 94305. *Symplectic cohomology relative normal crossings divisors in the topological limit.* Preliminary report.

Symplectic cohomology, first introduced by Floer and Hofer, is an important Floer-theoretic invariant of exact symplectic manifolds. Although it is very effective at distinguishing symplectic structures, very few complete computations are known, and even fewer of its ring structure. In this talk we study the case of complements of normal crossings divisors. We construct a spectral sequence for symplectic cohomology coming from the topology and combinatorics of a normal crossings compactification. Then, we show that in many cases (for instance when there are many ample divisors), this spectral sequence degenerates, giving a complete computation of the symplectic cohomology ring.

This is joint work with Daniel Pomerleano. (Received January 20, 2015)

1108-53-568 **Ivko M Dimitric*** (ivko@psu.edu), 2201 University Dr., Penn State University Fayette, Lemont Furnace, PA 15456. *Low-type submanifolds of complex space forms.* Preliminary report.

CR-submanifolds of low Chen-type in complex projective and hyperbolic spaces are studied. 2-type totally real submanifolds are characterized in terms of standard extrinsic invariants, the result further specialized to Lagrangian submanifolds with parallel mean curvature vector. We also prove some non-existence results for certain families of CR-submanifolds of Chen-type two. For example, there exist no holomorphic submanifolds of the complex hyperbolic space which are of 2-type via the standard embedding by the projectors. This is in contrast to the situation in a complex projective space, where there exist some parallel Einstein submanifolds of 2-type. We further show that there are no ruled hypersurfaces of Chen-type two in a complex space form. (Received January 20, 2015)

54 ► General topology

1108-54-253 **Kyle Larson***, klarson@math.utexas.edu, and **Jeffrey Meier**. *Fibered ribbon disks.*

We investigate fibered disks in B^4 and their relationship to fibered homotopy-ribbon knots and 2–knots (using classical work of Casson-Gordon and Cochran). We interpret monodromy changes in terms of surgery in the total space, and give analogues of the Stallings twist for disk-knots and 2-knots. As an application, we produce infinite families of distinct homotopy-ribbon disks with homotopy equivalent exteriors, with relevance to the Slice-Ribbon Conjecture. We show that any fibered ribbon 2–knot can be obtained by doubling infinitely many different disk-knots (sometimes in different contractible 4–manifolds). (Received January 15, 2015)

1108-54-573 **Margaret Doig*** (midoig@syr.edu). *Algebraic knots and $\bar{\mu}$ invariants.*

We will discuss the calculation of the Neumann-Siebenmann $\bar{\mu}$ invariants (equivalently, the Heegaard Floer d-invariants associated to the spin structures) for manifolds which are $1/s$-surgery on algebraic knots where s is odd. As a corollary, these invariants obstruct the manifolds from bounding rational homology 4-balls. (Received January 20, 2015)

57 ► Manifolds and cell complexes

1108-57-82 **Charles D Frohman*** (charles-frohman@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242, and **Sanjay L Kumar**, Department of Mathematics, The University of Iowa, Iowa City, IA 52242. *Tangle Functors for Quantum Groups at Roots of Unity.* Preliminary report.

The quantum group $U_q(sl_2)$ when q is a root of unity has center a finite extension of the coordinate ring of the algebraic group that is Poisson dual to $SL_2\mathbb{C}$. Contrary to popular belief, the $U_2(sl_2)$ is not quasitriangular, instead of an R-matrix there is an R-automorphism of $U_q(sl_2) \otimes U_q(sl_2)$ that takes comultiplication to its opposite. We work out explicit formulas based on this automorphism for a tangle functor. The tangle functor behaves differently than traditional tangle functors as the representations assigned to strands, change at the crossings. This work starts with investigations of Reshetikhin and Kashaev. (Received December 30, 2014)

1108-57-92 **Anh T. Tran*** (att140830@utdallas.edu), Department of Mathematical Sciences, University of Texas at Dallas, 800 W Campbell Rd, FO 35, Richardson, TX 75080. *Some conjectures about the colored Jones polynomial.*

I will discuss some important conjectures about the colored Jones polynomial. These include the volume conjecture, the AJ conjecture and the slope conjecture. This talk is partly based on joint works with Thang T.Q. Le and with Effie Kalfagianni. (Received January 03, 2015)

1108-57-107 **M. Hedden**, **C. Herald** and **P. Kirk*** (pkirk@indiana.edu). *The pillowcase and traceless representations of knot groups.* Preliminary report.

We define an elementary relatively Z/4 graded Lagrangian-Floer chain complex for restricted immersions of compact 1-manifolds into the pillowcase, and apply it to the intersection diagram obtained by taking traceless SU(2) character varieties of 2-tangle decompositions of knots. Calculations for torus knots are explained in terms of pictures in the punctured plane. The relation to the reduced instanton homology of knots is explored. (Received January 05, 2015)

1108-57-110 **Abhijit Champanerkar*** (abhijit@math.csi.cuny.edu), Department of Mathematics, College of Staten Island, CUNY, 2800 Victory Blvd, Staten Island, NY 10314, and **Ilya Kofman** and **Jessica Purcell**. *Spectra for volume and determinant density.*

We study the asymptotic behaviour of two basic knot invariants, a geometric invariant called the volume density defined as volume per crossing number, and a diagrammatic invariant called the determinant density defined as $2\pi \log \det(K)$ per crossing number. We will discuss theorems and conjectures relating the asymptotic behaviour of these invariants. (Received January 05, 2015)

1108-57-140 **D. B. McReynolds*** (dmcreyno@purdue.edu), 150 N. University, Purdue University, Department of Mathematics, West Lafayette, IN 47907, and **Alan W. Reid** (areid@math.utexas.edu). *The full surface spectrum of a hyperbolic 3-manifold.*

In this talk, I will discuss how one can use surfaces to recover the commensurability class of a closed hyperbolic 3-manifold. Moreover, there can only be finitely many closed 3-manifolds with the same set of surfaces. This work is joint with Alan Reid. (Received January 08, 2015)

1108-57-158 **Priyam Patel*** (patel376@purdue.edu). *Lifting immersed geodesics to embedded ones in finite covers.*

It is a well known result of Peter Scott that the fundamental groups of surfaces are subgroup separable. This algebraic property of surface groups also has important topological implications. One such implication is that every immersed (self-intersecting), closed geodesic on a surface lifts to an embedded one in a finite cover of the surface. A natural question that arises is: given a closed geodesic, what is the minimal degree of the covers in which the geodesic lifts to be embedded? In this talk we will discuss results answering the above question for hyperbolic surfaces, as well as several related questions regarding the relationship between geodesic length and geometric self-intersection number. (Received January 09, 2015)

1108-57-172 **Adam M Lowrance*** (adlowrance@vassar.edu) and **Radmila Sazdanovic**. *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 January 10, 2015)

1108-57-173 **Charles Frohman*** (charles-frohman@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242, and **Sanjay Kumar**. *Tangle Functors coming from $U_q(sl_2)$ at roots of unity.*

The unreduced quantum group $U_q(sl_2)$ has a large center which is a finite extension of the coordinate ring of the algebraic group that is Poisson dual to $SL_2\mathbb{C}$. The algebra $U_q(sl_2)$ is not quasitriangular in the strict sense, as instead of a universal R-matrix in $U_q(sl_2)\otimes U_q(sl_2)$ there is a universal R-automorphism, $R : U_q(sl_2)\otimes U_q(sl_2) \to U_q(sl_2) \otimes U_q(sl_2)$, that was developed by Reshetikhin and Reshetikhin and Kashaev in papers that appeared in 1994 and 2005. We give a careful description of the basic data for a tangle functor based on this operator, where the colors come from representations parametrized by elements of the Poisson dual of $SL_2\mathbb{C}$ and explore the properties of the functor. (Received January 10, 2015)

1108-57-175 **Christine Ruey Shan Lee*** (leechr29@msu.edu). *Crosscap number of an alternating link and the Jones polynomial.*

We discuss a two-sided linear bound of the crosscap number of an alternating link, obtained by studying the geometry of a corresponding augmented link complement. By writing this bound in terms of the coefficients of the Jones polynomial, we are able to improve known lower bounds of crosscap numbers for many alternating knots. The talk will sketch the main ideas of the proof, as well as discuss possible extensions of the result. This is joint work with Efstratia Kalfagianni. (Received January 10, 2015)

1108-57-182 **Charles Livingston*** (livingst@indiana.edu), Mathematics Department, Indiana University, Bloomington, IN 47405, and **Cornelia Van Cott**. *Knot signatures, upsilon, and the four-genus of knots.* Preliminary report.

The Levine-Tristram signature function and the recently defined Ozsvath-Stipsicz-Szabo upsilon function yield homomorphisms from the knot concordance group to the space of functions on [0,1]. Both provide bounds on the four-genus of a knot. In this talk I will review the definitions of these functions. Connected sums of torus knots will be used to illustrate their strengths and complementary nature in determining the four-genus of knots. (Received January 15, 2015)

1108-57-228 **Colin Adams*** (cadams@williams.edu), Bronfman Science Center, 18 Hoxsey St., Williamstown, MA 01267. *Hyperbolic volumes and generalized augmented alternating links.*

Adding trivial "vertical" components bounding twice-punctured disks to an alternating projection is known to yield a hyperbolic link. These augmented alternating links have proved useful in a variety of applications. Here, we generalize so that the disks can be n-punctured. This has applications to both volume bounds and to explicit volumes of links. (Received January 14, 2015)

1108-57-230 **Kristen Hendricks*** (hendricks@math.ucla.edu). *A spectral sequence for the Floer cohomology of symplectomorphisms of trivial polarization class.*

If M is an exact symplectic manifold with stably trivial tangent bundle, then a symplectomorphism of M induces a map from M to the infinite symplectic group via the induced map on the tangent bundle. We show that if this map is nulhomotopic (and other common technical requirements are satisfied), Seidel and Smith's localization theory for Floer cohomology implies the existence of a spectral sequence from the Floer cohomology of the square of the symplectomorphism to the Floer cohomology of the symplectomorphism itself, and a corresponding rank inequality. (Received January 14, 2015)

1108-57-235 **Matthew Hedden**, **Christopher M. Herald*** (herald@unr.edu) and **Paul Kirk**. *Traceless representations, tangles and a Lagrangian-Floer theory in the pillowcase.* Preliminary report.

We discuss a relatively Z/4 graded Lagrangian-Floer chain complex for a particular class of 1-manifolds in the pillowcase, that is, the traceless character variety of the four-punctured 2-sphere. Given an appropriate 2-tangle decomposition of a knot, the traceless SU(2) character varieties of the tangles give rise to Lagrangian submanifolds in the pillowcase. A Lagrangian-Floer chain complex is then generated by intersections, which correspond to the generators of Kronheimer-Mrowka singular instanton chain complex for the knot. We discuss the Atiyah-Floer conjecture relating these two Floer homology theories. (Received January 16, 2015)

1108-57-236 **Matthew Hedden**, **Christopher M. Herald*** (herald@unr.edu) and **Paul Kirk**. *Traceless representations, tangles and a Lagrangian-Floer theory in the pillowcase.* Preliminary report.

We discuss a relatively Z/4 graded Lagrangian-Floer chain complex for a particular class of 1-manifolds in the pillowcase, that is, the traceless character variety of the four-punctured 2-sphere. Given an appropriate 2-tangle

decomposition of a knot, the traceless SU(2) character varieties of the tangles give rise to Lagrangian submanifolds in the pillowcase. A Lagrangian-Floer chain complex is then generated by intersections, which correspond to the generators of Kronheimer-Mrowka singular instanton chain complex for the knot. We discuss the Atiyah-Floer conjecture relating these two Floer homology theories, and the prospects for showing the Lagrangian-Floer complex is a knot invariant. (Received January 14, 2015)

1108-57-237 **Tye Lidman*** (tlid@math.utexas.edu) and **Steven Sivek**. *Quasi-alternating links with small determinant.*

Quasi-alternating links are a generalization of alternating links as a natural class of links with simple Floer and Khovanov homologies. Greene classified the quasi-alternating links with determinant at most 3. We will extend this classification to some higher determinants. (Received January 14, 2015)

1108-57-243 **Radmila Sazdanovic*** (rsazdanovic@math.ncsu.edu), NCSU Department of Mathematics, 3210 SAS Hall 2311 Stinson Drive, PO Box 8205, Raleigh, NC 27695, and **Vladimir Baranovsky**. *Chromatic homology and graph configuration spaces.*

We present a proof of a conjecture due to M. Khovanov relating the algebraic and topological categorification of the chromatic polynomial. In particular, we show that there is a spectral sequence whose E_1 term is the chromatic graph homology that converges to the homology of the graph configuration space. (Received January 15, 2015)

1108-57-251 **Saul Schleimer** and **Henry Segerman*** (segerman@math.okstate.edu), OK. *Veering Dehn surgery.* Preliminary report.

Veering structures on ideal triangulations of cusped manifolds were introduced by Ian Agol, who showed that every pseudo-Anosov mapping torus over a surface, drilled along all singular points of the measured foliations, has an ideal triangulation with a veering structure. Any such structure coming from Agol's construction is necessarily layered, although a few non-layered structures have been found by randomised search. We introduce veering Dehn surgery, which can be applied to certain veering triangulations, to produce veering triangulations of a surgered manifold. As an application we find an infinite family of transverse veering triangulations none of which are layered. Until recently, it was hoped that veering triangulations might be geometric, however the first counterexamples were found recently by Issa, Hodgson and the second author. We also apply our surgery construction to find a different infinite family of transverse veering triangulations, none of which are geometric.
(Received January 15, 2015)

1108-57-260 **Susan M Abernathy** and **Patrick M Gilmer***, Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Even and odd Kauffman bracket ideals for genus-1 tangles.*

We adapt a basis of Habiro's for the even Kauffman bracket skein module of the solid torus to define bases for the even and odd skein modules of the solid torus relative to two points. We discuss genus-1 tangle embeddings, and define an even and odd version of the Kauffman bracket ideal for genus-1 tangles. These even and odd Kauffman bracket ideals are obstructions to even and odd tangle embeddings. Using our even and odd bases for the relative skein modules, we show how to compute a finite list of generators for the even and odd Kauffman bracket ideals of a genus-1 tangle. We do this explicitly for some genus-1 tangles. We relate these ideals to determinants of closures of genus-1 tangles. We give an example of a genus-1 tangle which cannot be embedded in an unknot but which is not detected by the Kauffman bracket ideal but which is detected by the even and odd Kauffman bracket ideals working in tandem. (Received January 15, 2015)

1108-57-273 **Jeffrey Meier*** (jlmeier@indiana.edu) and **Alexander Zupan**. *Bridge trisections of knotted surfaces in S^4.*

Recently, Gay and Kirby introduced a new way of describing a 4–manifold called a *trisection*, which involves decomposing the 4–manifold into three 4–dimensional handlebodies and serves as a 4–dimensional analogue to a Heegaard splitting of a 3–manifold. We adapt their approach to the setting of knotted surfaces in S^4; namely, we show that every such surface $\mathcal{K}$ admits a *bridge trisection*, which is a decomposition of $(S^4, \mathcal{K})$ into three pieces, each of which is a collection of trivial disks in B^4. A bridge decomposition associates two complexity parameters to $\mathcal{K}$, which are analogous to the bridge number of a classical knot, and we give a classification of knotted surfaces with low bridge number. We also introduce a new way to describe knotted surfaces in S^4 diagrammatically in terms of a triple of classical tangles called a *tri-plane diagram*. This is joint work with Alexander Zupan. (Received January 16, 2015)

1108-57-289 **Tim Cochran**, **Shelly Harvey**, **Constance Leidy** and **Peter Horn*** (pdhorn@syr.edu), 215 Carnegie, Syracuse, 13244-1150. *Noncommutative knot Floer homology.* Preliminary report.

Noncommutative knot Floer homology (ncHFK) is a variant of combinatorial knot Floer homology with an Alexander 'filtration' taking values in a nonabelian group. The noncommutative grading lifts the integer-valued Alexander filtration in a certain sense. In this talk I will define the noncommutative Alexander filtration and the chain complex for ncHFK and discuss the difficulties that lie ahead. (Received January 16, 2015)

1108-57-302 **Ying Hu***, Department of Mathematics, Louisiana State University, Baton Rouge, LA 70802. *Left-orderability and cyclic branched covers.* Preliminary report.

A group is called left-orderable if one can put a total order $<$ on the set of group elements so that inequalities are preserved by group multiplication on the left. The left-orderability of 3-manifold groups is closely related to the concepts of L-spaces and taut foliations, as conjectured by Boyer-Gordon-Watson. In this talk, we will discuss the left-orderability of fundamental groups of cyclic branched covers of the three sphere. (Received January 16, 2015)

1108-57-335 **Douglas J LaFountain*** (d-lafountain@wiu.edu). *Botany of transverse knots.* Preliminary report.

We study transverse knot representatives of an oriented topological knot type $\mathcal{K}$ in $\mathbb{R}^3$ with its tight contact structure. The classical invariant of transverse isotopy is the self-linking number *sl*, and as such presents both a geography and botany problem. The geography problem for transverse knots, namely what values of *sl* can be realized by transverse knot representatives of $\mathcal{K}$, was solved in principle by Bennequin: there is a maximal self-linking number $\overline{sl}(\mathcal{K})$, and all other *sl*-values realized are of the form $\overline{sl}(\mathcal{K}) - 2n$ for $n \in \mathbb{N}$. The botany problem for transverse knots, namely what transverse isotopy classes exist at a fixed value of *sl*, has remained open in general, although for certain knot types a number of interesting botanical features have been shown to exist. In this talk we present partial solutions of the botany problem that hold for arbitrary knot types $\mathcal{K}$. (Received January 18, 2015)

1108-57-345 **Ryan Kowalick**, **Jean-François Lafont** and **Barry Minemyer*** (minemyer.1@osu.edu), 231 W. 18th Ave, MW458, Columbus, OH 43210. *A Combinatorial Systolic Inequality.*

The systole of a Riemannian manifold M, denoted $\mathrm{sys}_{\pi_1}(M)$, is the length of the shortest noncontractible closed geodesic in M. Gromov proved that for any n-dimensional essential manifold M

$$\mathrm{sys}_{\pi_1}(M) \leq C_n \sqrt[n]{\mathrm{Vol}(M)}$$

where the constant C_n depends only on n and *not* on M. The property of a manifold being essential is a topological condition, and for simplicity one may instead consider M to be aspherical (all aspherical manifolds are essential).

In this paper we consider tuples $(M, \mathcal{T})$ of manifolds equipped with a fixed smooth triangulation, and we consider an analogous combinatorial systolic inequality. We prove that a topological class of smooth manifolds satisfies this combinatorial systolic inequality if and only if it satisfies Gromov's systolic inequality. In particular, the class of smooth triangulations for essential smooth manifolds satisfies a combinatorial systolic inequality. (Received January 18, 2015)

1108-57-360 **Tye Lidman** and **Steven Sivek***, Fine Hall, Washington Road, Princeton, NJ 08544-1000. *Contact structures and reducible surgeries.*

We apply results from both contact topology and exceptional surgery theory to study when Legendrian surgery on a knot yields a reducible manifold. In particular, if the maximal Thurston-Bennequin number $\overline{tb}(K)$ is nonnegative, we show that any reducible surgery on K must have slope at least $\overline{tb}(K)$; we also obtain strong restrictions in the case $\overline{tb}(K) < 0$. As an application, we will show that a reducible surgery on a non-cabled positive knot of genus g must have slope $2g - 1$, leading to a proof of the cabling conjecture for positive knots of genus 2. (Received January 18, 2015)

1108-57-366 **Charles Frohman** and **Joanna Kania-Bartoszynska*** (jkaniaba@nsf.gov). *Two examples of extended Topological Quantum Field Theories.*

We describe skein theoretic constructions of two extended Topological Quantum Field Theories. One underlies the Witten-Reshetikhin-Turaev invariants of 3-manifods and the second underlies quantum hyperbolic geometry. (Received January 18, 2015)

1108-57-369 **Chris Connell*** (connell@indiana.edu), **Benson Farb** and **Ben McReynolds**. *A gap in the homological dimensions of discrete subgroups of $Sp(n;1)$ and F_4^{-20}*. Preliminary report.

Let G be a torsion-free, finitely generated discrete subgroup of either the isometry group of quaternionic or Cayley hyperbolic space; that is, up to isogeny, $G < Sp(n;1)$ for $n \geq 2$ or $G < F_4^{-20}$. We prove that if G contains no parabolics then there is a gap in the possible homological dimension hd(G) of G. Namely, if $G < Sp(n;1)$, either $hd(G) = 4n$ or $hd(G) \leq 4n-2$, and if $G < F_4^{-20}$, then either $hd(G) = 16$ or $hd(G) \leq 12$. This result does not hold in the real or complex hyperbolic cases, or if G is allowed to have parabolics (even for subgroups of lattices). Our method requires a generalization of work of Besson–Courtois–Gallot on estimates of p–Jacobians of natural maps. We also generalize an inequality of M. Kapovich between the homological dimension and critical exponent for discrete subgroups of the isometry group of real hyperbolic n–space. This is joint work with Benson Farb and Ben McReynolds. (Received January 18, 2015)

1108-57-370 **Christian R Millichap*** (christian.millichap@gmail.com). *Commensurability classes and geometric invariants of hyperbolic knot complements.*

This talk will discuss a construction used to create large classes of hyperbolic knot complements that have a number of geometric invariants in common yet are pairwise incommensurable, i.e., don't share a common finite-sheeted cover. A topological cut and paste operation known as mutation will play an essential role in creating these geometrically similar hyperbolic 3-manifolds. A careful cusp analysis of such knot complements will be used to examine their commensurability classes. We will also briefly discuss how these techniques can be generalized to examine commensurability classes and geometric invariants of other types of hyperbolic knot complements. (Received January 18, 2015)

1108-57-377 **Helen Wong*** (hwong@carleton.edu), 1 N College St, Northfield, MN 55057, and **Martin Bobb** and **Dylan Peifer**. *The Kauffman arc algebra is finitely generated.* Preliminary report.

We exhibit a finite set of generators for the Kauffman arc algebra, which Roger and Yang recently defined to be a quantization of Penner's decorated Teichmüller space. (Received January 19, 2015)

1108-57-388 **David Futer*** (dfuter@temple.edu), Mathematics Department, Temple University, 1805 North Broad St., Philadelphia, PA 19122, and **Christian Millichap** (christian.millichap@gmail.com), Mathematics Department, Temple University, 1805 North Broad St., Philadelphia, PA 19122. *Geometrically similar knots.* Preliminary report.

There are several known ways to produce hyperbolic 3-manifolds that isospectral (i.e. have the same spectrum of geodesic lengths) but not isometric. All known constructions of of this sort involve tricks with finite covers, leading Reid to ask whether this is a necessary feature. That is, are isospectral manifolds necessarily commensurable? I will describe a way to build pairs of knot complements that are incommensurable but have the same closed geodesics up to length L, where L is as large as one likes. This is joint work with Christian Millichap. (Received January 19, 2015)

1108-57-391 **Thomas E Mark*** (tmark@virginia.edu), PO Box 400137, Kerchof Hall, University of Virginia, Charlottesville, VA 22904, and **Bulent Tosun** (bt5t@virginia.edu), PO Box 400137, Kerchof Hall, University of Virginia, Charlottesville, VA 22904. *Tightness of positive rational contact surgeries.*

We consider the problem of tightness of a contact structure obtained by contact surgery along a Legendrian knot in the three-sphere, with positive rational surgery coefficient. Our main tool is a generalization of a theorem of Baldwin on the effect on the Ozsváth-Szabó contact invariant of capping off of binding components of open book decompositions. We will describe this result and outline the applications to positive rational contact surgeries, which complement and extend work of Golla and Lisca-Stipsicz. (Received January 19, 2015)

1108-57-450 **Seungwon Kim*** (math751@gmail.com). *Link diagrams with Turaev genus one.* Preliminary report.

The Turaev genus of a link is a topological measure of how far a given link is from being alternating. We show that every prime Turaev genus one link is a cycle of alternating 2-tangles. The proof provides a new way to obtain a meridian-longitude basis for the Turaev surface from the link diagram. (Received January 20, 2015)

1108-57-466 **Nicholas Troy Zufelt*** (nzufelt@math.utexas.edu). *The combinatorics of reducible Dehn surgeries.* Preliminary report.

We use the combinatorial techniques of graphs of intersection to study reducible Dehn surgeries on knots in the three-sphere. In particular, in the event that such a reducible surgery produces a manifold with more than two connected summands, we show that the surgery coefficient is bounded above by the bridge number of the knot. As a consequence, this possibility is ruled out for knots with bridge number less than six and for positive braid closures. (Received January 19, 2015)

1108-57-471 **John A. Baldwin** (john.baldwin@bc.edu) and **Adam S. Levine*** (asl2@math.princeton.edu). *Khovanov homology and knot Floer homology.* Preliminary report.

There are spectral sequences relating 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. (Received January 19, 2015)

1108-57-478 **Katherine Walsh*** (k3walsh@math.arizona.edu). *The Middle Coefficients of the Colored Jones Polynomial.* Preliminary report.

The colored Jones polynomial assigns to each knot a sequence of Laurent polynomials. This talk will focus on the patterns in the coefficients of these polynomials. While much work has been done looking at the leading sequence of coefficients, we will discuss work that has been done to try to move towards understanding the middle coefficients. This will include small steps like looking at what the second N coefficients of the Nth colored Jones polynomial of certain knots stabilize to and larger steps like looking at the growth rate of the coefficients and looking the the patterns present in the coefficients under various re-normalizations. (Received January 19, 2015)

1108-57-480 **Allison H Moore***, Department of Mathematics, Rice University, 6100 Main St., Houston, TX 77005, and **Tye Lidman**, Department of Mathematics, University of Texas at Austin, 2515 Speedway Stop C1200, Austin, TX 78712. *Cosmetic crossing changes in knots.* Preliminary report.

The cosmetic crossing conjecture asserts that the only crossing changes which preserve the oriented isotopy class of knot are nugatory. We will discuss techniques in Heegaard Floer homology which can be used to address the cosmetic crossing conjecture for certain classes of knots. This work is joint with Lidman. (Received January 19, 2015)

1108-57-486 **Kate Petersen*** (petersen@math.fsu.edu) and **Anh Tran**. *Character Varieties of Double Twist Links.*

I'll discuss the character varieties of the double twist links, an infinite family of two component links. These links can all be realized as Dehn fillings of two components of a three component link, and these character varieties are all ruled surfaces. I'll discuss the invariants of the character varieties and how these are related to the fact that these are all Dehn surgeries on a common link. (Received January 19, 2015)

1108-57-487 **Kate Petersen*** (petersen@math.fsu.edu). *Knots and their A-polynomials.* Preliminary report.

The A-polynomial is a 2-variable polynomial which encodes how the length of the meridian and longitude change in deformations of the knot complement. It defines a complex curve, and geometric data about this complex curve can be read from the associated Newton polygon. For example, Baker famously proved that the genus of the curve is at most the number of integral points in the interior of the Newton polygon. I'll discuss the association between the geometry of the knot complement and the A-polynomial curve, focusing on what data we can see from the Newton polygon and on the specific case of 2-bridge knots. (Received January 19, 2015)

1108-57-488 **William H. Kazez** and **Rachel Roberts*** (roberts@wustl.edu). *Approximating continuous taut foliations.*

Taut foliations, volume preserving flows, and tight contact structures are important topological structures on 3-manifolds. We will define these structures and describe some of the ways in which they are important. In particular, we will discuss these structures in the context of the following result of Eliashberg and Thurston: any smooth taut co-oriented foliation can be approximated by a pair of tight contact structures, one positive and one negative. I will discuss work, joint with Will Kazez, in which we show that the smoothness assumption on the foliation can be dropped; namely, any continuous co-oriented taut foliation can be approximated by a pair of tight contact structures, one positive and one negative. (Received January 19, 2015)

1108-57-493 **David Krcatovich*** (dk27@rice.edu). *Alexander polynomials of L-space knots.*
In this talk, we examine what restrictions can be placed on the Alexander polynomial of a knot which admits a lens space surgery, or more generally, an L-space surgery. This in turn gives some information on the "geography" of knot Floer complexes, as discussed by Hedden and Watson. (Received January 19, 2015)

1108-57-502 **Yajing Liu*** (yajingleo@math.ucla.edu), 3777 Mentone Ave, 411, Los Angeles, CA 90034. *Heegaard Floer homology from a surgery viewpoint.*
I will also talk about how to define Floer homology for 3-manifolds from the data of links based on link surgery formula due to Manolescu and Ozsvath. The invariance under Kirby moves is derived from a mapping cone formula of the generalized Floer complexes. This work is motivated by the problem of showing the combinatorial invariance of Manolescu-Ozsvath-Thurston algorithm for computing 3-manifolds Floer homology. (Received January 20, 2015)

1108-57-511 **Neal W Stoltzfus*** (stoltz@math.lsu.edu), Dept of Math, Louisiana State University, Baton Rouge, LA 70803. *Toward a theory of Skein-Theoretic Knot Concordance Invariants.* Preliminary report.
Based on the work of Massayeux-Turav and extending the results Cameron-Gordon, we develop skein-theoretic obstructions to handlebody bordism. (Received January 20, 2015)

1108-57-538 **Joshua Sabloff*** (jsabloff@haverford.edu), Department of Mathematics and Statistics, Haverford College, 370 Lancaster Ave., Haverford, PA 19041. *Explorations of Lagrangian Cobordisms using Generating Families.*
I will discuss the use of generating families in producing constructions of and obstructions to Lagrangian cobordisms between Legendrian submanifolds, with applications to the geography of generating family homology, homotopy groups of spaces of Legendrians, and bounds on the lengths of Lagrangian cobordisms. Various parts of the talk are joint with F. Bourgeois, M. Sullivan, and L. Traynor. (Received January 20, 2015)

1108-57-543 **Hans U. Boden*** (boden@mcmaster.ca), 1280 Main St W, Hamilton, Ontario L9H-4C3, Canada, **Emily Dies**, University of Toronto, and **Anne Isabel Gaudreau** and **Adam Gerlings**, University of Calgary, and **Andrew J Nicas**, McMaster University. *A classical approach to virtual knots.*
Given a virtual knot K, there are various groups naturally associated to K. We will discuss the invariants obtained from the elementary ideal theory of the virtual knot group VG_K. For instance, associated to the k=0 ideal is a polynomial $H_K(s,t,q)$ in three variables, and we show how the q-width of $H_K(s,t,q)$ gives information about the virtual crossing number of K. The polynomial $H_K(s,t,q)$ satisfies a skein formula, and one can define a twisted polynomial invariant of virtual knots for any representation from VG_K to $GL_n(R)$. Time permitting, we will also discuss recent work on almost classical knots, which are virtual knots with a diagram that admits an Alexander numbering. (Received January 20, 2015)

1108-57-549 **Hans U. Boden**, **Anne Isabel Gaudreau** and **Eric Harper***, eharper@math.mcmaster.ca, and **Andrew J. Nicas** and **Lindsay White**. *Virtual Knot Group Duality and Almost Classical Knots.* Preliminary report.
A virtual knot can be viewed as an equivalence class of virtual knot diagrams. We can associate to any representative virtual knot diagram an Alexander numbering. We will use this Alexander numbering to show that the virtual knot group VG_K, the extended knot group EG_K of Silver and Williams, and the quandle knot group QG_K of Manturov, are determined by the reduced knot group $\overline{G}_K$. In particular, we will show that EG_K and QG_K are isomorphic. The notion of an Alexander numbering can be extended to virtual knots. Virtual knots that admit Alexander numberings are called almost classical knots. We will show that for almost classical knots, the virtual knot groups above depend only on the classical knot group G_K. This leads us to study the Alexander invariants of G_K for almost classical knots. (Received January 20, 2015)

1108-57-553 **Jonathan Hanselman***, Mathematics Department, 2515 Speedway, Stop C1200, Austin, TX 78712. *Splicing integer framed knot complements.*
An L-space is a rational homology 3-sphere with minimal Heegaard Floer homology. We determine when splicing two integer framed knot complements produces an L-space. This extends a result of Hedden and Levine, who showed that splicing 0-framed knot complements never produces an L-space. For arbitrary integer framings the manifold obtained by splicing is not an L-space unless both knots are L-space knots and the framings fall in appropriate ranges. The proof relies on bordered Heegaard Floer homology. We also discuss work towards a

more general result which applies to arbitrary gluing maps and more general manifolds with torus boundary. (Received January 20, 2015)

1108-57-559 **Alexander Borland** and **Thomas Kerler*** (kerler.2@osu.edu), The Ohio State University, Department of Mathematics, Columbus, OH 43202. *Hopf Algebra Valued Knotoid Invariants.* Preliminary report.

In 2011 Turaev introduced the monoid of Knotoids $\mathcal{K}$. Given a ribbon Hopf algebra $\mathcal{H}$ together with a ribbon automorphism ϕ on $\mathcal{H}$ we construct a morphism of monoids $\mathcal{K} \to \mathcal{H}$. In the case of a trivial automorphisms the construction specializes to known knot invariants that associate to a knot an element in the center of $\mathcal{H}$. Moreover, when specialized to the fundamental representation of the quantum group $U_q(\mathfrak{sl}_2)$ our invariant is related to Turaev's knotoid bracket polynomial that contains an additional parameter which, in our picture, corresponds to a one-paramenter family of ribbon automorphisms. The method readily implies colored versions of Tuarev's invariant as well as multi-parameter generalizations to higher rank quantum groups. (Received January 20, 2015)

1108-57-561 **Andrew Donald*** (adonald@math.msu.edu) and **Faramarz Vafaee**. *A slicing obstruction from Furuta's* 10/8 *theorem.*

An obstruction to a knot being smoothly slice can be derived from Furuta's 10/8 theorem via spin structures on the 3-manifold obtained by 0-surgery. We will discuss applications of this method to examples of twisted torus knots. (Received January 20, 2015)

1108-57-566 **Christopher William Davis*** (daviscw@uwec.edu), Christopher Davis, Department of Mathematics, Hibbard Humanities Hall 508, University of Wisconsin, Eaul Claire, Eau Claire, WI 54703. *On the Levine-Tristram signature function, Infection, and knot concordance (Joint with Tim Cochran).* Preliminary report.

In a recent joint work with Tim Cochran we found that, contrary to a conjecture of Louis Kauffmann, there exist slice knots which have a genus one Seifert surface on which no curve of self linking zero is slice, or even has vanishing Levine-Tristram signature function. In doing so we produce unexpected doubling operators which are non-injective on knot concordance. In a current project we attempt to explain these examples. In doing so we study solvability of satellite operations and find that for many doubling operators, P, if P(J) is slice then J has vanishing signature function. (Received January 20, 2015)

1108-57-580 **Forrest Gordon** and **Peter Lambert-Cole*** (pblamber@indiana.edu), Department of Mathematics, Indiana University, 831 E 3rd Street, Bloomington, IN 47405. *Pretzel knots and knot Floer homology.*

Knot Floer homology associates to each knot K in S^3 a bigraded abelian group $HFK^-(K)$. The pretzel knot $P(p_1, p_2, \ldots, p_n)$ is obtained as the closure of n integer tangles of length $p_1, \ldots, p_n$. We give an explicit, closed-form description of the knot Floer homology groups in terms of the integers $n, p_1, \ldots, p_n$. (Received January 20, 2015)

1108-57-586 **Rosemary K Guzman*** (rosemary-guzman@uiowa.edu), University of Iowa, Department of Mathematics, 14 Maclean Hall, Iowa City, IA 52242. *Special subgroups of hyperbolic 3-manifold groups.*

In the 1990's, Culler, Shalen, and their co-authors initiated a program to understand the relationship between the topology and geometry of a closed hyperbolic 3-manifold. I extend those results to the setting of hyperbolic 3-manifolds with $k = 5$-free fundamental group.

I have shown that the following geometric statement is true modulo the group-theoretic statement that proceeds it: Geometric Statement: If M is a closed, orientable, hyperbolic 3-manifold such that $\pi_1(M)$ is k-free with $k \geq 5$, then when $\lambda = \log(2k-1)$, there exists a point P in M such that the set of all elements of $\pi_1(M, P)$ that are represented by loops of length less than λ is contained in a subgroup of $\pi_1(M)$ of rank $\leq k-3$. Group-Theoretic Statement: Given two rank $m = k-2$ subgroups of a free group whose intersection has rank $\geq m = k-2$, their join must have rank $\leq m = k-2$ $(m \geq 2)$.

We will discuss a special case of the geometric statement, the $k = 5$ case, which I have shown is a theorem and discuss possible implications. (Received January 20, 2015)

1108-57-588 **Christopher W Scaduto*** (scaduto@math.ucla.edu), University of California, Department of Mathematics, 520 Portola Plaza, Los Angeles, CA 90095-1555. *Instantons and odd Khovanov homology.*

Consider the double cover of the 3-sphere branched over a link. We will discuss how the instanton homology of this 3-manifold is related to the Khovanov homology of the link. When signs (integer coefficients) are taken into account, the relevant link homology is odd Khovanov homology, which is genuinely distinct from Khovanov homology. This material is motivated by work of Ozsváth and Szabó in the Heegaard-Floer setting. (Received January 21, 2015)

58 ► Global analysis, analysis on manifolds

1108-58-28 **Daniel F Cibotaru** and **Liviu I Nicolaescu*** (lnicolae@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN. *Riemann-Roch and Morse theory.*

We investigate the Dolbeault operator on a pair of pants, i.e., an elementary cobordism between a circle and the disjoint union of two circles. This operator induces a canonical selfadjoint Dirac operator D_t on each regular level set C_t of a fixed Morse function defining this cobordism. We show that as we approach the critical level set C_0 from above and from below these operators converge in the gap topology to (different) selfadjoint operators $D_\pm$ that we describe explicitly. We also relate the Atiyah-Patodi-Singer index of the Dolbeault operator on the cobordism to the spectral flows of the operators D_t on the complement of C_0 and the Kashiwara-Wall index of a triplet of finite dimensional lagrangian spaces canonically determined by C_0. (Received November 19, 2014)

1108-58-88 **Xing Wang**, Department of Mathematics, Johns Hopkins University, Baltimore, MD 21218, and **Jiuyi Zhu*** (jzhu43@math.jhu.edu), Department of Mathematics, Johns Hopkins University, Baltimore, MD 21218. *Doubling estimates, vanishing order and nodal sets of Steklov eigenfunctions.*

We study the doubling estimates, vanishing order and nodal sets of the Steklov eigenfunctions on smooth manifolds with boundary. The eigenfunction is given by a Dirichlet-to-Neumann map which is a non-local pseudodifferential differential operator with order 1. We improve the doubling property shown by Bellova and Lin by Carleman estimates. Furthermore, we obtain the optimal vanishing order of Steklov eigenfunctions. We are able to show a lower bound of nodal sets of Steklov eigenfunctions. Some of the work in the talk is joint with X. Wang. (Received January 15, 2015)

1108-58-274 **Alex S Waldron*** (awaldron@scgp.stonybrook.edu), 158 Sheep Pasture Rd, Port Jefferson, NY 11777. *Yang-Mills flow in dimension four.*

I will describe my current results on long-time behavior of four-dimensional Yang-Mills flow. (Received January 16, 2015)

1108-58-319 **Alfonso Romero*** (aromero@ugr.es), Dep. Geometria yTopologia, Facultad de Ciencias, Universidad de Granada, 18071 Granada, Granada, Spain. *Uniqueness of complete maximal hypersurfaces in spatially parabolic Generalized Robertson-Walker spacetimes.*

A Generalized Robertson-Walker (GRW) spacetime such that the universal Riemannian covering of the fiber is parabolic (thus so is the fiber) is said to be spatially parabolic. Spatially parabolic GRW spacetimes extend to spatially closed GRW spacetimes from the point of view of the geometric-analysis of the fiber. On the contrary to spatially closed GRW spacetimes, these spacetimes could be compatible with certain cosmological principle, and they can be used for modelling open relativistic universes. A complete spacelike hypersurface in a spatially parabolic GRW spacetime inherits the parabolicity, whenever some boundedness assumptions on the restriction of the warping function to the spacelike hypersurface and on the hyperbolic angle between the unit normal vector field and a certain timelike vector field are assumed. Conversely, the existence of a simply connected parabolic spacelike hypersurface, under the previous assumptions, in a GRW spacetime also leads to its spatial parabolicity. All the complete maximal hypersurfaces in a spatially parabolic GRW spacetime are determined in several cases. As an application, all the entire solutions of the maximal hypersurface equation on a parabolic Riemannian manifolds are found, solving new Calabi-Bernstein problems. (Received January 19, 2015)

1108-58-356 **Emily B. Dryden*** (ed012@bucknell.edu), **Diana Macedo** and **Rosa Sena-Dias**. *Can you hear the metric on a sphere?*

Asking whether you can "hear" a geometric attribute of a surface is an informal way of asking about the relationship between the attribute and the vibration frequencies of the surface. In the simple setting of metrics on S^2 that are invariant with respect to a natural circle action, we examine situations in which the metric can be determined by the vibration frequencies plus information coming from the action. (Received January 18, 2015)

1108-58-364 **Nikhil A Savale*** (nsavale@nd.edu). *Spectral asymptotics for magnetic Dirac operators.*

Spectral asymptotics for coupled Dirac operators are considered in the large magnetic field limit. Sharp estimates on the asymptotics are investigated via a semiclassical approach and computations on Kahler manifolds. (Received January 18, 2015)

1108-58-433 **Steven Bradlow*** (bradlow@uiuc.edu), department of mathematics, UIUC, urbana, IL 61801, and **Laura Schaposnick**. *Higgs bundles, spectral data, and isomorphisms among low dimensional Lie groups.* Preliminary report.

We will explore some interesting relations among Higgs bundles, from the point of view of spectral data, that result from special isomorphisms among low dimensional Lie algebras and Lie groups.

Higgs bundles provide an algebro-geometric description of surface group representations into complex reductive Lie groups, and also into their real forms, say G. The defining data for such G-Higgs bundles can be given as a closed Riemann surface (Σ), a holomorphic principal bundle ($E \to \Sigma$), and a Higgs field (Φ) which is a holomorphic section of an associated vector bundle. Alternatively, in many cases the defining data can be encoded in a ramified cover $S \to \Sigma$ (the spectral curve) and a line bundle in a component of the Jacobian of the spectral curve. The resulting spectral data sets depend on the curve Σ and the group G. If two groups, say G_1 and G_2, are related by a group homomorphism, one can expect the corresponding Higgs bundles and their spectral data sets to inherit induced relationships. We will explore this phenomenon in the case of isogenies resulting from accidental isomorphisms among low dimensional lie algebras. (Received January 19, 2015)

1108-58-459 **Nima Anvari*** (anvarin@math.mcmaster.ca), Hamilton, Ontario , Canada. *Equivariant Gauge Theory and the Poincaré Homology Sphere.*

The Brieskorn homology 3-spheres bound canonical smooth definite 4-manifolds obtained by plumbing disk bundles over 2-spheres. We will show that certain free cyclic group actions on the Poincaré homology sphere do not extend smoothly, with isolated fixed points, to its even negative definite resolution. We use equivariant Yang-Mills moduli spaces and discuss applications to equivariant splitting of 4-manifolds. (Received January 19, 2015)

1108-58-567 **Brian Benson*** (babenson@math.ksu.edu), Kansas State University, Mathematics Department, 138 Cardwell Hall, Manhattan, KS 66506. *Towards Computing the Cheeger Constant of Hyperbolic Surfaces.* Preliminary report.

The Cheeger constant is an invariant on a Riemannian manifold M which is related to the isoperimetric problem on the manifold and provides bounds on the spectrum of the Laplacian on M. Buser proved that whenever M is compact, there is a top-dimensional integral current which is a subset of M, having volume less than or equal to half that of M, and whose isoperimetric ratio is equal to the Cheeger constant of M. When M is non-compact, such a current need not exist, even when one assumes that M has finite volume. We will discuss ideas for proving existence of these currents for some collections of non-compact, finite area 2-manifolds. By showing that these currents exist in the case of finite area hyperbolic surfaces, we outline a theoretical algorithm for directly computing the Cheeger constant of such a hyperbolic surface. (Received January 20, 2015)

1108-58-576 **Aliakbar Daemi*** (adaemi@scgp.stonybrook.edu). *Abelian Gauge Theory and Khovanov Homology.*

Plane Floer homology is a functor from the category of 3-manifolds and cobordisms to the category of modules, defined with the aid of abelian gauge theory. This invariant can be utilized to define plane knot homology, itself an invariant of knots and links in the 3-dimensional sphere. In my talk, after giving the definition of plane Floer homology, I will discuss the relationship between this invariant and various Khovanov-type homologies. (Received January 20, 2015)

60 ► *Probability theory and stochastic processes*

1108-60-7 **Alexander Schnurr*** (aschnurr@math.tu-dortmund.de) and **Herold Dehling**. *Detecting Changes in the Dependence Structure Between two Time-series.* Preliminary report.

Using so called ordinal patterns we analyze whether there is a (possibly non-linear) dependence between given time series. If we find a dependence structure, we tackle the question whether this dependence changes over time.

Considering short-range or long-range dependent time-series, different techniques are used and different limit theorems are obtained. Applications include time series appearing in mathematical finance, biology, medicine and hydrology. (Received October 10, 2014)

1108-60-8 **Michael L Stein*** (stein@galton.uchicago.edu), 5734 University Ave., Department of Statistics, Chicago, IL 60637. *Is this long range dependence?*

A standard definition of a long range dependent stationary process is that it has an unbounded spectral density in a neighborhood of the origin. Another way to think about a long range dependent process is in terms of observations far from a prediction time having a nontrivial impact on the prediction. This talk describes a model with a bounded spectrum for which, under a certain asymptotic framework, distant observations nonnegligibly improve optimal predictions beyond what can be obtained from even a large number of observations nearer to the prediction time. Some implications of this result for practical modeling of real-world processes will be discussed. (Received October 16, 2014)

1108-60-9 **Erhan Bayraktar*** (erhan@umichedu), Department of Mathematics, 530 Church Street, Ann Arbor, MI 48109. *Stochastic Perron's Method.*

We show that the value function of a stochastic control problem is the unique solution of the associated Hamilton-Jacobi-Bellman (HJB) equation, completely avoiding the proof of the so-called dynamic programming principle (DPP). Using Stochastic Perron's method we construct a super-solution lying below the value function and a sub-solution dominating it. A comparison argument easily closes the proof. The program has the precise meaning of verification for viscosity-solutions, obtaining the DPP as a conclusion. It also immediately follows that the weak and strong formulations of the stochastic control problem have the same value. Using this method we also capture the possible face-lifting phenomenon in a straightforward manner. This method becomes especially handy in problems with Knightian uncertainty. (Received October 16, 2014)

1108-60-16 **Hongwei Mei*** (ev0554@wayne.edu) and **George Yin**. *Strong Invariance for Switching Diffusions.*

This work is concerned with switching diffusions in which the switching depends on the diffusion process. It has been shown in the literature that if such a process is positive recurrent then it is ergodic. This paper further develops a law of iterated logarithms for the estimates on the aforementioned convergence rate. The law of iterated logarithms gives us a sharp bound on the estimation error sequence. (Received November 02, 2014)

1108-60-18 **Chunsheng Ma*** (cma@math.wichita.edu), Department of Mathematics and Statistics, Wichita State University, Wichita, KS 67260-0033. *Multifractional vector Brownian motions and their generalizations.*

In this talk we introduce three types of covariance matrix structures for Gaussian or elliptically contoured vector random fields in space and/or time, which include fractional, bifractional, and trifractional vector Brownian motions as special cases, and reveals the relationships among these vector random fields, with an orthogonal decomposition established for the multifractional vector Brownian motion. (Received November 06, 2014)

1108-60-19 **Quan Yuan*** (quanyuan@wayne.edu) and **George Yin**. *Analyzing Convergence and Rates of Convergence of Particle Swarm Optimization Algorithms Using Stochastic Approximation Methods.*

Recently, much progress has been made on particle swarm optimization (PSO). A number of works have been devoted to analyzing the convergence of the underlying algorithms. Nevertheless, in most cases, rather simplified hypotheses are used. For example, it often assumes that the swarm has only one particle. In addition, more often than not, the variables and the points of attraction are assumed to remain constant throughout the optimization process. In reality, such assumptions are often violated. Moreover, there are no rigorous rates of convergence results available to date for the particle swarm, to the best of our knowledge. In this paper, we consider a general form of PSO algorithms, and analyze asymptotic properties of the algorithms using stochastic approximation methods. We introduce four coefficients and rewrite the PSO procedure as a stochastic approximation type iterative algorithm. Then we analyze its convergence using weak convergence method. It is proved that a suitably scaled sequence of swarms converge to the solution of an ordinary differential equation. We also establish certain stability results. Moreover, convergence rates are ascertained by using weak convergence method. A centered and scaled sequence of the estimation errors is shown to have a diffusion limit. (Received November 09, 2014)

1108-60-26 **Dan Pirjol***, 277 Park Avenue, New York, NY 10172. *Can one price Eurodollar futures in the Black-Derman-Toy model?*

Considering the simulation of the Black-Derman-Toy model in discrete time and with continuous state variable, we note an explosive behavior of the Eurodollar future prices at a critical value of the volatility. In the limit of a very small simulation time step, the singularity appears for any volatility and reproduces the well-known Hogan-Weintraub singularity which is generic for short rate interest rate models with log-normally distributed rates. We study the conditions under the singularity appears, and give upper and lower bounds on the critical volatility. (Received November 17, 2014)

1108-60-39 **Jinghai Shao*** (shaojh@bnu.edu.cn). *Stability and recurrence of regime-switching diffusion processes.*

In this talk, we introduce some criteria on the stability of regime-switching diffusion processes. The regime-switching diffusion processes can be looked on as diffusion processes in a random environment characterized by a continuous time Markov chain. These processes can provide us more practical models and have been used in biology and mathematical finance, etc. Both the state-independent and state-dependent regime-switching diffusion processes with switching in a finite state space and an infinite countable state space are studied in this work. We provide two methods to deal with switching processes in an infinite countable state space. One is a finite partition method based on the nonsingular M-matrix theory. Another is an application of principal eigenvalue of a bilinear form. Our methods can deal with both linear and nonlinear regime-switching diffusion processes. (Received December 04, 2014)

1108-60-40 **Semere Habtemicael*** (semere.habtemicael@ndsu.edu), Department of Mathematics, North Dakota State University, NDSU Dept # 2750, Minard Hall 408, Fargo, ND 58103, and **Indranil SenGupta**. *Pricing of variance and volatility swap for financial derivatives.*

Swap is a financial derivative in which two counter parties exchange cash flows of financial instrument. Variance and volatility swaps are becoming increasingly popular in financial market. These are financial instruments that provide an easy way for investors to gain exposure to the future level of volatility. In this presentation we use non-Gaussian Ornstein-Uhlenbeck process driven by Lévy subordinators to model the dynamics of stock price and used this model to price variance, volatility, covariance and correlation swaps. We use S&P500 index data for our regression fit. (Received December 08, 2014)

1108-60-44 **Hao Wu*** (hao.wu.proba@gmail.com), Mathematics Department of MIT, E18-374, 77 Massachusetts Avenue, Cambridge, MA 02139. *Conformal Restriction: the chordal and the radial.*

When people tried to understand two-dimensional statistical physics models, it is realized that any conformally invariant process satisfying a certain restriction property has corssing or intersection exponents. Conformal field theory has been extremely successful in predicting the exact values of critical exponents describing the bahvoir of two-dimensional systems from statistical physics. The main goal of this talk is to investigate the restriction property and related critical exponents. First, we will introduce Brownian intersection exponents. Second, we discuss Conformal Restriction—the chordal case — and the relation to halp-plane Browinian intersection exponents. Finally, we discuss Conformal Restriction—the radial case —and the relation to whole-plane Brownian intersection exponents. (Received December 11, 2014)

1108-60-45 **Mohammad Abbas Rezaei*** (rezaei@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824, and **Dapeng Zhan** (zhan@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Higher moments of the natural parameterization for SLE curves.*

In this paper, we will show that the higher moments of the natural parametrization of SLE curves in any bounded domain in the upper half plane is finite. We prove this by estimating the probability that an SLE curve gets near n given points. (Received December 11, 2014)

1108-60-60 **Celine Lacaux** and **Gennady Samorodnitsky*** (gs18@cornell.edu), Scoll of ORIE, Cornell University, Ithaca, NY 14851. *Time-changed extremal process as a random sup measure.*

A functional limit theorem for the partial maxima of a long memory stable sequence produces a limiting process that can be described as a β-power time change in the classical Fréchet extremal process, for β in a subinterval of the unit interval. Any such power time change in the extremal process for $0 < \beta < 1$ produces a process with stationary max-increments. This deceptively simple time change hides the much more delicate structure of the resulting process as a self-affine random sup measure. We uncover this structure and show that in a certain range of the parameters this random measure arises as a limit of the partial maxima of the same long memory stable sequence, but in a different space. These results open a way to construct a whole new class of self-similar Fréchet processes with stationary max-increments. (Received December 17, 2014)

1108-60-62 **Harvey Stein***, 731 Lexington Ave, New York, NY 10022. *Model Molding for Exposure Computations.*

Exposure calculations such as expected exposures (EEs) and potential future exposures (PFEs) are a fundamental part of credit risk modeling. They are used for sizing risks and drive regulatory capital requirements. The difficulty of computing exposures coupled with the similarity of exposure calculations to credit valuation adjustment (CVA) calculations has led industry participants to compute exposures using CVA infrastructure, which yields risk neutral exposures instead of real world exposures. This is with the blessing of the regulators.

Here we show that risk neutral exposures can be gamed; risk neutral exposures can be set to any desired level. We also show that commonly used risk neutral measures can yield differences in exposures of a factor of 3 or more.

We then show three ways to make use of the CVA infrastructure for computing real world exposures. We show how a measure change can be leveraged for the computation. Commonly, however, such a measure change does not exist. In this case, we show how a pseudo-measure change can be used, and how to combine models so as to synthesize the needed change of measure. (Received December 18, 2014)

1108-60-63 **Michael Curran*** (michael.curran@bmo.com), 1 First Canadian Place, Toronto, ON M5X 1H3, Canada. *Backtesting General Spectral Risk Measures with Application to Expected Shortfall.*

In this talk, I will present a simple, practical and easily implementable coverage test to backtest any spectral risk measure. Our test gives a single decision at a specified confidence level and is perfectly consistent with the binomial test for VaR. Particular attention is given to the special case of Expected Shortfall (joint work with Nick Costanzino, UT-RiskLab). (Received December 18, 2014)

1108-60-76 **Mei Yin***, 2280 S Vine St, Denver, CO 80208, and **Lingjiong Zhu**. *Reciprocity in directed networks.*

Reciprocity is an important statistics in directed networks and has been widely used in the modeling of World Wide Web, email, social, and other complex networks. We take a statistical physics point of view and study the limiting entropy and free energy densities from the microcanonical ensemble, the canonical ensemble, and the grand canonical ensemble whose sufficient statistics are given by edge and reciprocal densities. The sparse case is also studied for the grand canonical ensemble. Joint work with Lingjiong Zhu. (Received December 29, 2014)

1108-60-77 **Nick Costanzino*** (nick.costanzino@gmail.com), Toronto, Ontario , Canada. *Pricing Recovery Swaps in the Madan-Bakshi-Zhang Framework.*

In this talk I will price recovery swaps in a hazard rate framework when the recovery rate, hazard rate, and interest rate are all correlated and driven by single diffusion. In particular, the default and recovery rates are modeled via a Madan-Bakshi-Zhang type model in which the interest rate is the only risk driver and assumed to follow a CIR process. The pricing problem leads to a one dimensional partial differential equation which is solved exactly in closed form in particular parameter regimes. For other parameter regimes we use the Dyson-Taylor commutator method to compute time-asymptotic expansions. We then make comparisons with A. Berd's arbitrage-free pricing relationship. (Received December 29, 2014)

1108-60-79 **H D Nguyen**, **N H Du** and **G Yin*** (gyin@math.wayne.edu), Department of Mathematics, Wayne State University, Detroit, MI 48202. *Dynamic Systems under Random Perturbations: A Multi-scale Approach.* Preliminary report.

This work examines stochastic differential equations with both rapidly-varying random switching and small diffusion. A multi-scale formulation is proposed using two small parameters ε and δ. Associated with the given systems, there are averaged or limit systems. Suppose that for each pair of the parameters, the solution of the corresponding equation has an invariant probability measure $\mu^{\varepsilon,\delta}$, and that the averaged equation has a limit cycle in which there is an averaged occupation measure μ^0 for the averaged equation. Our main effort is to prove that $\mu^{\varepsilon,\delta}$ converges weakly to μ^0 as $\varepsilon \to 0$ and $\delta \to 0$ under suitable conditions. In addition, our results are applied to a stochastic predator-prey model for demonstration. (Received December 29, 2014)

1108-60-96 **Ananda P. Weerasinghe*** (ananda@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011, and **Chao Zhu**, Department of Mathematics, University of Wisconsin-Milwaukee, Milwaukee, WI 53211. *Optimal control of a process with a path-dependent cost structure.*

Motivated by inventory control problems, we consider an infinite-horizon discounted control problem for a linear SDE where the cost rate at a given time depends on the history of the process. State process represents the inventory level and the control process represents the inventory reduction effort. The cost structure constitute of two types of costs: a control cost and a capacity expansion cost. We derive an optimal control policy which is path-dependent and use this solution to address two other cost minimization problems: a control cost minimization problem with a capacity constraint and the associated long-run average cost minimization problem. We derive explicit optimal strategies in each case. Finally, we address the discounted control problem in the presence of regime-switching of the drift and diffusion coefficients in the SDE for the state process. (Received January 04, 2015)

1108-60-97 **Nikolai N. Leonenko**, **Mark M. Meerschaert**, **Rene L. Schilling** and **Alla Sikorskii*** (sikorska@stt.msu.edu), 619 Red Cedar Road, Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824. *Correlation structure of time-changed Lévy processes.*

Time-changed Lévy processes are obtained by replacing the deterministic time by a positive non-decreasing stochastic process. The processes used to model random time include subordinators and inverse subordinators, and the time-changed Lévy processes include the fractional Poisson process and the scaling limit of a continuous time random walk. The use of time-changed processes in modeling often requires the knowledge of their second order properties such as the correlation function. This paper provides the explicit expression for the correlation function for time-changed Lévy processes. Several examples useful in applications are discussed. (Received January 04, 2015)

1108-60-101 **Rajeev Bhaskaran*** (brajeev@isibang.ac.in), stat-math unit, Indian Statistical Institute Bangalore Centre, 8th Mile Mysore Road, Bengaluru,, Karnataka 560059, India. *Translation Invariant Diffusions.*

In this talk we present a correspondence between finite dimensional diffusions and a special class of stochastic partial differential equations. The solutions of the SPDE have the structure of translations of the given initial value by the solutions of the finite dimensional diffusion . (Received January 05, 2015)

1108-60-106 **Hans-Peter Scheffler** (scheffler@mathematik.uni-siegen.de), Siegen, Germany, and **Stilian A Stoev*** (sstoev@umich.edu), 1085 S. University, Ann Arbor, MI 48109. *Implicit Extremes and Implicit Max–Stable Laws.*

Let $X_1, \cdots, X_n$ be iid random vectors and $f \geq 0$ be a non–negative function. Let also $k(n) = \mathrm{Argmax}_{i=1,\cdots,n} f(X_i)$. We are interested in the distribution of $X_{k(n)}$ and their limit theorems. In other words, what is the distribution the random vector where a function of its components is extreme. This question is motivated by a kind of inverse problem where one wants to determine the extremal behavior of X when only explicitly observing $f(X)$. We shall refer to such types of results as to *implicit extremes*. It turns out that as in the usual case of explicit extremes, all limit *implicit extreme value* laws are *implicit max–stable.* We characterize the regularly varying implicit max–stable laws in terms of their spectral and stochastic representations and illustrate the theory with examples drawing connections to *hidden regular variation* and regular variation on general cones. (Received January 05, 2015)

1108-60-113 **Albert Cohen*** (albert@math.msu.edu), C336 Wells Hall, 619 Red Cedar Rd., East Lansing, MI 48824, and **Nick Costanzino**. *Bond and CDS Pricing with Stochastic Recovery: Moody's PD-LGD Correlation Model.*

Classical credit risk and pricing models typically assume that the expected recovery at default is constant, or at the very least independent of the default probability. However, a large body of recent empirical evidence has challenged this assumption and shown that default rates are in fact negatively correlated with recovery rates. Recently, Moody's Analytics proposed a model in the context of credit capital which incorporates this empirically observed correlation within a structural framework. In this work we revisit Moody's PD-LGD (Probability of Default- Loss Given Default) and in the process complete and extend several results. We then price Bond and Credit Default Swaps with recovery risk using the PD-LGD model under both the Merton and Black-Cox default assumptions, and in addition compute associated risk metrics and Greeks. Our results are then compared with classical results which assume no recovery risk. (Joint work with Nick Costanzino, RiskLab,University of Toronto) (Received January 05, 2015)

1108-60-118 **Leszek Gawarecki*** (lgawarec@kettering.edu), Kettering University, Department of Mathematics, Flint, MI 48504, and **Vidyadhar Mandrekar** (atma1m@gmail.com), Michigan State University, Department of Statistics and Probability, East Lansing, MI 48823. *Existence, Uniqueness and Asymptotic Properties of Variational Solutions to SDE's Driven by Poisson Random Measures.* Preliminary report.

We consider the problem of existence and uniqueness of variational solutions to stochastic differential equations driven by compensated Poisson random measures. The problem is set up in a Gelfand triplet $V \hookrightarrow H \hookrightarrow V^*$ of real separable Hilbert spaces. For example, when the linear term is the second derivative, it can be viewed as an operator from a Sobolev space $W_0^{1,2}(\mathbb{R})$ to its dual $W_0^{-1,2}(\mathbb{R})$. Under usual assumptions on the coefficients a weak solution is produced as a weak limit of finite dimensional approximations. Asymptotic properties of the solution will also be discussed. (Received January 06, 2015)

1108-60-124 **Sunder Sethuraman*** (sethuram@math.arizona.edu), Department of Mathematics, University of Arizona, Tucson, AZ 85750. *Fractional KPZ stochastic Burgers equations arising from microscopic dynamics.*

We consider interacting particle systems on $\mathbb{Z}$ where particles may displace by y with (weakly-asymmetric) rates proportional to $|y|^{-(1+\alpha)}$. For $\alpha \geq 2$, when the jump law has more than 2 moments, the behavior of many things are the same as if the system had short range interactions.

But, when $0 < \alpha < 2$, the evolution of the 'bulk' mass density and its fluctuations are different. We describe some recent work which derives two types of equations for the limit fluctuation fields, namely fractional KPZ stochastic Burgers and heat equations, depending on a phase transition in terms of the strength of α.

This work is based on http://arxiv.org/pdf/1409.0944v1.pdf (Received January 06, 2015)

1108-60-145 **Mark M Meerschaert*** (mcubed@stt.msu.edu), Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824. *Random field models for hydraulic conductivity in ground water flow.*

A standard model in ground water hydrology uses random fields to interpolate sparse data on hydraulic conductivity. The resulting random field is used to parameterize a partial differential equation model for flow and transport, which is then solved by numerical methods. This talk will review the state of the art in such models, and discuss open problems. (Received January 08, 2015)

1108-60-157 **Milton Jara**, IMPA, Estrada Dona Castorina, 110, Horto, Rio de Janeiro, Brazil, and **Jonathon Peterson*** (peterson@purdue.edu), Purdue University, Dept. of Mathematics, 150 N University St, West Lafayette, IN 47907. *Hydrodynamic limits for directed traps and systems of independent RWRE.*

We study the evolution of a system of independent random walks in a common random environment (RWRE). Previously a hydrodynamic limit was proved in the case where the environment is such that the random walks are ballistic (i.e., transient with non-zero speed $v_0 \neq 0$). In this case it was shown that the asymptotic particle density is simply translated deterministically by the speed v_0. In this talk we will consider the more difficult case of RWRE that are transient but with $v_0 = 0$. Under the appropriate space-time scaling, we prove a hydrodynamic limit for the system of random walks. The statement of the hydrodynamic limit that we prove is non-standard in that the evolution of the asymptotic particle density is given by the solution of a random (rather than a deterministic) PDE. The randomness in the PDE comes from the fact that under the hydrodynamic scaling the effect of the environment does not "average out" and so the specific instance of the environment chosen actually matters.

The proof of the hydrodynamic limit for the system of RWRE will be accomplished by coupling the system of RWRE with a simpler model of a system of particles in an environment of "directed traps." This talk is based on joint work with Milton Jara. (Received January 09, 2015)

1108-60-162 **Nicolas Lanchier*** (nlanchie@asu.edu), School of Mathematical, and Statistical Sciences, Arizona State University, Tempe, AZ 85287. *Flux and fixation in the one-dimensional Axelrod model.*

The Axelrod model is a spatial stochastic model for the dynamics of cultures which includes two important social factors: social influence, the tendency of individuals to become more similar when they interact, and homophily, the tendency of individuals to interact more frequently with individuals who are more similar. Each individual is characterized by a set of cultural features, and pairs of neighbors interact at a rate proportional to the number of features they share, which results in the interacting pair having one more cultural feature in common. This model has been extensively studied during the past ten years based on numerical simulations while there is a lack of analytical results. This talk gives rigorous flux and fixation results for the one-dimensional system that sometimes confirm sometimes refute some of the conjectures formulated by statistical physicists and social scientists. (Received January 09, 2015)

1108-60-163 **Chunfeng Huang*** (huang48@indiana.edu), 309 North Park Ave., Bloomington, IN 47401, and **Haimeng Zhang** and **Scott M Robeson**. *Intrinsic Random Functions and Universal Kriging on the Circle.* Preliminary report.

Intrinsic random functions (IRF) provide a versatile approach when the assumption of second-order stationarity is not met. Here, we develop the IRF theory on the circle with its universal kriging application. Unlike IRF in Euclidean spaces, where differential operations are used to achieve stationarity, our result shows that low-frequency truncation of the Fourier series representation of the IRF is required for such processes on the circle. All of these features and developments are presented through the theory of reproducing kernel Hilbert space. In addition, the connection between kriging and splines is also established, demonstrating their equivalence on the circle. (Received January 09, 2015)

1108-60-170 **Leonid Petrov*** (lenia.petrov@gmail.com), Department of Mathematics, University of Virginia, 141 Cabell Drive, Kerchof Hall, Charlottesville, VA 22902. *Dynamics of interacting particle systems via spectral properties.*

Many interesting stochastic particle systems are “integrable”, i.e., their distributions and asymptotics can be studied by algebraic methods. I will discuss particle systems on the discrete line whose integrability is triggered by an underlying spectral theory (involving noncommutative Fourier-type transforms). The spectral theory is closely tied with (coordinate) Bethe ansatz. This provides a unified way of obtaining exact distribution formulas with arbitrary initial data for a number of particle systems, including ASEP, q-TASEP, and systems related to the six-vertex model. (Received January 09, 2015)

1108-60-180 **Idan Perl** and **Arnab Sen***, arnab@math.umn.edu, and **Ariel Yadin**. *Extinction Window of Mean Field Branching Annihilating Random Walk.*

We consider a model of growing population that competes for resources. The dynamics takes place on a complete graph on n vertices where at each time step all existing particles reproduce and the offsprings randomly move to neighboring sites. However, if any site has more than one offspring, then all the particles on that site are annihilated.

We examine the extinction window of this model, that is, how long it takes the population to go extinct, once it has been conditioned to do so. We show that in the supercritical regime although the population tends to survive for exponential time on average, the extinction window is logarithmic. This is a non-monotone model, which makes the analysis difficult. (Received January 11, 2015)

1108-60-186 **Rodrigo Banuelos*** (banuelos@math.purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907, and **Luis Acuna Valverde**, Department of Mathematics, Purdue University, West Lafayette, IN 47907. *Heat trace and heat content asymptotics for nonlocal operators.*

In this talk we will look at some problems on heat trace and heat content asymptotics when the Lapalcian, the generator of Brownian motion, is replaced by the generator of a more general Lévy process, in particular the stable and relativistic stable processes. The central question is the identification of the so called ”heat invariants”. We look at both, the Dirichlet problem in domains of d-dimentional Euclidean space and Schrd̈inger operators on R^d. The techniques are both probabilistic and analytic. In case of Schrd̈inger operators, some of the results are new even for the Laplacian. (Received January 12, 2015)

1108-60-192 **Yong Zeng*** (zengy@umkc.edu), Dept of Math and Stat, 5100 Rockhill Rd, Kansas City, MO 64110, **Brent Bundick**, Research Department, 1 Memorial Drive, Kansas City, MO 64198, **Xing Hu**, School of Economics and Finance, Hong Kong, Hong Kong, **David R Kuipers**, Department of Finance, Henry W. Bloch School of Management, Kansas City, MO 64110, and **Junqi Yin**, National Institute for Computational Sciences, Knoxville, TN 37996. *Bayesian Inference via Filtering Equations for Financial Ultra-High Frequency Data.*

We propose a general partially-observed framework of Markov processes with marked point process observations for ultra-high frequency (UHF) transaction price data, allowing other observable economic or market factors. We develop the corresponding Bayesian inference via filtering equations to quantify parameter and model uncertainty. Specifically, we derive filtering equations to characterize the evolution of the statistical foundation such as likelihoods, posteriors, Bayes factors and posterior model probabilities. Given the computational challenge, we provide a convergence theorem, enabling us to employ the Markov chain approximation method to construct

consistent, easily-parallelizable, recursive algorithms. The algorithms calculate the fundamental statistical characteristics and are capable of implementing the Bayesian inference in real-time for streaming UHF data, via parallel computing for sophisticated models. The general theory is illustrated by specific models built for U.S. Treasury Notes transactions data from GovPX and by Heston stochastic volatility model for stock transactions data. This talk consists joint works with B. Bundick, X. Hu, D. Kuipers and J. Yin. (Received January 12, 2015)

1108-60-194 **Dan Cheng*** (`cheng@stt.msu.edu`), 2311 Stinson Drive, Campus Box 8203, Raleigh, NC 27695-8203, and **Armin Schwartzman**. *Multiple testing of local maxima for detection of peaks in random fields.*

A topological multiple testing scheme is presented for detecting peaks in images under stationary ergodic Gaussian noise, where tests are performed at local maxima of the smoothed observed signals. Two methods are developed according to two different ways of computing p-values: (i) using the exact distribution of the height of local maxima, available explicitly when the noise field is isotropic; (ii) using an approximation to the overshoot distribution of local maxima above a pre-threshold, applicable when the exact distribution is unknown, such as when the stationary noise field is non-isotropic. The algorithms, combined with the Benjamini-Hochberg procedure for thresholding p-values, provide asymptotic strong control of the False Discovery Rate (FDR) and power consistency as the search space and signal strength get large. Simulations show that FDR levels are maintained in non-asymptotic conditions. The methods are illustrated in an example on brain image. (Received January 12, 2015)

1108-60-195 **Yong Zeng*** (`zengy@umkc.edu`), Dept of Math and Stat, 5100 Rockhill Rd, Kansas City, MO 64110, **Jie Xiong**, Department of Mathematics, Avenida da Universidade, Taipa, Macau, Macau, **Shuaiqi Zhang**, School of Economics and Commerce, Guangzhou, Guangdong , Peoples Rep of China, and **Xiangdong Liu**, Department of Statistics, Guangzhou, Guangdong , Peoples Rep of China. *Mean-Variance Portfolio Selection for Partially-Observed Marked Point Processes.*

In a ultra-high frequency trading environment, we study the classical mean–variance portfolio selection problem in an incomplete market with one bond and multiple stocks. Each stock price is modeled as a marked point process, the noisy observation of the intrinsic value process. With incomplete information, we obtain a separation principle. Using the maximum principle for stochastic control of FBSDEs with jump, we explicitly derive the efficient strategies, which rely on filtering. (Received January 12, 2015)

1108-60-201 **Stefan Tappe*** (`tappe@stochastik.uni-hannover.de`), Leibniz Universität Hannover, Institut für Mathematische Stochastik, Welfengarten 1, 30167 Hannover, Germany. *Invariance of closed convex cones for stochastic partial differential equations.*

In this talk, we provide necessary and sufficient conditions for stochastic invariance of closed convex cones in Hilbert spaces for semilinear stochastic partial differential equations driven by Wiener processes and Poisson random measures. Several examples accompany our results. (Received January 13, 2015)

1108-60-205 **Thomas G. Kurtz** and **Richard H. Stockbridge*** (`stockbri@uwm.edu`). *Linear Programming Formulations of Singular Stochastic Control Problems.*

Many stochastic models include control actions which take effect instantly, for example, reflection at a boundary or instantaneous jumps to new locations. These types of actions are singular with respect to Lebesgue measure of time. This talk will develop equivalent linear programming formulations of singular control; the dynamics also allow absolutely continuous controls to be present. A key to the equivalence is the definition of relaxed controls for the absolutely continuous controls, but more importantly for the singular controls as well. The reformulation depends on characterizing the expected stochastic behavior of the states and controls through appropriate expected occupation measures that satisfy particular adjoint equations corresponding to the cost criterion. These characterizations in terms of expected behavior are nevertheless rich enough to capture the full stochasticity of the processes through existence of relaxed solutions to the singular martingale problem. A consequence of these existence results is the equivalence of infinite-dimensional linear programming formulations for the stochastic problems. Under appropriate conditions, the existence of optimal measures and corresponding optimal controls in feedback form are obtained. (Received January 13, 2015)

1108-60-226 **Liudas Giraitis*** (l.giraitis@qmul.ac.uk), School of Economics and Finance, Mile End Road, London, E1 4NS, United Kingdom, and **Donatas Surgailis** and **Andrius Skarnulis**. *Integrated AR and ARCH processes and the FIGARCH model: origins of long memory.*

Although properties of ARCH(∞) model are well investigated, existence of long memory FIGARCH and IARCH solution was not established in the literature. These two popular ARCH type models which are widely used in applied literature, were causing theoretical controversy because of suspicion that other solutions besides the trivial zero one, do not exist. Since ARCH models with non-zero intercept have a unique stationary solution and exclude long memory, existence of finite variance FIGARCH and IARCH models and, thus, possibility of long memory in ARCH setting was doubtful. The present paper solves this controversy by showing that FIGARCH and IARCH equations have a non-trivial covariance stationary solution, and that such solution exhibits long memory. Existence and uniqueness of stationary Integrated AR(∞) processes is also discussed, and long memory as inherited their feature is established. Summarizing, we show that covariance stationary IARCH, FIEGARCH and IAR(∞) processes exist, their class is wide, and they always have long memory. (Received January 14, 2015)

1108-60-227 **Hermine Biermé**, **Olivier Durieu** and **Yizao Wang*** (yizao.wang@uc.edu), University of Cincinnati, Department of Mathematical Sciences, 2815 Commons Way, Cincinnati, OH 45221-0025. *Phenomena of critical regimes in invariance principles for operator-scaling Gaussian random fields.* Preliminary report.

Hammond and Sheffield introduce a model of correlated random walk that scales to a fractional Brownian motion with long-range dependence. In this paper, we consider a natural generalization of this model in higher dimension. We define a Z^d-indexed random field with dependence relations governed by an underlying random graph, and we study the scaling limit properties of its partial sums. An interesting phenomenon appears: under different regimes of summation, several kinds of limit fields could be reached. There is a critical regime where the limit field is an operator scaling process that inherits of the full structure of the discrete model, whereas it is not the case under other regimes. (Received January 14, 2015)

1108-60-263 **Mark Meerschaert** and **Farzad Sabzikar*** (sabzika2@stt.msu.edu), East Lansing, MI 48824. *Stochastic Integration for Tempered Fractional Brownian Motion.*

Tempered fractional Brownian motion is obtained when the power law kernel in the moving average representation of a fractional Brownian motion is multiplied by an exponential tempering factor. We develop the theory of stochastic integrals for tempered fractional Brownian motion. Along the way, we develop some basic results on tempered fractional calculus. (Received January 15, 2015)

1108-60-264 **Dapeng Zhan***, Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48823, and **Steffen Rohde**. *Tip of SLE at Fixed Capacity Time.*

We study the tip of forward SLE using backward SLE. Let $\kappa \in (0,4)$. The backward chordal SLE$_\kappa$ generates a welding, which is a random involution ϕ of $\mathbb{R} \cup \{\infty\}$ with two fixed points: 0 and ∞. It was proved that the welding ϕ satisfies the symmetry that $x \mapsto 1/\phi(1/x)$ has the same distribution as ϕ. Using this symmetry and the conformal removability property of SLE$_\kappa$ curve, we prove that for $\kappa \in (0,4)$, the forward whole-plane SLE$(\kappa;\kappa+2)$ trace stopped at fixed capacity time satisfies the reversibility. This result is then used to show that the tip of a chordal or radial SLE$_\kappa$ trace ($\kappa \in (0,4)$) stopped at a fixed capacity time behaves similarly to the initial part of a whole-plane SLE$(\kappa;\kappa+2)$ trace. (Received January 15, 2015)

1108-60-265 **Dapeng Zhan***, Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48823. *Time Reversal Symmetry for Schramm-Loewner Evolution.*

The Schramm–Loewner evolution with parameter $\kappa > 0$ (SLE$_\kappa$) is a family of random planar curves that have been proven to be the scaling limit of a variety of two-dimensional lattice models in statistical mechanics. SLE$_\kappa$ is defined by solving Loewner differential equation with driving function being $\sqrt{\kappa}B(t)$, where $B(t)$ is a standard Brownian motion. In this review talk, I will first describe the Loewner differential equation, and how it generates an SLE$_\kappa$ curve. Then I will list results of time reversal symmetry for SLE that have been proved so far, and briefly explain the ideas of the proofs. (Received January 15, 2015)

1108-60-272 **Erhan Bayraktar**, MI, and **S. David Promislow** and **Virginia R. Young*** (vryoung@umich.edu), 530 Church Street, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Purchasing Term Life Insurance to Reach a Bequest while Consuming.*

We determine the optimal strategies for purchasing term life insurance and for investing in a risky financial market in order to maximize the probability of reaching a bequest goal. We extend our previous work (Bayraktar et al. (2014a), Purchasing life insurance to reach a bequest goal, to appear, *Insurance: Mathematics and Economics*) in two important ways: (1) we assume that the individual consumes from her investment account, and (2) we add a risky asset to the financial market. We learn that if the rate of consumption is large enough, then the individual will purchase term life insurance at any level of wealth, a surprising result. We also determine when the individual optimally invests more in the risky asset than her current wealth, so-called *leveraging*. (Received January 16, 2015)

1108-60-286 **Peter Carr** and **Lingjiong Zhu*** (zhul@umn.edu), 206 Church St SE, Minneapolis, MN 55455. *Variable Volatility and Financial Failure.*

Structural models of corporate default, e.g. Merton's model typically impose a rigid parametric specification on the volatility of the firm's assets. We propose a nonparametric structural model whose volatility is a function of the distance to default. We develop closed form formulas which relate RNDP and equity value to this asset volatility function and to asset price. We also show how to explicitly determine the implied RNDP and the implied asset value from the market price of the equity and from the market prices of calls written on the equity. Remarkably, the RNDP formula is independent of both the initial asset level and the debt level. Generalizations to incorporate interest rates, dividend yield, CEV, stochastic volatility into the model will also be discusses. This is based on the joint work with Peter Carr. (Received January 16, 2015)

1108-60-299 **Nguyet T. Nguyen***, One University Plaza, Youngstown, OH 44555, Department of Mathematics and Statistics, Youngstown State University. *Hidden Markov Models for Financial Market Predictions.*

Hidden Markov Models (HMMs) are typically used to predict hidden regimes of observation data. Therefore they are used in many different areas such as speech recognition systems, computational molecular biology, and financial market predictions.

I use HMMs for both single observation data and multiple observation data to predict regimes of some macro economics variables such as: Inflation (CPI), Economics Growth (GDP), Stock Market Index (S&P500) and Market Volatility (VIX). HMMs' parameters were calibrated and then used to predict economic trends and stock prices. I also avoid overfitting by analyzing relationships between macro economic regimes and stock performances to make stock selections. (Received January 16, 2015)

1108-60-323 **Tom Alberts*** (alberts@math.utah.edu), Department of Mathematics, 155 S 1400 E RM 235, Salt Lake City, UT 84112. *Remarks on SLE Boundary Intersections.*

I will discuss some recent results on the intersection set of an SLE curve with the boundary of its domain. This will include the dimension of the set, the natural covariant measure of the set, and its partitioning according to the "angle" at which the curve hits the boundary. (Received January 17, 2015)

1108-60-327 **Yuval Peres***, 1 Microsoft Way, Redmond, WA 98052. *Monotone restrictions of Brownian motion, variable drift and self-affine graphs.*

I will present two recent fractal studies of Brownian graphs. Let $\{B(t)\colon 0 \le t \le 1\}$ be a linear Brownian motion and let $\alpha > \frac{1}{2}$. In joint work with Richard Balka (University of Washington), we prove that, almost surely, there is no set $A \subset [0,1]$ such that its Hausdorff dimension $\dim A > \frac{1}{2}$ and $B\colon A \to \mathbb{R}$ is α-Hölder continuous. The proof uses Kaufman's dimension doubling theorem for planar (!) Brownian motion. We deduce that, almost surely, there is no set $A \subset [0,1]$ such that $\dim A > \frac{1}{2}$ and $B\colon A \to \mathbb{R}$ is weakly increasing. The second topic is joint work with Perla Sousi (Cambridge). For any Borel function f from the unit interval to $\mathbf{R}^d$, we express the Hausdorff dimension of the image and the graph of $B + f$ in terms of f. When the graph of f is a self-affine McMullen-Bedford carpet, we obtain an explicit formula for the dimension of the graph of $B + f$ in terms of the generating pattern. In particular, we show that it can be strictly bigger than the maximum of the Hausdorff dimensions of the graphs of f and B. Despite the random perturbation, the Minkowski and Hausdorff dimensions of the graph of $B + f$ can disagree. (Received January 17, 2015)

1108-60-329 **Litan Yan*** (litanyan@hotmail.com), 2999 North Renmin Rd., Songjiang, Shanghai 201620, P.R. China, Shanghai, Peoples Rep of China. *Some functionals for fractional Brownian motion.*

Let B^H be a fractional Brownian motion with Hurst index $H \in (0,1)$. In this talk, we consider the functional

$$\mathcal{K}_t^{H,f}(a) := \int_0^t f(B_s^H - a, s) ds^{2H}$$

with $t \geq 0$ and $a \in \mathbb{R}$, where f is a Borel function. We shall mainly devote to study some analysis questions with respect to the function. In particular, when f is time-independent and non locally integrable we consider some principal value questions.
(Received January 17, 2015)

1108-60-331 **Tuan Anh Hoang*** (tuan.hoang@wayne.edu), 1110 Faculty/Administration Building, 656 W. Kirby, Detroit, MI 48202, and **Yin George Gang** and **Xi Fubao**. *Numerical Solutions of Regime-Switching Jump Diffusions.*

This work develops numerical algorithms for approximating the solutions of stochastic differential equations that involve switching jump diffusion processes, in which the switching is a random process that depends on the jump diffusion. Being non-standard due to the jump diffusion dependent switching makes the problem far more difficult to deal with. Using decreasing step sizes, we construct the algorithm, which is in the spirit of Euler-Maruyama method. We then discuss the convergence of the proposed algorithm and provide numerical examples for demonstrating its performance. (Received January 18, 2015)

1108-60-375 **Yimin Xiao*** (xiao@stt.msu.edu), Department of Statistics and Probability, 619 Red Cedar Road, Michigan State University, East Lansiing, MI 48824. *Gaussian Random Fields: Separation of Fractal Properties and Long Range Dependence.* Preliminary report.

In this talk, we discuss various properties of Gaussian random fields such as self-similarity, anisotropy, fractal dimensions and long range dependence. We present some recent results on asymptotic and geometric properties of anisotropic Gaussian random fields. Our focus is on separating the fractal properties from long range dependence.
(Received January 18, 2015)

1108-60-399 **Xiaoguang Wang*** (wang913@purdue.edu), 2113 Willowbrook Dr Apt 129, West Lafayette, IN 47906, and **Michael Levine** and **Frank (Jian) Zou**. *Asymptotic properties of functionals of increments of a continuous semi-martingale with stochastic trading times, with applications in integrated volatility estimation.*

As the ultra-high frequency data becomes available, nowadays new methods for integrated volatility estimation which can take use of as much high frequency data as we can are needed. Because of the complexity of the ultra-high frequency data, those new methods mostly are following non-parametric frameworks constructed on the blocks / functionals of the price data. However, most of those nonparametric methods require the price data to be equally spaced to obtain asymptotic result, such as the realized kernel method, and so on. On the other hand, the ultra-high frequency data available in the market is generally non-equally spaced, which indicates that applying those nonparametric methods means to throw away most of the data available to make the data equally spaced.

In our work, we constructed several LLNs and CLTs for functional of unequally-spaced data sampled from a continuous semi-martingale. We showed that based on appropriate constrains, the effect of randomness in sampling time or trading time can be controlled well to obtain useful asymptotic results on the functional of the differences of price data. And the CLTs provide us important tools to further construct nonparametric methods to estimate integrated volatility using ultra-high frequency data. (Received January 19, 2015)

1108-60-429 **Erik D Slivken*** (erikslivken@math.ucdavis.edu), 1303 F St, Davis, CA 95616. *Jigsaw Percolation on Erdös-Renyí Random Graphs.*

We analyze the jigsaw percolation model introduced by Brummitt, Chatterjee, Dey, and Sivakoff by considering graphs where both underlying people and puzzle graphs are Erdös-Rényi random graphs. Let p_{ppl} and p_{puz} denote the probability that an edge exists in the respective people and puzzle graphs and define $p_{\mathrm{eff}} = p_{\mathrm{ppl}} p_{\mathrm{puz}}$, the effective probability. We show that if $p_{\mathrm{eff}}(n \log n) < e^{-5}$ the people graph will not solve the puzzle graph *a.s.s.*, whereas if $p_{\mathrm{eff}}(n \log n) > \pi^2/6$, the people graph will solve the puzzle graph *a.s.s.* as long as both p_{ppl} and p_{puz} are greater than $\log n/n$. (Received January 19, 2015)

1108-60-437 **Marianne Clausel*** (marianne.clausel@imag.fr), 38010 Grenoble, France, **Francois Roueff** (roueff@telecom-paristech.fr), 46 rue Barrault, 75634 Paris, 75634 Paris, France, and **Murad Taqqu** (murad@bu.edu), Departement of Mathematics and Statistics, Boston, MA. *Large scale reduction principle and application to hypothesis testing.*

Consider a non–linear function $G(X_t)$ where X_t is a stationary Gaussian sequence with long–range dependence. The usual reduction principle states that the partial sums of $G(X_t)$ behave asymptotically like the partial sums of the first term in the expansion of G in Hermite polynomials. In the context of the wavelet estimation of the long–range dependence parameter, one replaces the partial sums of $G(X_t)$ by the wavelet scalogram, namely the partial sum of squares of the wavelet coefficients. Is there a reduction principle in the wavelet setting, namely is the asymptotic behavior of the scalogram for $G(X_t)$ the same as that for the first term in the expansion of G in Hermite polynomial? The answer is negative in general. This paper provides a minimal growth condition on the scales of the wavelet coefficients which ensures that the reduction principle also holds for the scalogram. The results are applied to testing the hypothesis that the long-range dependence parameter takes a specific value. (Received January 19, 2015)

1108-60-447 **Panki Kim**, **Renming Song*** (rsong@math.uiuc.edu) and **Zoran Vondracek**. *Minimal thinness for symmetric Markov processes.*

Minimal thinness is a very important concept in potential theory and it describes the smallness of a set at a boundary point. In this talk, I will present some recently established criteria for minimal thinness with respect for a large class of symmetric Levy processes and a large class of subordinate killed Borwnian motions. (Received January 19, 2015)

1108-60-449 **Tony Wirjanto** and **Yi Shen*** (yi.shen@uwaterloo.ca). *Stationarity as a Path Property.*

Stationarity is the shift invariance of the distribution for a stochastic process or a random field. In this work we rediscover stationarity as a path property rather than a distributional property. More precisely, we characterize a set of paths denoted as A, which corresponds to the notion of stationarity in the following sense: on one hand, the set A is shown to be large enough, so that for any stationary process/random field, almost all of its paths are in A; on the other hand, we prove that any path in A will behave in the optimal way under any stationarity test satisfying some mild conditions. The results justify our intuition about how a "typical" stationary process/random field should look like, and potentially lead to new families of stationarity tests. This is a joint work with Tony Wirjanto. (Received January 19, 2015)

1108-60-451 **Ewain Gwynne** and **Jason Peter Miller*** (jpmiller@mit.edu), Massachusetts Institute of Technology, Department of Mathematics, E18-470, 77 Massachusetts Avenue, Cambridge, MA 02139, and **Xin Sun**. *Almost sure multi-fractal spectrum of SLE.*

Suppose that η is a Schramm-Loewner evolution (SLE_κ) in a smoothly bounded simply connected domain $D \subset \mathbb{C}$ and that ϕ is a conformal map from $\mathbb{D}$ to a connected component of $D \setminus \eta([0,t])$ for some $t > 0$. The multifractal spectrum of η is the function $(-1,1) \to [0,\infty)$ which, for each $s \in (-1,1)$, gives the Hausdorff dimension of the set of points $x \in \partial\mathbb{D}$ such that $|\phi'((1-\epsilon)x)| = \epsilon^{-s+o(1)}$ as $\epsilon \to 0$. We rigorously compute the a.s. multifractal spectrum of SLE, confirming a prediction due to Duplantier. As corollaries, we confirm a conjecture made by Beliaev and Smirnov for the a.s. bulk integral means spectrum of SLE and we obtain a new derivation of the a.s. Hausdorff dimension of the SLE curve for $\kappa \leq 4$. Our results also hold for the $\mathrm{SLE}_\kappa(\underline{\rho})$ processes with general vectors of weight $\underline{\rho}$. (Received January 19, 2015)

1108-60-456 **Brent Morehouse Werness*** (bwerness@math.washington.edu). *Convergence of discrete holomorphic functions for random maps.*

The theory of discrete holomorphic functions has been studied by researchers from a diverse set of fields from classical complex analysts to applied computer scientists. Through work of Smirnov, Chelkak, Duminil-Copin and coauthors, discrete holomorphicity has found a central role in the study of conformally invariant random processes on lattices where the convergence of discrete holomorphic functions associated with these processes to continuous ones often allows an identification of limiting processes for the random curves as forms of Schramm–Loewner evolution.

In parallel, there has been an increase in understanding of random planar maps, with one of the primary conjectures being that these conformally invariant random processes coupled with random planar maps should also converge to forms of Schramm–Loewner evolution. In this talk we will provide a generalization of existing convergence results to lattices which include those obtained from some models of random planar maps. (Received January 19, 2015)

1108-60-458 **Asaf Cohen*** (asafc@umich.edu), University of Michigan, Department of Mathematics, 2859 East Hall, 530 Church St., Ann Arbor, MI 48109, and **Rami Atar**. *A Multiclass Queueing Model in the Moderate-Deviation Heavy-Traffic Regime.* Preliminary report.

We consider a multiclass single-server queueing control problem in the moderate-deviation heavy-traffic regime with a discounted risk-sensitive cost. In the scaling limit, an optimal control problem associated with the model is shown to be governed by a differential game that can be explicitly solved and that admits an optimal stationary feedback policy. We also present a stationary asymptotic optimal policy that satisfies a state space collapse property. (Received January 19, 2015)

1108-60-461 **Laurence S. Field*** (laurie@math.uchicago.edu) and **Gregory F. Lawler**. *Escape probability and transience for SLE.*

We give estimates for the probability that a chordal, radial or two-sided radial SLE_κ curve retreats far from its terminal point after coming close to it, for $\kappa \leq 4$. The estimates are uniform over all initial segments of the curve, and are sharp up to a universal constant. The proofs involve several new estimates concerning the Brownian excursion measure. (Received January 19, 2015)

1108-60-463 **Ivan Matic*** (ivan.matic@baruch.cuny.edu), One Bernard Baruch Way, New York, NY 10010. *Large deviations for deterministic walks in excited random environments.*

The walk occurs on an integer lattice whose each site contains the direction that the walker must follow upon visiting that site. The initial distribution of these directions is IID, but the directions do not change once the walk begins.

If the first M visits (for some fixed M) to a particular site in the lattice are followed by random jumps, but the visits after the M-th are deterministic, the process is called deterministic walk in an excited random environment.

These two models do not posses Markov property and are related to the class of random walks in random environments. We will outline the reason why the laws of large numbers and central limit theorems are degenerate for these two models, and present some large deviations results.

The talk is based on joint work with David Sivakoff. (Received January 19, 2015)

1108-60-473 **Vladas Pipiras*** (pipiras@email.unc.edu), Chapel Hill, NC 27599. *On circulant matrix embeddings in synthesis of stationary Gaussian fields.*

Circulant matrix embedding is one of the most popular and efficient methods for the exact generation of a Gaussian stationary (possibly long-range dependent) univariate series, given its autocovariance function. Although the circulant matrix embedding has also been used for the generation of Gaussian stationary (possibly long-range dependent) random fields, there are many practical covariance structures of random fields where the classical embedding method breaks down, in the sense that some of the eigenvalues of the covariance embedding are negative. In this talk, I will discuss several approaches to modify the classical circulant matrix embedding so that all the eigenvalues are nonnegative.

The talk is based on joint work with S. Kechagias (University of North Carolina), H. Helgason (University of Iceland), and P. Abry (ENS Lyon). (Received January 19, 2015)

1108-60-494 **Antonio Auffinger*** (auffing@math.northwestern.edu), Department of Mathematics, 2033 Sheridan Road, Evanston, IL. *The Parisi measure.*

Spin glasses are magnetic systems exhibiting both quenched disorder and frustration, and have often been cited as examples of "complex systems." As mathematical objects, they provide several fascinating structures and conjectures. This talk will cover recent progress that shed more light in the mysterious and beautiful solution proposed 30 years ago by G. Parisi. We will focus on properties of the functional order parameter of the famous Sherrington-Kirkpatrick model and we will explain a proof of uniqueness of the Parisi functional. Based on joint works with Wei-Kuo Chen. (Received January 19, 2015)

1108-60-499 **Dang Hai Nguyen*** (dangnh.maths@gmail.com), **George Yin** and **Du Huu Nguyen**. *Some asymptotic results on a stochastic predator-prey model with Beddington- DeAngelis funtional response.*

This talk considers a stochastic predator-prey system. The main effort focuses on asymptotic properties. We obtain sufficient and almost necessary conditions for permanence and ergodicity of the stochastic predator-prey model with Beddington-DeAngelis functional response for both non-degenerate and degenerate diffusions. We also prove the convergence in total variation norm of the transition probability to an invariant probability measure and describe the support of the invariant measure. Comparisons to existing literature and related matters to other stochastic predator-prey models are also given. (Received January 20, 2015)

1108-60-503 **Erick Herbin*** (erick.herbin@centralesupelec.fr), Erick Herbin, CentraleSupelec, Grande Voie des Vignes, 92295 Chatenay-Malabry, France. *Set-indexed processes and integration.*

We consider the issue of generalized stochastic processes, indexed by an abstract set of indices. What should the minimal required conditions on the indexing collection be, to study some of the usual properties of these processes, such as increment stationarity, martingale and Markov properties or integration question? The already known examples of processes indexed by functions or metric spaces can be addressed by this way.

We show how the set-indexed framework of Ivanoff-Merzbach allows to study these generalized processes.

Some set-indexed processes can be considered as random measures on some δ-ring. Some generalized processes can be defined as an integral with respect to some measure on the indexing collection. The example of set-indexed Lévy processes is considered. The links with function-indexed processes could be discussed.

If time permits, we could also discuss regularity issue : continuity or Hölder regularity.

This talk is based on three works in collaboration with Ely Merzbach and Alexandre Richard. (Received January 20, 2015)

1108-60-508 **Hoi Huu Nguyen*** (nguyen.1261@osu.edu), 231 W 18 Ave., Columbus, OH 43210. *On roots repulsion of random systems.*

I will address certain repulsion behavior of roots of random polynomials and of eigenvalues of random matrices, together with some applications of this phenomenon. (Received January 20, 2015)

1108-60-518 **Jinho Baik*** (baik@umich.edu), 530 Church Street, Ann Arbor, MI 48109. *Phase transition of the free energy for random matrix.*

The largest eigenvalue of a random matrix can be regarded as the free energy at zero temperature. Motivated by the recent development in directed polymers, we introduce the free energy at finite temperature and consider the large dimension limit. We prove the existence of the phase transition and evaluate the limiting distribution for both sub and super critical cases for Wigner matrices and invariant ensembles. This is a joint work with Ji Oon Li. (Received January 20, 2015)

1108-60-540 **Partha Sarathi Dey*** (psdey@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, and **Nikos Zygouras**. *High temperature limits for (1+1)-D directed polymer with heavy-tailed disorder.*

The directed polymer model at intermediate disorder regime was introduced by Alberts-Khanin-Quastel in 2012. It was proved that at inverse temperature $\beta n^{-\gamma}$ with $\gamma = 1/4$ the partition function, centered appropriately, converges in distribution and the limit is given in terms of the solution of the stochastic heat equation. This result was obtained under the assumption that the disorder variables posses exponential moments, but its universality was also conjectured under the assumption of six moments. We show that this conjecture is valid and we further extend it by exhibiting the non-universal limiting behavior in the case of less than six moments. We also explain the behavior of the scaling exponent for the log-partition function under different moment assumptions and values of γ. (Received January 20, 2015)

1108-60-550 **S. Ng** and **M. Walters*** (mwalter4@u.rochester.edu), Department of Mathematics, University of Rochester, 500 Joseph Wilson Blvd., Rochester, NY 14627. *Random Operator Compressions.*

Let A be a Hermitian operator of order n. We show that for $k \leq n$ sufficiently large, the eigenvalues of a compression of A to a k-dimensional subspace are almost the same for all subspaces. We prove this result using the methods introduced in a paper by Chatterjee and Ledoux on eigenvalues of principle submatrices. We show that by choosing an appropriate Markov chain, the methods of Chatterjee and Ledoux can be applied to give a more general result on operator compressions. As an additional application of this method, we prove concentration of measure of the length of the longest increasing subsequence of a random walk distributed under the invariant measure for the asymmetric exclusion process (Received January 20, 2015)

1108-60-572 **Gerard P Brunick***, gerard.brunick@constellation.com. *A Constructive Approach to Local Volatility Models.*

The traditional approach to local volatility models uses the Fokker-Planck or Kolmogorov forward equation to connect the one-dimensional marginal distributions and the infinitesimal generator of a diffusion process. In this talk, we will offer a construction approach to local volatility models which avoids the use of PDEs. This approach has the advantage that it extends naturally to handle some path-dependent options, and it also allows for the relaxation of the technical conditions which seem to be necessary for a PDE-based argument. (Received January 20, 2015)

1108-60-583 **Jack T Hanson*** (jthanson@indiana.edu), 831 E 3rd St, Rawles Hall, Bloomington, IN 47405. *Toppling critical exponents in the Abelian Sandpile on Z^d.*

The Abelian sandpile is a so-called "self-organized critical" model on graphs. Grains of sand are randomly added at sites, which topple when they have sufficiently many grains; these topplings cause large avalanches on scales up to the system size and induce long-range correlations in the sand heights.

Letting $N(x,y)$ denote the number of topplings occurring at site y after adding to site x, it is known that $E[N(0,x)] \sim \|x\|^{2-d}$ on Z^d; many other such power laws are conjectured. We show new bounds for several exponents characterizing the size of the avalanche, including the exponent η defined by $P(N(0,x) > 0) \sim \|x\|^{2-d-\eta}$. Joint work with S. Bhupatiraju and A. Jarai. (Received January 20, 2015)

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1108-62-29 **Linyuan Li*** (linyuan@cisunix.unh.edu), 33 Academic Way, Department of Mathematics and Statistics, University of New Hampshire, Durham, NH , and **Yimin Xiao** (xiao@stt.msu.edu), Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824. *On the Minimax Optimality of Block Thresholded Wavelet Estimators on Random Fields.* Preliminary report.

Hall et al. (1999, p.33-49, Statistica Sinica) proposed block thresholding methods to estimate mean regression functions with fixed design and independent normal random errors. They showed that block thresholded wavelet estimators attain optimal minimax convergence rates over a large function space involving a wide variety of irregularities. In this paper, we consider analogous block thresholded wavelet estimators of spatial regression functions on stationary Gaussian random fields observed over a rectangular domain indexed with $\mathbb{Z}^2$, whose covariance function is assumed to satisfy some weak condition. We investigate their asymptotic rates of convergence when spatial regression function belongs to a large range of Besov function classes. Based on a result that the discrepancy between empirical wavelet coefficients and true wavelet coefficients is within certain small rate across a large range of Besov function classes, we are able to show that these estimators achieve optimal minimax convergence rates over the above function spaces. Therefore, wavelet estimators still achieve optimal convergence rates for random fields and provide explicitly the extraordinary local adaptability. (Received November 19, 2014)

1108-62-38 **Timothy D Rey*** (trey1@steelcase.com), GH-4W, 901 44th Street, SE, Grand Rapids, MI 49508. *The Curse of Dimensionality in a Real Life Industrial Problem.* Preliminary report.

Industrial data mining (supervised learning) problems generally involve wrestling with the "curse of dimensionality". Data collected in an industrial transaction environment is rarely if ever intended to be used in a modeling problem, let alone in a "cause and effect" modeling problem. Thus the contradiction between cause and effect (ala the use of the scientific method and proper design of experiments) and "prediction" is before us. This curse of dimensionality seems to prevent analytics professionals from finding true cause and effect. Data sets not intended for modeling generally have significant multicollinearity, lack of balance and often are too wide (p being inappropriate for n). Approaches for solving these issues can be broken down into three classes; dimension reduction, parameter adjustment and data structure adjustment. This talk will show an industrial data mining problem where the curse is present in all its glory. Each of the three basic methods for supposed "solutions" to the problem will be presented using modern day technologies. (Received December 02, 2014)

1108-62-204 **Jia Li*** (jl410@duke.edu), Box 90097 Duke Univ, Durham, NC 27708, and **Dacheng Xiu** (dacheng.xiu@chicagobooth.edu), University of Chicago Booth School of Busines, 5807 S. Woodlawn Avenue, Chicago, IL 60637. *Generalized Method of Integrated Moments for High-Frequency Data.*

We propose a semiparametric two-step estimation procedure for a finite-dimensional parameter based on integrated moment conditions. These moment conditions take form of temporally integrated functionals of state variable processes, which include the latent stochastic volatility process of an asset. In the first step, we nonparametrically recover the volatility path from high frequency asset returns and then form sample moment functions. A high-order nonlinearity bias due to the nonparametric volatility estimation needs to be corrected. In the second step, we conduct GMM estimation using the bias-corrected sample moment functions. We show that the proposed estimator is consistent and asymptotically mixed Gaussian, and propose a consistent estimator for the conditional asymptotic variance. A Bierens-type consistent specification test is also constructed. These infill asymptotic results are based on a novel empirical-process-type theory for general integrated functionals of noisy semimartingale processes. (Received January 13, 2015)

1108-62-231 **Jianqing Fan**, **Alex Furger** and **Dacheng Xiu*** (dacheng.xiu@chicagobooth.edu), 5807 S Woodlawn Avenue, Chicago, IL 60637. *Incorporating Global Industrial Classification Standard into Portfolio Allocation: A Simple Factor-Based Large Covariance Matrix Estimator with High Frequency Data.*

We document a striking block-diagonal pattern in the factor model residual covariances of the S&P 500 Equity Index constituents, after sorting the assets by their assigned Global Industry Classification Standard (GICS) codes. Cognizant of this structure, we propose combining a location-based thresholding approach based on sector inclusion with the Fama-French and SDPR sector Exchange Traded Funds (ETF's).

We investigate the performance of our estimators in an out-of-sample portfolio allocation study. We find that our simple and positive-definite covariance matrix estimator yields strong empirical results under a variety of factor models and thresholding schemes. Conversely, we find that the Fama-French factor model is only suitable for covariance estimation when used in conjunction with our proposed thresholding technique. Theoretically, we provide justification for the empirical results by jointly analyzing the in-fill and diverging dimension asymptotics. (Received January 14, 2015)

1108-62-290 **Jose E. Figueroa-Lopez*** (figueroa@purdue.edu), 250 N. University Street, West Lafayette, IN 47907. *Optimally Thresholded Realized Power Variations for Stochastic Volatility Models with Jumps.* Preliminary report.

Thresholded Realized Power Variations are popular nonparametric estimators for continuous-time processes with jumps. An important issue in their application lies in the necessity of choosing a suitable threshold for the estimator. In Figueroa-Lopez and Nisen [Optimally thresholded realized power variations for Levy jump diffusion models, Stochastic Processes and their Applications 123(7), 2648-2677, 2013], a selection method for the threshold is proposed, in which the expected total number of jump misclassifications is minimized. For a jump-diffusion Levy model, existence and uniqueness of the optimal threshold sequence are established together with an explicit short-time asymptotic characterization. In this work, an optimal threshold selection methods is developed in the presence of a stochastic volatility risk component. To this end, we further develop current kernel based estimators for the spot volatility, which in turn yield new optimal bandwidth selection procedures for stochastic volatility models. (Received January 16, 2015)

1108-62-339 **Chengyong Tang*** (yongtang@temple.edu), 1810 North 13th Street, Philadelphia, PA 19122. *On Quasi-Maximum Likelihood Approach for Integrated Covariance Matrix Estimation with High Frequency Data.*

Estimating the integrated covariance matrix (ICM) from high frequency financial trading data is crucial to reflect the volatilities and covariations of the underlying trading instruments. Such an objective is difficult due to contaminated data with microstructure noises, asynchronous trading records, and increasing data dimensionality. We study a quasi-maximum likelihood (QML) approach for estimating an ICM from high frequency financial data. We explore a novel multivariate moving average time series device that is convenient for evaluating the estimator both theoretically for its asymptotic properties and numerically for its practical implementations. We demonstrate that the QML estimator is consistent to the ICM, and is asymptotically normally distributed. Efficiency gain of the QML approach is theoretically quantified, and numerically demonstrated via extensive simulation studies. (Received January 18, 2015)

1108-62-420 **Philip Schniter*** (schniter.1@osu.edu), Dept. ECE, 2015 Neil Ave, Columbus, OH 43210. *Compressive Phase Retrieval via Bethe Free Energy Minimization.* Preliminary report.

We recently developed a novel approach to the problem of compressive phase retrieval (PR) based on belief propagation and, in particular, on the generalized approximate message passing (GAMP) algorithm. Numerical experiments suggest that PR-GAMP has state-of-the-art i) sample complexity, ii) computational complexity, and iii) noise robustness. For example, they show PR-GAMP reliably recovering i) K-sparse N-length signals from $M \geq 2K \log_2(N/K)$ phaseless random measurements for $K \ll N$, ii) 6k-sparse 65k-pixel grayscale images from 32k randomly masked and blurred Fourier intensity measurements in under 10 seconds, and iii) noise-corrupted signals at a MSE that is only about 3 dB worse than that of phase-oracle GAMP over a wide SNR range. The original version of PR-GAMP, however, requires knowledge of both noise variance and signal sparsity K. In this work, we describe an extension that learns both the noise variance and the signal sparsity from the phaseless measurements themselves. For this, we interpret the larger inference problem as Bethe Free Energy minimization, and we show how the GAMP iterations can be combined with a few additional steps to tackle this problem and thereby accomplish joint phase retrieval and parameter tuning. (Received January 19, 2015)

1108-62-497 **Maalee N Almheidat*** (almhe1mn@cmich.edu), 1506 E Gaylord St, Mount Pleasant, MI 48858, and **Felix Famoye** and **Carl Lee**. *Some generalized families of Weibull distribution.*

In this paper, six new families of T-WeibullY distributions arising from the quantile function of a random variable Y are introduced to generalize Weibull distribution. Some of their properties are studied. Different examples of the T-WeibullY distributions are presented and the flexibility of these examples are illustrated by some applications to real life data sets. (Received January 20, 2015)

1108-62-584 **Chen Lin***, 632 Bogue Street, East Lansing, MI 48823, and **Douglas Bowman**. *Consumer Decisions Across Seemingly Disparate Categories: Latent-Trait Segmentation.*

This research takes a first step in modeling latent processes that govern consumer decision making by examining consumption across seemingly disparate categories. We propose a hierarchical multinomial processing tree model to empirically examine the driver, which is defined as the "latent trait", which governs consumer choices across five seemingly disparate product categories through a dataset consisting of 5,014 consumers in the United States. We further investigate how consumer behavior systematically varies from one category to another and finally suggest new approaches to segment and profile consumers based on latent traits across multiple categories. In doing so, this paper contributes to the consumer decision literature in three ways: 1) theoretically, the latent- trait approach provides rich support in examining the underlying psychological processes; 2) methodologically, the relative merits of models with continuous versus discrete representations of consumer heterogeneity are discussed; and, 3) substantively, new insights on targeting and profiling based on latent processes rather than observed behavior are presented with respect to managing across seemingly unrelated product categories. (Received January 20, 2015)

65 ► Numerical analysis

1108-65-65 **J Austin Murphy*** (jamurphy@oakland.edu), Oakland University, SBA, Lake Orion, MI 48360, and **Terry Benzschawel** and **Liang Fu**. *Systematic Risk and Yield Premiums in the Bond Market.*

This research shows traditional measures of systematic risk of bonds based on unadjusted past returns have very large downward biases. After developing an improved method for calculating the market betas of credit instruments, an empirical evaluation indicates that yield spreads are highly related to such estimates of systematic risk. These betas along with yields enable estimation of the price of risk that is found to be useful in predicting future returns on the aggregate market. The ex-ante systematic risk premiums are discovered to be negatively related to past market returns on bonds and be positively associated with past market volatility. (Received December 20, 2014)

1108-65-108 **Jizhou Li*** (jl48@rice.edu), Department of Computational and Applied Math, 6100 Main MS-134, Houston, TX 77005. *High order discontinuous Galerkin method for reservoir flow simulations.*

We present a high order discontinuous Galerkin method for miscible displacement simulation in porous media. The method uses weighted average stabilization technique and flux reconstruction post-processing. The mathematical model is decoupled and solved sequentially. We apply domain decomposition and algebraic multigrid preconditioner for the linear system resulting from the high order discretization. The accuracy and robustness of the method are demonstrated in the convergence study with analytical solutions and heterogeneous porous media respectively. We also investigate the effect of grid orientation and anisotropic permeability using high order discontinuous Galerkin method in contrast with cell-centered finite volume method. The study of the parallel implementation shows the scalability and efficiency of the method on parallel architecture. We also verify the simulation result on highly heterogeneous permeability field from the SPE10 model. (Received January 05, 2015)

1108-65-126 **Mark Iwen** and **Aditya Viswanathan*** (aditya@math.msu.edu), Michigan State University, Department of Mathematics, 619 Red Cedar Road, East Lansing, MI 48824, and **Yang Wang**. *Fast Phase Retrieval for High-Dimensions.*

Phase retrieval refers to the problem of recovering a signal from its magnitude or intensity measurements. This problem occurs in certain imaging modalities such as x-ray crystallography. In this talk, we develop a fast phase retrieval method based on block circulant measurement constructions which is near-linear time, making it computationally feasible for large dimensional signals. Theoretical and experimental results demonstrating the method's speed, accuracy and robustness will be presented. We then use this new phase retrieval method to construct the first known sublinear-time compressive phase retrieval algorithm capable of recovering a given s-sparse signal $x \in \mathbb{C}^d$ in just $\mathcal{O}(s \log^5 s \cdot \log d)$-time using only $\mathcal{O}(s \log^4 s \cdot \log d)$ magnitude measurements. (Received January 06, 2015)

1108-65-238 **Leo G Rebholz*** (rebholz@clemson.edu) and **Mengying Xiao**. *Removing splitting error in Yosida methods for Navier-Stokes equations with grad-div stabilization.*

After reviewing some recent results on removing splitting error in 'split-then-discretize' projection methods for solving Navier-Stokes equations by using grad-div stabilization, we discuss how grad-div can also be used to remove splitting error in the 'discretize-then-split' Yosida factorization methods. We prove that if pointwise divergence-free element discretizations are used together with grad-div stabilization (with parameter γ), then solutions of Yosida methods converge to the divergence-free solution of the unsplit system as $\gamma \to \infty$. Several numerical experiments are given, and also a comparison of these Yosida-penalty methods to iterated penalty methods. (Received January 14, 2015)

1108-65-246 **Susanne C. Brenner**, **Peter B. Monk** and **Jiguang Sun*** (jiguangs@mtu.edu). *C0IPG Method for Biharmonic Eigenvalue Problems.*

We investigate the C0 interior penalty Galerkin (C0IPG) method for biharmonic eigenvalue problems with the boundary conditions of the clamped plate, the simply supported plate and the Cahn-Hilliard type. We prove the convergence of the method and present numerical results to illustrate its performance. We also compare the C0IPG method with the Argyris C1 finite element method, the Ciarlet-Raviart mixed finite element method, and the Morley nonconforming finite element method. (Received January 15, 2015)

1108-65-301 **Jianliang Qian***, Department of Mathematics, Michigan State University, East Lansing, MI 48823. *Adjoint State Method for the Identification Problem in SPECT.*

Motivated by recent theoretical results obtained by the third author for the identification problem arising in single-photon emission computerized tomography (SPECT), we propose an adjoint state method for recovering both the source and the attenuation in the attenuated X-ray transform. Our starting point is the transport-equation characterization of the attenuated X-ray transform, and we apply efficient fast sweeping methods to solve static transport equations and adjoint state equations. Numerous examples are presented to demonstrate various features of the identification problem, such as uniqueness and nonuniqueness, stability and instability, and recovery of the wave front set. (Received January 16, 2015)

1108-65-349 **Ohannes Karakashian*** (ohannes@math.utk.edu) and **Craig Collins**. *Schwarz Methods for Discontinuous Galerkin Approximations of Elliptic problems.*

We consider overlapping and non overlapping Schwarz methods for the solution of the linear systems resulting from Interior Penalty Discontinuous Galerkin discretizations of elliptic problems. In particular, we focus on the dependence of the condition numbers of the preconditioned systems on the penalty parameter and give an analytical and experimental study of this dependence. (Received January 18, 2015)

1108-65-390 **Alexander Labovsky*** (aelabovs@mtu.edu). *A Defect Correction Approach to Turbulence Modeling.*

A method for resolving turbulent flow problems is presented, aiming at competing with the existing mathematical tractable Approximate Deconvolution Models in terms of accuracy, and outperforming these models in terms of the computational time needed. Full numerical analysis is performed, and the method is shown to be stable, easy to implement and parallelize, and computationally fast. The proposed method employs the defect correction approach to solve spatially filtered Navier-Stokes equations. A simple numerical test is provided, that compares the method against the Approximate Deconvolution turbulence model (ADM). When resolving a fluid flow at high Reynolds number, the numerical example verifies the key feature of the method: while having the accuracy comparable to that of the ADM, the method computes in less than 80% of the time needed for the turbulence model - even before the parallelization. (Received January 19, 2015)

1108-65-411 **Liping Chen** (chenlipi@msu.edu), 619 Red Cedar Road, East Lansing, MI 48824, **Lixing Han*** (lxhan@umflint.edu), 303 East Kearsley Street, Flint, MI 48502, and **Liangmin Zhou** (zhoulian@msu.edu), 619 Red Cedar Road, East Lansing, MI 48824. *Computing Eigenvalues and Eigenvectors of Tensors via Homotopy Continuation.*

Eigenvalues and eigenvectors of tensors have found applications in automatic control, data analysis, higher order diffusion tensor imaging, image authenticity verification, optimization, and other areas. Recently, several algorithms have been proposed for computing certain eigenpairs of symmetric tensors or nonnegative tensors. However, there is a lack of efficient methods that can compute all eigenpairs of general tensors. In this talk, we will describe a method that is based on HOM4PS (an implementation of the homotopy method) and deflation method for computing tensor eigenpairs. If implemented properly, this method can efficiently find all isolated eigenpairs of a tensor and some eigenpairs contained in the positive dimensional components. We will also describe methods for computing real eigenpairs based on the found complex eigenpairs. We wish to thank Professor T.Y. Li for his encouragement and support. (Received January 19, 2015)

1108-65-418 **Ke Shi***, shike@math.tamu.edu, and **Raytcho Lazarov**, **Yalchin Efendiev** and **Minam Moon**. *Multiscale Hybridizable DG methods for flows in heterogeneous media.*

In this talk, we will briefly discuss multiscale problems and review some classical multiscale finite element methods for these problems. Then we present a general framework on coupling the hybridization technique with multiscale finite element approach. Several numerical examples will be presented in the end. (Received January 19, 2015)

1108-65-432 **Tianran Chen*** (chentia1@msu.edu). *A homotopy method for locating critical points with a given Morse-index.*

The problem of locating the critical points of a real-valued functions is an important problem in physics, chemistry, engineering, and mathematical biology. Among a wide range of different computational approaches for finding critical points, the homotopy continuation methods have been proved to be a versatile family of numerical methods that offers some unique advantages.

It is often the case that critical points having a certain Morse-index are of special interest. Examples include the study of atomic clusters where critical points of Morse-index 1 corresponds to the "transition states" between stable configurations. This talk discusses a specialized homotopy construction that directly targets the real critical points of a given Morse-index. (Received January 19, 2015)

1108-65-440 **Gideon Simpson*** (simpson@math.drexel.edu), Korman Center - Room 206, 33rd and Market Streets, Department of Mathematics, Philadelphia, PA 19104. *Petviashvilli's method for the Dirichlet problem.*

Nonlinear bound states, including solitons, play an important role in the dynamics of many nonlinear partial differential equations. To explore their dynamics and stability in simulation, it is of value to have an algorithm which can efficiently compute such solutions. These nonlinear bound states typically solve semilinear elliptic equations of the form $\phi - \Delta\phi = |\phi|^{p-1}\phi$ on $\mathbb{R}^d$, vanishing at infinity. This introduces the challenge that since zero is a solution, there is little, a priori, preventing a nonlinear solver from converging to the zero solution instead of something more interesting. This motivated the development of robust algorithms, such as Petviashvilli's method, which can accommodate very poor starting guesses, yet still converge to nontrivial solutions. In this talk, I will present new results towards an explanation of the apparent global convergence of these algorithms, when the problem is considered on a bounded domain with Dirichlet boundary conditions. Numerical examples in 1D and 2D will be given and open problems will be highlighted. (Received January 19, 2015)

1108-65-441 **David A Fischer*** (dfischer@qedenv.com), PO Box 3726, Ann Arbor, MI 48106, and **Hongli Gao** (gaohongl@msu.edu), Lansing, MI. *Mathematical Methods as Applied to Landfill Gas Data.* Preliminary report.

Solid waste landfills collect data from the operation of landfill gas (LFG) collection systems. Systems have 50-200 LFG collection wells, with up to 10 data elements collected semimonthly (130K-500K values/year). Data is collected over the full life of the landfill (50+ years) and includes meta-data (barometric pressure, etc.). This data is vital for regulatory reporting and system control. Automated data collection methods (IoT) are under consideration to improve efficiency. IoT will increase data density and require better improved analysis. QED has worked with the MSIM program to investigate analysis approaches. Efforts include data "cleaning", statistical tests, Artificial Neural Network (ANN) modeling, hierarchical clustering and classification and graphical methods.

The ANN model has been widely used in pattern recognition, data classification, etc., and will be presented in this talk. In the methane capture modeling, the input vector of selected variables (input neurons) and the methane capture (output neuron) are used to start the network. After being weighted and transformed by activation function the activations of these neurons are passed onto the next layer of neurons. This process is repeated until the Mean Square Error of methane percentage is minimized. (Received January 19, 2015)

1108-65-444 **Jan Verschelde** and **Xiangcheng Yu*** (xyu30@uic.edu), Dept. of Math., Stats., and Computer Science, University of Illinois at Chicago, 851 S. Morgan St. (m/c 249), Chicago, IL 60607. *Accelerating Polynomial Homotopy Continuation on a Graphics Processing Unit.* Preliminary report.

Numerical continuation methods apply predictor-corrector algorithms to track a solution path defined by a family of systems. The systems we consider are defined by polynomials in several variables. For larger dimensions and degrees, the numerical conditioning worsens and double precision becomes often insufficient. With double double and quad double arithmetic, larger problems can be solved accurately, but at a higher computational cost. This cost overhead can be compensated by acceleration on a Graphics Processing Unit (GPU).

We describe our implementation and report on computational results on two benchmark polynomial systems. The first benchmark consists of two sequences of Pieri homotopies. In the second benchmark, we applied monodromy to the cyclic n-roots problems. In case the linear algebra dominates the total computational cost of a path tracker, the dimension needs to be of the order of at least several hundreds. For general polynomials of higher degrees, already in smaller dimensions, acceleration may offset the cost of higher precision arithmetic. (Received January 19, 2015)

1108-65-462 **Hengguang Li*** (hli@math.wayne.edu), Department of Mathematics, Wayne State University, Detroit, MI 48202, and **Qinghui Zhang** (zhangqh6@mail.sysu.edu.cn), Department of Scientific Computing, and Computer Applications, Sun Yat-Sen University, Guangzhou, Guangdong 510275, Peoples Rep of China. *Optimal Quadrilateral Finite Elements on Polygonal Domains.*

We propose three quadrilateral mesh refinement algorithms to improve the convergence of the finite element method approximating the singular solutions of elliptic equations, which are due to the non-smoothness of the domain. These algorithms result in graded meshes consisting of convex and shape-regular quadrilaterals. With rigorous analysis in weighted spaces, we provide the selection criteria for the grading parameter, such that the optimal convergence rate can be recovered for the associated finite element approximation. Various numerical tests verify the theory. (Received January 19, 2015)

1108-65-490 **Zhonggang Zeng*** (zzeng@neiu.edu), Department of Mathematics, Northeastern Illinois University, Northeastern Illinois University, Chicago, IL 60625. *Computing a defective eigenvalue using perturbed matrix data.* Preliminary report.

Multiple defective eigenvalues are infinitely sensitive to data perturbations and present a challenge in numerical computation. In this talk, we present an error analysis on a defective eigenvalue under constrained perturbation so that the smallest elementary Jordan block size is preserved. We prove that the sensitivity of a defective eigenvalue is finitely bounded under such constrained perturbations. An iterative algorithm based on Gauss-Newton iteration is designed to take advantage of such a well-posedness and is capable of calculating defective eigenvalues accurately without extending the hardware precision even if the matrix data is perturbed. The resulting algorithm is applicable in the computation of numerical Jordan Canonical Forms of matrices. (Received January 19, 2015)

1108-65-523 **Xianping Li*** (lixianp@umkc.edu) and **Weizhang Huang** (whuang@ku.edu). *Anisotropic mesh adaptation for 3D anisotropic diffusion problems.*

Anisotropic diffusion problems arise from many fields of science and engineering. One of the challenge tasks for those problems is to avoid non-physical solutions or spurious oscillations in the numerical computations. A common approach is to design a proper discretization scheme and/or a proper mesh so that the numerical solution satisfies the discrete maximum principle (DMP). In this talk, the mesh adaptation strategies for three-dimensional anisotropic diffusion problems are presented. The results for 2D problems are extended to 3D problems and the conditions on mesh qualities such that numerical solutions satisfy DMP are developed. Some numerical examples are presented. (Received January 20, 2015)

1108-65-532 **Jonathan Hauenstein***, University of Notre Dame, Notre Dame, IN 46556, and **Adam Mahdi** and **Claudio Pessoa**. *The center-focus problem.*

The stability of parameterized system of ODEs is a fundamental problem encountered in various branches of science and engineering. The center-focus problem is one of the simplest and well-known stability questions. For this problem, one would like to determine conditions on the parameters to distinguish between a center and a local focus. This talk will describe an approach based on numerical algebraic geometry which we have used to solve a three-dimensional center-focus problem. (Received January 20, 2015)

1108-65-535 **Tianran Chen** (`chentia1@msu.edu`) and **Tien-Yien Li*** (`li@math.msu.edu`). *Parallel algorithms for computing the degree of the solution sets of systems of binomial equations.*

The problem of solving a system of polynomial equations numerically is one of the most fundamental problems in applied mathematics. Among them, the problem of solving a system of binomial equations form an important subclass for which specialized techniques exist. For both theoretic and applied purposes, the degree of the solution set of a system of binomial equations often play an important role in understanding the geometric structure of the solution set. It, however, can be computationally intensive. This talk discusses the recent developments in the parallel algorithms for computing the degree of the solution set of large scale systems of binomial equations on a variety of parallel computing architectures including a specialized parallel algorithm for GPU devices that takes advantage of their massively parallel nature. The preliminary implementation shows remarkable efficiency and scalability when compared to its closest CPU-based counterpart. In certain cases, 30 to 50 fold speedup ratios have been achieved, enabling the discovery of previously unknown results. (Received January 20, 2015)

1108-65-563 **Di Liu*** (`richardl@math.msu.edu`), 619 Red Cedar, East Lansing, MI 48824. *A Multiscale Method for Optical Responses of Nano Structures.*

We introduce a new framework for the multiphysical modeling and multiscale computation of nano-optical responses. The semi-classical theory treats the evolution of the electromagnetic field and the motion of the charged particles self-consistently by coupling Maxwell equations with Quantum Mechanics. To overcome the numerical challenge of solving high dimensional many body Schrödinger equations involved, we adopt the Time Dependent Current Density Functional Theory (TD-CDFT). In the regime of linear responses, this leads to a linear system of equations determining the electromagnetic field as well as current and electron densities simultaneously. A self-consistent multiscale method is proposed to deal with the well separated space scales. Numerical examples are presented to illustrate the resonant condition. (Received January 21, 2015)

68 ► Computer science

1108-68-385 **Anna Gilbert***, 2074 East Hall, 530 S. Church Street, Ann Arbor, MI 48109, and **Mahmoud A. Khamis**, **Hung Q. Ngo** and **Atri Rudra**. *Sparse Approximation, List Decoding, and Uncertainty Principles.*

We consider list versions of sparse approximation problems, where unlike the existing results in sparse approximation that consider situations with unique solutions, we are interested in multiple solutions. We introduce these problems and present the first combinatorial results on the output list size. These generalize and enhance some of the existing results on threshold phenomenon and uncertainty principles in sparse approximations. Our definitions and results are inspired by similar results in list decoding. We also present lower bound examples that bolster our results and show they are of the appropriate size. (Received January 19, 2015)

1108-68-510 **Soledad Villar*** (`mvillar@math.utexas.edu`), speedway 2515, RLM 8.100, Math department, Austin, TX 78712, and **Pranjal Awasthi**, **Afonso S Bandeira**, **Moses Charikar**, **Ravishankar Krishnaswamy** and **Rachel Ward**. *Convex relaxations in geometric clustering.*

We study exact recovery conditions for convex relaxations of point cloud clustering problems, focusing on two of the most common optimization problems for unsupervised clustering: k-means and k-median clustering. (Received January 20, 2015)

1108-68-537 **Anna C. Gilbert**, **Yi Li**, **Ely Porat** and **Martin J. Strauss*** (`martinjs@umich.edu`), Univ. Michigan/Department of Math, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109-1043. *Closing in on Optimal Sparse Recovery.*

An approximate sparse recovery system consists of a matrix, Φ, and a recovery algorithm, R. Given a vector, x, the system approximates x from linear measurements Φx as $R(\Phi x)$, which must satisfy

$$\|R(\Phi x) - x\| \leq (1+\varepsilon)\|x_{\text{opt}} - x\|,$$

where x_{opt} is the best possible k-term approximation to x. Among the figures of merit are the number of rows in Φ, the runtime of R, the choice of norms, and whether x can depend on (random) Φ. We survey results in this area up to recent work. (Received January 20, 2015)

78 ► Optics, electromagnetic theory

1108-78-159 **Andrew William Wharmby*** (awharmby@gmail.com) and **Ronald Laird Bagley**. *Modifying Maxwell's equations for dielectric materials based on techniques from viscoelasticity and concepts from fractional calculus.*

A mathematical model of viscoelasticity employing fractional order derivatives is adapted and applied to model the dielectric behavior of materials while remaining consistent with thermodynamic principles. The model is then incorporated into Maxwell's equations using techniques from viscoelasticity. The modified Maxwell's equations are found to yield a fractional order wave equation that is solved analytically and is found to remain consistent with dissipative and dispersive phenomena. (Received January 09, 2015)

1108-78-203 **John C Schotland*** (schotland@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Inverse transport and acousto-optic imaging.*

A method to reconstruct the optical properties of a highly-scattering medium from acousto-optic measurements is proposed. The method is based on the solution to an inverse problem for the radiative transport equation with internal data. A stability estimate and a direct reconstruction procedure are described. (Received January 13, 2015)

1108-78-217 **Mark A. Anastasio*** (anastasio@wustl.edu), Washington University in St. Louis, Dept. of Biomedical Engineering, St. Louis, MO 63110. *Optimization-based Image Reconstruction Methods for Photoacoustic Computed Tomography.*

Photoacoustic computed tomography (PACT) is an emerging soft-tissue imaging modality that has great potential for a wide range of preclinical and clinical imaging applications. It can be viewed as a hybrid imaging modality in the sense that it utilizes an optical contrast mechanism combined with ultrasonic detection principles, thereby combining the advantages of optical and ultrasonic imaging while circumventing their primary limitations. In this talk, we review our recent advancements in practical image reconstruction approaches for PACT. Such advancements include physics-based models of the measurement process and associated inversion methods for reconstructing images from limited data sets in acoustically heterogeneous media. Applications of PACT to transcranial brain imaging and breast cancer detection will be discussed. (Received January 14, 2015)

1108-78-519 **Wenjing Liao*** (wjliao@math.duke.edu), 3611 University Drive, Apt 11R, Durham, NC 27707, and **Albert Fannjiang** (fannjiang@math.ucdavis.edu), Department of Mathematics, One Shields Avenue, Davis, CA 95616. *Fourier phase retrieval with phase-uncertain mask.*

Fourier phase retrieval is the problem of recovering images from their Fourier intensity data. The standard Fourier phase retrieval (without a mask) is known to have many solutions which cause the standard phasing algorithms to stagnate and produce wrong or inaccurate solutions. In this talk Fourier phase retrieval is studied with the introduction of a randomly fabricated mask. Uniqueness of solution with exact knowledge of the mask was previously proved by Fannjiang. Recently we have extended the uniqueness result to the case that only rough information about the mask is known. New phasing algorithms alternating between the object update and the mask update are demonstrated to have the capability of recovering both the object and the mask (within the object support) simultaneously, consistent with the uniqueness result. We also show that phase retrieval with phase-uncertain mask is robust with respect to the correlation in the mask as well as the Gaussian and Poisson noises. (Received January 20, 2015)

81 ► Quantum theory

1108-81-74 **Sven Bachmann**, **Eman Hamza**, **Bruno Nachtergaele** and **Amanda Young*** (amyoung@math.ucdavis.edu), Department of Mathematics, University of California Davis, One Shields Ave, Davis, CA 95616. *The Dependence of Spectral Properties on the Infinite Boundary for a Family of Quantum Spin Systems.*

I introduce the class of single species PVBS models defined on a finite, connected subset of $\mathbb{Z}^d$. I will give the finite volume ground states and provide a criterion for the dimension of the weak-* infinite volume ground state space that is dependent on the model parameters and the geometry of the infinite volume. Furthermore, I will show that the existence of the spectral gap in the thermodynamic limit depends on the model parameters and the geometry of the infinite volume to which we take the limit. (Received December 27, 2014)

1108-81-188 **Alexander Elgart** and **Daniel Schmidt*** (dfs@vt.edu). *Eigenvalue Statistics for Alloy-Type Models.*

We present an estimate on the number of eigenvalues of a matrix in a small interval, phrased in terms of the properties of a submatrix. We then apply this result to prove a theorem on the eigenvalue statistics of certain random Schrödinger operators. Specifically, we establish Wegner, Minami, and higher-order estimates for a class of one-dimensional alloy-type models. (Received January 12, 2015)

1108-81-306 **Houssam Abdul-Rahman*** (houssam@uab.edu), Department of Mathematics, 1300 University Blvd. Campbell Hall room 452, Birmingham, AL 35294-1170, and **Günter Stolz** (stolz@math.uab.edu), Department of Mathematics, 1300 University Blvd. Campbell Hall room 452, Birmingham, AL 35294-1170. *An area law for entanglements of eigen states in a disordered XY chain.*

We will consider an XY spin chain with a random magnetic field. We will use Wick's rule and results from the Anderson localization to show how the dynamical localization of the resultant effective one particle Hamiltonian implies an area law for the bipartite entanglement entropy of the eigen states. Moreover, we will introduce the Local Jordan-Wigner fermionic operators to prove the result with respect to any connected subinterval of the chain. (Received January 17, 2015)

1108-81-365 **Robert Sims***, Department of Mathematics, 617 N. Santa Rita Avenue, Tucson, AZ 85721, and **Simone Warzel**, 85748 Garching b. Munchen, Boltzmannstrasse 3, Garching, Germany. *On Correlation Decay in the Random XY-Model.* Preliminary report.

We consider the XY-model in a random transverse field. For this model we prove that, upon disorder average, both the ground state and thermal state correlations decay exponentially. Our methods are based on a deterministic bound which is valid for both dynamic and static multi-point correlations of general one-dimensional, quasi-free states. This is joint work with Simone Warzel. (Received January 18, 2015)

1108-81-465 **Joe P. Chen*** (joe.p.chen@uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269-3009, **Stanislav A. Molchanov** (smolchan@uncc.edu), Department of Mathematics, University of North Carolina at Charlotte, Charlotte, NC 28223, and **Alexander Teplyaev** (alexander.teplyaev@uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269-3009. *Spectral dimension and Bohr's formula for Schrodinger operators on unbounded fractal spaces.*

We establish a sharp asymptotic formula for the eigenvalue counting function of the Schrodinger operator $-\Delta+V$ for unbounded potentials V on several types of unbounded fractal spaces. Such an asymptotic formula is often attributed to Niels Bohr in the Euclidean setting. We identify a set of sufficient conditions for Bohr's formula to hold on metric measure spaces which admit a cellular decomposition, and then verify these conditions for fractafolds and fractal fields based on nested fractals. In particular, we are able to answer a question of Fan, Khandker, and Strichartz regarding the spectral asymptotics of the harmonic oscillator potential on the infinite blow-up of a Sierpinski gasket. (Received January 19, 2015)

1108-81-476 **Meg Walters** and **Shannon Starr*** (slstarr@uab.edu). *Eigenvector overlap functions in non-Hermitian random matrices.*

We have considered eigenvector overlap functions for non-Hermitian random matrices. One may view this as a problem growing out of trying to apply mathematical methods from spin glasses to random matrix theory. In the complex Ginibre ensemble it is easy to calculate mixed matrix moments. But these involve eigenvector overlaps as well as the eigenvalue distributions. Physicists Chalker and Mehlig have considered this before. We discuss some of their results, some of our proofs of their conjectures, and other conjectures which remain open. Fyodorov and coauthors have shown that this also relates to resonances in quantum systems. We will also discuss this. (Received January 19, 2015)

1108-81-492 **John Z. Imbrie*** (imbrie@virginia.edu), Department of Mathematics, University of Virginia, P. O. Box 400137, Charlottesville, VA 22904-4137. *On many-body localization for quantum spin chains.*

We consider random matrices that arise in the physics of disordered systems. These represent quantum mechanical Hamiltonians for systems of interacting particles or spins. For strong disorder, the matrices are on average diagonally dominant, so one might conjecture that the eigenvectors resemble the initial basis vectors, in an appropriate sense. This is the phenomenon of many-body localization; it leads to a lack of transport and a lack of ergodicity in the quantum system.

We show that a particular one-dimensional spin chain with random local interactions exhibits many-body localization. The proof depends on a physically reasonable assumption that limits the amount of level attraction in the system. The construction uses a sequence of local unitary transformations to diagonalize the Hamiltonian and connect the exact many-body eigenfunctions to the original basis vectors. (Received January 19, 2015)

1108-81-514 **Aurel Iulian Stan*** (stan.7@osu.edu), 1465 Mount Vernon Avenue, Marion, OH 43302, and **Gabriela Popa** (popag@ohio.edu), Department of Physics, College of Arts and Sciences, 240 Elton Hall, Zanesville, OH 43701. *A characterization of Meixner random variables in terms of semi-quantum operators.* Preliminary report.

The commutators of the quantum operators: creation, preservation, and annihilation can be used to describe the class of Meixner random variables, due to the almost Lie Algebra structure of this class. However, to describe completely the Meixner random variables in this way, we must split this class into the symmetric and non-symmetric random variables, and describe each of these two subclasses separately. By splitting the annihilation operators into two halves, and combining one half with the creation operator and the other half with the annihilation operator, we form the semi-quantum operators. Using the commutators of the semi-quantum operators, we can describe the entire class of Meixner random variables in a simple and unitary way. Moreover, the semi-quantum operators allow us to define the notion of d-dimensional n-Meixner random vectors, for any d and n natural numbers. We describe completely the class of 2-dimensional 1-Mexiner random vectors. (Received January 20, 2015)

1108-81-547 **Michael Bishop*** (mbishop@math.ucdavis.edu), Department of Mathematics, One Shields Ave, Davis, CA 95616. *Gap Dependency on Half Planes in the Product Vacua and Boundary State models.*

The Product Vacua and Boundary States models are a class of quantum spin models defined on the lattices $\Lambda \subset \mathbb{Z}^d$. In 2014, Bachmann, Hamza, Nachtergaele, and Young investigated the single species version in d-dimensions, studying the ground state space and spectral gap. The gap of these Hamiltonians showed an odd dependence on the subset Λ. This talk will discuss recent progress with Nachtergaele and Young on this dependence: for a given set of parameters, the Hamiltonians have an open spectral gap for almost every half plane in $\mathbb{Z}^d$, except for a specific half plane where the gap closes. (Received January 20, 2015)

82 ► Statistical mechanics, structure of matter

1108-82-135 **Bruno Nachtergaele*** (bxn@math.ucdavis.edu), Department of Mathematics, University of California, Davis, Davis, CA 95616, and **Robert Sims**. *Strongly Continuous Approximations of Continuum Fermion Dynamics.* Preliminary report.

The Heisenberg dynamics for quantum spin systems is given by a strongly continuous one-parameter group of automorphisms of the C^*-algebra of quasi-local observables, including in the thermodynamic limit. The strong continuity is used in the proofs of many important results about the dynamics and statistical mechanics of quantum lattice systems. The dynamics of quantum many-body systems in continuous space, however, is generally not strongly but only weakly continuous. An important exception is the quasi-free dynamics of fermions, which can be constructed explicitly and is easily seen to be strongly continuous. We argue that including genuine two-body interactions between the fermions will destroy the strong continuity. This makes direct generalization of results for quantum spin models to many-body systems in the continuum impossible. As an approach to overcoming this hurdle in the study of continuum Fermi systems, we propose a systematic strongly continuous approximation of the dynamics. (Received January 07, 2015)

1108-82-342 **David Damanik**, damanik@rice.edu, **Milivoje Lukic***, mlukic@math.toronto.edu, and **William Yessen**, yessen@rice.edu. *Ballistic transport in the XY spin chain.*

Dynamical properties of spin chains are usually expressed in terms of Lieb-Robinson bounds. In particular, the anisotropic XY spin chain can be studied via an associated block Jacobi matrix, using the Jordan-Wigner transform. We use this connection to prove ballistic propagation, i.e. a nonzero lower bound on the Lieb-Robinson velocity, for the periodic XY spin chain, and some related results. (Received January 18, 2015)

1108-82-394 **Wenrui Hao***, Jennings Hall 3rd Floor, 1735 Neil Ave., Columbus, OH 43210, and **Andrew Sommese** and **Rafael Nepomechie**. *Homotopy continuation method and Bethe equations.*

In this talk, we will use homotopy continuation method to explore the Bethe equations, which have many applications in mathematics and physics. Using homotopy continuation, we solve the Bethe equations numerically for different cases, and numerically prove the conjecture that we proposed. (Received January 19, 2015)

1108-82-409 **Kyle E Besing*** (kebesing@uab.edu). *Localization Properties of the Random Mass Laplacian.* Preliminary report.

Let $\Gamma = (V, E)$ be a connected graph of bounded degree. Let $k : V \to \mathbb{R}$, $m : V \to (0, \infty)$ and $b : E \to (0, \infty)$. An effective one-particle Hamiltonian, H, for a system of quantum harmonic oscillators is given by

$$H = m^{-\frac{1}{2}}(L + k)m^{-\frac{1}{2}} \tag{1}$$

where m and k denote the multiplication operators generated from m and k, respectively, and

$$(L\varphi)(x) = \sum_{y:\{x,y\}\in E} b(\{x, y\})(\varphi(x) - \varphi(y)). \tag{2}$$

Allowing any of these sequences to be i.i.d random variables produces interesting models to study. One can see that setting $b \equiv 1 \equiv m$ and defining k as a sequence of i.i.d. random variables gives the well-known Anderson model.

One of the models of interest, named the Random Edge Laplacian L_b, is given by assigning $m \equiv 1$, $k \equiv 0$, and allowing b to be a sequence of i.i.d random variables. Additionally, we want to study the model given by setting $b \equiv 1$, $k \equiv 0$, and defining m to be a sequence of i.i.d. random variables, to which we give the name the Random Mass Laplacian K_m. In this talk, we will focus on the latter model and some of the localization properties which can be shown via the Fractional Moment Method. (Received January 19, 2015)

1108-82-551 **Rajinder S Mavi*** (rsm8y@virginia.edu). *Random nonmonotonic multichannel Schrödinger operators.*

Recently there has been increased interest in studying random multiparticle and manybody quantum systems and demonstrating the Anderson localization they are expected to obey. Anderson localization is by now well understood for standard random Schrodinger operators. There are of course several aspects arising in more-than-one body systems which prevent an immediate application of the methods of one body systems. In systems such as random Ising models, energy levels of the system may depend analytically on (finite truncations of) random parameters. Of course in the standard Anderson model the dependence of the energy levels on the random parameters is linear which leads to the celebrated Wegner estimate which allows the usual multiscale analysis. In our talk, we consider a single body model with energies depending analytically on the random parameters. In multichannel Schrodinger models, the potentials at each site of the lattice are matrices which may depend analytically on the random parameters, eg, these models can be realized as tight binding models in Z^D with dilute randomness. In the multichannel model, we show unique continuation principles of energies with respect to the random environment, then obtain stretched exponential localization of eigenfunction correlations. (Received January 20, 2015)

90 ► Operations research, mathematical programming

1108-90-17 **Rebecca Stockbridge*** (rstockbridge@math.wayne.edu) and **Guzin Bayraksan**. *Variance Reduction Techniques for Sequential Sampling in Stochastic Programming.*

We apply variance reduction techniques, specifically antithetic variates and Latin hypercube sampling, to optimality gap estimators used in sequential sampling algorithms to solve stochastic programs. We discuss both theoretical and computational results on a range of test problems. (Received November 06, 2014)

1108-90-500 **Paul E. Hand*** (hand@rice.edu), CAAM Dept MS-134, Rice University, 6100 Main Street, Houston, TX 77004. *PhaseLift is stable to a fixed fraction of arbitrary errors.*

In this talk, we will consider the phase retrieval problem where a small fraction of the measurements have arbitrary errors. Such errors can arise in imaging problems through sensor failure, occlusion, and other causes. Without such gross errors, the semidefinite program known as PhaseLift is provably successful when the number of Gaussian measurements scales linearly with the ambient dimensionality. In this talk, we will discuss a variant of PhaseLift that is provably robust to a small but fixed fraction of arbitrary errors, even when the number of measurements is linear in the ambient dimensionality. We will also see empirical evidence for this scaling. (Received January 20, 2015)

91 ► Game theory, economics, social and behavioral sciences

1108-91-21 **Ruihua Liu*** (rliu01@udayton.edu), 300 College Park, Dayton, OH 45469. *Optimal Stopping and American Option in A State Dependent Regime-Switching Model.*

We consider an infinite-horizon optimal stopping problem in a switching diffusion model with state-dependent switching rates. We prove that the value function is the unique viscosity solution of the associated Hamilton-Jacobi-Bellman (HJB) equation, which is given by a system of coupled variational inequalities. We examine the problem of pricing perpetual American options in the model. A numerical procedure is developed based on the dynamic programming approach and an efficient discrete tree approximation of the continuous stock price process. (Received November 12, 2014)

1108-91-143 **Jin Hyuk Choi*** (jinhyuk@andrew.cmu.edu), Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213, and **Kasper Larsen**. *Taylor approximation of incomplete Radner equilibrium models.*

In the setting of exponential investors and uncertainty governed by Brownian motions we first prove the existence of an incomplete equilibrium for a general class of models. We then introduce a tractable class of exponential-quadratic models and prove that the corresponding incomplete equilibrium is characterized by a coupled set of Riccati equations. Finally, we prove that these exponential-quadratic models can be used to approximate the incomplete models we studied in the first part. (Received January 08, 2015)

1108-91-187 **Jia Li*** (jl410@duke.edu), Box 90097 Duke Univ, Durham, NC 27708, and **Dacheng Xiu** (dacheng.xiu@chicagobooth.edu), University of Chicago Booth School of Busines, 5807 S. Woodlawn Avenue, Chicago, IL 60637. *Generalized Method of Integrated Moments for High-Frequency Data.*

We propose a semiparametric two-step estimation procedure for a finite-dimensional parameter based on integrated moment conditions. These moment conditions take form of temporally integrated functionals of state variable processes, which include the latent stochastic volatility process of an asset. In the first step, we nonparametrically recover the volatility path from high frequency asset returns and then form sample moment functions. A high-order nonlinearity bias due to the nonparametric volatility estimation needs to be corrected. In the second step, we conduct GMM estimation using the bias-corrected sample moment functions. We show that the proposed estimator is consistent and asymptotically mixed Gaussian, and propose a consistent estimator for the conditional asymptotic variance. A Bierens-type consistent specification test is also constructed. These infill asymptotic results are based on a novel empirical-process-type theory for general integrated functionals of noisy semimartingale processes. (Received January 12, 2015)

1108-91-242 **Xuwei Yang*** (yangx@pstat.ucsb.edu), Dept. of Statistics & Applied probability, University of California, Santa Barbara, CA 93106-3110. *Mean Field Game Approach to Production and Exploration of Exhaustible Commodities.*

We study energy market with a continuum of players who produce energy with exhaustible resources. Each one chooses quantity of production to optimize profit that is a function of market price and quantity of production. The players interact with each other through the market price that depends on the production of all the players. We employ mean field game approach to solve for Nash equilibrium of the game. The game with a continuum of players is characterized by a system of partial differential equations: a backward Hamilton-Jacobi-Bellman (HJB) equation for the value function of a representative player and a forward transport equation for the distribution of the players. Through the system we compute players' Nash equilibrium strategies, and the resulted total energy production, market price, and reserves distribution. The novelty is that we study the exploration effect in the mean field game framework. The exploration is modeled through a controlled Poisson process that leads to stochastic increment to the reserves level. The jumps resulted from the Poisson process leads to a partial integral-differential equation for the transport equation, and a forward-delay term in the HJB equation, which involve more analytic and numerical complexity. (Received January 15, 2015)

1108-91-247 **W C Abram** (wabram@hillsdale.edu), 33 East College Street, Hillsdale, MI 49242, and **Kadeem Noray*** (knoray@hillsdale.edu), 10 E. Fayette Street, Hillsdale, MI 49242. *Political Corruption and Public Advocacy: An Evolutionary Game Theoretic Analysis.* Preliminary report.

We consider a two population evolutionary game that models the role of public advocacy as a deterrent to political corruption. A population of politicians chooses whether or not to engage in corrupt behavior, and a population of citizens decide whether or not to advocate for corruption reform, with the potential to impact detection and punishment levels for corruption. We study the pure and mixed strategy Nash equilibrium structure of this game. We also conduct an evolutionary analysis, finding evolutionary stable strategies and studying the evolution of strategies over time via the replicator dynamics for a two population game. (Received January 15, 2015)

1108-91-443 **Eric Scorsone*** (scorsone@msu.edu), 90 Morrill Hall of Agriculture, East Lansing, MI 48824. *Pension Finance and the Fall and Rise of Detroit City Government.* Preliminary report.

In 2014, the city of Detroit Emergency Manager laid out in bankruptcy court that the city pension systems faced a nearly 4 billion underfunded status. In the process of the bankruptcy trial, the city government, along with mediators, negotiated an impressive feat of securing foundation and state government support for a bail out of the city of Detroit two pension systems. In exchange for such a bailout, the employee unions and retiree agreed not to go after the city art collection, arguably worth billions, in the bankruptcy process to receive payoffs and make the pension whole. While this story received widespread media attention, the more interesting story are the financial details of the pensions both pre and post-bankruptcy including the issuance of controversial certification of participation obligations of 1 billion to help shore the underfunding of the pension system at that time. This talk will focus on the details of the pre and post-bankruptcy Detroit pension systems. (Received January 19, 2015)

1108-91-460 **Minsuk Kwak** and **Traian A Pirvu*** (tpirvu@math.mcmaster.ca). *Cumulative prospect theory with skewed return distribution.* Preliminary report.

We investigate a one-period portfolio optimization problem of a cumulative prospect theory (CPT) investor with multiple risky assets and one risk-free asset. The returns of multiple risky assets follow multivariate generalized hyperbolic (GH) skewed t distribution. We obtain a three-fund separation result of two risky portfolios and risk-free asset. Furthermore, we reduce the high dimensional optimization problem to two 1-dimensional optimization problems and derive the optimal portfolio. We show that the optimal portfolio composition changes as some of investor-specific parameters change. It is observed that the consideration of skewness of stock return distribution has considerable impact on the distribution of CPT investor's wealth deviation, and leads to less total risky investment. (Received January 19, 2015)

92 ► Biology and other natural sciences

1108-92-42 **Ranadhir Roy*** (rroy@utpa.edu), Mathematics Department, University of Texas-Pan American, 1201 W University Drive, Edinburg, TX 78539. *Molecular imaging: inverse problems.*

Optical tomography (inverse) problems arise in medical (molecular) imaging for cancer screening. Molecular imaging is formulated as an optimization problem and I solved by a gradient based optimization method is. We applied the penalty/modified barrier function (PMBF) method instead of Tikhonov regularization technique to make the inverse problem well-posed. Different numerical methods are used to solve the inverse problem. We found that the reconstructed image improves as more a prior information is included in our model. (Received December 08, 2014)

1108-92-78 **Isabel K. Darcy*** (idarcymath@gmail.com), MLH 14, Mathematics Department, University of Iowa, Iowa City, IA 52242. *Tangle analysis of protein-DNA complexes.*

Just like local knots can occur in long extension cords, such knots can also appear in DNA. DNA can be be either linear or circular. Some proteins will cut DNA and change the DNA configuration before resealing the DNA. Thus, if the DNA is circular, the DNA can become knotted. Protein-DNA complexes were first mathematically modeled using tangles in Ernst and Sumners seminal paper, Ä calculus for rational tangles: applications to DNA recombination" (Math Proc Camb Phil Soc, 1990). A tangle consists of arcs properly embedded in a ball. In order to model protein-bound DNA, the protein is modeled by the ball while the segments of DNA bound by the protein can be thought of as arcs embedded within the protein ball. This is a very simple model of protein-DNA binding, but from this simple model, much information can be gained. The main idea is that when modeling protein-DNA reactions, one would like to know how to draw the DNA. For example, are there any crossings trapped by the protein complex? How do the DNA strands exit the complex? Is there significant bending? Tangle analysis cannot determine the exact geometry of the protein-bound DNA, but it can determine the overall entanglement of this DNA, after which other techniques may be used to more precisely determine the geometry. (Received December 29, 2014)

1108-92-214 **Kathleen A. Hoffman**, **Hye-Won Kang*** (hwkang@umbc.edu) and **Phyllis R. Robinson**. *A stochastic model of the melanopsin phototransduction cascade.*

Melanopsin is a photopigment expressed in a small subset of intrinsically photosensitive ganglion cells (ipRGCs). Melanopsin signaling is involved in non-image forming vision, and controls circadian rhythms, pupillary light reflex, and sleep. The biochemical cascade underlying the light response in ipRGCs has not been fully understood. We suggest a hypothesized melanopsin phototransduction cascade and develop a stochastic model for the cascade using a continuous-time Markov jump process. Parameter values in the signaling pathway under several different environments are estimated based on the experimental results. Comparing the simulation results to the experimental data, our stochastic model can qualitatively reproduce experimental results. We perform parameter sensitivity analysis using a method of partial rank correlation coefficient (PRCC), which suggests that the melanopsin phototransduction pathway is robust as the one in Drosophila photoreceptors. This is joint work with R.L. Brown, E. Camacho, E.G. Cameron, C. Hamlet, K.A. Hoffman, P.R. Robinson, K.S. Williams, and G.R. Wyrick. (Received January 13, 2015)

1108-92-279 **Bo Deng*** (bdeng@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Deriving Nernst and GHK Potentials By Ion Pump Dynamics and Electrical Neutrality.* Preliminary report.

Two physiological properties are well known for excitable cell — the existence of electrical resting potential of the cell membrane and the electrical neutrality of the cell outside an immediate vicinity of the membrane. These contrasting facts have not been reconciled in a unified theory. In this talk we will first demonstrate that the long-term effect of an ion pump model is equivalent to the existence of an resting potential (battery) in series with a conductor. We will then show that under the electrical neutrality condition and the Fick's law of diffusion the resting potentials must be given by the Nernst formula for individual ions and by the Goldman-Hodgkin-Katz formula for the membrane. This treatment suggests a mechanistic justification for the conceptual setup for the sodium and potassium channels in the Hodgkin-Huxley model. (Received January 16, 2015)

1108-92-337 **Kelin Xia***, 619 Rred Cedar Road, East Lansing, MI 48824. *Geometric modeling of biomolecules.*

Recently, the structure, function, stability, and dynamics of subcellular structures, organelles, and multiprotein complexes have emerged as a leading interest in structural biology. Geometric modeling not only provides visualizations of shapes for large biomolecular complexes but also fills the gap between structural information and theoretical modeling, and enables the understanding of function, stability, and dynamics. We introduce a suite of computational tools for volumetric data processing, information extraction, surface mesh rendering, geometric measurement, and curvature estimation of biomolecular complexes. Particular emphasis is given to the modeling of cryo-electron microscopy data. Analytical models are designed to test the computational accuracy and convergence of proposed algorithms. We finally demonstrate the efficacy of the proposed algorithms in handling biomolecular surfaces and explore the capability of geometric characterization of binding targets. We offer a comprehensive protocol for the geometric modeling of subcellular structures, organelles, and multiprotein complexes. (Received January 18, 2015)

1108-92-341 **Dhagash Mehta*** (dmehta@nd.edu), 152B Hurley Hall, University of Notre Dame, Notre Dame, IN 46556. *Homotopy continuation methods to explore potential energy landscapes.*

Finding the stationary points of a potential energy function, which is a multivariate nonlinear function, arising from scientific and engineering phenomena is an important problem. In this talk, I will explain how homotopy continuation methods can be of great help here with a mention of various examples. (Received January 18, 2015)

1108-92-413 **Timothy D Comar*** (tcomar@ben.edu), **Olcay Akman** and **Daniel Hrozencik**. *Monte Carlo Model Selection for Integrated Pest Management.*

We discuss how impulsive differential equations (IDE) have been used to model integrated pest management (IPM) systems. We extend existing IDE models for IPM by including stage structure for both predator and prey as well as by adding stochastic elements in the birth rate of the prey. Based on our model, we present an approach that incorporates various competing stochastic components. This approach, using Monte Carlo simulation, enables us to select a model with optimally determined weights for maximum consistency, accuracy, and precision in parameter estimation. This is significant in the case of integrated pest management because the proposed model accommodates varying unknown environmental and climatic conditions, which affect the resources needed for pest eradication. (Received January 19, 2015)

1108-92-434 **Winfried Just***, Department of Mathematics, Ohio University, Athens, OH 45701.
Transmission of infectious diseases and of catchy ideas.

Transmission of ideas in human populations is not unlike transmission of infectious diseases and can be modeled in a similar way. Moreover, knowledge or beliefs about a certain disease may induce a behavioral response that can modify the probability of infection. There has been growing interest in the recent literature in modeling the interplay of the spread of a disease, the spread of awareness about the disease, and the behavioral response triggered by the awareness. This talk will highlight some research on this topic, including recent work of the presenter. (Received January 19, 2015)

1108-92-474 **Anastasios Matzavinos*** (`matzavinos@brown.edu`), Brown University, 182 George Street, Providence, RI 02912. *Dissipative particle dynamics simulations of polymer networks.*

Networks of entangled or cross-linked polymers, such as the actin cytoskeleton, are ubiquitous in phenomena pertaining to cellular and molecular biology. In many cases, the structure of these networks is dynamically altered by the mechanical feedback of biological lipid membranes and cytoplasmic flows. However, current modeling and computational approaches neglect such mechanical feedback for the sake of computational tractability.

In this talk, we present a dissipative particle dynamics approach to simulating the meso-scale dynamics of polymer networks. Our simulations explicitly include mechanical interactions with other meso-scale structures (e.g., lipid membranes) and cytoplasmic flows. We compare the results of our approach to those of Brownian dynamics simulations. We also discuss ongoing work on stochastic homogenization, bridging the gap between the meso-scale description and macroscopic models of bulk mechanical properties. (Received January 19, 2015)

1108-92-522 **Raina Robeva*** (`robeva@sbc.edu`). *Algebraic and Discrete Mathematical Methods in Biology – Connecting the Undergraduate Curriculum with Modern Biomathematics Research.*

The field of mathematical biology has been transformed over the past 15 years by research based on methods from discrete mathematics and computational algebra to tackle old and new problems. These ideas have impacted a wide range of topics such as gene regulatory networks, RNA folding, genomics, infectious disease modeling, phylogenetics, and ecological networks and food webs. In some cases they have even spawned completely new research areas. In contrast, there is a noticeable and troubling lag between the standard basic knowledge among researchers and standard basic material included in the undergraduate curriculum where difference and differential equation models still dominate. The talk will outline several areas of active research where modern algebra approaches have proved to be a natural fit and will highlight appropriate undergraduate resources related to such ongoing work for use in mathematics and biology courses or as starting points for student research projects. Topics will include gene regulatory and signal transduction networks, system behaviors emerging from local interactions, infectious disease transmission networks, and CpG island identification. (Received January 20, 2015)

1108-92-545 **Weishi Liu*** (`wsliu@ku.edu`), University of Kansas, 1460 Jayhawk Blvd., Snow 405, Lawrence, KS 66045. *A geometric framework for analyzing Poisson-Nernst-Planck systems and applications to ion channel problems.* Preliminary report.

In this talk, we will briefly review a dynamical system framework for analyzing Poisson-Nernst-Planck (PNP) type systems, mainly in the content of ionic flow through membrane channels. The framework relies on a combination of a *general theory* of geometric singular perturbations and of *specific structures* of PNP type systems. An unusual advantage of this framework is that it often provides detailed and robust information on solutions, and in turn, it allows one to obtain concrete characteristics of solutions that have direct implications to ionic flow properties. As applications of this framework, a number of meaningful results obtained with my collaborators will be discussed. (Received January 20, 2015)

1108-92-546 **Weishi Liu*** (`wsliu@ku.edu`), University of Kansas, 1460 Jayhawk Blvd., Snow 405, Lawrence, KS 66045. *A geometric framework for analyzing Poisson-Nernst-Planck systems and applications to ion channel problems.* Preliminary report.

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93 ► Systems theory; control

1108-93-11 **Zhixin Yang*** (yangzhix@uwec.edu), HHH 420 Department of Mathematics, University of Wisconsin-Eau Claire, Eau Claire, WI, and **George Yin** and **Qing Zhang**. *Mean-variance type controls involving a hidden Markov chain: models and numerical approximation.*

This work develops models and numerical methods for controlled regime-switching systems that stem from a mean-variance formulation. Distinct from the prior treatments, the switching process is a hidden Markov chain. Assuming a noisy observation of switching process corrupted by white noise is available, we focus on minimizing the variance subject to a fixed terminal expectation. Using the Wonham filter, we convert the partially observable system to a completely observable one first. Because closed-form solutions are virtually impossible to obtain, our main effort is devoted to designing a numerical algorithm. Convergence of the algorithm is obtained. A numerical example is provided to demonstrate the results. (Received October 21, 2014)

1108-93-382 **Ky Quan Tran*** (kytran@wayne.edu), 656 W. Kirby, 1244 Faculty/Administration Building, Detroit, MI 48202, and **George Yin**. *Stochastic Competitive Lotka-Volterra Ecosystems under Partial Observation.*

This work is concerned with Lotka–Volterra models formulated using stochastic differential equations with regime switching represented by a continuous-time Markov chain. Different from the existing literature, the Markov chain is hidden and can only be observed in a Gaussian white noise in our work. For such partially observed problems, we use a Wonham filter to estimate the Markov chain from the observable evolution of the given process, and convert the original system to a completely observable one. We then establish the regularity, positivity, stochastic boundedness, and sample path continuity of the solution. Moreover, stochastic permanence and extinction using feedback controls are investigated. Numerical experiments are conducted to validate the theoretical findings and demonstrate how feedback controls perform in practice. (Received January 19, 2015)

94 ► Information and communication, circuits

1108-94-149 **Shuyang Ling***, 1 Shield Avenue, Davis, CA 95616, and **Thomas Strohmer**, 1 Shield Avenue, Davis, CA 95616. *Self-calibration and bilinear compressive sensing.*

This talk brings together two seemingly unrelated concepts that both have attracted considerable attention in recent years. Compressive sensing is an ingenious strategy to sample sparse signals in an efficient way and has become a game changer in several areas of signal- and image processing. Self-calibration is an increasingly important concept, since the need for precise calibration of sensing devices manifests itself as a major roadblock in many scientific and technological endeavors. The idea of self-calibration is to equip a hardware device with a smart algorithm that can compensate automatically for the lack of calibration. We show how several self-calibration problems can be treated efficiently within the framework of bilinear compressive sensing. More specifically, we consider a bilinear system of equations y = DAx, where x and the diagonal matrix D (which models the calibration error) are unknown. We describe how one can "lift" this bilinear inverse problem to an underdetermined sparse problem and derive explicit theoretical guarantees under which both x and D can be recovered exactly, robustly, and numerically efficiently via linear programming. Applications in array calibration, wireless communications, and image processing will be discussed. (Received January 08, 2015)

1108-94-325 **Hau-Tieng Wu*** (hauwu@math.toronto.edu), Department of Mathematics, University of Toronto, Toronto, Ontario , Canada, and **Noureddine El Karoui**, **Stefano Marchesini**, **Yu-Chao Tu** and **Amit Singer**. *Graph connection Laplacian and ptychographic image processing.*

Spectral methods like Diffusion Maps and Laplacian Eigenmaps in data analysis are based on eigenvectors and eigenvalues of graph Laplacians. Recently, we introduced a generalized framework called the graph connection Laplacian (GCL) as a new framework to data science. In this talk, in addition to showing that under the principle bundle framework, the eigenvectors and eigenvalues of the GCL converge to the connection Laplacian of the associated vector bundle in the limit of infinitely many i.i.d. random samples, we show how the noise impacts the GCL framework. An application of this framework to the ptychography imaging problem based on GCL will be discussed to show the strength of the proposed framework. This is a joint work with Noureddine El Karoui, Stefano Marchesini, Yu-Chao Tu and Amit Singer. (Received January 17, 2015)

1108-94-333 **Cheng Cheng**, **Yingchun Jiang** and **Qiyu Sun***, Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Spatially Distributed System for Sampling and Reconstruction of Signals on a Graph.* Preliminary report.

A spatially distributed sampling and reconstruction system consists of huge amounts of small sensing devices with limited computing and telecommunications capabilities. In this talk, we will discuss robustness of such a system and develop a distributed algorithm for fast signal reconstruction. (Received January 18, 2015)

HUNTSVILLE, AL, March 27–29, 2015

Abstracts of the 1109th Meeting.

00 ► General

1109-00-260 **Adam Blumenthal*** (amb0047@auburn.edu) and **Peter Johnson**. *A Note on Stable Matchings.*

The Gale-Shapley Theorem, sometimes called the Stable Marriage Theorem, asserts that there is a stable matching in every finite locally ordered bipartite graph. We show that this statement characterizes bipartite graphs, among finite simple graphs. (Received February 02, 2015)

05 ► Combinatorics

1109-05-49 **Jason Behrstock*** (jason.behrstock@gmail.com). *Random graphs and applications to Coxeter groups.* Preliminary report.

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 Hagen and Susse. (Received January 16, 2015)

1109-05-70 **Christian Barrientos** and **Sarah Minion*** (sarah.m.minion@gmail.com). *A Classification of Alpha Graphs.*

When a graceful labeling of a bipartite graph places the smaller labels in one of the stable sets of the graph, it becomes an α-labeling. This is the most restrictive type of difference-vertex labeling and it is located at the very core of this research area. Here we use an extension of the adjacency matrix to count, not only, the number of α-labeled graphs of size n but also to count and classify them according to their order and boundary value. (Received January 20, 2015)

1109-05-74 **Robert A. Beeler*** (beelerr@etsu.edu). *Peg Solitaire on Graphs: 2015 and Beyond!*

In a 2011 paper by Beeler and Hoilman generalized the traditional game of peg solitaire to graphs. Since then, a number of papers have expanded on ideas of this paper. In this talk, we survey many of the more interesting results discovered so far. We will also discuss a couple variations of peg solitaire. In addition, this talk highlights many of the more interesting (and difficult) open problems and conjectures regarding peg solitaire on graphs. (Received January 21, 2015)

1109-05-79 **Anant Godbole*** (godbolea@etsu.edu). *Acquisition and Domination: Paths, Randomness, and Abundance.* Preliminary report.

This will be a talk in which the key themes are domination and acquisition on the n-path. The definitions are modified, however, so that we speak of (i) online domination when the vertices of a graph are *randomly revealed* one at a time by an adversary who knows that the graph is indeed a path; and (ii) The concentration of the total acquisition number of the n-path when n units of weight are *randomly* placed on its vertices. We end by presenting a series of results on abundance of minimum dominating sets of size γ given a graph G with domination number γ. This is joint work with Chris Coscia, Jon Dewitt, Elizabeth Kelley, Tom Kelly, Emily Kurtz, Fan Yang, and Yiguang Zhang. (Received January 31, 2015)

1109-05-86 **Jian Cheng*** (jiancheng@math.wvu.edu). *Vector Flows and Integer Flows.*

A vector S^d-flow is a flow whose flow values are vectors in S^d, where S^d is the set of all unit vectors in $\mathbb{R}^{d+1}$. DeVos and Thomassen proved that a graph has a vector S^1-flow if it has a nowhere-zero integer 3-flow. Thomassen pointed out that a graph admitting a vector S^1-flow may not necessarily admit a nowhere-zero integer 3-flow and presented a family of examples showing that the converse is not true.

The rank of a vector S^1-flow (D, f) is defined as the rank of linear space generated by all balanced vectors $\epsilon(v) = (\epsilon_1(v), \epsilon_2(v), \ldots, \epsilon_b(v))$ for all $v \in V(G)$, where $\epsilon_i(v)$ is the difference between the number of outcoming edges with flow value α_i from v and the number of ingoing edges with the same flow value to v. We prove that G admits a nowhere-zero integer 3-flow if G admits a vector S^1-flow with rank at most two. This result is sharp since there are examples that admit vector S^1-flows with rank at least 3, but no nowhere-zero integer 3-flows.

This is joint work with R. Luo, Y. Wang and C.-Q. Zhang from West Virginia University. (Received January 24, 2015)

1109-05-97 **Suil O*** (suilo@gsu.edu), Atlanta, GA 30308. *Edge-connectivity in regular multigraphs from eigenvalues.*

Fiedler's result stating that $\kappa(G) \geq \mu_2(G)$ for a non-complete simple graph G, stimulated a lot of research in spectral graph theory, where $\kappa(G)$ and $\mu_2(G)$ are the connectivity and the second smallest Laplacian eigenvalue of a graph G, respectively. In 2004, for a d-regular simple graph G, Chandran gave an upper bound for $\lambda_2(G)$ to guarantee that $\kappa'(G) = d$, where $\lambda_2(G)$ and $\kappa'(G)$ is the second largest eigenvalue and the edge-connectivity of a graph G, respectively. Krivelevich and Sudakov slightly improved Chandran's result. In 2010, Cioabă gave an upper bound for $\lambda_2(G)$ to guarantee that $\kappa'(G) \geq t+1$ for any positive integer t.

In this talk, we extend Cioabă's result to multigraphs. (Received January 26, 2015)

1109-05-100 **Shaohui Wang*** (swang4@go.olemiss.edu), The University of Mississippi, University, MS 38677, and **Bing Wei** (bwei@olemiss.edu), The University of Mississippi, Oxford, MS 38655. *Padmakar - Ivan index of k-trees.*

The Padmakar - Ivan (PI) index is a distance-based topological index and a molecular structure descriptor, which recently has found numerous chemical applications. In this paper, we obtain the upper bounds about PI-indices of the generalized trees, the k-trees, and characterize the extremal graphs. Also, we give the exact values of PI-indices for some classes of k-trees. (Received January 26, 2015)

1109-05-102 **Rong Luo*** (rluo@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26505. *Neighbor distinguishing and Neighbor sum distinguishing edge colorings and total colorings.*

A proper k-edge coloring of a graph G with colors $\{1, 2, \cdots, k\}$ is neighbor distinguishing (or neighbor sum distinguishing) if for any two adjacent vertices the sets (or sums) of colors of the edges incident to each of them are distinct. The neighbor distinguishing and neighbor sum distinguishing total colorings are defined similarly. There are some conjectures on those four colorings. In this talk I will survey the results on those problems and present some new results. (Received January 26, 2015)

1109-05-104 **A. V. Kostochka**, University of Illinois at Urbana-Champaign, **Xiangwen Li**, Huazhong Normal University, **W. Ruksasakchai**, KhonKaen University, **Mike Santana**, University of Illinois at Urbana-Champaign, **Tao Wang**, Henan University, and **Gexin Yu*** (gyu@wm.edu), 127 Jones Hall, Department of Mathematics, College of William and Mary, Williamsburg, VA 23185. *Strong Chromatic Index of Subcubic Planar Multigraphs.* Preliminary report.

The strong chromatic index of a multigraph is the minimum k such that the edge set can be k-colored requiring that each color class induces a matching. We verify a conjecture of Faudree, Gyárfás, Schelp, and Tuza, showing that every planar multigraph with maximum degree at most three has strong chromatic index at most 9, which is sharp. (Received January 26, 2015)

1109-05-105 **Peter D. Johnson*** (johnspd@auburn.edu), Department of Mathematics and Statistics, Auburn University, AL 36849, and **Xiaoya Zha**. *Chromatic Numbers Under Scheduling Restrictions.*

Both the chromatic number and the fractional chromatic number have interpretations related to scheduling. We apply these interpretations to pose optimization problems about scheduling under constraints additional to the usual graphical ones. The main additional constraints are of the form: no more than k actions scheduled can be taking place simultaneously at any instant. (Received January 26, 2015)

1109-05-114 **Matthew Devilbiss**, **Bradley Fain*** (bcf0007@auburn.edu), **Ryan Matzke** and **Peter Johnson**. *Note on the Secure-Domination Number of a Graph.*

It is shown that the ratio of the secure-domination number of a graph to its order can be bounded away from $\frac{1}{2}$ in families including arbitrarily large connected graphs. Infinitely many trees and infinitely many connected graphs of girth 6 are found in which the ratio is $\frac{4}{7}$. (Received January 27, 2015)

1109-05-124 **Yan Wang*** (yanwang@gatech.edu), 686 Cherry Street NW, Room 117, Atlanta, GA 30332, and **Qiqin Xie** and **Xingxing Yu**. *Induced Forests in Bipartite Planar Graphs.*

Akiyama and Watanabe, and independently, Albertson and Haas conjectured that every simple planar bipartite graph on n vertices contains an induced forest on at least $5n/8$. In this paper, we apply the discharging method to bipartite planar graphs and show that every simple bipartite planar graph on n vertices contains an induced forest on at least $\lceil (4n+3)/7 \rceil$ vertices. (Received January 27, 2015)

1109-05-140 **Michael D. Plummer***, Department of Mathematics, Vanderbilt University, Nashville, TN 37240, **Art Finbow**, Halifax, Canada, and **Bert Hartnell**, Halifax, Canada.
Well-covered Pentagonalizations. Preliminary report.

A graph G is *well-covered* if every maximal independent set of vertices in G is maximum. Well-covered plane triangulations and quadrangulations have been previously characterized by the authors. In this talk, we investigate the one remaining class of planar face-regular well-covered graphs: the well-covered pentagonalizations ($\mathcal{WCP}$). Using a known result of Finbow, Hartnell and Nowakowski, we obtain a polynomial recognition algorithm for the girth 5 subclass of $\mathcal{WCP}$. We then show that every graph in $\mathcal{WCP}$ contains at least two disjoint pairs of adjacent vertices of degree 2 and provide infinitely many examples to show that this result is best possible. Finally, we show that every connected plane graph is an induced subgraph of some member of $\mathcal{WCP}$.

This is joint work with Art Finbow and Bert Hartnell. (Received January 28, 2015)

1109-05-157 **Guantao Chen***, Dept. of Math and Stat, Georgia State University. *Forbidden Pairs for Spanning Halin Subgraphs.*

A *Halin graph* is a plane graph $H = T \cup C$ consisting of a spanning tree T with no vertices of degree 2 and a cycle C induced by the leaves of the tree T. The family of Halin graphs is a natural generalization of the family of wheels, where T is a star. Halin [**?**] constructed this family of edge-minimal 3-connected plane graphs, which are named *Halin graphs* by Lovász and Plummer. In this talk, we discuss forbidden subgraph conditions for graphs containing a spanning Halin subgraph. (Received January 29, 2015)

1109-05-161 **Richard P Anstee** and **Linyuan Lu*** (lu@math.sc.edu), Columbia, SC 29208.
Unavoidable Multicoloured Families of Configurations.

Balogh and Bollobás [*Combinatorica 25, 2005*] prove that for any k there is a constant $f(k)$ such that any set system with at least $f(k)$ sets reduces to a k-star, an k-costar or an k-chain. They proved $f(k) < (2k)^{2^k}$. Here we improve it to $f(k) < 2^{ck^2}$ for some constant $c > 0$.

This is a special case of the following result on the multi-coloured forbidden configurations at 2 colours. Let r be given. Then there exists a constant c_r so that a matrix with entries drawn from $\{0, 1, \ldots, r-1\}$ with at least $2^{c_r k^2}$ different columns will have a $k \times k$ submatrix that can have its rows and columns permuted so that in the resulting matrix will be either $I_k(a, b)$ or $T_k(a, b)$ (for some $a \neq b \in \{0, 1, \ldots, r-1\}$), where $I_k(a, b)$ is the $k \times k$ matrix with a's on the diagonal and b's else where, $T_k(a, b)$ the $k \times k$ matrix with a's below the diagonal and b's elsewhere. We also extend to considering the bound on the number of distinct columns, given that the number of rows is m, when avoiding a $tk \times k$ matrix obtained by taking any one of the $k \times k$ matrices above and repeating each column t times. We use Ramsey Theory. (Received January 30, 2015)

1109-05-174 **Jessica McDonald***, Department of Mathematics and Statistics, Auburn, AL 36849. *A list analog of Vizing's theorem for graphs without long odd cycles.*

We prove that if G is a simple graph with no odd cycles of length 5 or longer, then G is $(\Delta + 1)$-list-edge-colorable, where Δ is the maximum degree of G. Our method involves manipulating Galvin's proof that the list-edge-coloring conjecture holds for bipartite graphs. (Received January 30, 2015)

1109-05-183 **Xiaofeng Gu*** (xgu@uwsuper.edu), Mathematics and Computer Science Department, University of Wisconsin-Superior, Superior, WI 54880. *Edge-disjoint spanning 2-connected k-edge-connected subgraphs and spanning trees.*

It is proved that every $(4kp - 2p + 2q)$-connected graph contains edge-disjoint p spanning subgraphs G_i for $1 \leq i \leq p$ and q spanning trees such that each G_i is k-edge-connected, essentially $(2k-1)$-edge-connected, and $G_i - v$ is $(k-1)$-edge-connected for all $v \in V(G)$. This extends the well-known result of Nash-Williams and Tutte on packing spanning trees, a theorem of Jordán that every $6p$-connected graph contains p edge-disjoint spanning 2-connected subgraphs, and a theorem of Cheriyan et al. that every $(6p+2q)$-connected graph contains edge-disjoint p spanning 2-connected subgraphs and q spanning trees. (Received January 31, 2015)

1109-05-184 **Shaohui Wang** and **Bing Wei*** (bwei@olemiss.edu). *Bounds on multiplicative Zagreb indices of k-trees.*

Let G be a graph with vertex set $V(G)$ and edge set $E(G)$. The first generalized multiplicative Zagreb index of G is defined as $\Pi_{1,c}(G) = \Pi_{v \in V(G)} d(v)^c$ for a real number $c > 0$, and the second multiplicative Zagreb index is defined as $\Pi_2(G) = \Pi_{uv \in E(G)} d(u)d(v)$, where $d(u)$; $d(v)$ are the degrees of the vertices of u and v. The multiplicative Zagreb indices have been the focus of considerable research in computational chemistry dating back to Narumi and Katayama in 1980s. In this talk, we will first introduce the generalized multiplicative Zagreb index, and then present some new bounds on the multiplicative Zagreb indices for k-tree ($k \geq 1$), which extend the results of Gutman for the case when $k = 1$. Additionally, we characterize the extremal graphs and determine the exact bounds of these indices of k-trees, which attain the lower and upper bounds. (Received January 31, 2015)

1109-05-198 **Jie Han**, **Chuanyun Zang** and **Yi Zhao*** (yzhao6@gsu.edu), Department of Math & Stat, Georgia State University, Atlanta, GA 30338. *Minimum vertex degree threshold for tiling complete* 3*-partite* 3*-graphs.*

Given positive integers $a \leq b \leq c$, let $K_{a,b,c}$ denote a complete 3-partite 3-uniform hypergraph (3-graph) with three parts of size a, b, c. Let H be a 3-graph on n vertices with n divisible by $a + b + c$. We asymptotically determine the minimum vertex degree of H that guarantees a perfect $K_{a,b,c}$-tiling, that is, a spanning subgraph of H consists of vertex-disjoint copies of $K_{a,b,c}$. This partially answers a question of Mycroft, who proved an analogous result in terms of codegree for k-uniform hypergraphs for all $k \geq 3$. Our proof uses the absorbing method, the concept of fractional tiling, and a recent result on shadows for 3-graphs. (Received February 01, 2015)

1109-05-203 **Mark Ellingham*** (mark.ellingham@vanderbilt.edu) and **Bin Jia**. *Link graphs and an unexpected application of topological graph theory.* Preliminary report.

A k-link in a graph is a walk of length k that never uses the same edge twice in succession; a link and its reverse are considered equal. For a given graph G, the k-link-graph $L_k(G)$ has as its vertices the k-links of G, where two k-links are adjacent if they are initial and final subsequences of the same $(k+1)$-link. This generalizes the idea of the line graph, which is the 1-link graph. A natural question is whether $L_k(G)$ uniquely determines the graph G. Whitney proved that $L_1(G)$ determines G for connected G, except in one small case. Xueliang Li showed that $L_2(G)$ determines G for G of minimum degree at least 3. We show that $L_k(G)$ determines G for G of minimum degree at least 3 for all $k \geq 2$. Somewhat surprisingly, part of the proof uses the classification of quadrangular embeddings of 4-regular graphs, which are always on the torus or Klein bottle. (Received February 01, 2015)

1109-05-209 **Robert E. Jamison*** (rejam@clemson.edu), 289 White Pine Drive, ASheville, NC 28805. *Geometric Decomposition Graphs.*

A *decomposition* of a *host* graph H over a family of *prototype* graphs is a partition of the edge set of H such that the subgraph induced by the edges in each part of the partition is isomorphic to some prototype graph. The *intersection graph* of the decomposition has a vertex for each part of the partition and two parts A and B are adjacent iff they share a common node in H. A graph arising as the intersection graph of a decomposition is a *decomposition graph.* This talk will consider decompositions of a complete graph into parts that form the lines of a linear space. (Received February 01, 2015)

1109-05-217 **Laura Sheppardson*** (sheppard@olemiss.edu), University of Mississippi, Department of Mathematics, PO Box 1848, University, MS 38677-1848. *Completeness of the Graph Bicycle Spectrum.*

The numerous results concerning cycle spectra of graphs (the collection of all cycle lengths) translate directly to graphic matroids. Motivated by the study of bicircular matroids, we consider the sizes of graph bicycles. We give an update on graph properties which guarantee bicycles of many sizes, analogous to pancyclic graphs. (Received February 02, 2015)

1109-05-221 **John Asplund*** (jasplund@daltonstate.edu), Dalton State College, 650 College Drive, Sequoya 153, Dalton, GA 30720, and **Joe Chaffee** and **James Hammer**. *Decompositions into paths and cycles.* Preliminary report.

How do you ensure that you can pair up an entire class room of students day after day without repeating partners? Is it possible to seat 9 students at six round tables with 4, 5, 5, 6, 8, and 9 chairs? These questions and more will be answered! Graph theory will help give a more visual representation of the problems. The focus of this talk will be on seating n students at a single straight table of size m and analogues of this problem type. (Received February 02, 2015)

1109-05-229 **Joshua Adam Gray** and **Talmage James Reid*** (mmreid@gmail.com), Department of Mathematics, P.O. Box 1848, University, MS 38677, and **Xiangqian Zhou**. *Clone Sets in Matroids.* Preliminary report.

We investigate the maximum size of a clone set in a matroid that is representable over a finite field. The bounds given are tight for some fields. Connections with k-arcs in projective geometry and recent results in that area are also mentioned. (Received February 02, 2015)

1109-05-237 **Edward Dobson*** (dobson@math.msstate.edu), Department of Mathematics and Statistics, PO Drawer MA, Mississippi State, MS 39759. *Automorphism groups of codes.*

In a recent ArXiV posting, Muzychuk noticed a relationship between the isomorphism problem for Cayley digraphs of a group G and the isomorphism problem for codes permutation invariant under G. For cyclic groups, he showed that in fact the permutation isomorphism problem for cyclic codes reduces to the isomorphism problem for circulant digraphs. This latter problem has been completely solved, and so Muzychuk produced a solution to the permutation isomorphism problem for cyclic codes. We consider the problem of computing the automorphism group of cyclic codes (and codes invariant under other groups as well). We first give a sufficient condition to decompose a code C into two subcodes C_1 and C_2, both invariant under the permutation automorphism group of C, and which are determined by codes codes of smaller length. Additionally, we show that $\mathrm{PAut}(C) = \mathrm{PAut}(C_1) \cap \mathrm{PAut}(C_2)$. This sufficient condition corresponds to an existing sufficient condition that gives a similar decomposition of a vertex-transitive digraph. We then use this to determine strong constraints on the permutation automorphism groups of cyclic codes of length pq, where p and q are prime. This is joint work with Mikhail Muzychuk of Netanya Academic College. (Received February 02, 2015)

1109-05-242 **Hehui Wu*** (noshell@hotmail.com) and **Bojan Mohar**. *Fractional chromatic number of random subgraphs.* Preliminary report.

For a graph G, let G_p denote the subgraph of G, in which each edge of G is in G_p with probability p independently at random. Boris Bulk asked whether there is a constant $c > 0$ so that $E(\chi(G_{1/2})) > c\chi(G)/\log\chi(G)$. We give a answer for the fraction chromatic version of this: there exists a constant $c \geq 1/8$, such that $E(\chi_f(G_{1/2})) > c\chi_f(G)/\log\chi_f(G)$. (Received February 02, 2015)

1109-05-248 **Johnathan Barnett*** (jbb0027@tigermail.auburn.edu), Department of Mathematics and Statistics, 221 Parker Hall, Auburn University, AL 36849, and **Peter Johnson**. *The fractional chromatic number versus the Hall ratio.* Preliminary report.

The Hall ratio of a finite simple graph G, denoted rho(G), is the maximum over all induced subgraphs of G of the ratio of the order of the subgraph to the vertex independence number of the subgraph. The Hall ratio is never greater than the fractional chromatic number, and for many graphs, including all of the "usual suspects" and the Kneser graphs, the two are equal. It has been known for some time that the difference of the two can be arbitrarily large; what about the ratio? This talk will survey the small amount of work that has been done on this question, and will expose recent developments. (Received February 02, 2015)

11 ► Number theory

1109-11-54 **Joseph A Vandehey*** (vandehey@uga.edu). *New constructions of normal continued fraction expansions.*

Consider the sequence of rational numbers

$$\frac{1}{2}, \frac{1}{3}, \frac{2}{3}, \frac{1}{4}, \frac{2}{4}, \frac{3}{4}, \ldots.$$

Alder, Keane, and Smorodinsky showed that if we concatenate the continued fraction (CF) expansions of the above rationals, the resulting expansion will be normal with respect to the CF expansion. This is the only known "simple" construction of a CF-normal number and was discovered over 30 years ago. By replacing an inexplicit ergodic result with a more explicit analytic result, we produce a much larger class of constructions. (Received January 18, 2015)

1109-11-68 **Tristan Freiberg*** (freibergt@missouri.edu), Department of Mathematics, University of Missouri, 202 Mathematical Sciences Bldg, Columbia, MO 65211, and **Carl Pomerance** (carl.pomerance@dartmouth.edu), Department of Mathematics, Dartmouth College, Hanover, NH 03755. *A note on square totients.*

A well-known conjecture asserts that there are infinitely many primes p for which $p-1$ is a perfect square. We obtain upper and lower bounds of matching order on the number of pairs of distinct primes $p, q \leq x$ for which $(p-1)(q-1)$ is a perfect square. (Received January 20, 2015)

1109-11-78 **Abel Castillo*** (acasti8@uic.edu) and **Rainer Dietmann**. *An effective version of Hilbert's Irreducibility Theorem.*

Let $f(X, t_1, \ldots, t_k)$ be a polynomial in X with coefficients in $\mathbb{Z}[t_1, \ldots, t_k]$. Hilbert's Irreducibility Theorem tells us that for "almost all" integer specializations of $(t_1, \ldots, t_k)$, the resulting polynomial in X has the "largest possible" Galois group over $\mathbb{Q}$. Effective versions of Hilbert's Irreducibility Theorem typically give upper bounds for the number of integer specializations of bounded height that fail to have the largest possible Galois group over $\mathbb{Q}$. In this talk we will discuss an upper bound for specializations whose Galois group is a fixed subgroup H, where the bound becomes stricter for smaller choices of H. (Received January 22, 2015)

1109-11-91 **Dylan Airey*** (dylan.airey@utexas.edu) and **Bill Mance** (mance@unt.edu). *Unexpected distribution phenomenon resulting from Cantor series expansions.*

We explore in depth the number theoretic and statistical properties of certain sets of numbers arising from their Cantor series expansions. As a direct consequence of our main theorem we deduce numerous new results as well as strengthen known ones. (Received January 25, 2015)

1109-11-93 **Wai Kiu Chan*** (wkchan@wesleyan.edu) and **James Ricci** (jricci@daemen.edu). *The representation of integers by positive ternary quadratic polynomials.*

An integral quadratic polynomial is called regular if it represents every integer that is represented by the polynomial itself over the reals and over the p-adic integers for every prime p. It is called complete if it is of the form $Q(x+v)$, where Q is an integral quadratic form in the variables $x = (x_1, \ldots, x_n)$ and v is a vector in $\mathbb{Q}^n$. Its conductor is defined to be the smallest positive integer c such that $cv \in \mathbb{Z}^n$. We prove that for a fixed positive integer c, there are only finitely many equivalence classes of positive primitive ternary regular complete quadratic polynomials with conductor c. This generalizes the analogous finiteness results for positive definite regular ternary quadratic forms by Watson in 1954 and for ternary triangular forms by Chan and Oh in 2013. (Received January 25, 2015)

1109-11-119 **Anna Haensch*** (haenscha@duq.edu), Department of Mathematics and Computer Sci., 600 Forbes Ave., Duquesne University, Pittsburgh, PA 15282. *Kneser-Hecke operators for quaternary codes.* Preliminary report.

Codes can be viewed as a lattices via a classical construction, and consequently, many of the concepts of lattice theory can be adapted to the setting of codes. One particularly interesting association exists between weight-enumerators for codes and theta-series for lattices, which brings with it some of the tools of modular forms. There is a well defined analogue of Heck-operators for theta series in the setting of codes over finite fields, namely, the Kneser-Hecke-operator. In this talk we will discuss a similar construction for codes over finite chain rings, in particular, exploring the graph associated to the Kneser-Hecke-operator. (Received January 27, 2015)

1109-11-142 **Wai Kiu Chan** and **Lenny Fukshansky*** (lenny@cmc.edu), 850 Columbia Avenue, Department of Mathematics, Claremont McKenna College, Claremont, CA 91711, and **Glenn R. Henshaw**. *Height bounds on zeros of quadratic forms over $\overline{\mathbb{Q}}$.* Preliminary report.

We prove the existence of a nontrivial small-height zero of a system of k quadratic forms in an L-dimensional subspace of $\overline{\mathbb{Q}}^N$, $N \geq L \geq \frac{k(k+1)}{2} + 1$. Further, assuming a system of one or two inhomogeneous quadratic polynomials and m inhomogeneous linear polynomials in $N \geq m+4$ variables has a nontrivial common zero over $\overline{\mathbb{Q}}$, we prove the existence of a such zero of bounded height. Our investigation extends previous results on small zeros of quadratic forms, including Cassels' theorem and its various generalizations and contributes to the literature of so-called "absolute" Diophantine results with respect to height. All bounds on height are explicit. (Received January 28, 2015)

1109-11-150 **Guillermo Mantilla-Soler*** (g.mantilla691@uniandes.edu.co), Bogotá., Colombia. *A space of weight 1 modular forms attached to totally real cubic number fields.*

The main goal of this talk is to exhibit a canonical subspace of a space of weight 1 modular forms that is parametrized by the set of isomorphism classes of cubic fields of a fixed fundamental discriminant. In case that the fields have ramification at infinity, the construction is known and I will briefly recall it. Here, using the theory of integral traces, I will show how to construct such a subspace for cubic fields with no ramification at infinity i.e., totally real cubic fields. (Received January 29, 2015)

1109-11-151 **Roger C. Baker**, **William D. Banks** and **Victor Z. Guo*** (zgbmf@mail.missouri.edu), 202 Mathematical Sciences Bldg, University of Missouri, Columbia, MO 65201, and **Aaron M. Yeager**. *Piatetski-Shapiro primes from almost primes.*

Let $\lfloor\cdot\rfloor$ be the floor function. In this talk, we show that for any fixed $c \in (1, \frac{77}{76})$ there are infinitely many primes of the form $p = \lfloor n^c \rfloor$, where n is a natural number with at most eight prime factors (counted with multiplicity). (Received January 29, 2015)

1109-11-153 **Andrew G. Earnest*** (aearnest@siu.edu), Department of Mathematics, Southern Illinois University, Carbondale, IL 62901. *Codimension one sublattices of quadratic lattices.*

From classical theory, it is known that integral binary quadratic forms are determined up to equivalence by the integers they represent, with the exception of one anomalous case. In this talk we will discuss the general question of the extent to which quadratic lattices over rings of algebraic integers are determined up to isometry by their sublattices of codimension one, and describe a new result in this direction obtained in joint work with N.D. Meyer. (Received January 29, 2015)

1109-11-156 **Suresh Venapally***, Department of Mathematics and CS, 400 Dowman Dr, Atlanta, GA 30322. *Local-global principle for reduced norms.*

Let F be the function field of a curve over a p-adic field and D a central division algebra over F of index coprime to p. We show that an element of F is a reduced norm from D if and only if it is a reduced norm from D extended to the completions of F at various discrete valuations. (Received January 29, 2015)

1109-11-175 **Mits Kobayashi*** (mkobayashi@cpp.edu), Department of Mathematics and Statistics, Cal Poly Pomona, 3801 West Temple Avenue, Pomona, CA 91768. *A generalization of a series for the density of abundant numbers.* Preliminary report.

We call a number abundant if the sum of its proper divisors exceeds the number itself. In 1933, Davenport proved that the set of abundant numbers has a natural density. Since then, several improvements have been made to determine upper and lower bounds for this density. A recent result uses the multiplicative function $\sigma(n)/n$ to express the density as a series which can be used to find a lower bound for the density. We generalize this result to a large class of multiplicative functions. (Received January 30, 2015)

1109-11-179 **Andreas Weingartner*** (weingartner@suu.edu), Southern Utah University, 351 W Univ. Blvd., Cedar City, UT 84720. *On practical numbers and related topics.*

An integer n is called practical if every $m \leq n$ can be written as a sum of distinct divisors of n. We will outline the ideas behind the proof that the number of practical numbers below x is asymptotic to $cx/\log x$, as conjectured by Margenstern. We will also discuss analogous results concerning the distribution of integer divisors, the degree distribution of polynomial divisors and the cycle structure of permutations. (Received January 31, 2015)

1109-11-185 **Lee T Troupe*** (ltroupe@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30602. *The number of prime factors of $s(n)$.*

Let $\omega(n)$ denote the number of distinct prime divisors of a natural number n. In 1917, Hardy and Ramanujan famously proved that the normal order of $\omega(n)$ is $\log\log n$; in other words, a typical natural number n has about $\log\log n$ distinct prime factors. Erdős and Kac later generalized Hardy and Ramanujan's result, showing (roughly speaking) that $\omega(n)$ is normally distributed and thereby giving rise to the field of probabilistic number theory. In this talk, we'll discuss the normal order of $\omega(s(n))$, where $s(n)$ is the usual sum-of-proper-divisors function. This new result supports a conjecture of Erdős, Granville, Pomerance, and Spiro; namely, that if a set of natural numbers has asymptotic density zero, then so does its preimage under s. (Received January 31, 2015)

1109-11-188 **Nathan G McNew***, nathan.g.mcnew.gr@dartmouth.edu. *The most popular largest prime divisors.*

Consider the largest prime factor of each of the integers in the interval $[2, x]$ and let $q(x)$ denote the prime number which shows up most often in this list. In addition to investigating the behavior of this function as x

tends to infinity, we look at the range of $q(x)$ and see that it misses most of the primes. We conjecture that the set of these "popular primes" is related to other interesting subsets of the prime numbers. (Received January 31, 2015)

1109-11-189 **Roger C Baker** (baker@math.byu.edu), Department of Mathematics, Brigham Young University, Provo, UT 84602, **William D Banks*** (bankswd@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, **Zhenyu V Guo** (zgbmf@mail.missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, and **Igor E Shparlinski** (igor.shparlinski@unsw.edu.au), Department of Pure Mathematics, University of New South Wales, Sydney, NSW 2502, Australia. *Squarefree numbers of the form* $[p^c]$. Preliminary report.

For a fixed real number c in the interval $(1, \frac{149}{87})$ we give an asymptotic formula for the number of primes $p \leq x$ such that $[p^c]$ is squarefree, where $[\cdot]$ is the floor function. (Received January 31, 2015)

1109-11-190 **William D. Banks**, Columbia, MO, **Tristan Freiberg**, Columbia, MO , and **Caroline Turnage-Butterbaugh*** (cturnagebutterbaugh@gmail.com), Fargo, ND. *Consecutive Primes in Tuples.*

Maynard and Tao have recently shown that if k is sufficiently large in terms of m, then for an admissible k-tuple $\mathcal{H}(x) = \{gx+h_j\}_{j=1}^k$ of linear forms in $\mathbb{Z}[x]$, the set $\mathcal{H}(n) = \{gn+h_j\}_{j=1}^k$ contains at least m primes for infinitely many $n \in \mathbb{N}$. In this talk, we deduce that $\mathcal{H}(x)$ contains at least m consecutive primes for infinitely many n. As an application, we answer an old question of Erdős and Turán by producing strings of $m+1$ consecutive primes whose successive gaps form an increasing (respectively decreasing) sequence. (Received January 31, 2015)

1109-11-192 **Paul Pollack** and **Lola Thompson*** (lola.thompson@oberlin.edu). *Runs of consecutive primes via the Maynard-Tao method.*

In this talk, we will describe how Maynard and Tao's method for producing many primes in intervals of bounded length can be applied to problems involving runs of consecutive primes. For example, one can show that, for each of the arithmetic functions $f \in \{\varphi, \sigma, \omega, \tau\}$ and every natural number K, there are infinitely many solutions to the inequalities $f(p_n - 1) < f(p_{n+1} - 1) < \cdots < f(p_{n+K} - 1)$, and similarly for $f(p_n - 1) > f(p_{n+1} - 1) > \cdots > f(p_{n+K} - 1)$. We will also discuss the answers to some questions of Sierpiński on the digit sums of consecutive primes. This talk is based on joint work with Paul Pollack. (Received January 31, 2015)

1109-11-194 **Raman Parimala*** (parimala@mathcs.emory.edu), Department of Mathematics & Computer Science, Emory University, Atlanta, GA, **Eva Bayer-Fluckiger**, EPFL, Lausanne, Switzerland, and **Ting-Yu Lee**, EPFL, Lausanne, Switzerland. *Explicit obstructions to embedding maximal tori in classical groups.*

Embedding maximal tori into classical groups is equivalent to embedding étale algebras with involution into central simple algebras with involution. We give a concrete description of the obstruction to the Hasse principle for the above embedding problem over global fields. (Joint with E. Bayer-Fluckiger and Ting-Yu Lee). (Received January 31, 2015)

1109-11-197 **Eva Bayer-Fluckiger*** (eva.bayer@epfl.ch). *On the Euclidean Division.*

If a and b are two integers, with b non zero, then there exist two integers q and r such that $a = bq + r$, and that $|r| < |b|$. This so-called Euclidean division property plays a fundamental role in the arithmetic of the usual integers. It is natural to try to generalize this to more general rings, for instance rings of integers of algebraic number fields. This idea leads to the notions of Euclidean number fields and Euclidean minima. Both are very classical topics of number theory. The aim of this talk is to survey old and new results concerning this subject, such as new Euclidean number fields and upper bounds for Euclidean minima. In particular, we will survey the history and recent developments concerning a classical conjecture of Minkowski. (Received February 01, 2015)

1109-11-205 **Alexander Berkovich*** (alexb@ufl.edu). *On some implications of 1907 Hurwitz formula.*

I start by showing that 1907 Hurwitz formula is a special case of the Siegel formula for ternary quadratic forms. I then employ 1907 Hurwitz formula and a special case of the Jacobi triple product identity to prove certain conjectures of Kaplansky. In particular, I will show that $9x^2 + 16y^2 + 36z^2 + 16yz + 4xz + 8xy$ represents, exclusively, all positive integers not of the form 4^a(8m+7), 4^a(8m+3), a=0,1,2 4^a(4m+2), a=0,1,2 4^a(8m+5),a=0,1 M^2,4M^2 where a, m, M are non-negative integers and M is generated by one and primes congruent to 1 modulo 4 (Received February 01, 2015)

1109-11-218 **Dylan Airey**, TX , and **Bill Mance*** (mance@unt.edu). *The Hausdorff dimension of sets of numbers defined by their Q-Cantor series expansions.*

Following in the footsteps of P. Erdős, A. Rényi, and T. Šalát we compute the Hausdorff dimension of sets of numbers whose digits with respect to their Q-Cantor series expansions satisfy various statistical properties. In particular, we consider difference sets associated with various notions of normality and sets of numbers with a prescribed range of digits. (Received February 02, 2015)

1109-11-249 **Michael Filaseta** (filaseta@math.sc.edu) and **Robert Wilcox*** (wilcoxr2@math.sc.edu), Department of Mathematics, University of South Carolina, 1523 Greene Street, Columbia, SC 29208. *An explicit universal Hilbert set with asymptotic density 1.*

A universal Hilbert set is an infinite set $\mathcal{H} \subset \mathbb{Z}$ with the following property: for any $f(x,y) \in \mathbb{Z}[x,y]$ irreducible in $\mathbb{Q}[x,y]$, the polynomial $f(x,h) \in \mathbb{Z}[x]$ is irreducible in $\mathbb{Q}[x]$ for all but finitely many $h \in \mathcal{H}$. Bilu in 1996 and Debes and Zannier in 1998 showed non-constructively the existence of such a set of asymptotic density 1. In this talk, we describe a correspondence between irreducible bivariate polynomials and integer points on a curve. Using Siegel's theorem on integer points, we present an explicit construction of a universal Hilbert set of asymptotic density 1. (Received February 02, 2015)

1109-11-256 **Brian McDonald*** (bmcdon11@u.rochester.edu), **Andrew Best**, **Patrick Dynes**, **Xixi Edelsbrunner**, **Steven J. Miller**, **Kimsy Tor**, **Caroline Turnage-Butterbaugh** and **Madeleine Weinstein**. *Benford Behavior of Generalized Zeckendorf Decompositions.*

We prove connections between Zeckendorf decompositions and Benford's law. Recall that if we define the Fibonacci numbers by $F_1 = 1, F_2 = 2$ and $F_{n+1} = F_n + F_{n-1}$, every positive integer can be written uniquely as a sum of non-adjacent elements of this sequence; this is called the Zeckendorf decomposition, and similar unique decompositions exist for sequences arising from recurrence relations of the form $G_{n+1} = c_1 G_n + \cdots + c_L G_{n+1-L}$ with c_i positive and some other restrictions. Additionally, a set $S \subset \mathbb{Z}$ is said to satisfy Benford's law base 10 if the density of the elements in S with leading digit d is $\log_{10}(1 + \frac{1}{d})$; in other words, smaller leading digits are more likely to occur. We prove that as $n \to \infty$ for a randomly selected integer m in $[0, G_{n+1})$ the distribution of the leading digits of the summands in its generalized Zeckendorf decomposition converges to Benford's law almost surely. Our results hold more generally: one obtains similar theorems to those regarding the distribution of leading digits when considering how often values in sets with density are attained in the summands in the decompositions. (Received February 02, 2015)

1109-11-261 **Michael Filaseta*** (filaseta@math.sc.edu), Mathematics Department, 1523 Greene Street, University of South Carolina, Columbia, SC 29063. *The distribution of primes in determining classes of irreducible polynomials.* Preliminary report.

Many classical polynomials are believed to be irreducible or nearly irreducible. For the most part, explanations for these factorizations remain unknown. In some cases, however, for the Hermite polynomials and the Bessel polynomials, for example, explanations have been given. This talk will discuss how results about the distribution of primes have played a major role in these arguments. Some open questions will also be discussed. (Received February 02, 2015)

1109-11-266 **Judy Holdener*** (holdenerj@kenyon.edu), Department of Mathematics and Statistics, 201 N College Road, Gambier, OH 43022, and **Zachary Weiner** (weinerz@kenyon.edu). *A Search Technique for Identifying Abundancy Outlaws of the form $(\sigma(N)+t)/N$.* Preliminary report.

Let k/l be a rational number greater than 1, and let $I : \mathbb{N} \to \mathbb{Q} \cap (1, \infty)$ be the map defined by $I(n) = \sigma(n)/n = (\sum_{d|n} d)/n$. Then k/l is said to be an *abundancy outlaw* if $k/l \notin \text{Image}(I)$. In this talk, we present a search technique for identifying abundancy outlaws of the form $(\sigma(N)+t)/N$, where $(\sigma(N)+t, N) = 1$. Defining m_N to be the largest divisor of m each of whose prime factors divide N, and v the multiple of N yielding minimal $I(v)$ satisfying $\sigma(v)_N | (v/N)$, $(\sigma(N)+t)/N$ is an abundancy outlaw for all $t < I(v)N - \sigma(N)$. (Received February 02, 2015)

1109-11-268 **Carrie E. Finch***, finchc@wlu.edu. *Irreducibility of Polynomials with Nexus Numbers modulo m as Coefficients.* Preliminary report.

Nexus numbers are d-dimensional figurate numbers $N_d(n) = (n+1)^{d+1} - n^{d+1}$. For fixed values of d and m, we form polynomials using $N_d(n) \pmod m$ as the coefficient of x^n. In this talk, we consider the irreducibility of these polynomials. (Received February 02, 2015)

1109-11-269 **Paul Pollack*** (pollack@uga.edu). *Big doings with small gaps.*
This is a survey talk concerning gaps between primes. We discuss the history of the subject from its ancient origins up through the startling recent breakthroughs of Yitang Zhang, James Maynard, and Terry Tao. We also highlight some of the many applications that the method of Maynard and Tao has already inspired. (Received February 03, 2015)

1109-11-272 **Michael J. Mossinghoff*** (mimossinghoff@davidson.edu), Davidson College, Davidson, NC 28035-6996, and **Timothy S. Trudgian** (timothy.trudgian@anu.edu.au), Mathematical Sciences Institute, The Australian National University, Canberra, ACT 0200, Australia. *A zero-free region for the Riemann zeta-function.*
In his work on the Prime Number Theorem, de la Vallée Poussin proved that the Riemann zeta function $\zeta(\sigma+it)$ has no zeros in the region $\sigma > 1 - 1/(R\log|t|)$ and $|t| \geq 2$, with $R \approx 30.47$. While a zero-free region of this form is superseded asymptotically by results of Vinogradov and Ford, for more limited heights this classical region remains of interest, and finds application in various problems in number theory. As a result, a number of researchers have reduced the value of R in the de la Vallée Poussin zero-free region over the years, including Kadiri, who showed in 2005 that one can take $R = 5.69693$. We report on some experimental and analytic work on reducing this constant further. (Received February 03, 2015)

1109-11-283 **Ognian Trifonov*** (trifonov@math.sc.edu), Department of Mathematics, LeConte College, 1523 Greene Street, Univ. of South Carolina, Columbia, SC 29229. *Lattice points close to a smooth curve and applications.*
We prove new estimates for the number of lattice points close to a curve and use them to improve on a result of Luca and Sparlinski on the number of certain extremal finite fields. We also to obtain formulas for the number of representations of an integer as a difference of a k-free number and a small prime. (Received February 03, 2015)

1109-11-284 **Pete L. Clark*** (plclark@gmail.com). *Quadratic Forms and the Geometry of Numbers.*
I will give a survey of recent work – much of it joint with my student Jacob Hicks – on a certain abstract algebraic generalization of Geometry of Numbers and its applications to representation theorems for quadratic forms over S-integer rings in global fields. (Received February 03, 2015)

1109-11-294 **Tom Wright*** (tjw980@yahoo.com), 429 N. Church St., Spartanburg, SC 29302. *Variants of Carmichael numbers.*
Korselt's Criterion, a necessary and sufficient condition for Carmichael numbers, states that a number n is Carmichael if and only if n is square-free and for each prime p that divides n, $p-1|n-1$. In this talk, we show that under the assumption of a conjecture about the least prime in an arithmetic progression, one can prove that for any $a \in \mathbb{Z}$, there are infinitely n for which $p|n$ implies $p-a|n-a$. This is an improvement of a result of Ekstrom, Pomerance, and Thakur. (Received February 03, 2015)

1109-11-317 **Zhu Cao*** (zcao@kennesaw.edu), 1100 S Marietta Pkwy, Marietta, GA 30060, and **Yong Hu**. *Exact covering systems and Ramanujan's forty identities for the Rogers-Ramanujan functions.*
For a nonsingular integer matrix B, we consider the the exact covering system (ECS) of $\mathbb{Z}^n$ corresponding to the quotient group $\mathbb{Z}^n/B\mathbb{Z}^n$. We use these ECS to obtain transformations in $\mathbb{Z}^n$ and then apply these transformations to prove identities involving functions defined on $\mathbb{Z}^n$. In particular, we study product identities for theta functions and show that a large portion of the forty identities for the Rogers-Ramanujan functions can be explained naturally using this approach. (Received February 04, 2015)

1109-11-318 **Chadwick Gugg*** (chadwick.gugg@gsw.edu), Chadwick Gugg, Georgia Southwestern State University, 800 GSW State University Drive, Americus, GA 31709. *On Conjectures of Somos for identities for the Rogers-Ramanujan functions.* Preliminary report.
S. Ramanujan recorded in his notebooks 40 identities for the Rogers-Ramanujan functions. M. Somos used numerical methods to rediscover some of these relations, as well further new ones. K. Bringmann and H. Swisher subsequently proved these identities using the theory of modular forms. We revisit some of these identities using more elementary methods "in the spirit of Ramanujan", and derive some further relations in the process. (Received February 04, 2015)

12 ► Field theory and polynomials

1109-12-213 **David B. Leep*** (leep@email.uky.edu), Department of Mathematics, 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506-0027. *Subspaces of zeros of pairs of quadratic forms and the u-invariant of a rational function field.* Preliminary report.

I will report on continued investigations on the connections between finding subspaces of zeros of pairs of quadratic forms and the computation of the u-invariant of a rational function field $k(t)$ where the characteristic of k is not 2. (Received February 01, 2015)

14 ► Algebraic geometry

1109-14-25 **Changho Keem*** (ckeem1@gmail.com), Department of Mathematics, College of Natural Sciences, Seoul National University, Seoul, 151-742, South Korea, and **Yun-Hwan Kim**, Department of Mathematics, College of Natural Sciences, Seoul National University, Seoul, 151-742, South Korea. *On rigid components of the Hilbert scheme of smooth projective curves.*

Denote by $\mathcal{H}_{d,g,r}$ the Hilbert scheme of smooth curves which is the union of components whose general point corresponds to smooth irreducible and non-degenerate curve of degree d and genus $g > 0$ in $\mathbb{P}^r$. A rigid component of $\mathcal{H}_{d,g,r}$ is an irreducible component of $\mathcal{H}_{d,g,r}$ whose image under the natural map $\pi : \mathcal{H}_{d,g,r} \to \mathcal{M}_g$ is just one point. In this note, we provide a proof of the fact that $\mathcal{H}_{d,g,r}$ has no rigid component for $r = 3$. In case $r \geq 4$, we also prove the non-existence of a rigid component in a certain range of d, g and r . (Received December 31, 2014)

1109-14-28 **Andrei S. Rapinchuk*** (asr3x@virginia.edu), Department of Mathematics, University of Virginia, P.O. Box 400137, Charlottesville, VA 22904-4137. *On algebraic groups with the same tori.* Preliminary report.

We will report on some recent developments dealing with the problem of characterizing finite-dimensional division algebras having the same maximal subfields and absolutely almost simple algebraic groups having the same maximal tori. Joint work with V.Chernousov and I.Rapinchuk. (Received January 04, 2015)

1109-14-167 **Alexander R Duncan***, Department of Mathematics, 530 Church Street, Ann Arbor, MI 48109. *Automorphisms of pencils of quadrics.* Preliminary report.

The plane Cremona group is the group of birational automorphisms of the projective plane. Over an algebraically closed field of characteristic zero, its finite subgroups have been (mostly) classified up to conjugacy. An analogous classification in positive characteristic is still open. To study these groups, it suffices to consider certain rational surfaces on which the group acts by ordinary automorphisms. One such class of surfaces are the del Pezzo surfaces of degree 4.

A del Pezzo surface of degree 4 is the intersection of two quadrics in projective space of dimension 4. With this as motivation, I describe the automorphism group of a variety given by the intersection of two quadratic forms in projective space. Of particular interest is the case where the base field has characteristic 2 and the ambient space is of even dimension. (Received January 30, 2015)

1109-14-225 **Nivedita Bhaskhar*** (nbhaskh@emory.edu). *A proof by patching of the cyclicity of prime degree algebras over p-adic curves.* Preliminary report.

It is well-known by a result of Saltman that any central division algebra D over the function field of a p-adic curve of prime degree q (not equal to p) is cyclic. The proof involves a detailed analysis of the shape of the algebra at the nodal points on the ramification locus of D and the residual Brauer classes at co-dimension one points. In this talk, we give a different proof of Saltman's theorem by using the patching techniques of Harbater-Hartmann-Krashen to construct a cyclic "lift of residues" which splits the algebra under consideration. (Received February 02, 2015)

1109-14-259 **Caroline Junkins*** (cjunkins@uwo.ca). *Rational Bundles in the Grothendieck group of a Twisted Grassmannian.*

For a group G of type A_n, we consider a parabolic subgroup P and the projective homogeneous variety given by G/P. If G is non-split, then a result of Panin states that the Grothendieck group of G/P can be described in terms of the Steinberg basis and the set of Tits algebras of G.

In this talk, we construct elements in the Grothendieck group of this twisted Grassmannian which are independent of the Tits algebras of G and relate these so-called rational bundles to other invariants of the group G. (Received February 02, 2015)

16 ► Associative rings and algebras

1109-16-27 **Adam Chapman*** (adchapman@math.msu.edu), Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48824. *Subfields of quaternion algebras in characteristic 2.*

We discuss the situation where two quaternion algebras over a field of characteristic 2 have the same subfields. We show how to construct pairs of nonisomorphic quaternion algebras sharing the subfields, and give examples of fields over which quaternion algebras that have the same subfields must be isomorphic. (Received January 04, 2015)

1109-16-103 **David J Saltman*** (saltman@idaccr.org), 805 Bunn Dr, Princeton, NJ 08540. *Division algebras and separable subfields.* Preliminary report.

If D/F is a division algebra (finite dimensional) and K/F is a Galois maximal subfield then this forces D/F to be a crossed product, which is a strong constraint on the algebra structure of D. Generic separable K/F have Galois group the symmetric group S_n (i.e. the Galois group of its Galois closure) but one can ask whether there are algebraic consequences of D/F having maximal K/F where the Galois group of K/F is smaller than S_n (but bigger than order n). With the machinery we develop we answer questions about the asymptotic behavior of $(KaK)^m$ and characterize when aK consists entirely of n power central elements. This is joint work with Eli Matzri, Louis Rowen, and Uzi Vishne. (Received January 26, 2015)

1109-16-277 **Daniel Brice*** (dbrice@tuskegee.edu). *Parabolic Lie algebras are zero product determined.*

An algebra, $(A, *)$ is said to be *zero product determined* if for every bilinear map $\varphi : A \times A \to X$ (with X an arbitrary vector space) satisfying $\varphi(x, y) = 0$ whenever $x * y = 0$ there is a linear map $\tilde{\varphi} : A^2 \to X$ such that $\varphi(x, y) = \tilde{\varphi}(x * y)$. Let $\mathfrak{q}$ be a parabolic subalgebra of a reductive Lie algebra $\mathfrak{g}$. Building on the results of D. Wang, et al, and the previous work of B– and Huang, we show that $\mathfrak{q}$ and $\operatorname{Der}\mathfrak{q}$ are zero product determined, including the special case where $\mathfrak{q} = \mathfrak{g}$. (Joint work with Huajun Huang). (Received February 03, 2015)

1109-16-282 **Daniel Krashen*** (dkrashen@uga.edu) and **Max Lieblich**. *The Clifford Algebra of a Finite Morphism.*

The classical Clifford construction, which produces an associative algebra from a quadratic form has been generalized to other types of higher degree forms by a number of authors. In this talk, I'll give a new construction, generalizing the classical one, of a Clifford algebra associated to a finite morphism of schemes, and describe applications of this construction to the period-index problem for genus 1 curves. (Received February 03, 2015)

20 ► Group theory and generalizations

1109-20-88 **Valentina Disarlo*** (vdisarlo@indiana.edu). *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. Its combinatorics is crucial in works of Thurston and Penner's decorated Teichmuller theory. 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 January 25, 2015)

1109-20-89 **Caglar Uyanik*** (cuyanik2@illinois.edu), Department of Mathematics, 1409 W. Green Street, Urbana, IL 61801, and **Grace Work**. *The distribution of gaps for saddle connections on the octagon.*

I will discuss the notion of *gap distribution* for slopes of saddle connections associated to flat surfaces. In particular, we explicitly compute the gap distribution associated to the flat surface obtained by gluing opposite sides of a regular octagon. Moreover, we give a recipe to compute the gap distribution for every Veech surface by constructing a Poincare section to the horocycle flow on the moduli space. (Received January 25, 2015)

1109-20-90 **Richard Kent*** (rkent@math.wisc.edu), 480 Lincoln Dr, Madison, WI 53706. *Thoughts on convex cocompactness in mapping class groups.*

I will talk about some ideas related to Farb and Mosher's notion of convex cocompactness in mapping class groups. (Received January 25, 2015)

1109-20-106 **Matthew Durham** and **Samuel J Taylor*** (s.taylor@yale.edu). *Stability and convex cocompactness in mapping class groups.*

Convex cocompact subgroups of mapping class groups were introduced by Farb and Mosher and have important connections to the geometry of Teichmüller space, the curve complex, and surface group extensions. In this talk, I will discuss a new characterization of such subgroups that involves only the geometry of the mapping class group. This characterization involves a strong notion of quasiconvexity, which we call stability, and captures the intuition that convex cocompact subgroups are "highly hyperbolic" subgroups of mapping class groups. (Received January 26, 2015)

1109-20-109 **Priyam Patel*** (patel376@purdue.edu). *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 low-dimensional topology and geometry. We begin this talk by defining two separability properties of RAAGs, 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 January 26, 2015)

1109-20-110 **Joan Birman**, **Nathan Broaddus*** (broaddus@math.osu.edu) and **William Manasco**. *Finite rigid sets and homologically nontrivial spheres in the curve complex of a surface.*

Aramayona and Leininger have provided a "finite rigid subset" $\mathfrak{X}(\Sigma)$ of the curve complex $\mathcal{C}(\Sigma)$ of a surface $\Sigma = \Sigma_g^n$, characterized by the fact that any simplicial injection $\mathfrak{X}(\Sigma) \to \mathcal{C}(\Sigma)$ is induced by a unique element of the mapping class group $\mathrm{Mod}(\Sigma)$. In this paper we prove that, in the case of the sphere with $n \geq 5$ marked points, the reduced homology class of the finite rigid set of Aramayona and Leininger is a $\mathrm{Mod}(\Sigma)$-module generator for the reduced homology of the curve complex $\mathcal{C}(\Sigma)$, answering in the affirmative a question posed by Aramayona and Leininger. For the surface $\Sigma = \Sigma_g^n$ with $g \geq 3$ and $n \in \{0, 1\}$ we find that the finite rigid set $\mathfrak{X}(\Sigma)$ of Aramayona and Leininger contains a proper subcomplex $X(\Sigma)$ whose reduced homology class is a $\mathrm{Mod}(\Sigma)$-module generator for the reduced homology of $\mathcal{C}(\Sigma)$ but which is not itself rigid. (Received January 27, 2015)

1109-20-111 **Spencer Dowdall***, 1409 W Green Street, Urbana, IL 61801, and **Ilya Kapovich** and **Christopher J. Leininger**. *Unbounded asymmetry of free group automorphism stretch factors.*

Every automorphism of a finte rank free group has a well-defined "stretch factor" measuring the exponential growth rate of words under iteration of the automorphism. It is easy to see that the stretch factor of an automorphism and its inverse need not agree. However, Handel and Mosher showed that this discrepency is uniformly bounded among all fully irreducible automorphisms of the group. In this talk, I will explain how to use new technology describing the splittings of a free-by-cyclic group to show that this uniform bound necessarily depends on the rank of the group. More precisely, I will describe an infinite family ϕ_n of fully irreducible automorphisms for which ratio of the logarithm of the stretch factor of ϕ_n to that of ϕ_n^{-1} tends to ininify. This is joint work with Ilya Kapovich and Christopher J. Leininger. (Received January 27, 2015)

1109-20-113 **Thomas Koberda** and **Johanna Mangahas***, mangahas@buffalo.edu, and **Samuel J Taylor**. *The geometry of purely loxodromic subgroups of right-angled Artin groups.*

We prove that finitely generated *purely loxodromic* subgroups of a right-angled Artin group $A(\Gamma)$ fulfill equivalent conditions that parallel characterizations of convex cocompactness in mapping class groups $\mathrm{Mod}(S)$. In particular, such subgroups are quasiconvex in $A(\Gamma)$. In addition, we identify a milder condition for a finitely generated subgroup of $A(\Gamma)$ that guarantees it is free, undistorted, and retains finite generation when intersected with $A(\Lambda)$ for subgraphs Λ of Γ. These results have applications to both the study of convex cocompactness in $\mathrm{Mod}(S)$ and the way in which certain groups can embed in right-angled Artin groups. (Received January 27, 2015)

1109-20-120 **Neil J. Fullarton*** (neil.fullarton@rice.edu). *Palindromic automorphisms of free groups.*

The palindromic automorphism group of a free group consists of automorphisms that take each member of some (fixed) free basis X to a palindrome on X; that is, a word which is equal to its reverse. This group has striking connections with hyperelliptic mapping class groups and congruence subgroups of $\mathrm{GL}_n(\mathbb{Z})$. I will demonstrate these connections in order to motivate the study of palindromic automorphisms, and discuss recent results in this area. (Received January 27, 2015)

1109-20-122 **Dan Margalit** (margalit@math.gatech.edu) and **S Oyku Yurttas*** (syurttas3@math.gatech.edu). *Computations in the mapping class group via global coordinates.*

We compute the invariant measured foliations and dilatation of a given a pseudo-Anosov mapping class using global coordinates on the boundary of Teichmüller space. This gives a linear time algorithm with respect to word length which we illustrate with Dynnikov Coordinates on the finitely punctured disk. This is joint work with Dan Margalit. (Received January 27, 2015)

1109-20-127 **Kevin Wortman*** (wortman@math.utah.edu). *Word metrics for arithmetic groups.* Preliminary report.

We'll discuss the efficiency of paths in an arithmetic group with its word metric, and whether paths between pairs of points can be chosen to avoid large bounded sets. This is joint work with Lucy Lifschitz. (Received January 28, 2015)

1109-20-147 **Neha Gupta*** (ngupta10@illinois.edu). *The primitivity index function for a free group, and untangling closed curves on surfaces.*

A theorem of Scott shows that any closed geodesic on a surface lifts to an embedded loop in a finite cover. Our motivation is to find a worst-case lower bound for the degree of this cover, in terms of the length of the original loop. We establish, via probabilistic methods, lower bounds for certain analogous functions, like the Primitivity Index Function and the Simplicity Index Function, in a free group. These lower bounds, when applied in a suitable way to the surface case, give us some lower bounds for our motivating question. This is joint work with Ilya Kapovich. (Received January 28, 2015)

1109-20-170 **Matt Clay*** (mattclay@uark.edu), Department of Mathematical Sciences, SCEN 309, 1 University of Arkansas, Fayetteville, AR 72701, and **Funda Gultepe** and **Kasra Rafi**. *Tori in the double handlebody.* Preliminary report.

I will describe joint work in progress with Kasra Rafi and Funda Gültepe regarding tori in the doubled handlebody $S^1 \times S^2 \# \cdots \# S^1 \times S^2$. (Received February 03, 2015)

22 ► Topological groups, Lie groups

1109-22-312 **Dongwen Qi***, Department of Mathematics, Georgia Southwestern State University, Americus, GA 31709. *Some Remarks on the Covering Groups of a Topological Group.*

In this short note we discuss the connection between Chevalley's definition of a covering space and the usual definition given in a topology course. Then we indicate some theorems about the covering groups of a topological group can be proved from the global point of view, without using local isomorphisms between topological groups. (Received February 03, 2015)

30 ► Functions of a complex variable

1109-30-59 **Eze R. Nwaeze*** (ern0002@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849, and **Narendra K. Govil**, Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849. *Growth of Polynomials not vanishing inside a circle.* Preliminary report.

Let $p(z) = a_0 + a_1 z + a_2 z^2 + a_3 z^3 + \cdots + a_n z^n$ be a polynomial of degree n, where the coefficients a_k may be complex. A well-known theorem of Rivlin states that if $p(z) \neq 0$ for $|z| < 1$, then $\max_{|z|=r} |p(z)| \geq \left(\frac{1+r}{2}\right)^n \max_{|z|=1} |p(z)|$ for $r \leq 1$. We improve on this result and give also analogous inequality for polynomials with gaps. A special case of our result amounts to the above result due to Rivlin. (Received January 19, 2015)

1109-30-172 **Tim Ferguson*** (tjferguson1@ua.edu), Department of Mathematics, The University of Alabama, Box 870350, Tuscaloosa, AL 35487-0350. *The p-Harmonic Equation and Extremal Problems in Bergman Spaces.*

We discuss linear extremal problems for Bergman spaces of analytic functions and their relation to the complex analogue of the p-harmonic equation. Khavinson and Stessin used this relation to derive a regularity result for extremal problems with polynomial kernels. We discuss their result and its applications to a recent result of ours dealing with another aspect of regularity for extremal problems. (Received January 30, 2015)

34 ► Ordinary differential equations

1109-34-10 **K. Renee Fister*** (kfister@murraystate.edu), **Maeve McCarthy** and **Seth Oppenheimer**. *Optimal control of insects through sterile insect release and habitat modification.*

This paper develops an optimal control framework for an ordinary differential equation model to investigate the introduction of sterile mosquitoes to reduce the incidence of mosquito-borne diseases. Existence of a solution given an optimal strategy and the optimal control is determined in association with the negative effects of the disease on the population while minimizing the cost due to this control mechanism. Numerical simulations have shown the importance of effects of the bounds on the release of sterile mosquitoes and the bounds on the likelihood of egg maturation. (Received November 20, 2014)

1109-34-26 **Layachi Hadji*** (lhadji@ua.edu), Mathematics Department, 345 Gordon Palmer Hall, Tuscaloosa, AL 35487, and **Rishad Shahmurov**, Mathematics Department, 345 Gordon Palmer Hall, Tuscaloosa, AL 35487. *Nonlinear convection in unbounded regions.*

In the past half century, perturbations methods have been successful in finding stable solutions to the equations governing nonlinear convection, namely the Navier-Stokes equations coupled with the energy conservation equation, in systems with horizontal boundaries such as the Rayleigh-Bénard set-up. In the absence of horizontal boundaries, such as the infinite vertical channel (IVC) problem or unbounded and uniformly stratified (UUS) regions, the methods fail to capture the nonlinear solutions. In this talk, I will discuss the recently found similarity solutions to the IVC problem which reduce the governing equations to a set of coupled nonlinear ODE's. These solutions are found to be stable to general two-dimensional, time-dependent disturbances. Furthermore, when the analysis is extended to the UUS case, we find that the fluid becomes linearly unstable through a Batchelor-Nitsche (BN) instability mechanism. Thus, the nonlinear solutions are obtained through a long wavelength expansion. Thus, our analysis also provides the nonlinear development of the BN instability. (Received December 31, 2014)

1109-34-115 **Evan M Milliken*** (evmilliken@ufl.edu), Department of Mathematics, University of Florida, Gainesville, FL 32611, and **Sergei S Pilyugin**, Departement of Mathematics, University of Florida, Gainesville, FL 32611. *Persistence in a 2-patch SIV model coupled via diffusion.* Preliminary report.

Infectious Salmon Anemia virus is a flu-like member of the Orthomyxoviridae family of viruses which affects a variety of finfish, including Atlantic Salmon. The virus has caused devastating outbreaks of Infectious Salmon Anemia in populations of farmed Salmon. Susceptible host species can become infected either by direct contact with an infected individual or by contact with the virus in the environment. A 2-patch model is presented to study the dynamics of an infection in the setting of a large Salmon farm in close proximity to a wild Salmon population. Each patch is modeled by a Susceptible - Infected - Virus model and the patches are coupled via linear diffusion in the viral compartment. The basic reproduction number $\mathcal{R}_0$ is determined and conditions given for the existence of equilibria as well as for persistence or extinction of the virus. (Received January 27, 2015)

1109-34-146 **Yun Kang*** (yun.kang@asu.edu), Science and Mathematics Faculty, 6073 S. Backus Mall, Wanner 301G, Arizona State University, Mesa, AZ 85212, and **Krystal Blanco** and **Talia Davis Kang**. *Disease dynamics of Honeybees with Varroa destructor as parasite and virus vector.*

We propose a honeybee-mite-virus model that incorporates (1) interactions between honeybee and its parasitic mite; (2) four virus transmissions: among honeybees, from adult honeybees to phoretic mites, from reproductive mites to honeybee brood, and from honeybees to phoretic mites. Interesting findings from our analytical work include (a) In the absence of mite and virus, the honeybee experiences Allee effects generated by the internal organization of honeybee including division of labor. Thus, initial conditions are essential for the survival of the colony; (b) In the absence of virus, the honeybee and mite population can have fluctuated dynamics, which may lead to catastrophe event where both honey bee and mite go extinct suddenly. This dynamical property is inherited by the full honeybee-mite-virus model; (c) In the absence of mite, the disease dynamics has only equilibrium dynamics. Our results show that virus infection may prevent the extinction of honeybee under certain conditions; (d) In the absence of health mite, the infected honeybee population is more likely to be persistent. Our study suggests that the synergy effects of the parasitic mite Varroa destructor and the related virus infection in honeybee may be a cause for Colony Collapse Disorder (CCD) of honeybee. (Received January 28, 2015)

1109-34-204 **Shouzong Liu*** (shliu@siu.edu), Department of Mathematics, Southern Illinois University, 1245 Lincoln Drive, Carbondale, IL 62901, and **John Reeve** and **Mingqing Xiao** (mxiao@math.siu.edu), Department of Mathematics, Southern Illinois University, 1245 Lincoln Drive, Carbondale, IL 62901, and **Dashun Xu** (dashunxu@siu.edu), Department of Mathematics, Southern Illinois University, 1245 Lincoln Drive, Carbondale, IL 62901. *Stability analysis and Hopf bifurcation of a host-parasitoid model.*

Population dynamics between parasitoids and their hosts have been studied for decades and several mechanisms causing population cycles were discovered. Here we develop a stage-structured model with negative binomial predation to explore possible mechanisms causing population cycles. The permanence of the model and local stabilities of equilibria are studied. The conditions for Hopf bifurcations of the model are obtained. In this talk, some numerical simulations is also going to be presented to support the theoretical results. As a part of our on-going project, we next will discuss the mechanisms of population cycles of a specific host-parasitoid system in our lab by comparing the model predictions with lab data. (Received February 01, 2015)

1109-34-244 **Richard C Ewool*** (rce2m@mtmail.mtsu.edu), Department of Mathematics, 1301 East Main Street, Murfreesboro, TN 37132, and **Zachariah Sinkala** (zsinkala@mtsu.edu), Department of Mathematics, 1301 East Main Street, Murfreesboro, TN 37132. *Computational Modeling and Simulation of a Multiscale Tumor Induced Angiogenesis Model.* Preliminary report.

Angiogenesis, the formation of new blood vessels from pre- existing vasculature is one of the main processes that helps in the growth and spread of tumors connecting the benign avascular phase and the prospectively harmful vascular stage of the tumor. Angiogenesis is a process that involves a well organised sequence of events including tumor angiogenic factor signaling; endothelial cell migration and proliferation; degradation of extra-cellular matrix and directed blood flow. The use of Mathematical and Computational approach to investigating cancer growth and spread has been identified ed as a complementary approach to scientific c investigation. Experimentalist and medical practitioners can depend on the results obtained from mathematical and computational models to redefine their hypotheses, focus experiments, and enable more accurate predictions. It is in this light that we propose a multiscale continuum model that describes the effect of hypoxia on pathological angiogenesis in conjunction with a discrete model to capture vascular structure of the blood vessels growing towards the tumor. (Received February 02, 2015)

1109-34-265 **Susmita Sadhu*** (susmita.sadhu@gcsu.edu). *Mixed mode oscillations in a singular perturbed three-species model.*

We consider a three dimensional singularly perturbed predator-prey model with two predators competing directly for the same prey under Holling Type II predator functional response. As the predating efficiency of one of the predators is varied, the system exhibits relaxation oscillations, as well as complex dynamics such as mixed mode oscillations (which feature alternating short amplitude oscillations and relaxation oscillations). Relaxation oscillations reflect the presence of boom and bust of population of the species, whereas mixed mode oscillations delay the time intervals between two consecutive outbreaks/crashes, and are thus ecologically significant. Using the standard singular perturbation theory, existence of stable relaxation oscillations can be explained. On the other hand, mixed mode oscillations in the system arise due to canards and singular Hopf mechanisms. Canards exist due to presence of a folded node singularity which allows trajectories entering a special region called the "funnel" to pass through it from the attractive to the repelling slow manifold. As the input parameter reaches a critical value, the mixed mode oscillations are influenced by the interaction of both canard and singular Hopf mechanisms. (Received February 02, 2015)

1109-34-267 **Omar Saucedo*** (osaucedo1987@ufl.edu), **Maia Martcheva** and **Juliet Pulliam**. *Competition Between Low Pathogenic and High Pathogenic Avian Influenza in a Two Patch System.* Preliminary report.

Over the last decade, epidemiology of avian influenza has undergone a significant transformation. Not only have we seen an increase in the number of outbreaks of the deadly strain known as high pathogenic avian influenza (HPAI), but the number of birds infected, and the cost of control has risen drastically. Live poultry farms play a huge role in the bird to bird transmission of avian influenza. We develop a two patch model to determine the competition between LPAI and HPAI strains. We define the two patches as live bird markets in which the patches are connected though migration. We use a system of differential equations to analyze the existence-stability of the equilibriums, and established results for the critical threshold R0. We observed that migration plays a key role in determining whether LPAI and HPAI can invade. (Received February 02, 2015)

1109-34-276 **Minh V Nguyen*** (nguyen_minh2@columbusstate.edu), 4225 University Ave, Columbus, GA 31907. *A Katznelson-Tzafriri Type Theorem for almost periodic linear evolution equations.*

In this paper we present an extension of a theorem due to Katznelson and Tzafriri to non-autonomous linear differential equations with almost periodic coefficients of the form $x'(t) = A(t)x(t)$. To this end, we consider the evolution semigroup associated with the equation in a small invariant function space consisting of almost periodic functions with frequencies contained in the semi-module generated by the spectrum of $A(t)$. The obtained (Perron type) conditions are stated in terms of the solvability of inhomogeneous equations associated with the equation under investigation. (Received February 03, 2015)

35 ► Partial differential equations

1109-35-30 **Anna Ghazaryan*** (ghazarar@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056, and **Yuri Latushkin** and **Stephen Schecter**. *Nonlinear stability of fronts and pulses for a class of partly parabolic systems that arise in chemical reaction models.*

I will discuss linear and nonlinear stability results for traveling waves in a class of partly parabolic systems that arise in chemical reaction models. The semigroups generated by linearizing these systems about the waves are not sectorial. Nevertheless, our linear stability result shows that spectral stability implies linearized stability against bounded perturbations. In addition, a result on nonlinear stability in exponentially weighted spaces provides a detailed description of the time evolution of the perturbations to the wave. (Received January 06, 2015)

1109-35-31 **King-Yeung Lam** and **Yuan Lou***, Department of Mathematics, Ohio State University, Columbus, OH 43210, and **Frithjof Lutscher** and **Peng Zhou**. *Dispersal in advective environments.*

We consider some mathematical models in one-dimensional advective environments. Individuals are exposed to unidirectional flow, with the possibility of being lost through the boundary. We will investigate the persistence and range of a single species. When the diffusion and advection rates are small and comparable, we determine some criterion for the existence of evolutionarily stable dispersal strategies (Received January 07, 2015)

1109-35-34 **Pruss Jan**, **Gieri Simonett** and **Yuanzhen Shao*** (yuanzhen.shao@vanderbilt.edu). *Regularity of the interface of a thermo-dynamically consistent two-phase Stefan problem.*

We study the regularity of solutions to a thermo-dynamically consistent two-phase Stefan problem with or without kinetic undercooling. It is shown that the free interface of the problem immediately becomes analytic jointly in time and space, provided the initial surface satisfies a mild regularity assumption. The proof is based on a combination of a family of parameter-dependent diffeomorphisms, Lp-maximal regularity theory, and the implicit function theorem. (Received January 12, 2015)

1109-35-35 **Yuanzhen Shao*** (yuanzhen.shao@vanderbilt.edu). *Continuous maximal regularity on manifolds with singularities and applications to geometric flows.*

In this talk, we study continuous maximal regularity theory for a class of degenerate or singular differential operators on manifolds with singularities. Based on this theory, we show that the Yamabe flow can start with an initial metric of unbounded curvature, and immediately evolves into metrics of bounded curvatures. (Received January 12, 2015)

1109-35-36 **Erkan Nane*** (ezn0001@auburn.edu), 221 Parker Hall, Auburn, AL 36830. *Intermittence and time fractional stochastic partial differential equations.*

I will consider time fractional stochastic heat type equations. The time fractional stochastic heat type equations might be used to model phenomenon with random effects with thermal memory. In this talk I discuss: (i) Existence an uniqueness of solutions and existence of a continuous version of the solution; (ii) absolute moments of the solutions of this equation grows exponentially; and (iii) the distances to the origin of the farthest high peaks of those moments grow exactly linearly with time. These results extend the results of Mohammud Foondun and Davar Khoshnevisan, (Intermittence and nonlinear parabolic stochastic partial differential equations, Electron. J. Probab. 14 (2009), no. 21, 548–568) and Conus and Khoshnevisan (On the existence and position of the farthest peaks of a family of stochastic heat and wave equations, Probab. Theory Related Fields 152 (2012), no. 3-4, 681–701) on the parabolic stochastic heat equations.

These results are our recent joint work with Jebessa B Mijena. (Received January 14, 2015)

1109-35-41 **Zhaosheng Feng*** (zsfeng@utpa.edu), 1201 W. Unviersity Dr., Edinburg, TX 78539. *Qualitative Behaviors of Degenerate Reaction-Diffusion Systems.*

The history of the theory of reaction-diffusion systems begins with the three famous works by Luther (1906), Fisher and Kolmogorov etc. (1937). Since these seminal papers much research has been carried out in an attempt to extend the original results to more complicated systems which arise in several fields. In this talk, we study the case that some species migrate from densely populated areas into sparsely populated areas to avoid crowding, and investigate a more general reaction-diffusion system by considering density-dependent dispersion as a regulatory mechanism of the cyclic changes. Here the probability that an animal moves from the point x_1 to x_2 depends on the density at x_1. Under certain conditions, we apply the higher terms in the Taylor series and the center manifold method to obtain the local behavior around a non-hyperbolic point of codimension one in the pase plane, and use the Lie symmetry reduction method to explore bounded traveling wave solutions. (Received January 15, 2015)

1109-35-45 **Yixiang Wu*** (yxw2228@louisiana.edu), 200 Theater Street, Apt 533, Lafayette, LA 70506, and **Keng Deng**. *Long Time Behavior for a Reaction-Diffusion Population Model with Delay.*

In this talk, we consider a reaction-diffusion population model with time delay in an unbounded domain. By introducing a new auxiliary function, we first establish a comparison principle for coupled upper/lower solutions. Our new auxiliary function is useful to prove comparison principles for other reaction-diffusion models in unbounded domain. We then prove the existence and uniqueness result for the model. Finally, we show the global asymptotic behavior of the model by constructing a sequence of successively improved upper/lower solutions. (Received January 16, 2015)

1109-35-53 **Hakima Bessaih*** (bessaih@uwyo.edu), Department of Mathematics, 1000 E. University Ave. Dept. 3036, Laramie, WY 82071, and **Florian Maris** and **Yalchin Efendiev**. *Homogenization of the stochastic Navier-Stokes equation in perforated domains.* Preliminary report.

Some stochastic models are considered including the two dimensional Navier-Stokes equation in a perforated domain with a dynamical slip boundary condition. The dynamics are driven by a noise on the interior and on the boundary of the domain. Different scalings are considered that give rise to different limit problems.

For a particular scaling used on the Navier-Stokes equations, we obtain a Darcy's law with memory. We mainly use the two scale convergence method to pass to the limit. Moreover, the passage to the limit is performed on the variational formulation. (Received January 18, 2015)

1109-35-56 **Sze-Bi Hsu** and **Junping Shi*** (jxshix@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23187, and **Feng-Bin Wang**. *Further Studies of a Reaction-Diffusion System for an Unstirred Chemostat with Internal Storage.*

The dynamics of a reaction-diffusion system for two species of microorganisms in an unstirred chemostat with internal storage is studied. It is shown that the diffusion coefficient is a key parameter of determining the asymptotic dynamics, and there exists a threshold diffusion coefficient above which both species become extinct. On the other hand, for diffusion coefficient below the threshold, either one species or both species persist, and in the asymptotic limit, a steady state showing competition exclusion or coexistence is reached. (Received January 19, 2015)

1109-35-62 **Luan Hoang** (luan.hoang@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, **Truyen Nguyen** (tnguyen@uakron.edu), Department of Mathematics, University of Akron, Akron, OH 44325, and **Tuoc Phan*** (phan@math.utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 37936. *Gradient estimates and global existence of smooth solutions to a cross-diffusion system.*

We investigate the global time existence of smooth solutions for the Shigesada-Kawasaki-Teramoto system of cross-diffusion equations of two competing species in population dynamics. If there are self-diffusion in one species and no cross-diffusion in the other, we show that the system has a unique smooth solution for all time in bounded domains of any dimension. We obtain this result by deriving global $W^{1,p}$-estimates of Calderón-Zygmund type for a class of nonlinear reaction-diffusion equations with self-diffusion. These estimates are achieved by employing Caffarelli-Peral perturbation technique together with a new two-parameter scaling argument. (Received January 20, 2015)

1109-35-64 **Abbas Momeni*** (momeni@math.carleton.ca). *New variational principles of symmetric boundary value problems.* Preliminary report.

The object of this talk is to present new variational principles for symmetric boundary value problems. Let V be a Banach space and V^* its topological dual. We shall consider problems of the type $\Lambda u = D\Phi(u)$ where $\Lambda : V \to V^*$ is a linear symmetric operator and $\Phi : V \to \mathbb{R}$ is a differentiable convex function whose derivative is denoted by $D\Phi$. It is established that solutions of the latter equation are associated with critical points of functions of the type

$$I_{\lambda,\mu}(u) := \mu\Phi^*(\Lambda u) - \lambda\Phi(u) - \frac{\mu-\lambda}{2}\langle \Lambda u, u\rangle,$$

where λ, μ are two real numbers and Φ^* is the fenchel dual of the function Φ. By assigning different values to λ and μ one obtains variety of new and classical variational principles associated to the equation $\Lambda u = D\Phi(u)$. Namely, Euler-Lagrange principle ($\mu = 0, \lambda = 1$), Clarke-Ekeland least action principle ($\mu = 1, \lambda = 0$), Brezis-Ekeland variational principle ($\mu = 1, \lambda = -1$) and of course many new variational principles such as

$$I_{1,1}(u) = \Phi^*(\Lambda u) - \Phi(u),$$

which corresponds to $\lambda = 1$ and $\mu = 1$. (Received January 20, 2015)

1109-35-65 **Brian Pigott** (raynorsg@wfu.edu), Winston Salem, NC 27104, and **Sarah Raynor*** (raynorsg@wfu.edu). *Asymptotic Stability of KdV Solitons in Weighted H^s spaces.*

In this work, we consider the stability of solitons for the KdV equation below the energy space, using spatially-exponentially-weighted norms. Using a combination of the I-method and spectral analysis following Pego and Weinstein, we are able to show that, in the exponentially weighted space, the perturbation of a soliton decays exponentially for arbitrarily long times. The finite time restriction is due to a lack of global control of the unweighted perturbation. (Received January 20, 2015)

1109-35-71 **Emine Celik*** (emine.celik@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Broadway and Boston, Lubbock, TX 79409-1042, and **Luan Thach Hoang** and **Thinh Tri Kieu**. *General Forchheimer-Ward equations for compressible fluids.*

We study generalized Forchheimer flows in porous media for compressible fluids including isentropic gases and slightly compressible fluids. By using J.C. Ward's dimension analysis we derive a doubly nonlinear parabolic equation for appropriately defined "pseudo-pressure". The volumetric flux boundary condition is then converted naturally to a time-dependent Robin-type boundary condition. We establish both interior and global L^∞-estimates for the pseudo-pressure in terms of the initial and boundary data. The proofs rely upon a modification of the Moser's iteration and a version of trace theorem suitable for the considered Robin-type boundary condition. This is joint work with Luan Hoang and Thinh Kieu. (Received January 20, 2015)

1109-35-116 **Zhongwei Shen*** (zzs0004@auburn.edu), Auburn University, 221 Parker Hall, Auburn, AL 36830. *Front propagation in reaction-diffusion equations.*

Front propagation phenomenon in reaction-diffusion equations has been attracting a lot of study due to its applications in scientific areas such as biology, chemical kinetics, combustion theory and so on. In this talk, I will present the developments of front propagation in diffusive media of monostable type, bistable type and ignition type, with the focus on traveling waves in homogeneous media and their generalizations in heterogeneous media. (Received January 27, 2015)

1109-35-123 **Bingtuan Li*** (bing.li@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Sharon Bewick**, **Jin Shang** and **William F Fagan**. *Persistence and spread of a species with a shifting habitat edge.*

We discuss a reaction-diffusion model that describes the growth and spread of a species along a shifting habitat. It is assumed that the linearized species growth rate is positive near positive infinity and is negative near negative infinity. We show that the persistence and spreading dynamics depend on the speed of the shifting habitat edge c and a number c* that is determined by the maximum linearized growth rate and the diffusion coefficient. We demonstrate that if c>c* then the species will become extinct in the habitat, and that if c<c* then the species

will persist and spread along the shifting habitat gradient at an asymptotic spreading speed c*. (Received January 27, 2015)

1109-35-129 **Necibe Tuncer*** (ntuncer@fau.edu), **Hayriye Gulbudak**, **Vincent Cannataro** and **Maia Martcheva**. *Identifiability Issues In A Nested Model Of Immuno-Epidemiological Model: The case of Rift Valley Fever Virus.*

In this talk, I will present a mathematical model that links immunological model and epidemiological model. This model allows us to understand dynamical interplay of infectious diseases at two different scales; immunological response of the host at individual scale and the disease dynamics at population scale. Once the host is infected, it triggers the immune response which produces anitgen-specific antibodies to clear the pathogen. The pathogen and antibody levels are often monitored in laboratory experiments. But how can we use the data generated in the laboratory experiments to estimate the parameters of the immunological model. Clearly, the parameters of the within-host immunological model has an effect of the epidemiological characteristics of disease such as reproduction number and prevalence. I will present the identifiability issues in parameter estimation of the immunological model. (Received January 28, 2015)

1109-35-130 **Fatin Alawam*** (alawamf@uab.edu), Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294, and **Ian Knowles**, Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294. *Parameter Estimation for a Nonlinear Parabolic System arising from Oilfield Modeling.* Preliminary report.

The subsurface flow of weakly compressible fluids such as oil and water is governed by a nonlinear parabolic system of partial differential equations. A crucial precursor to the practical modeling of such multi-phase flow is the estimation of the associated subsurface parameters, such as permeability, throughout the whole region under study using measurements obtained from a limited number of discrete locations. The combination of the natural instabilities associated with an inverse problem and the presence of delta functions that model the flow at the discrete locations gives rise to a very difficult inverse problem. We show that these difficulties can be successfully circumnavigated by the use of a new variational approach for this problem. (Received January 28, 2015)

1109-35-138 **Brian Pigott*** (pigottbj@wofford.edu), Department of Mathematics, Wofford College, 429 North Church Street, Spartanburg, SC 29303, and **Sarah Raynor** (raynorsg@wfu.edu), Department of Mathematics, Wake Forest University, PO Box 7388, Winston-Salem, NC 27109. *Asymptotic stability for KdV solitons in weighted spaces via iteration.*

We consider the KdV equation in exponentially weighted spaces introduced by Pego and Weinstein. We show that the perturbation (weighted and unweighted) is locally well-posed in the Besov space $X^{1,1/2,1}$. This local well-posedness result is then iterated to establish asymptotic stability for KdV solitons in H^1. (Received January 28, 2015)

1109-35-139 **Zhiwu Lin***, 490 stedford ln, Johns creek, GA 30097. *Stability of traveling waves of Gross-Pitaevskii equation.*

The Gross-Pitaevskii equations are widely used in modeling superfluids and Bose-Einstein condensates. The GP equation has traveling waves solutions which have non-vanishing limit at infinity, first discovered by physicists (Jones, Roberts et al.) in 1980s. The existence of such traveling waves has been studied a lot in recent years by Betheul, Saut, Maris and many others. However, the stability and dynamical behaviors of these traveling waves are not well understood. With Zhengping Wang and Chongchun Zeng, we proved a nonlinear stability criterion for 3D traveling waves as conjectured in the physical literature, under a non-degeneracy assumption. Moreover, the unstable (stable) manifolds are constructed near unstable traveling waves.This result is also extended for general nonlinear terms and higher dimensions. We also proved that any 2D traveling wave of (GP) is transversely unstable and located the sharp interval for unstable transverse wave numbers. (Received January 28, 2015)

1109-35-159 **Nam Q. Le*** (nqle@indiana.edu), Department of Mathematics, Indiana University, Bloomington, 831 E 3rd St, Bloomington, IN 47405. *Global second derivative estimates for the second boundary value problem of the prescribed affine mean curvature equation.*

The second boundary value problem of the prescribed affine mean curvature equation is a nonlinear, fourth order, geometric partial differential equation. It was introduced by N. S. Trudinger and X. J. Wang in 2005 (The affine plateau problem, *J. Amer. Math. Soc.* **18**(2005), 253-289) in their investigation of the affine Plateau problem in affine geometry. In this talk, we discuss recent developments in obtaining global second derivative estimates for this equation when the affine mean curvature is not necessarily bounded and does not have a fixed sign.

A key ingredient in these developments is the boundary regularity for the linearized Monge-Ampere equation. (Received January 30, 2015)

1109-35-160 **Cameron J Browne*** (cameron.j.browne@vanderbilt.edu). *Within-host virus models with cell infection-age structure.*

Modeling of viruses, such as HIV, has been an extensive area of research over the past two decades. In order to describe the heterogeneities of the infected cell lifecycle, the standard ODE within-host virus model can be generalized by incorporating first order hyperbolic PDEs representative of infected cells stratified by infection-age. In this talk, I will discuss recent results in the analysis of these within-host virus models with cell infection-age structure. First, I consider the model with multiple virus strains. For each viral strain, a quantity called the reproduction number is defined. The main result is that the single-strain equilibrium corresponding to the virus strain with maximal reproduction number is a global attractor, i.e. competitive exclusion occurs. As an application of the model, HIV evolution is considered and simulations are conducted. In particular, we consider the effect of CTL (Cytotoxic T Lymphocyte) immune response acting at different times in the infected-cell lifecycle based on recent studies demonstrating superior viral clearance efficacy of certain CTL clones that recognize infected cells early in their lifecycle. Interestingly, explicit inclusion of early recognition CTLs can cause oscillatory dynamics. (Received January 30, 2015)

1109-35-162 **Rudi Weikard*** (rudi@math.uab.edu), Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294-1170. *Solving the Camassa-Holm Equation by Inverse Scattering.*

The Camassa-Holm equation is an integrable system with an associated Lax pair. Therefore it is possible to solve it by an inverse scattering transform. However, the scattering problem is for the left-definite equation $-y'' + 1/4y = \lambda wy$ where w may be of varying sign. The emphasis of the talk lies on the corresponding scattering and inverse scattering problem.

This is joint work with Malcom Brown and Christer Bennewitz. (Received January 30, 2015)

1109-35-164 **M. N. Nkashama*** (nkashama@math.uab.edu), Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294-1170. *Asymptotic behavior for neutral functional PDEs with general boundary conditions.* Preliminary report.

Some recent applications lead to neutral functional partial differential equations. We will present convergence results for initial boundary value problems for neutral functional partial differential equations for which each constant function is a stationary solution. As a special case, we derive asymptotic constancy results for delay functional PDEs. (Received January 30, 2015)

1109-35-173 **Garrett L Otto*** (glotto01@cardmail.louisville.edu), Garrett Otto c/o dept of Mathematics, University of Louisville, 328 natural sciences bldg., Louisville, KY 40292, and **Sharon Bewick**, **Bingtuan Li** and **Bill Fagan**. *Phenologically Explicit Reaction-Diffusion Model.*

We discuss a phenologically explicit reaction-diffusion model to analyze the spatial spread of an annual species. It is applicable to an insect species with three explicit life stages: adult, larval, and pupae, and a fourth implicit egg stage modeled as a time delay between oviposition and emergence as a larva. To account for the phenology (biological timing) of emergence of adults from the pupal stage and oviposition, we introduce two time dependent phenological distributions. This allows us to directly accommodate a wide variety of alternative phenologies into our model. In the case impulsive emergence , impulsive ovipostion and immobile larvae we are able to find an explicit expression for the spreading speed. We offer some interpretation of the impact of phenological parameters in this case on the spreading speed. We also consider other biological scenarios, where we use numerical simulation to study the effects of phenology on spreading speed, addressing cases with emergence and oviposition windows of finite width as well as for mobile larvae. (Received January 30, 2015)

1109-35-178 **Cao Tien Dat** and **Igor Verbitsky***, Department of Mathematics, University of Missouri, Columbia, MO 65211. *Quasilinear elliptic equations with singular gradient terms of natural growth.*

We give necessary and sufficient conditions for the existence of solutions to quasilinear elliptic equations with singular natural growth in the gradient terms of the type $-\Delta_p v = b\,\frac{|\nabla v|^p}{v} + \sigma$ on $\mathbf{R^n}$, where $v > 0$, $b > 0$, and $\sigma \geq 0$ is an arbitrary locally integrable function, or measure, and $\Delta_p u = \mathrm{div}(\nabla u|\nabla u|^{p-2})$ is the p-Laplacian, $p > 1$. Sharp global pointwise estimates and regularity properties of solutions are obtained. The results are new even in the classical case $p = 2$. This is joint work with Cao Tien Dat. (Received January 30, 2015)

1109-35-180 **Karthik Adimurthi*** (kadimu1@lsu.edu), 303 Lockett Hall, Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803, and **Cong Phuc Nguyen** (pcnguyen@math.lsu.edu), 303 Lockett Hall, Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *End point weighted global gradient estimates for quasilinear equations with applications.*

A weighted norm inequality involving A_1 weights is obtained at the natural exponent for gradients of solutions to quasilinear elliptic equations in Reifenberg flat domains. Certain gradient estimates in Lorentz-Morrey spaces below the natural exponent are also obtained as a consequence of our analysis. We use these estimates to prove existence of solutions to quasilinear elliptic equations with gradient term on the right. (Received February 01, 2015)

1109-35-186 **Dat Tien Cao***, Department of Mathematics, University of Missouri, Columbia, MO 65211, and **Igor E. Verbitsky**, Department of Mathematics, University of Missouri, Columbia, MO 65211. *Potential theory for sublinear elliptic equations.*

We study weak solutions to the homogeneous quasilinear elliptic equation $-\Delta_p u = \sigma\, u^q$ on $\mathbb{R}^n$ in the case $0 < q < p-1$ (sub-natural growth), where $\Delta_p u = \nabla \cdot (\nabla u |\nabla u|^{p-2})$ is the p-Laplacian and σ is a nonnegative function (or measure) on $\mathbb{R}^n$. We will introduce new nonlinear potentials of Wolff type associated with this problem, and give necessary and sufficient conditions for the existence of a positive solution, together with bilateral pointwise estimates. This is joint work with Igor E. Verbitsky. (Received January 31, 2015)

1109-35-191 **Paul G. Schmidt*** (pgs@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849-5310, and **Monica Lazzo** (monica.lazzo@uniba.it), Dipartimento di Matematica, Universita di Bari, via Orabona 4, 70125 Bari, Italy. *Blow-up at the boundary in polyharmonic elliptic equations with power-type nonlinearities.*

We study radial solutions with finite exit radius of semilinear elliptic PDEs involving an integer power of the Laplacian and a power-type nonlinearity with exponent greater than 1. Depending on the sign and monotonicity of the nonlinearity, two very different types of blow-up behavior are observed. Type-1 solutions diverge to infinity or negative-infinity; their blow-up profile is by now fairly well understood. Type-2 solutions, which do not occur in the classical second-order case, are unbounded from above and from below, oscillating wildly with ever-increasing amplitude and frequency; details of their blow-up behavior are just beginning to emerge. Our analysis employs dynamical-systems methods, applied to an associated system of asymptotically autonomous ODEs. (Received January 31, 2015)

1109-35-195 **Fang Li**, **Xing Liang** and **Wenxian Shen*** (wenxish@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36830. *Spreading Speeds and Semi-Wave Solutions of Diffusive KPP Equations with a Free Boundary in Time Almost Periodic Environments.* Preliminary report.

The current talk is concerned with spreading speeds and semi-wave solutions of diffusive KPP equations with a free boundary in time almost periodic environments. It first discusses the criteria for the spreading to occur in such equations. It then provides a characterization of the spreading speeds and shows the existence of almost periodic semi-wave solutions in the case that the spreading occurs. It should be pointed out that the spreading may not occur in diffusive KPP equations with a free boundary. This talk is based my joint work with Fang Li and Xiang Liang. (Received January 31, 2015)

1109-35-206 **Timo Heister*** (heister@clemson.edu), **Mary F Wheeler** and **Thomas Wick**. *A parallel solution approach for crack propagation using adaptive mesh refinement.*

We present an algorithm based on the active set strategy to simulate crack propagation using a quasi-static fracture model. The crack is discretized using a phase-field approach, which allows merging and joining of cracks. The non-linear system is discretized using the Finite Element method and solved in a monolithic fashion. We include a new strategy for adaptive mesh refinement. The whole scheme is parallelized and scales to a large number of cores. (Received February 01, 2015)

1109-35-207 **Georg Hetzer*** (hetzege@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849-5310. *Trajectory Attractor for a Reaction-Diffusion Problem from Climate Modeling.* Preliminary report.

Energy balance climate models lead to reaction-diffusion problems with slow diffusion and a set-valued reaction term on the 2-sphere. A hysteresis term accounts for a frequent repetition of sudden and fast warming followed by much slower cooling as observed from paleoclimate proxy data. Existence of global solutions and of a trajectory attractor will be discussed. (Received February 01, 2015)

1109-35-211 **Gieri Simonett*** (gieri.simonett@vanderbilt.edu), Department of Mathematics, Vanderbilt University, Nashville, TN 37240, and **Jan Prüss** and **Rico Zacher**. *On a thermodynamically consistent Stefan problem with surface tension.*

The model considered is derived from fundamental principles in physics and thermodynamics. Existence of solutions and stability properties of equilibria will be investigated. It will pointed out that all equilibria are located at the critical points of an entropy functional, and it will be shown that multiple-equilibria comprise unstable configurations. (Received February 01, 2015)

1109-35-215 **Craig Cowan*** (craig.cowan@umanitoba.ca) and **Shangbing Ai**. *Perturbations of Lane-Emden equations.* Preliminary report.

We consider some perturbations of the Lane-Emden equation given by

$$-\Delta u + a(x)\cdot\nabla u + V(x)u = u^p + |\nabla u|^q \quad \text{ in } R^N$$

where $a(x)$ and $V(x)$ satisfy certain decay assumptions. We prove the existence of positive classical solutions. This is joint work with Shangbing Ai. (Received February 01, 2015)

1109-35-220 **Marcelo M Disconzi*** (marcelo.disconzi@vanderbilt.edu), 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240. *The Einstein-Navier-Stokes system.*

We consider Lichnerowicz's formulation of the relativistic Navier-Stokes equations coupled to Einstein's equations. We show that the system is well-posed and has a well-defined speed of propagation of disturbances that is at most the speed of light. Implications for a formulation of a relativistic theory of viscous fluids are discussed. (Received February 02, 2015)

1109-35-223 **Thomas Hagen*** (thagen@memphis.edu), 367 Dunn Hall, Department of Mathematical Sciences, The University of Memphis, Memphis, TN 38152. *Analytical problems in the theory of thin free films.*

The theory of thin free films provides robust models for viscous fluid sheets and films forming in the ambient air. Models are given under various simplifying assumptions in the form of nonlinear transport equations coupled with elliptic momentum balances in low dimensions.

This presentation will focus on central analytical problems pertaining to the solvability of the governing equations and regularity of the linearized semigroup. To this end, we will make use of methods from complex analysis, spectral and operator theory as well as pde specific techniques. Part of this work was done jointly with S. Ceci. (Received February 02, 2015)

1109-35-228 **Atanas G. Stefanov*** (stefanov@ku.edu), 1460, Jayhawk Blvd, Department of Mathematics, Lawrence, KS 66045. *Some recent developments in the spectral stability of waves in Hamiltonian PDE's.*

We consider the spectral stability of special solutions of some Hamiltonian PDE's, mostly traveling waves. In the last ten years, there have been several important developments in the theory of instability indices counting formulas, most notably the 2004 work of Kapitula-Kevrekidis-Sandstede. We present several new results in this direction (which are notably not covered by the existing results) including index counting for second order in time equations, KdV type problems on the line, as well as the stability of peakons of the Ostrovsky/short pulse problem. In all of our examples, we have a complete characterization of the stability of the waves. This research was carried out in collaboration with (various subsets of) S. Hakkaev, T. Kapitula, M. Stanislavova. (Received February 02, 2015)

1109-35-231 **Hai Dang*** (dang@math.msstate.edu), Mississippi State, MS 39762. *On a strong comparison principle for the p-Laplacian.*

Consider the problems

$$\begin{cases} -\Delta_p u = f \ \text{ in } \Omega, \ \ u=0 \ \text{ on } \partial\Omega, \\ -\Delta_p v = g \ \text{ in } \Omega, \ \ v=0 \ \text{ on } \partial\Omega, \end{cases}$$

where Ω is a bounded domain in $\mathbb{R}^n$ with smooth boundary $\partial\Omega$, $\Delta_p z = div(|\nabla z|^{p-2}\nabla z), p>1$. We prove a strong comparison principle that allows $f-g$ to change sign. An application to singular asymptotically p-linear boundary problems is given. (Received February 02, 2015)

1109-35-240 **David Cruz-Uribe**, **Moen Kabe*** (kabe.moen@ua.edu) and **Rodney Scott**. *Degenerate Sobolev spaces, elliptic equations, and matrix A_p weights.*

We will give a brief introduction into the theory of matrix weighted Sobolev spaces. As a result we derive local regularity for non linear elliptic equations when the defining matrix belongs to matrix A_p. (Received February 02, 2015)

1109-35-245 **Michael Frazier*** (frazier@math.utk.edu), Department of Mathematics, University of Tennessee, 1403 Circle Drive, Knoxville, TN 37996-1320, and **Igor Verbitsky** (verbitskyi@missouri.edu), Department of Mathematics, University of Missouri - Columbia, Columbia, MO 65211. *Existence of positive solutions to certain Schrödinger equations.* Preliminary report.

Given a smooth bounded domain Ω and a nonnegative potential $q \in L^1_{loc}(\Omega)$, we consider the time-independent homogeneous Schrödinger equation $(-\triangle - q)\varphi = 0$ in Ω with $\varphi = 1$ on $\partial\Omega$. We obtain sufficient conditions for the existence of a positive weak solution φ. These conditions are that a certain operator be bounded with norm less than 1 on $L^2(q)$, and that $CP^*(\delta q)$, where δ is the distance to the boundary and P^* denotes the balyage, be exponentially integrable on the boundary of Ω for a sufficiently large constant C. With different constants, conditions of the same form are necessary. The main tool used in the proof is a result of Frazier-Nazarov-Verbitsky yielding kernel estimates for operators obtained from Neumann series. (Received February 02, 2015)

1109-35-262 **Pablo Seleson*** (selesonpd@ornl.gov), Oak Ridge National Laboratory, One Bethel Valley Road, P.O. Box 2008, MS 6164, Oak Ridge, TN 37831, and **Youn Doh Ha**, **Samir Beneddine** and **Serge Prudhomme**. *A Concurrent Multiscale Blending Scheme for Local/Nonlocal Coupling.*

Many complex systems, such as those involving material failure or anomalous transport, are not well described by classical local continuum models. To properly describe such systems, nonlocal models have been proposed. In solid mechanics, peridynamics (PD) has been proposed to model cracks and their evolution. As opposed to classical continuum mechanics (CCM) models, which depend on deformation gradients, PD models depend on finite deformation vectors and thus they remain valid along discontinuities. Cracks can then be naturally represented in PD. Models in PD are based on integro-differential equations, which make them computationally more expensive than CCM models. As a consequence, efficient and accurate simulations of PD problems involving cracks can be achieved by applying PD models only in critical regions, where cracks are present or may be generated, whereas employing CCM models elsewhere, where displacement fields are smooth. The challenge is to design proper algorithms to concurrently couple these local and nonlocal models. Using inherent connections between PD and CCM, we derive blending schemes for local/nonlocal coupling, which avoid common artifacts present in these types of methods. We demonstrate the performance of the coupling schemes analytically and numerically. (Received February 04, 2015)

1109-35-264 **Wenzhang Huang*** (huangw@uah.edu), 301 Sparkman Dr., Huntsville, AL 35899. *Traveling Wave Solutions for Some Classes of Diffusive Predator-Prey Models.* Preliminary report.

We investigate the traveling wave solutions for several types of diffusive predator-prey systems that have served as models to study the dynamics of predator-prey interaction in the spatially inhomogeneous environments. The method used to show the existence of traveling waves and to identify minimum wave speed consists of two steps. First we obtain globally defined solutions by a shooting argument that is a modification of a recently developed method. We then show the convergence of these global solutions to an interior equilibrium point by the construction of a Liapunov function. (Received February 02, 2015)

1109-35-303 **Shangbing Ai*** (ais@uah.edu), 301 Sparkman Drive, Huntsville, AL 35899, and **Reem Albashaireh**. *Traveling wave solutions for a chemotaxis model.* Preliminary report.

The talk concerns the existence and stability of traveling wave solutions for a chemotaxis model, which consists of a coupled reaction-diffusion equations. Existence of traveling waves is obtained by the construction of an invariant set, and the stability of these waves (in some special cases) is proved by the study of their spectrum. (Received February 03, 2015)

1109-35-307 **Tzu-Chu Lin*** (lin@uwm.edu), Department of Mathematical Sciences, University of Wisconsin-Milwaukee, P.O.Box 413, Milwaukee, WI 53201. *Helmholtz's equation and its inverse problems.*

Integral equation methods are the dominant methods for solving the exterior boundary value problems of Helmholtz's equation. The partial differential operator and the integral operators used in solving Helmholtz's equation are linear operators. The inverse problems of these problems, however, are nonlinear and ill-posed. In this talk, we will give a brief introduction to one of these problems. (Received February 03, 2015)

1109-35-320 **Jerome Goddard II*** (jgoddard@aum.edu) and **R. Shivaji** (r_shivaj@uncg.edu).
Stability results for positive solutions for classes of semilinear elliptic boundary value problems with nonlinear boundary conditions.

In this talk, we will investigate the stability properties of positive steady state solutions of semilinear initial-boundary value problems with nonlinear boundary conditions. In particular, we will employ a Principle of Linearized Stability for this class of problems to prove sufficient conditions for stability and instability of positive steady state solutions. These results shed some light on the combined effects of the reaction term and the boundary nonlinearity on stability properties. (Received February 04, 2015)

37 ► Dynamical systems and ergodic theory

1109-37-40 **Gregory Varner*** (gvarner@jbu.edu), 2000 West University Street, Siloam Springs, AR 72761. *Invariant Measure for the Time-Dependent Navier-Stokes Equations.*

We will discuss recent results on the existence and uniqueness of time-invariant measure for the time-dependent two-dimensional Navier-Stokes equations on the sphere under a random kick-force. In particular, for the time-periodic deterministic forces the problem is reduced to the study of the associated Markov chain and necessary conditions for the existence and uniqueness of the measure are presented. Possible extensions to the full time-dependent equations are also discussed. (Received January 15, 2015)

1109-37-87 **Israel Ncube***, Alabama A & M University, Department of Mathematics, 4900 Meridian Street North, Huntsville, AL 35762. *Existence and stability of synchronous and mirror-reflecting equilibria of a neural network.*

We consider a network of three identical neurons with delayed output. The model for such a network is a system of nonlinear delay differential equations, consisting of multiple discrete delays. Our goal in this article is to establish the existence, and to give a detailed account of the linear stability, of synchronous and mirror-reflecting equilibria. (Received January 24, 2015)

1109-37-92 **Sergey Bezuglyi*** (sergii-bezuglyi@uiowa.edu), University of Iowa, Iowa City, IA 52241. *Measures on path spaces of Bratteli diagrams.*

We are interested in finding all ergodic invariant measures and their supports for a homeomorphism T of a Cantor set Y. It is known that any aperiodic homeomorphism T admits its realization as a Vershik map acting on the path space X_B of a corresponding Bratteli diagram B. The structure of B helps to clarify the dynamical properties of T.

We are going to discuss the following problems in the talk:

(A) Given a subdiagram B' of B and an ergodic measure μ on X_B, under what condition on B' is the subset $X_{B'}$ of positive measure μ in X_B?

(B) Let ν be a measure supported by the path space $X_{B'}$ of a subdiagram $B' \subset B$. Then ν is extended to the subset $\mathcal{R}(X_{B'})$ by invariance with respect to the tail equivalence relation $\mathcal{R}$. Under what conditions is $\nu(\mathcal{R}(X_{B'}))$ finite (or infinite)?

(C) Let B be a Bratteli diagram of finite rank k. It is known that B can support at most k ergodic (finite and infinite) measures. Is it possible to determine which properties of incidence matrices of B would guarantee exactly k ergodic measures?

Our main results give affirmative answers (in some cases, partial answers) to the questions above. (Received January 25, 2015)

1109-37-99 **David Samuel Simmons*** (simmons.465@osu.edu), 231 W. 18th St, Columbus, OH 43210. *Geometric (re)definitions of Patterson–Sullivan measures.*

Given a geometrically finite Kleinian group G, two naturally associated objects are the limit set Λ and the Patterson–Sullivan measure μ. In this talk we discuss the question of whether or not μ can be "defined in terms of" Λ. The answer turns out to depend on the Poincaré exponent δ and the extremal cusp ranks $k_{\min}$ and $k_{\max}$; namely, if δ is strictly between $k_{\min}$ and $k_{\max}$, then μ cannot be defined in terms of Λ via a Hausdorff or packing measure construction based on a gauge function. (Received January 26, 2015)

1109-37-118 **Semyon Litvinov*** (snl2@psu.edu), 76 University Drive, Hazleton, PA 18222, and **Vladimir Chilin**. *On positive linear operators in L^p-spaces, $1 \leq p \leq \infty$, of a semifinite measure.* Preliminary report.

We show that, in the case of semifinite measure, Garsia's class of the so-called positive $L^1 - L^\infty$ contractions (see also Krengel's book) coincides with the class of positive Dunford-Shcwartz operators. (Received January 27, 2015)

1109-37-136 **Zhiqiang Li***, lizhiqiangfly@gmail.com. *Ergodic theory of expanding Thurston maps.*

Thurston maps are a class of branched covering maps on the 2-sphere that arose in W. Thurston's characterization of postcritically finite rational maps. By imposing a natural expansion condition, M. Bonk and D. Meyer investigated a subclass of Thurston maps known as expanding Thurston maps, which turned out to enjoy nice topological, metric, and dynamical properties.

This talk will be a brief summary of known results and new developments on the ergodic theory for expanding Thurston maps. We will first introduce expanding Thurston maps with some motivation from their connection to other topics of mathematics. We will then discuss measures of maximal entropy, and equilibrium states for such maps. Equidistribution results of periodic points and preimages will also be discussed.

If time permits, we will also mention some results on the weak expansion properties of expanding Thurston maps, which are closely related to the existence of the measures mentioned above. (Received January 28, 2015)

1109-37-141 **Elizabeth Sattler***, elizabeth.sattler.1@ndsu.edu. *Fractal Dimension of the Canopy of Tree Fractals.* Preliminary report.

Tree fractals are constructed using an iterated function system that contains the identity map. The canopy of a tree fractal, defined as the set of points in the fractal which is fixed by the contractive maps in the IFS, appears in the limiting case, but is absent in any finite iteration. By finding a topological pressure function and appropriate measure supported on the canopy, we show that the Hausdorff dimension of the canopy of a tree fractal must be equal to the unique zero of the topological pressure function. (Received January 28, 2015)

1109-37-144 **Dogan Comez*** (dogan.comez@ndsu.edu), Department of Mathematics, NDSU, 1210 Albrecht Blvd., Fargo, ND 58108. *Recurrence theorems for admissible superadditive processes.* Preliminary report.

This talk concerns recurrence properties of strongly bounded admissible superadditive processes. In particular, an analogue of Furstenberg's multiple recurrence theorem for such processes will be presented. (Received January 28, 2015)

1109-37-149 **Carl P Dettmann*** (carl.dettmann@bris.ac.uk), University Walk, Bristol, England BS8 1TW, United Kingdom. *How sticky is the chaos/order boundary?*

Hamiltonian dynamical systems with mixed phase space are ubiquitous, but notoriously poorly understood, partly due to complicated structure of the boundary between chaotic and ordered regions. Mushroom billiards were introduced by Bunimovich in 2001 as an example of sharply divided phase space. Here, a billiard comprises a point particle moving uniformly in a specified region except for mirror-like reflections from the boundary, here shaped like a mushroom with a semicircular cap and polygonal stem. Later, Altmann and others pointed out that almost all mushroom billiards have parabolic orbits embedded in the chaotic region leading to "stickiness," algebraic slowing of the chaotic expansion and mixing properties. A zero measure set of mushroom parameters for which these orbits are absent, and the remaining stickiness, originating from the boundary of the chaotic region itself, will be characterised using Diophantine approximation methods. The results may shed light on the parameter dependence of stickiness in more general Hamiltonian systems. (Received January 29, 2015)

1109-37-182 **Jan P. Boroński***, jan.boronski@osu.cz, and **Piotr Oprocha**. *More on constructions of R.H. Bing's pseudo-circle in surface dynamics.*

In 1951 R.H. Bing constructed a pseudo-circle, the unique hereditarily indecomposable circle-like cofrontier. The pseudo-circle, a fractal-like object, often makes its appearences as an attractor in dynamical systems. Motivated by the results in [1], we study circle maps f that give the pseudo-circle as the inverse limit space $lim_{\leftarrow}(\mathbb{S}^1, f)$. We show that any such map exhibits the following properties: (1) there exists an entropy set for f with infinite topological entropy; i.e. $h(f) = \infty$; (2) the rotation set $\rho(f)$ is a nondegenerate interval.

This shows that the Anosov-Katok type constructions of the pseudo-circle as a minimal set in volume-preserving smooth dynamical systems, or in complex dynamics, obtained previously by Handel, Herman and Chéritat cannot be modeled on inverse limits.

[1] Boronski J.P.; Oprocha P., Rotational chaos and strange attractors on the 2-torus, Mathematische Zeitschrift DOI10.1007/s00209-014-1388-1 (Received January 31, 2015)

1109-37-201 **Artur Avila**, **David Damanik** and **Zhenghe Zhang*** (zzhang@rice.edu). *The Subshift Conjecture.*

In the talk we discuss Barry Simon's subshift conjecture, which states that the spectrum of 1D discrete Schrödinger operator associated with a minimal aperiodic subshift has zero Lebesgue measure. We use approximation with subshifts of finite type along with an analysis of the spectra associated with periodic orbits in them to produce a counterexample. This is joint work with Artur Avila and David Damanik. (Received February 01, 2015)

1109-37-202 **máté wierdl*** (wierdlmate@gmail.com), dept of math sci, univ of memphis, memphis, TN 38152. *Differentiation and the ergodic theorem compared.*

I will examine what happens when differentiation and ergodic averaging are combined. T

here has been quite a lot of work done in comparing ergodic theorems to differentiation results.

It's well known that the Hardy-Littlewood maximal theorem (the essential result behind the Lebesgue differentiation theorem) also implies the pointwise ergodic theorem.

Some research also showed essential differences between differentiation and ergodic theorems.

Continuing work I started with Joe Rosenblatt 25 years ago, I show some interesting interplay between the two averaging, ergodic and differentiation.

The work was inspired by a question I was asked at this meeting one year ago in Knoxville. (Received February 01, 2015)

1109-37-210 **Mrinal K Roychowdhury*** (roychowdhurymk@utpa.edu), 1201 West University Drive, Edinburg, TX 78539, and **Nina Snigireva** (nina.snigireva@ucd.ie), School of Mathematical Sciences, University College Dublin, Belfield, Dublin 4, Ireland. *Quantization dimension and fractal dimensions.*

Quantization dimension measures the speed at which the specified measure of the error, when a continuous probability measure is approximated by a probability measure with finite support containing n points, tends to zero as n tends to infinity. Recently, it has been shown that with respect to geometric mean error the quantization dimension of a probability measure has a relationship with some other dimensions of the measure. My talk will be about it. (Received February 01, 2015)

1109-37-212 **James T Campbell*** (jcampbll@memphis.edu), Department of Mathematical Sciences, Dunn Hall 373, Memphis, TN 38152, and **Jared T Collins**, **Steven Kalikow**, **Raena King** and **Randall McCutcheon**. *An Alpern tower independent of a given partition.* Preliminary report.

Given a measure-preserving transformation T of a probability space $(X, \mathcal{B}, \mu)$ and a finite measurable partition P of X, we show how to construct an Alpern tower of any height whose base is independent of the partition P. That is, given a natural number N, there exists a Rohlin tower of height N, with base B and error set E, so that B is independent of P, and $T(E) \subset B$. (Received February 01, 2015)

1109-37-219 **Nandor J Simanyi*** (simanyi@uab.edu), UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170, and **Caleb C Moxley** (ccmoxley@uab.edu), UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170. *On homotopical rotation numbers.* Preliminary report.

In a billiards system in $\mathbb{R}^n/\mathbb{Z}^n \setminus \{\text{obstacles}\}$ one lifts the billiard orbit to the universal covering space $\mathbb{R}^n$ of $\mathbb{R}^n/\mathbb{Z}^n$, and takes the average displacement vector in $\mathbb{R}^n$ as the rotation vector of the considered orbit. For systems with one obstacle, the topological study of the arising rotation vectors and sets was carried out by A. Blokh, M. Misiurewicz and myself in 2006. The next step is to consider 2D billiards in a billiard table Q with highly non-commutative (hyperbolic) fundamental group $\pi_1(Q)$, and to lift the billiard orbits to the Cayley graph of the group $\pi_1(Q)$, and investigate the following: In what directions ω and at what speed s can the lifted path converge to a point on the infinite horizon of (the Cayley graph of) the group $\pi_1(Q)$? The ordered pair (ω, s) will be called the "homotopical rotation number" of the investigated orbit. Initial results for some 2D billiards were obtained by L. Goswick and myself in 2011. We present a research plan, joint with C. Moxley, on getting generalizations of those results for some higher-dimensional billiards with intriguing fundament groups $\pi_1(Q)$. (Received February 02, 2015)

1109-37-222 **Caleb C Moxley*** (ccmoxley@uab.edu) and **Nandor J Simanyi**. *On the rotation set of a 3D flat torus with three obstacles.* Preliminary report.

We report on on-going research regarding the rotation set of a billiard system describing the inertia motion of a point particle in the 3D flat torus with three small, cylindrical, mutually intersecting and orthogonal scatterers.

Members of the rotation set are naturally identified with ordered pairs (ω, s), where ω is an element of the infinite horizon of the fundamental group F_3 of our billiard table (the direction of escaping to infinity), and $s \geq 0$ is the speed of escape. We constructively identify a subset of the full rotation set, containing the closed ball of radius $\frac{1}{\sqrt{3}+\sqrt{2}}$, and provide an upper bound for the radial size of the full rotation set. (Received February 02, 2015)

1109-37-226 **Marta Canadell*** (mcc7@math.gatech.edu) and **Alex Haro** (alex@maia.ub.es). *Computation of normally hyperbolic invariant manifolds.*

In this talk we explain a method for the computation of normally hyperbolic invariant manifolds (NHIM) in discrete dynamical systems. The method is based in finding a parameterization for the manifold formulating a functional equation. We solve the invariance equation using a Newton-like method taking advantage of the dynamics and the geometry of the invariant manifold and its invariant bundles. The method allows us to compute a NHIM and its internal dynamics, which is a-priori unknown. We implement this method to continue the invariant manifold with respect to parameters, and to explore different mechanisms of breakdown.

This is a joint work with Alex Haro. (Received February 02, 2015)

1109-37-235 **Brian C Ryals*** (ryals@usc.edu) and **Bob Sacker** (rsacker@usc.edu). *Revisiting Global Stability in the 2D Ricker Model.* Preliminary report.

This talk will focus on an analytic and numerical study of the 2D Ricker Competition Model, a four parameter system. The interest will be determining conditions on the parameters where one has global attraction to the coexistence fixed point. We will summarize prior work on the model where a rather strict set of assumptions were used, and show that there is a large set of parameters not covered in previous studies. We will show numerically some of the troublesome issues one encounters in the more general case, in spite of the seemingly simple appearance of the equations. (Received February 02, 2015)

1109-37-243 **Alexander Blokh*** (ablokh@math.uab.edu), Dept of Math, Birmingham, AL 35294, **Lex Oversteegen** (overstee@uab.edu), Dept of Math, Birmingham, AL 35294, and **Ross Ptacek** and **Vladlen Timorin**. *On families of complex cubic polynomials.*

We discuss dynamical properties of certain families of complex cubic polynomials. (Received February 02, 2015)

1109-37-258 **Tushar Das*** (tdas@uwlax.edu). *Pseudorectifiability and topological rigidity of Kleinian groups and IFSes in infinite-dimensions.*

We begin with a short unified proof of a topological rigidity phenomenon situated in the theories of finite-dimensional Kleinian groups (discrete subgroups of $\mathrm{Isom}(\mathbb{H}^n)$), conformal iterated function systems (both finite and infinite) and rational maps acting on the Riemann sphere, respectively. Roughly speaking, in each of these analogous scenarios, if the Hausdorff dimension of the non-conical limit set is strictly smaller than an integer which equals the Hausdorff and topological dimensions of the limit set, then the entire limit set is contained in a geometric sphere. We introduce a generalization of the notion of rectificability called *pseudorectifiability* to resolve analogous rigidity questions in infinite-dimensional Hilbert space. These results are joint-work with David Simmons (Ohio State) and Mariusz Urbański (North Texas). (Received February 02, 2015)

1109-37-279 **Ernest Fontich** and **Rafael de la Llave*** (rafael.delallave@math.gatech.edu), School of Mathematics, 686 Cherry St., Atlanta, GA 20332, and **Yannick Sire**. *Quasi-periodic and almost periodic solutions in coupled systems.*

We consider systems of coupled hamiltoninas.

We assume that the system is coupled and that the coupling decays suitably fast with the distance (some power law decays suffice).

We assume that the Hamiltonian at each site has KAM tori and hyperbolic fixed points and that satisfies some non-degeneracy conditions.

We present two theorems: One is that if the couplings are weak enough, there is a large measure set of the tori of one site that survive the coupling with the system.

The second theorem asserts that a for a full measure set of the frequencies that survive in the first theorem, we can find orbits in which a sequence of sites is excited with the frequencies. Note that the second theorem does not require that the coupling is small and does not require to excise any measure.

The main technique is an a-posteriori theorem formulated in spaces which are carefully designed to capture the notion of decaying interaction. (Received February 03, 2015)

1109-37-280 **Brian Chapman*** (brian.chapman@ndsu.edu), North Dakota State University, Department of Mathematics, PO Box 6050, Fargo, ND 58108-6050. *Some Properties of the Pascal Adic Transformation and a Related Subsystem.* Preliminary report.

In this talk, we will investigate some properties of the Pascal adic transformation and those of a related subsystem, the Catalan adic transformation. We will discuss the construction of the Catalan adic transformation and show how some selected properties follow from those of the Pascal adic. (Received February 03, 2015)

1109-37-286 **Joanna Furno*** (jfurno@wesleyan.edu) and **Lorelei Koss** (koss@dickinson.edu). *Two fourth-degree families: A comparison of Julia sets.* Preliminary report.

We compare two families of fourth-degree rational functions. These two families have similar critical orbit diagrams, differing only in the placement of one critical point of multiplicity two. We compare and contrast the possibilities for the structure of the Julia sets, giving examples that are the whole sphere, Cantor sets, or similar to the Sierpinski gasket. (Received February 03, 2015)

1109-37-287 **Terrence M. Adams** and **Cesar E. Silva***, Department of Mathematics and Statistics, Williams College, Williamstown, MA 01267. *Weak Rational Ergodicity Does Not Imply Rational Ergodicity.*

We extend the notion of rational ergodicity to β-rational ergodicity for $\beta > 1$. Given $\beta \in \mathbb{R}$ such that $\beta > 1$, we construct an uncountable family of rank-one infinite measure preserving transformations that are weakly rationally ergodic, but are not β-rationally ergodic. The established notion of rational ergodicity corresponds to 2-rational ergodicity. Thus, this paper answers an open question by showing that weak rational ergodicity does not imply rational ergodicity. (Received February 03, 2015)

1109-37-289 **May Mei*** (meim@denison.edu), Department of Mathematics & Computer Science, Denison University, Granville, OH 43023-0810. *Fractal Spectra Arising in Models of Quasicrystals.*

In this talk, we will discuss Cantor sets that appear as spectra of discrete Schrödinger operators with potentials given by primitive invertible substitution sequences. Such operators are a one-dimensional model of quasicrystals, a material whose structure is highly ordered but not periodic. (Received February 03, 2015)

1109-37-292 **Michael P Cohen*** (michael.cohen@ndsu.edu), 1861 39th St S Apt 305, Fargo, ND 58103, and **Robert R Kallman**. *Groups lacking nice topologies in interval and circle dynamics.*

I'll discuss the history of an uncommon phenomenon: groups of cardinality continuum whose algebraic structure precludes the existence of a Polish (separable completely metrizable) group topology. Many of the few known examples arise among full groups of ergodic measure-preserving dynamical systems, as well as their topological analogues. I'll present joint work with Robert R. Kallman, in which we provide new examples of groups lacking Polish topologies arising in the context of the dynamics of one-dimensional manifolds. (Received February 03, 2015)

1109-37-295 **Russell Jeter*** (russell.jeter@outlook.com), Department of Mathematics and Statistics, Georgia State University, 30 Pryor street, Atlanta, GA 30303, and **Igor Belykh** (ibelykh@gsu.edu), Department of Mathematics and Statistics, Georgia State University, 30 Pryor street, Atlanta, GA 30303. *Synchrony in Metapopulations with on-off Stochastic Dispersal: Windows of Opportunity.*

We consider ecological networks in which migration between patches and other intrinsic system parameters are stochastic in nature. We study the role of this stochasticity and how it relates to synchronization, especially in cases when the time scale of the stochastic process is slow with regard the inherent time scale of the system. We find that such a system can favor synchrony, despite the network being disconnected for large time intervals. We also reveal unexpected windows of intermediate switching periods in which metapopulation synchronization becomes stable even though it is unstable in the fast-switching network and/or its static analog where the stochastic connections are replaced by their mean. (Received February 03, 2015)

1109-37-301 **Francesco Cellarosi*** (fcellaro@illinois.edu), 1409 W Green Street, URBANA, IL 61801. *Quadratic Weyl sums, Automorphic Functions, and Invariance Principles.*

In 1914, Hardy and Littlewood published their celebrated approximate functional equation for quadratic Weyl sums. Their result provides, by iterative application, a powerful tool for the asymptotic analysis of such sums. We construct a related, almost everywhere non-differentiable automorphic function, which approximates quadratic Weyl sums up to an error of order one, uniformly in the summation range. This not only implies the approximate functional equation, but allows us to replace Hardy and Littlewood's renormalization approach by the dynamics

of a certain homogeneous flow. The great advantage of this construction is that the approximation is global, i.e., there is no need to keep track of the error terms accumulating in an iterative procedure. Our main application is a new functional limit theorem, or invariance principle, for theta sums. The interesting observation is that the paths of the limiting process share a number of key features with Brownian motion (scale invariance, invariance under time inversion, non-differentiability), although time increments are not independent, the value distribution at each fixed time is distinctly different from a normal distribution. Joint work with Jens Marklof. (Received February 03, 2015)

1109-37-309 **Martin J Schmoll*** (schmoll@clemson.edu), Martin Schmoll, Martin Hall O-229, Clemson University, Clemson, SC 29634. *Loci in strata of meromorphic differentials with special Lyapunov spectrum.* Preliminary report.

We explain and apply some ideas from a recent paper of Grivaux and Hubert, who construct closed $GL(2,\mathbb{R})$ invariant loci in strata of meromorphic differentials with fully degenerate Lyapunov spectrum. We apply those ideas to dynamics on infinite covers and explain possible geometric extension so Grivaux - Hubert. This is work in progress, for that reason we do not make more precise statements in this abstract. (Received February 03, 2015)

39 ► Difference and functional equations

1109-39-214 **Guihong Fan*** (fan_guihong@columbusstate.edu) and **Huaiping Zhu**. *Oscillation and driving mechanism in a model of West Nile virus with time delay.* Preliminary report.

West Nile virus is a typical vector-borne disease which is transmitted to humans or other animals by Culex mosquitoes. For the virus, avian birds serve as amplification hosts, yet vector mosquitoes play a critical role in the transmission and spread of the virus. To investigate the role of vector mosquitoes and the transmission dynamics of West Nile virus, we formulate a system of delay differential equations. Dynamical analysis shows that the population of vector mosquitoes can force the system to oscillate. However the model analysis suggests that the incidental interaction between mosquitoes and birds would not cause oscillations in the system. This result indicates that the population of vector mosquitoes is the fundamental driving factor for the oscillation in disease transmission when considering the impact of temperature. (Received February 01, 2015)

1109-39-234 **Chuanxi Qian*** (qian@math.msstate.edu), Department of Mathematics and Statistics, Mississippi State University, Mississippi State, MS 39762. *Global Attractivity of a Nonlinear Difference Equation of Higher Order and Applications.*

In this talk, we discuss the global attractivity of the following nonlinear difference equation of higher order

$$x_{n+1} = (1 - t_n)x_n + t_n f(x_{n-k}),\ n = 0, 1, \cdots$$

where f is a continuous mapping from an interval I to I, $\{t_n\}$ is an arbitrary sequence in $[0, 1]$ and k is a nonnegative integer. Applications to several difference equation models derived from a variety of biological and physical phenomena are also presented. (Received February 02, 2015)

1109-39-297 **Saber N. Elaydi*** (selaydi@trinity.edu), one Trinity place, san antonio, TX 78212, and **Laila Assas**, **Eddy Kwessi**, **George Livadiotis** and **Brian Dennis**. *Hierarchical models with the eAllee effects and fluctuating habitats.* Preliminary report.

In this talk we introduce a periodic difference equation to model a hierarchical system of multispecies with the strong Allee effect and periodically fluctuating habitat. We develop the mathematical foundation of nonautonomous triangular maps which will be applied to our hierarchical competition model with the strong Allee effect. (Received February 03, 2015)

1109-39-308 **Eddy A Kwessi***, 1 Trinity Place, San Antonio, TX 78212, and **Saber N Elaydi**, **Laila Assas**, **Brian Dennis** and **Georges Livadiotis**. *The study of population resilience subject to the Allee effect using potential functions.* Preliminary report.

In this paper, we study the dynamics of single and multiple populations subject to the Allee effect. We considered is a modified Berverton-holt model with the Allee effect. We show that for one species models, the resilience of the population is explained by a potential function, and we show that under demographic and environmental perturbations, there exists a quasistationary distribution explaining to the short term survival of the population. Extension of potential functions to a two species model is also discussed. (Received February 03, 2015)

1109-39-316 **Chi-Jen Wang*** (cwang463@math.gatech.edu), **Xiaofang Guo**, **Da-Jiang Liu** and **James Evans**. *Lattice differential equation analysis of wave and droplet-like behavior in spatial epidemic models.*

We consider a spatial epidemic model where a population of sick or healthy individual resides on an infinite square lattice. Sick individuals spontaneously recover at rate *p*, and healthy individual become infected at rate O(1) if they have two or more sick neighbors. As *p* increases, the model exhibits a discontinuous transition from an infected to an all healthy state. Relative stability of the two states is assessed by exploring the propagation of planar interfaces separating them (i.e., planar waves of infection or recovery). We find that the condition for equistability or coexistence of the two states (i.e., stationarity of the interface) depends on orientation of the interface. We also explore the evolution of droplet-like configurations (e.g., an infected region embedded in an all healthy state). We analyze this stochastic model by applying truncation approximations to the exact master equations describing the evolution of spatially non-uniform states. We thereby obtain a set of discrete (or lattice) reaction-diffusion type equations amenable to numerical analysis. (Received February 04, 2015)

46 ► *Functional analysis*

1109-46-33 **Ekaterina Nathanson*** (enathanson@ggc.edu), D 1470, 1000 University Center Lane, Lawrenceville, GA 30043, and **Palle Jorgensen**. *A global solution to the Schrodinger equation: from Henstock to Feynman.*

One of the key elements of Feynman's formulation of non-relativistic quantum mechanics is a so-called Feynman path integral. It plays an important role in the theory, but it appears as a postulate based on intuition rather than a well-defined object. No previous attempts to supply Feynman's theory with rigorous mathematics have been satisfactory. In the talk, we consider a new approach to defining the Feynman's path integral, based on the theory developed by P. Muldowney. Muldowney uses the Henstock integration technique, and non-absolute integrability of the Fresnel integrals in order to obtain a representation of the Feynman's path integral as a functional. This approach offers a mathematically rigorous definition supporting Feynman's intuitive derivations. But in his work, Muldowney gives only local in space-time solutions. A physical solution to the non-relativistic Schrödinger equation must be global, and it must be given in the form of a unitary one-parameter group in L2. The purpose of this talk is to show that one-dimensional Muldowney's local solutions may be extended to yield a global solution. Moreover, the global extension can be represented by a unitary one-parameter group acting in L2. (Received January 10, 2015)

1109-46-51 **F Botelho*** (mbotelho@memphis.edu), Department of Mathematical Sciences, Dunn Hall Rm 373, University of Memphis, Memphis, TN 38152. *Surjective Isometries and Hermitian Operators on Zygmund spaces.*

In this presentation we show that surjective linear isometries on the little Zygmund space are integral operators and the bounded hermitian operators are trivial. (Received January 17, 2015)

1109-46-82 **Peter G Casazza*** (casazzap@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Phase Retrieval.*

Over the 100 year history of phase retrieval, it has had broad application to x-ray crystallography, electron microscopy, diffractive imaging, DNA, x-ray tomography and much more. Phase retrieval will even be needed to align the mirrors of the new James Webb Space Telescope scheduled for launch in 2018. We will start with the fundamentals of phase retrieval and its applications which have garnered a dozen Nobel Prizes over the years. Only recently have mathematicians entered this area to give a solid mathematical foundation to phase retrieval. In the second half of this talk we will look at recent advances in the mathematics of phase retrieval. Phase retrieval is a class of highly non-linear problems. (Received January 23, 2015)

1109-46-300 **Bentuo Zheng*** (bzheng@memphis.edu). *Maximal Regularity for Banach Spaces.*

In this talk, maximal L_p-regularity for Banach spaces and several well known results of this topic will be introduced. Recent progress and open problems will be presented. (Received February 03, 2015)

47 ► Operator theory

1109-47-29 **Chang-Pao Chen*** (cpchen@math.nthu.edu.tw), Center for General Education, Hsuan Chuang University, Hsinchu, 30092, Taiwan, and **Jin-Wen Lan** (d937210@oz.nthu.edu.tw), Municipal Jianguo High School, Taipei, 10066, Taiwan. *Estimates of the modular-type operator norm of the general geometric mean operator.* Preliminary report.

In this paper, the modular-type operator norm of the general geometric mean operator is investigated. We give two applications of a new limit process, introduced by the present authors, to the establishment of Pólya-Knopp-type inequalities over spherical cones. Our results not only generalize Persson-Stepanov's and Wedestig's results, but also provide new proofs of these results. (Received January 06, 2015)

1109-47-251 **Anthony Hester*** (ahester1024@gmail.com), 7027 Old Madison Pike, Suite 108, Huntsville, AL. *Fixed Points of Random Operators.*

Traditionally, analysts have demonstrated random fixed points by first proving the existence of fixed points for almost all the deterministic mappings $T_\omega : X \to X$, defined by $T_\omega x = T(\omega, x)$ for each $x \in X$, then showing measurability after glueing together the fixed points produced by the deterministic theory. Since such proofs tend to involve complicated arguments somewhat limited in generality, the question arises can deterministic fixed point theory produce random results directly when viewed from the proper function spaces? In other words, why does $Tf = f$ not follow directly from deterministic theory? In this talk, we examine a case where deterministic theory does imply the existence of a random fixed point. In particular, we shall demonstrate, by constructing an appropriate metric space and applying the Banach contraction principle, that if X is a normed space, $f > g$, and

$$P\left(f(\|Tu - Tv\|) > t\right) \leq P\left(g(\|u - v\|) > t\right)$$

for all $t > 0$ and measurable $u, v : \Omega \to X$, then T has a random fixed point. (Received February 03, 2015)

1109-47-298 **Claudio H Morales*** (morales@math.uah.edu), Department of Mathematics, Huntsville, AL 35899. *Maximal monotone operators in Locally convex spaces.* Preliminary report.

Let X be a topological vector space, and let A from X into 2^{X^*} be a monotone operator. The main purpose of this presentation is to show various extensions of known results for Banach spaces to much general type of spaces. We shall discuss an extension the well known Minty's Lemma for general topological vector spaces under a mild type continuity assumption. This result would allow us to show that certain monotone operators are indeed single-valued. We shall also discuss results for maximal monotone operators. (Received February 03, 2015)

49 ► Calculus of variations and optimal control; optimization

1109-49-24 **Stephen Guffey***, stephen.guffey956@topper.wku.edu. *Optimal Control of a Parabolic PDE System Arising in Wound Healing.* Preliminary report.

We consider a control problem for a system of four parabolic PDEs. The model describes the behavior of oxygen, neutrophils, bacteria, and chemoattractant in a chronic wound, where the control represents the case of oxygen therapy. We wish to find the optimal level of supplemental oxygen to minimize both the bacteria count in the wound as well as the supplemental oxygen supplied. We discuss the existence of solutions for our system, the existence of an optimal control for our model, as well as the classification of the optimality system. (Received December 30, 2014)

1109-49-230 **Jochen Denzler*** (denzler@math.utk.edu). *A study of the oval problem.* Preliminary report.

The oval problem asks to minimize the principal eigenvalue λ of the Schrödinger operator on a closed loop of length 2π, whose potential is the curvature squared. Among the conjectured minimizers, one finds the circle as expected, but it lies within a 1-parameter family of ovals known to have the same principal eigenvalue $\lambda = 1$. The author proved existence of a minimizer, as well as regularity, planarity and convexity, but a full solution of the problem has been missing for over 10 years. The Euler-Lagrange equation for a minimizer, while elusive to solve, displays some promising structure that sheds some new light on the problem. This is work in progress. (Received February 02, 2015)

51 ► Geometry

1109-51-94 **Anja Bankovic*** (anja.bankovic@bc.edu), Department of Mathematics, Boston College, Carney Hall, Chestnut Hill, MA 02467, and **Christopher Leininger**. *Spectral rigidity for q-differential metrics.*

In this talk we will discuss the set of metrics coming from q-differentials defined on closed surfaces of genus g>1. For q>2, we will extend the notion of singular measured foliations and define immersed singular measured foliations. Using immersed singular measured foliations and geodesic currents, we will prove a strong marked length spectral rigidity result for the space of all such flat metrics. This is a joint work with Christopher Leininger. (Received January 26, 2015)

52 ► Convex and discrete geometry

1109-52-19 **Jeremiah D Bartz*** (jbartz@fmarion.edu), Francis Marion University, Department of Mathematics, PO Box 100547, Florence, SC 29502. *Complete Multinets.* Preliminary report.

Multinets are certain configurations of lines and points with multiplicities in the complex projective plane. They appear in the study of resonance varieties of complex hyperplane arrangement complements. In this talk, we will explore complete multinets, a class of multinets which satisfy an additional property, and their connections with $K(\pi, 1)$ arrangements. (Received December 26, 2014)

54 ► General topology

1109-54-107 **Steven Clontz*** (steven.clontz@gmail.com), Parker Hall, Auburn University, AL 36849. *Limited information strategies for a topological proximal game.*

The proximal property was introduced by Jocelyn Bell in 2014 to generalize collectionwise normality and countable paracompactness, and was shown by the author and Gary Gruenhage to characterize Corson compactness among compact spaces. The proximal property was originally characterized by the existence of a winning strategy for the first player in a certain game played on a uniform structure inducing the topology of the space. The author will outline an analogous purely topological game which also characterizes the proximal property, as well as results related to the existence of limited information (k-Markov and k-tactical) strategies in this topological proximal game. (Received January 26, 2015)

1109-54-154 **Jesse T. Prince-Lubawy*** (jprincelubawy@una.edu), One Harrison Plaza, Florence, AL 35632. *Equivalence of $\mathbb{Z}_4$-actions on handlebodies of genus g.*

We consider all orientation-preserving $\mathbb{Z}_4$-actions 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 $V(\Gamma(\mathrm{v}), \mathbf{G}(\mathbf{v})) \simeq V_g/\mathbb{Z}_4$. This algebraic characterization is used to enumerate the total number of $\mathbb{Z}_4$ group actions on such handlebodies, up to equivalence. (Received January 29, 2015)

1109-54-252 **Alan C Bertl*** (acb0039@auburn.edu), Auburn University, Department of Mathematics and Statistics, 221 Parker Hall, Auburn, AL 36849. *Category Theoretic Characterizations of Generalized Inverse Limits.*

Banič et al constructed a category $\mathcal{ICU}$ of generalized inverse sequences and a new category $\mathcal{CU}$ of topological spaces, but showed that the natural mapping from $\mathcal{ICU}$ to $\mathcal{CU}$ was not a functor. We construct a different category **GLim** of generalized inverse sequences which admits a functor mapping sequences to their limits (in both the topological and category theoretical sense) in the standard category **Top** of topological spaces. This functor is shown to be right adjoint to a functor mapping each topological space U to a generalized inverse sequence the limit of which is homeomorphic to U. These constructions give rise to two characterizations of generalized inverse limits in the language of category theory. (Received February 02, 2015)

1109-54-254 **Paul Fabel***, Department of Mathematics and Statistics, Mississippi State, MS 39762. *Topological R-trees and applications.*

An R-tree is a a uniquely arcwise connected metric space such that each arc is canonically isometric to a Euclidean segment. Finitely generated groups acting on R-trees play a prominent role in geometric group theory, notably the Rips machine.

A topological R-tree is a connected, metrizable locally path connected space. Every R-tree is a topological R-tree, but it is only within the last quarter century that the converse was established, every topological R-tree underlies some R-tree.

In this talk we will discuss a new proof of the latter claim, and also a recent topological characterization of complete R-trees.

Time permitting we will mention recent joint work with Jeremy Brazas which appears to yield a general construction in which topological R-trees replace the traditional universal cover. One application to topological dynamics is the following. For each Peano continuum X, each based map $f : (X, p) \to (X, p)$ lifts to a canonical self map $F : (X^{\tilde{}}, p) \to (X^{\tilde{}}, p)$ of a topological R-tree. (Received February 02, 2015)

1109-54-271 **Logan Hoehn** and **Lex Oversteegen*** (overstee@uab.edu), 1300 University Blvd, Birmingham, AL 35294. *A complete classification of homogeneous plane continua.*

A space X is *homogeneous* if for every pair of points $x, y \in X$ there exists a homeomorphism $h : X \to X$ so that $h(x) = h(y)$. Homogenous spaces are standard objects of mathematical study. For example, Euclidean spaces, manifolds and topological groups are homogeneous.

In 1920, Knaster and Kuratowski raised the question whether the unit circle is the only homogeneous plane continuum. To great surprise this question was answered in the negative by Bing who showed in 1948 that the pseudo-arc is another homogeneous plane continuum. Since then the question has been: what are all homogeneous plane continua?

A third example, the circle of pseudo-arcs, was added by Bing and Jones in 1959. We show in this talk that these three continua comprise the complete list of all homogeneous plane continua. As a consequence we also obtain a complete classification of all homogeneous plane compacta. The main technical result on which the above conclusions are based is the following new characterization of the pseudo-arc: a continuum is homeomorphic to the pseudo-arc if and only if it is hereditarily indecomposable and has span zero. (Received February 03, 2015)

1109-54-274 **Christopher G. Mouron*** (mouornc@rhodes.edu), 2000 N. Parkway, Memphis, TN 38112, **Veronica Martinez-de-la-Vega** (vmvm@matem.unam.mx), Circuito exterior, 04510 Cd. Universitaria, Mexico D.F, Mexico, and **Jorge Matinez** (jmarcosmm@gmail.com), Circuito exterior, 04510 Cd. Universitaria, Mexico D.F, Mexico. *The topology of spaces that admit mixing homeomorphisms.*

A map $h : X \longrightarrow X$ is *mixing* if $lim_{n\to\infty} d_H(X, h^n(U)) = 0$ for every nonempty open subset U of X. Here d_H is the Hausdorff metric. In this talk I will discuss the topological requirements of continua that admit mixing homeomorphisms. (Received February 03, 2015)

1109-54-285 **Stewart Baldwin*** (baldwsl@auburn.edu). *Finite Dimensional Uniquely Homogeneous Spaces.*

A topological space X is *uniquely homogeneous* if for every $a, b \in X$ there is *exactly one* homeomorphism $h : X \to X$ such that $h(a) = b$. The definition was first given by Burgess in 1955, and van Mill constructed the first nontrivial (i.e., more than two points) examples in 1983.

Using a weak version of Martin's Axiom (MA for countable orderings), for every integer $n \geq 2$ and every integer k with $1 \leq k \leq n - 1$, we construct k-dimensional uniquely homogeneous dense subsets of $\mathbb{R}^n$. The homeomorphism groups of these spaces are all non-abelian, and can be constructed to be free groups. These are the first known examples of finite-dimensional nontrivial uniquely homogeneous spaces, and the first known uniquely homogeneous spaces having non-abelian homeomorphism groups. (Received February 03, 2015)

1109-54-302 **Brandon L Barry*** (brandonb623@gmail.com), 2247 Aspen Run, Homewood, AL 35209. *Laminations corresponding to periodic polygons.*

Understanding polynomial dynamics on the complex plane is a goal of many mathematicians. Thanks to William Thurston, we have a combinatorial model which aids in this pursuit. This model is called a lamination which is defined as a collection of mutually interior disjoint chords in the unit disk. We define a type of lamination called a simplest lamination corresponding to a collection of periodic polygons. In particular, we study the forward orbit of an identity return polygon, a periodic polygon that first returns to itself by the identity. (Received February 03, 2015)

55 ► Algebraic topology

1109-55-48 **William W Menasco*** (menasco@buffalo.edu), Department of Mathematics, University at Buffalo-SUNY, Buffalo, NY 14260, and **Matthew Morse**, **Paul Glenn** and **Kayla Morrell**. *MICC: A tool for computing short distances in the curve complex.*

The curve complex $\mathcal{C}(S_g)$ of a closed orientable surface of genus $g \geq 2$ is the simplicial complex having a vertex for each isotopy class of essential simple closed curves in S_g. Two vertices share an edge if each isotopy class contains a disjoint representative in S_g. A metric is obtained on the 1-skeleton of $\mathcal{C}(S_g)$ by assigning unit length to each edge. Thus, the distance between two vertices, $d(v, w)$, corresponds to the length of a geodesic—a shortest edge-path between v and w. Although there are finite time algorithms for computing distance, their implementation is impractical. Recently, Joan Birman, Dan Margalit and the second author gave a new distance algorithm using *efficient geodesics*. In this note we introduce the software package MICC (*Metric in the Curve Complex*), a partial implementation of the Birman-Margalit-Menasco algorithm. We discuss the mathematics underlying MICC and give applications. In particular, we give examples of distance four vertex pairs in genus two and three. Previously, there was only one known pair, in genus two, due to John Hempel. (Received January 16, 2015)

57 ► Manifolds and cell complexes

1109-57-47 **Ser-Wei Fu*** (swfu@temple.edu), Rm 638 Wachman Hall, 1805 N. Broad Street, Philadelphia, PA 19122. *A logarithm law for the earthquake flow.* Preliminary report.

Earthquakes are deformations of a hyperbolic surface introduced by Thurston as generalized Dehn twists. The earthquake flow lives on the bundle of unit length measured laminations over the moduli space. Mirzakhani shown that the earthquake flow is ergodic, which motivates the study of logarithm laws for the earthquake flow. In this talk, I will describe some known logarithm laws then state a new logarithm law for the earthquake flow for the once-punctured torus. (Received January 16, 2015)

1109-57-81 **Tarik Aougab*** (tarik.aougab@yale.edu), Yale mathematics department, 10 Hillhouse Avenue, New Haven, CT 06511. *Using the geometry of the mapping class group to solve combinatorial problems.*

Masur and Minsky's celebrated distance formula relates the word metric on the mapping class group to distances in curve complexes of various subsurfaces. We show how to use this formula to improve upon the best known upper bounds for the size of a k-system, a collection of simple closed curves on a surface pairwise intersecting at most k times. (Received January 22, 2015)

1109-57-96 **Balazs Strenner*** (strenner@math.wisc.edu). *Algebraic degrees of pseudo-Anosov mapping classes.*

Thurston showed that the algebraic degrees of pseudo-Anosov stretch factors on the closed orientable surface of genus g are bounded from above by $6g - 6$. He claimed that this bound can be achieved, but he did not give a proof. When the invariant foliations are assumed to be orientable, the smaller upper bound $2g$ holds, and Shin has recently showed that it can be realized. In this talk we explain how to achieve the theoretical maximum $6g - 6$ as well as any smaller even degree. (Received January 26, 2015)

1109-57-112 **Rebecca R. Winarski*** (rebecca.winarski@gmail.com). *Mapping class groups and simple covers.*

Let $S \to X$ be a branched covering space of surfaces. Berstein and Edmonds show that if $S \to X$ is a simple branched cover and X is a disk with n branch points, there is a surjective vitual homomorphism from the mapping class group of the disk with branch points (the braid group) to the mapping class group of X. We find a partial converse to their result. If there is a surjective virtual homomorphism from the mapping class group of X to the mapping class group of S, then X must be a disk or sphere and all preimages of branch points under the covering map have ramification number 1 or 2. (Received January 27, 2015)

1109-57-117 **Joan S Birman*** (jb@math.columbia.edu), Barnard-Columbia Mathematics Department, 2990 Broadway, New York, NY 10027. *Efficient geodesics and distance in the complex of curves.*

Efficient geodesics are a concept that was introduced, in joint work by the speaker, Dan Margalit and William Menasco, to develop an algorithm that would be useful in computing examples of pairs of curves that fill a closed orientable surface and have low distance $d \geq 3$. In this talk I will discuss the underlying ideas that lead us to efficient geodesics, and show why there are at most finitely many efficient geodesics between any two vertices in the curve complex. The relationship between efficient geodesics and the tight geodesics of Masur and Minsky will be discussed. (Received January 27, 2015)

1109-57-125 **Hyunshik Shin*** (shin@math.uic.edu) and **Balazs Strenner** (strenner@math.wisc.edu). *Pseudo-Anosov mapping classes not arising from Penner's construction.*

We show that Galois conjugates of stretch factors of pseudo-Anosov mapping classes arising from Penner's construction lie off the unit circle. As a consequence, we show that for all but a few exceptional surfaces, there are examples of pseudo-Anosov mapping classes so that no power of them arises from Penner's construction. This resolves a conjecture of Penner. (Received January 27, 2015)

1109-57-131 **Eriko Hironaka*** (hironaka@math.fsu.edu), Department of Mathematics, Florida State University, 1017 Academic Way, Tallahassee, FL 32306-4510, and **Kasra Rafi** and **Yael Algom-Kfir**. *Dual Digraphs and Entropy.*

A 2-complex with semi-flow has a corresponding dual directed graph. In this talk, I will explain how to obtain from this information a polynomial invariant that is independent of homotopy equivalences preserving the semi-flow. Under certain conditions, we show that this is analogous to McMullen's Teichmueller polynomial, and computes the mondromy entropies of the fundamental group of the complex. This work is joint with Yael Algom-Kfir and Kasra Rafi. (Received January 28, 2015)

1109-57-181 **Dan Margalit*** (margalit@math.gatech.edu), 686 Cherry St., School of Mathematics, Atlanta, GA 30332. *Algebraic, geometric, and dynamical aspects of surfaces.*

To each homeomorphism of a surface we can associate a real number, called the entropy, which encodes the amount of mixing being effected. This number can be studied from topological, geometrical, dynamical, analytical, and algebraic viewpoints. We will start by explaining Thurston's beautiful insight for computing the optimal entropy within a homotopy class and explain a new, fast algorithm based on his ideas. Then we will discuss some classical results and recent progress on the problem of understanding phenomena related to small entropy. One theme is that algebraic complexity and geometric complexity both imply dynamical complexity. This work is joint with Ian Agol, Benson Farb, Chris Leininger, and Oyku Yurttas. (Received January 31, 2015)

1109-57-187 **Nguyen D Duong*** (ndduong@crimson.ua.edu) and **Lawrence P Roberts**. *Bordered Khovanov homology: spanning tree models and a planar algebra structure.* Preliminary report.

Khovanov homology is an invariant of oriented knots and links which categorifies the Jones polynomial. In an attempt to calculate Khovanov homology from tangles, L. Roberts defined a bordered version in Khovanov homology. In this talk, I will describe how to twist Roberts' invariants to obtain twisted invariants of tangles (type A and type D structures). The type A and type D structures admit explicit spanning tree models. I will also discuss work-in-progress with L. Roberts toward constructing a planar algebra structure in bordered Khovanov homology. We define an invariant (type DA structure) for tangles subordinate to disc configurations. This type DA structure will induce a morphism from the planar algebra of tangle diagrams to the category of A_∞ modules. (Received January 31, 2015)

60 ► Probability theory and stochastic processes

1109-60-13 **Antonio Auffinger*** (auffing@math.northwestern.edu), **Michael Damron** and **Jack T Hanson**. *Rate of convergence of the mean for sub-additive ergodic sequences.*

For a subadditive ergodic sequence $\{X_{m,n}\}$, Kingman's theorem gives convergence for the terms $X_{0,n}/n$ to some non-random number g. In this talk, I will discuss the convergence rate of the mean $EX_{0,n}/n$ to g. This rate turns out to be related to the size of the random fluctuations of $X_{0,n}$; that is, the variance of $X_{0,n}$, and the main theorems I will present give a lower bound on the convergence rate in terms of a variance exponent. The main assumptions are that the sequence is not diffusive (the variance does not grow linearly) and that it has a weak dependence structure. Various examples, including first and last passage percolation, bin packing, and longest common subsequence fall into this class. (Received December 17, 2014)

1109-60-14 **Celine Lacaux** and **Gennady Samorodnitsky*** (gs18@cornell.edu), School of ORIE, Cornell University, Ithaca, NY 14853. *Time-changed extremal process as a random sup measure.*

A functional limit theorem for the partial maxima of a long memory stable sequence produces a limiting process that can be described as a β-power time change in the classical Fréchet extremal process, for β in a subinterval of the unit interval. Any such power time change in the extremal process for $0 < \beta < 1$ produces a process with stationary max-increments. This deceptively simple time change hides the much more delicate structure of the resulting process as a self-affine random sup measure. We uncover this structure and show that in a certain range of the parameters this random measure arises as a limit of the partial maxima of the same long memory stable sequence, but in a different space. These results open a way to construct a whole new class of self-similar Fréchet processes with stationary max-increments. (Received December 17, 2014)

1109-60-15 **Yaozhong Hu*** (yhu@ku.edu), Department of Mathematics, University of Kansas, Lawrence, KS 66045, and **Khoa Le** (k3381392@ku.edu), Department of Mathematics, University of Kansas, Lawrence, KS 66045. *Brox Diffusion and its stochastic differential equations.* Preliminary report.

This paper studies the weak and strong solutions to the stochastic differential equation $dX(t) = -\frac{1}{2}\dot{W}(X(t))dt + d\mathcal{B}(t)$, where $(\mathcal{B}(t), t \geq 0)$ is a standard Brownian motion and $W(x)$ is a two sided Brownian motion, independent of $\mathcal{B}$. It is shown that the Itô-McKean representation associated with any Brownian motion (independent of W) is a weak solution to the above equation. It is also shown that the Itô-McKean representation for an appropriately chosen Brownian motion is a strong solution to the equation. The uniqueness of the strong solution is also obtained. The main idea to deal with the singularity of drift term $\int_0^T \dot{W}(X(t))dt$ is to use the local time and to use the polygonal approximation W_π. Some new results on the local time of Brownian motion needed in our proof are established. (Received December 18, 2014)

1109-60-21 **Leila Setayeshgar*** (lsetayes@providence.edu). *Large Deviations for a Stochastic Burgers' Equation.*

We prove the large deviations principle (LDP) for the law of the solutions to a stochastic Burgers' equation in the presence of an additive noise. Our proof is based on the weak convergence approach. (Received December 26, 2014)

1109-60-22 **Shannon L Starr*** (slstarr@uab.edu), UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170, and **Meg Walters**. *Fluctuations in the Mallows measure on permutations.*

We bound the fluctuations for the Mallows measures on the symmetric groups. For a number q>0 the probability of a permutation pi is proportional to q^ l(pi) where l(pi) is the "length" of pi. With the scaling n-to-infinity with q=q_n such that n*(1-q_n) converges to a number beta, we study the limit as well as the fluctuations in the form of a local central limit theorem. (Received December 26, 2014)

1109-60-37 **Hermine Biermé**, **Olivier Durieu** and **Yizao Wang*** (yizao.wang@uc.edu), University of Cincinnati, Department of Mathematical Sciences, 2815 Commons Way, Cincinnati, OH 45221-0025. *Phenomena of critical regimes in invariance principles for operator-scaling Gaussian random fields.* Preliminary report.

Hammond and Sheffield recently introduced a model of correlated random walk that scales to a fractional Brownian motion with long-range dependence. In this paper, we consider a natural generalization of this model in higher dimension. We define a Z^d-indexed random field with dependence relations governed by an underlying random graph, and we study the scaling limit properties of its partial sums. An interesting phenomenon appears: under different regimes of summation, several kinds of limit fields could be reached. There is a critical regime where the limit field is an operator scaling process that inherits of the full structure of the discrete model, whereas it is not the case under other regimes. (Received January 14, 2015)

1109-60-38 **Linda Allen**, **Sophia Jang** and **Lih-Ing W. Roeger*** (lih-ing.roeger@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409. *Predicting Population Extinction or Disease Outbreaks with Stochastic Models.* Preliminary report.

Random effects can lead to population extinction or the failure of a disease outbreak. However, randomness is a behavior not observed in deterministic models. To account for random effects, we formulate analogous stochastic models which are discrete-time Markov chains. A simple birth and death process leads to an analytical formula for the probability of extinction that depends on the initial population size. To illustrate the utility of the formula, it is applied to the logistic growth model and the SIR epidemic model during the exponential growth phase to predict population or disease extinction. (Received January 14, 2015)

1109-60-39 **Rodrigo Banuelos*** (banuelos@math.purdue.edu), Purdue University, West Lafayette, IN 47906, and **Dante DeBlassie**. *Geometric/analytic properties of ground state eigenfunctions for the fractional Laplacian.*

A classical result of Brascamp and Lieb asserts that the ground state eigenfunction for the Laplacian on convex domains is log-concave. This result has been extended in many directions in the PDE literature. Probabilistically, it can be obtained from similar properties for the finite dimensional distributions of Brownian motion. Several years ago the speaker raised similar questions for stable processes of order $0 < \alpha < 2$. Over the years these questions have received considerable attention from people in PDE and probability. In this talk we explain some of these problems and give an outline of a recent result of D. DeBlassie and the speaker on the superharmonicity of the ground state eigenfunction for the fractional Laplacian or order $\alpha = 2/m$ ($m > 2$ and integer) in Lipschitz domains. This result was first proved for the unit interval in the real line and $\alpha = 1$ by T. Kulczycki and the speaker in 2004 and for the unit ball in any dimension by M. Kaßmann and L. Silvestre (2014). (Received January 15, 2015)

1109-60-42 **Xia Chen*** (xchen@math.utk.edu), Knoxville, TN. *Intermittency and high moment asymptotics for parabolic Anderson equation with an (1 + 1)-dimensional white noise.*

In this talk, we establish $\lim_{t\to\infty} \frac{1}{t} Eu(t;x)^n = \frac{\theta^4}{24} n(n^2-1)$ and $\lim_{n\to\infty} \frac{1}{n^3} Eu(t;x)^n = \frac{\theta^4}{24} t$ for the parabolic Anderson equation $\partial_t u(t;x) = \frac{1}{2}\Delta u(t;x) + \theta u(t;x)\dot{W}(t;x)$ with a $(1+1)$-dimensional white noise $\dot{W}(t;x)$. Our treatment relies on Tanaka formula and our result appears as a correction of the work by Bertini and Cancrini (1995). (Received January 16, 2015)

1109-60-43 **Wlodek Bryc*** (brycw@math.uc.edu). *On integration with respect to the q-Brownian motion.*

For a parameter $0 < q < 1$, we use the Jackson q-integral to define integration with respect to the so called q-Brownian motion. Our main results are the q-analogs of the L_2-isometry and of the Ito formula for polynomial integrands. We also indicate how the L_2-isometry extends the integral to more general functions. (Received January 16, 2015)

1109-60-46 **Indranil SenGupta*** (indranil.sengupta@ndsu.edu), Department of Mathematics, NDSU Dept # 2750, Minard Hall 408E12, Fargo, ND 58108-6050, and **Semere Habtemicael**. *Volatility, Variance and Covariance swaps for Lévy process driven financial market.*

The variance, volatility and covariance swaps are financial tools which help for volatility hedging and speculation. In this presentation, we consider Lévy driven stochastic volatility models to price various swaps. Numerical evaluations of variance and volatility swaps for both Gaussian and Non-Gaussian models will be presented. It will be shown that such models have much better error margins than classical models such as Heston model. (Received January 16, 2015)

1109-60-52 **Dan Cheng** (cheng@stt.msu.edu), Department of Statistics, 2311 Stinson Drive, North Carolina State University, Raleigh, NC 27695-8203, and **Yimin Xiao*** (xiao@stt.msu.edu), Department of Statistics and Probability, 619 Red Cedar Road, Michigan State University, East Lansiing, MI 48824. *Excursion Probability of Gaussian Random Fields on Sphere.* Preliminary report.

Let $X = \{X(x) : x \in \mathbb{S}^N\}$ be a real-valued, centered Gaussian random field indexed on the N-dimensional unit sphere $\mathbb{S}^N$. Approximations to the excursion probability $\mathbb{P}\{\sup_{x\in\mathbb{S}^N} X(x) \ge u\}$, as $u \to \infty$, are obtained for two cases: (i) X is locally isotropic and its sample functions are non-smooth and; (ii) X is isotropic and its sample functions are twice differentiable. For case (i), the excursion probability can be studied by applying the results in Piterbarg (1996), Mikhaleva and Piterbarg (1997) and Chan and Lai (2006). It is shown that the asymptotics of $\mathbb{P}\{\sup_{x\in\mathbb{S}^N} X(x) \ge u\}$ is similar to Pickands' approximation on the Euclidean space which involves Pickands' constant. For case (ii), we apply the expected Euler characteristic method to obtain a more precise approximation such that the error is super-exponentially small. (Received January 18, 2015)

1109-60-58 **Olav Kallenberg*** (kalleoh@auburn.edu), Auburn, AL 36849. *Some highlights from the general theory of random measures.*

Whereas the basic theories of martingales, diffusion processes, and stochastic calculus are known to every serious student of stochastic processes, the equally important theory of random measures is still virtually unknown. In this talk I shall describe some recent results from different subareas, all taken from my forthcoming monograph on the subject. (Received January 19, 2015)

1109-60-60 **Aurel Iulian Stan*** (stan.7@osu.edu), 1465 Mount Vernon Avenue, Marion, OH 43302. *A Hölder-Young inequality for norms of generalized Gaussian Wick products.* Preliminary report.

The t-Wick products, for $0 \leq t \leq 2$, are connected to various types of stochastic integrals. Thus the 0-Wick product, also called the classic Wick product, is used in defining the Itô integral. The 1-Wick product, which is the point-wise product, is used in defining the Stratonovich integral. If the correct Wick product is used for each stochastic integral, then there is no need for an Itô formula, since the classic Leibniz-Newton Fundamental Theorem of Calculus works. Thus we can see that by using the appropriate Wick product, for each stochastic integral, a great unity between each Stochastic Gaussian Calculus and Classic Calculus is achieved. In Classic Calculus (Analysis), the Hölder inequality guarantees that the product of two functions, one from an L^p-space and another from an L^q-space, is a function in an L^r-space. To solidify the unity between any Gaussian Stochastic Calculus and Classic Calculus, we need to find sharp inequalities that guarantee that a t–Wick product of two random variables, one from an L^p-space and another from an L^q-space, is a random variable in an L^r–space. We present such inequalities in this talk. (Received January 19, 2015)

1109-60-61 **Wei-Kuo Chen*** (wkchen@math.uchicago.edu), Dept of Math, U of Chicago, 5734S, University Ave, E414, Chicago, IL 60637, and **Antonio Auffinger**. *On the uniqueness and properties of the Parisi measure.*

Spin glasses are disordered spin systems originated from the desire of understanding the strange magnetic behaviors of certain alloys in physics. As mathematical objects, they are often cited as examples of complex systems and have provided several fascinating structures and conjectures. This talk will be focused on one of the most famous mean-field spin glasses, the Sherrington-Kirkpatrick model. We will present results on the conjectured properties of the Parisi measure including its uniqueness and quantitative behaviors. This is based on joint works with A. Auffinger. (Received January 19, 2015)

1109-60-67 **F Baudoin**, **E Nualart** and **C Ouyang*** (couyang@math.uic.edu), 851 S. Morgan Street, 322 Science and Engineering Offices (M/C 249), Chicago, IL 60607, and **S Tindel**. *Hitting probabilities for stochastic differential systems driven by fractional Brownian motions.*

Study of stochastic differential equations driven by fractional Brownian motions has been an active area of current research for a while. In this talk, we present some results on hitting probabilities of sets by such systems (in terms of Newtonian capacities). In particular, we obtain the critical dimension for such systems to hit a point. (Received January 20, 2015)

1109-60-77 **Dang Hai Nguyen** (dangnh.maths@gmail.com), Department of Mathematics, Wayne State University, Detroit, MI 48202, **Nguyen Huu Du** (nhdu@viasm.edu.vn), Department of Mathematics, Mechanics and, Informatics, Hanoi National University, Vietnam, and **George Yin*** (gyin@math.wayne.edu), Departmet of Mathematics, Wayne State University, Detroit, MI 48202. *Limit Cycles with Random Perturbations Involving Fast Switching and Small Diffusion.*

This talk focuses on multi-scale stochastic systems. The motivation is to treat limit cycles under random perturbations involving fast random switching and small diffusion, which are represented by the use of two small parameters. Associated with the underlying systems, there are averaged or limit systems. Suppose that for each pair of the parameters, the solution of the corresponding equation has an invariant measure $\mu^{\varepsilon,\delta}$, and that the averaged equation has a limit cycle in which there is an averaged occupation measure μ^0 for the averaged equation. We prove that $\mu^{\varepsilon,\delta}$ converges to μ^0 as $\varepsilon \to 0$ and $\delta \to 0$ under suitable conditions. We also examine application to a stochastic predator-prey model. In addition, some numerical examples will also be reported. (Received January 22, 2015)

1109-60-83 **Tyrone E. Duncan***, duncan@ku.edu. *Explicit Optimal Controls for Some Stochastic Control Problems.*

A family of control problems for linear and nonlinear systems with their cost functionals are described that can be solved directly to obtain explicit optimal controls. These systems include linear systems with arbitrary fractional Brownian motion noise processes, linear systems with state and /or control dependent Brownian motions, nonlinear systems in rank one symmetric spaces with Brownian motions and linear stochastic partial differential equations with Brownian motions. Some related problems for stochastic differential games can also be explicitly solved. (Received January 23, 2015)

1109-60-98 **Le Chen**, **Michael Cranston** and **Davar Khoshnevisan*** (davar@math.utah.edu), Department of Mathematics, University of Utah, Salt Lake City, UT 84105, and **Kunwoo Kim**. *Dissipation and High Disorder.*

Given a field $\{B(x)\}_{x\in\mathbf{Z}^d}$ of independent standard Brownian motions, indexed by $\mathbf{Z}^d$, the generator of a suitable Markov process on $\mathbf{Z}^d$, $\mathcal{G}$, and sufficiently nice function $\sigma : [0,\infty) \to [0,\infty)$, we consider the influence of the parameter λ on the behavior of the system,

$$\mathrm{d}u_t(x) = \quad (\mathcal{G}u_t)(x)\,\mathrm{d}t + \lambda\sigma(u_t(x))\mathrm{d}B_t(x) \qquad [t>0,\ x\in\mathbf{Z}^d],$$
$$u_0(x) = c_0\delta_0(x),$$

We show that for any $\lambda > 0$ in dimensions one and two the total mass $\sum_{x\in\mathbf{Z}^d} u_t(x) \to 0$ as $t\to\infty$ while for dimensions greater than two there is a phase transition point $\lambda_c \in (0,\infty)$ such that for $\lambda > \lambda_c$, $\sum_{\mathbf{Z}^d} u_t(x) \to 0$ as $t\to\infty$ while for $\lambda < \lambda_c$, $\sum_{\mathbf{Z}^d} u_t(x) \not\to 0$ as $t\to\infty$. (Received January 26, 2015)

1109-60-101 **Adina Oprisan*** (aoprisan@barry.edu) and **Andrzej Korzeniowski**. *Large deviations for additive functionals of Markov processes and applications.*

In this talk I consider a family of stochastic additive functionals of Markov processes switched by jump Markov processes subject to the effect of small random perturbations. Random perturbations arising in connection with averaging principle as well as with those leading to diffusion processes are discussed. I will present asymptotic properties of the type of law of large numbers, central limit theorems, almost sure central limit theorems and large deviations along with examples and applications. (Received January 26, 2015)

1109-60-108 **Parisa Fatheddin*** (parisa.fatheddin@uah.edu), 301 Sparkman Drive, Huntsville, AL 35899, and **Jie Xiong** (jiexiong@umac.mo), Avenida da Universidade, Taipa, Macau, Peoples Rep of China. *Large and Moderate Deviations and Central Limit Theorem for A Class of SPDEs.*

We introduce a class of Stochastic Partial Differential Equations (SPDEs) with a non-lipschitz coefficient and prove large and moderate deviations and central limit theorem as the noise term tends to zero. As applications we derive these theorems for two important population models: super-Brownian motion and Fleming-Viot Process. (Received January 31, 2015)

1109-60-132 **Gary Webb*** (gmw0002@uah.edu), 301 Sparkman Drive, Huntsville, AL 35899, **Qiang Hu** (qh0001@uah.edu), 301 Sparkman Drive, Huntsville, AL 35899, and **Gang Li** (gang.li@uah.edu), 301 Sparkman Drive, Huntsville, AL 35899. *Alfvenic fluctuations and Alfven Simple Waves in the Solar Wind.*

We consider Hamiltonian equations for Alfven simple waves and their application to observations of large amplitude Alfven waves in the Solar Wind. One of the features of the data in the quiet solar wind, is that the magnetic field vector B to lowest order moves on a sphere in B space with constant magnitude B. After describing exact solutions of the equations in which the wave normal is a prescribed function of the wave phase, we consider the generalization of the ordinary differential equations to stochastic differential equations which take into account the fluctuations in B. Both dissipative and non-dissipative (Hamiltonian) stochastic differential equations describing the waves are developed. The ultimate aim is to provide a model to explain the spacecraft observations. (Received February 01, 2015)

1109-60-143 **Ernest Jum** and **Kei Kobayashi*** (kkobayas@utk.edu). *A strong and weak approximation scheme for stochastic differential equations driven by a time-changed Brownian motion.*

We establish a discretization scheme for a large class of stochastic differential equations driven by a time-changed Brownian motion with drift, where the time change is given by a general inverse subordinator. The scheme involves two types of errors: one generated by application of the Euler–Maruyama scheme and the other ascribed to simulation of the inverse subordinator. With the two errors carefully examined, the orders of strong and weak convergence are established. In particular, an improved error estimate for the Euler–Maruyama scheme is derived, which is required to guarantee the strong convergence. (Received January 28, 2015)

1109-60-145 **Kavita Ramanan*** (kavita_ramanan@brown.edu), Providence, RI 02912, and **Mohammadreza Aghajani**. *Stationary Distribution of an SPDE Associated with a Many-Server Queue.*

We study the existence and uniqueness of the stationary distribution of an infinite-dimensional Markov process that arises as the diffusion limit of many-server queues. This process consists of two coupled components, the first component being a real-valued Ito process X with a constant diffusion coefficient and the second being a process Z that takes values in a subset of the Hilbert function space $\mathbb{H}^1$ and satisfies a somewhat unusual stochastic partial differential equation (SPDE) with a boundary condition that depends on X. Standard Harris recurrence methods for studying uniqueness of stationary distributions are not applicable here because they are not well suited to establishing uniqueness of stationary distributions for infinite-dimensional Markov processes. Instead, we use an asymptotic coupling approach to establish uniqueness, thus demonstrating the applicability of this method in the context of non-standard SPDEs that arise in the analysis of queueing systems. This is joint work with Mohammadreza Aghajani. (Received January 28, 2015)

1109-60-148 **Carl P Dettmann*** (carl.dettmann@bris.ac.uk), University Walk, Bristol, England BS8 1TW, United Kingdom, and **Orestis Georgiou** and **Justin P Coon**. *Connectivity of random geometric graphs in domains with smooth or fractal boundaries.*

Random geometric graphs (RGGs) are constructed from a Poisson point process by linking points with mutual distance below a fixed bound. At high density, the probability that the graph is connected is controlled by isolated points, which are more likely near boundaries of the domain. This probability can be estimated using a sum over boundary components, if the boundaries are smooth, and the connection probability approaches unity. In contrast, fractal boundaries lead to stretched exponential decay of the probability with density. Connectivity of RGGs is a useful model for many wireless networks. (Received January 29, 2015)

1109-60-152 **A. F. Barghouty*** (abdulnasser.f.barghouty@nasa.gov), Huntsville, AL 35812. *Modeling the radiation quality factor as a linear 'time'-dependent Ornstein-Uhlenbeck process.*

In addition to its radio-biological effects, modeling of dose and risk associated with space radiation exposure are made difficult by the inherent complexity and variability in characterizing the radiation environment as well as its passage and interaction with matter. The empirical variability in the so-called radiation quality factor, or Q, which is typically used to differentiate among radio-biological effects, is a primary source of uncertainty in dose and risk estimates. This talk will present a stochastic dynamic model for Q based on a linear but 'time'-dependent Ornstein-Uhlenbeck process. (Received February 01, 2015)

1109-60-193 **Andreas Basse-O'Connor** and **Jan Rosinski*** (rosinski@math.utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 37996. *On infinitely divisible semimartingales.*

The objective of this work is to extend Stricker's theorem, which gives a characterization of a Gaussian process to be a semimartingale in its natural filtration, to non Gaussian infinitely divisible processes. The motivation comes from modeling, where non Gaussian long memory processes with possible jumps and high volatility are considered as driving motion for stochastic differential equations. We show that the problem when such a process is a semimartingale can often be reduced to a path property, when a certain associated infinitely divisible process is of finite variation. This gives the key to characterize the semimartingale property for many processes of interest, including linear fractional processes, moving averages, supOU processes, and more generally, Volterra processes driven by Lévy processes. (Received January 31, 2015)

1109-60-200 **Kyle Siegrist*** (siegrist@math.uah.edu), University of Alabama in Huntsville, Mathematics Department, Huntsville, AL 35899. *Stochastic processes on a space with a binary relation.* Preliminary report.

Suppose that $(S, \mathcal{S}, \lambda)$ is a measure space, and that $R \in \mathcal{S} \otimes \mathcal{S}$, so that R is a binary relation on S. For $x \in S$, let $A(x) = \{y \in S : (y, x) \in R\}$ and $B(x) = \{y \in S : (x, y) \in R\}$. Let $\boldsymbol{X} = (X_1, X_2, \ldots)$ be an IID sequence of random variables in S with common probability measure μ. We obtain results for certain moments of μ associated with the set function $A(x)$, the reference measure λ, and the "distribution function" $G(x) = \mu(B(x))$. We also obtain results for the process $\boldsymbol{Y} = (Y_1, Y_2, \ldots)$ obtained by thinning $\boldsymbol{X}$ so that $Y_1 = X_1$ and $Y_{n+1} \in B(Y_n)$ for $n \in \{1, 2, \ldots\}$. These results have a particularly nice form when μ has a density function f with respect to λ with the property that the "rate function" $f(x)/G(x)$ is constant. When the relation R is a partial order on S, our results generalize classical results on record variables and the Poisson process, but we consider other types of relations as well. Finally, we consider the case where the reference measure λ is also a probability measure on S. (Received February 02, 2015)

1109-60-238 **P. Sundar*** (sundar@math.lsu.edu), Department of Mathematics, Lockett Hall, Louisiana State University, Baton Rouge, LA 70803, and **Sergio Albeverio** and **Barbara Ruediger**. *McKean -Vlasov equations with jumps and associated PDEs in statistical physics.* Preliminary report.

McKean-Vlasov equations driven by compensated Poisson random measures are studied in the context of partial differential equations that arise in statistical physics. The existence of weak solutions to such stochastic systems

is established, and the marginal (in time) distribution of any solution is shown to be unique. Probabilistic behavior of the solution, in particular cases, will be described. (Received February 02, 2015)

1109-60-253 **Kenny Chowdhary*** (kennychowdhary@gmail.com), 4538 Park Boulevard, Oakland, CA 94602. *Bayesian Principle Component Analysis: A Random Subspace Approach.*

Principle Component Analysis, or PCA for short, is a common statistical procedure for reducing the dimensionality of a given data set. In a nutshell, PCA allows one to represent a data set as a linear combination of uncorrelated random variables via a change of basis. Moreover, this transformation is optimal in the least squares sense. In the first part of this talk, we will briefly go over the basics of PCA through examples. Then we will introduce an alternative Bayesian inference approach to PCA in which the basis vectors themselves are random. This will allow us to quantify the uncertainty in the principle components when we have limited samples of the data. In order to perform the Bayesian inference, an efficient Gibbs sampler over the space of orthonormal matrices is utilized. (Received February 02, 2015)

1109-60-255 **Vasileios Maroulas*** (maroulas@math.utk.edu), 1403 Circle Dr., Knoxville, TN 37996. *Computational Stochastic Filtering and Large Deviations.*

In this talk, we consider a nonlinear/non-Gaussian stochastic filtering problem in a small signal-to-noise ratio environment. A large deviation estimate is established by considering qualitative properties of perturbations of an equivalent observation process. Moreover, the posterior filtering distribution is approximated using a drift homotopy technique for stochastic differential equations (SDE). This computational implementation can be thought of as a stochastic analog of deterministic homotopy methods for solving nonlinear algebraic equations or as an SDE generalization of simulated annealing. A toy example based on small noise double-well stochastic dynamics is also presented. (Received February 02, 2015)

1109-60-257 **Jebessa B. Mijena*** (jebessa.mijena@gcsu.edu), 231 W. Hancock St, Campus Box 17, Department of Mathematics, Georgia College & State University, Milledgeville, GA 31061. *Correlation structure of time-changed fractional Brownian motion.*

Fractional Brownian motion (fBm) is a centered self-similar Gaussian process with stationary increments, which depends on a parameter $H \in (0,1)$ called the Hurst index. Time - fractional order Fokker-Planck-Kolmogorov type equations driven by a time-changed fractional Brownian motion was given by Hahn, Kobayashi and Umarov. In modeling, the use of time-changed processes in often requires the knowledge of their second order properties such as covariance function. This paper provides the explicit expression for the covariance function for time-changed fractional Brownian motion and some examples are discussed, as well. (Received February 02, 2015)

1109-60-296 **Raluca M Balan** and **Daniel Conus*** (daniel.conus@lehigh.edu), Mathematics Department, Christmas-Saucon Hall, 14 East Packer Avenue, Bethlehem, PA 18015. *Intermittency for a family of parabolic and hyperbolic SPDEs driven by fractional noise.*

We will describe results related to the notion of "intermittency", i.e. the property that a random field develops large values ("high peaks") when time gets large. We will remind how this phenomenon appears in the context of SPDEs. In particular, we will illustrate how the intermittent behavior of the solution to an SPDE depends on the type of driving noise in the cases of nonlinear stochastic heat and wave equations driven by fractional noise. In the latter case, the results are obtained via a Feynman-Kac representation similar to the one introduced by Dalang, Mueller and Tribe (2008). (Received February 03, 2015)

1109-60-310 **Rachel Leander**, **Zack Jones*** (zwj2a@mtmail.mtsu.edu) and **Darren Tyson**. *Implications of Stochasticity in Cellular Proliferation.* Preliminary report.

Cell division is one of the most fundamental processes of life, yet it is subject to significant random variation. Experiments have shown that, even in a population of homogeneous cells, the distribution of intermitotic times (IMTs) is highly variable. Furthermore, IMT distributions exhibit interesting temporal dynamics, especially in response to perturbations such as drug treatment. Using a top-down approach, we have developed a stochastic model of the cell cycle that is based on our conception of the cell cycle check point. This model enables us to frame the problem of determining a cell's IMT as a first exit time problem, through which we derive an expression for the distribution of IMTs. This distribution can be analyzed in order to relate distribution properties and dynamics to model parameters. (Received February 03, 2015)

1109-60-313 **Tyler Gomez** and **Jason Swanson***, University of Central Florida, Department of Mathematics, 4000 Central Florida Blvd, Orlando, FL 32816, and **Alexandru Tamasan**. *A filtering problem in stochastic tomography.* Preliminary report.

In tomography, one strives to recover an unknown function f on a domain D from its Radon transform, Rf. The Radon transform is a function on the space of lines through D, and $Rf(L)$ is the line integral of f along L. In medical imaging, f represents the density of a body, and Rf is measured by passing X-rays through the body. We consider a stochastic version of this problem, in which we observe a stochastic perturbation of Rf. We then wish to compute the conditional distribution of f, given this observation. This is work in progress with Tyler Gomez and Alexandru Tamasan of the University of Central Florida. (Received February 03, 2015)

1109-60-315 **Ibukun O.O. Amusan*** (ibukun.amusan@kysu.edu). *An approximate formula for option pricing under a stochastic volatility model with two noises.*

This paper considers the pricing of options under a coupled additive-multiplicative stochastic volatility model. An approximate formula for the vanilla option is presented and the results compared with other models. (Received February 03, 2015)

62 ► Statistics

1109-62-76 **Jamye Nichelle Curry*** (jcurry4@ggc.edu), School of Science and Technology, Georgia Gwinnett College, 1000 University Center Ln, Lawrenceville, GA 30043. *Rank Based Two-Sample Tests Under a General Alternative.*

Rank based formulations of a univariate two-sample distribution-free test are proposed. One form of the proposed test is the average of between-group distances of ranks. The other form of the test is the difference between the average of between-group distances of ranks and the average of within-group distances of ranks. Although they are different in formulation, they are closely related to the two-sample Cramér-von Mises criterion. The first one is a linear transformation of Cramér-von Mises criterion in the case the two samples have the same sample size. The second one is an alternative form of the Cramér-von Mises criterion. The properties of the test statistics based on the new formulation are studied by applying the Hájek projection in deriving the asymptotics of the test statistics. Rank-based formulations allow generalizations of the two-sample Cramér-von Mises test to the multivariate case by using different notions of multivariate rank functions. Two corresponding tests based on multivariate spatial ranks are proposed. Bootstrap and permutation procedures are used for yielding consistent approximations to the null distribution of the tests. A comparison with other popular tests demonstrates the competitive power performance of the proposed tests. (Received January 21, 2015)

65 ► Numerical analysis

1109-65-18 **Akil Narayan*** (akil.narayan@umassd.edu), 285 Old Westport Road, North Dartmouth, MA 02818, and **Dongbin Xiu**, **Xueyu Zhu** and **Claude Gittelson**. *Simulation of parameterized differential systems with multi-fidelity models.*

We present a novel algorithm for robustly incorporating inexpensive low-fidelity models and data into expensive high-fidelity simulations of differential equations. Our approach maintains high-fidelity model accuracy while requiring only low-fidelity computational effort. The method is non-intrusive and extensible, effectively working with black-box simulation tools. Our procedure can address multi-physics situations, missing parameters, and an arbitrary number of models with varying degrees of fidelity. (Received December 23, 2014)

1109-65-32 **Seong Jun Kim*** (skim396@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30332, and **Gil Ariel**, **Bjorn Engquist**, **Richard Tsai** and **Haomin Zhou**. *Multiscale computations for highly oscillatory dynamical systems.*

The main focus of this talk is to design efficient numerical algorithms for a class of highly oscillatory dynamical systems with multiple time scales. The objective is to allow long time computation of macroscopic/coarse/slow variables rather than the full state variables. Classical numerical methods for highly oscillatory solutions need to resolve the finest scale over the entire time interval of interest and thus become inefficient. In order to accelerate computations and improve the accuracy, the framework of the heterogeneous multiscale method (HMM) is considered as a general strategy both for the design and the analysis of multiscale methods. (Received January 07, 2015)

1109-65-55 **Alexander Labovsky*** (aelabovs@mtu.edu). *A Defect Correction Approach to Turbulence Modeling.*

A method for resolving turbulent flow problems is presented, aiming at competing with the existing mathematical tractable Approximate Deconvolution Models in terms of accuracy, and outperforming these models in terms of the computational time needed. Full numerical analysis is performed, and the method is shown to be stable, easy to implement and parallelize, and computationally fast. The proposed method employs the defect correction approach to solve spatially filtered Navier-Stokes equations. A simple numerical test is provided, that compares the method against the Approximate Deconvolution turbulence model (ADM). When resolving a fluid flow at high Reynolds number, the numerical example verifies the key feature of the method: while having the accuracy comparable to that of the ADM, the method computes in less than 80% of the time needed for the turbulence model - even before the parallelization. (Received January 19, 2015)

1109-65-63 **Yong Li** and **Catalin Trenchea*** (trenchea@pitt.edu), 301 Thackeray Hall, University of Pittsburgh, Mathematics, Pittsburgh, PA 15260. *Partitioned two-step second-order method for magnetohydrodynamics in Elsässer variables.* Preliminary report.

In this address we propose a partitioned, two step, second-order method for magnetohydrodynamics in Elsässer variables, which treats implicitly the subproblem terms and explicitly the coupling terms. The stability analysis shows that the method is unconditionally stable for the magnetic Prandtl number in the interval (0.5,2). In a large number of laboratory simulations, the magnetic Prandtl number is taken to be unity. The algorithm is shown to be long-time stable, and the finite element error analysis is presented with a numerical test supporting the theory. (Received January 20, 2015)

1109-65-72 **Manabu Machida***, 530 Church Street, Ann Arbor, MI 48109. *The Green's function by the 3D F_N method for inverse transport problems.*

Optical tomography is formulated as an inverse transport problem or by approximation as an inverse diffusion problem which determines coefficients of the equation from boundary values. Such inverse problems are nonlinear. Here we consider the inverse transport problem without diffusion approximation. Then the nonlinear map is given by the Green's function for the transport equation. Thus, it is crucial to precisely obtain the Green's function to solve inverse transport problems. The F_N method devised in 1978 is a numerical method which obtains the specific intensity of the one-dimensional transport equation. In this talk, we will obtain the Green's function by extending the F_N method to three dimensions. (Received January 20, 2015)

1109-65-80 **Paul Kuberry** (pkuberry@gmail.com) and **Hyesuk Lee*** (hklee@clemson.edu). *A decoupling algorithm for fluid-structure interaction problems based on optimization.*

Simulating fluid-structure interactions is challenging due to the tight coupling between the fluid and solid substructures. Explicit and implicit decoupling methods often either fail or require relaxation when densities of the two materials are close. In this talk, a fluid-structure interaction problem is formulated as a least squares problem, where the jump in velocities of the two substructures is minimized by a Neumann control enforcing the continuity of stress on the interface. A decoupling optimization algorithm is discussed, which requires few nonlinear solves at each time step, and numerical results are presented. (Received January 22, 2015)

1109-65-95 **Leo Rebholz*** (rebholz@clemson.edu). *The reduced order NS-α model for incompressible flow.*

This paper introduces a new, reduced-order NS-α (rNS-α) model for the purpose of efficient, stable, and accurate simulations of incompressible flow problems on coarse meshes. We motivate the new model by discussing the difficulties in efficient and stable algorithm construction for the usual NS-α model, and then derive rNS-α by using deconvolution as an approximation to the filter inverse, which reduces the fourth order NS-α formulation to a second order model. After proving the new model is well-posed, we propose a C^0 finite element spatial discretization together with an IMEX BDF2 timestepping to create a linearized algorithm that decouples the conservation of mass and momentum equations from the filtering. We rigorously prove the algorithm is well-posed, and provided a very mild timestep restriction, is also stable and converges optimally to the model solution. Finally, we give results of several benchmark computations that confirm the theory and show the proposed model/scheme is effective at efficiently finding accurate coarse mesh solutions to flow problems. (Received January 26, 2015)

1109-65-158 **Jinjie Liu*** (jliu@desu.edu), Delaware State University, 1200 N. Dupont Hwy, Dover, DE 19901. *Transformation Optics based FDTD method for solving nonlinear Maxwell's equations.*

Transformation optics (TO) is a special coordinate transformation technique that can be applied to create many interesting phenomenon, such as the well-known metamaterial invisibility cloak. A key feature of the transformation optics is the invariance of the Maxwell's equations after a coordinate transformation. Recently, we have developed a TO based FDTD method to numerically solve the Maxwell's equations with subgridding effect. The idea is to use TO to enlarge certain small sub-regions so that they look much larger in the transformed (virtual) space. Different from the subgridding methods that use small grid cells in small regions, the TO-FDTD solves the transformed problem on uniform grid using a recently developed stable anisotropic FDTD algorithm. In this talk, we will discuss the recent progress on TO based FDTD methods, including the extension to space-time domain and to dispersive and nonlinear media with application to optical pulse propagation. (Received January 30, 2015)

1109-65-169 **Lili Hu**, **Yao Li** and **Yingjie Liu*** (yingjie@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Further study of back and forth error compensation and correction method for advection and Hamilton-Jacobi equations.*

We further study the properties of the back and forth error compensation and correction (BFECC) method for advection equations such as those related to the level set method and for solving Hamilton-Jacobi equations on unstructured meshes. In particular, we develop a new limiting strategy. This new technique is very simple to implement even for unstructured meshes and is able to eliminate artifacts induced by jump discontinuities in derivatives of the solution as well as by jump discontinuities in the solution itself (even if the solution has large gradients in the vicinities of a jump). Typically, a formal second order method method for solving a time dependent Hamilton-Jacobi equation requires quadratic interpolation in space. A BFECC method on the other hand only requires linear interpolation in each step, thus is local and easy to implement even for unstructured meshes. (Received January 30, 2015)

1109-65-171 **Junshan Lin*** (jzl0097@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849. *Analysis and Computation of Electromagnetic Field Enhancement for Metallic Nano-gaps.*

There has been increasing interests in electromagnetic field enhancement and extraordinary optical transmission effect through subwavelength apertures in recent years, due to its significant potential applications in biological and chemical sensing, spectroscopy, terahertz semiconductor devices, etc. In this talk, I will present a quantitative analysis for the field enhancement when an electromagnetic wave passes through small metallic gaps. In particular, we show that enormous electric field enhancement occurs inside the gap, and the enhancement factor depends explicitly on the geometry of the metallic structure. The analysis also leads to a natural asymptotic method for numerical approximation of the electromagnetic fields. (Received January 30, 2015)

1109-65-176 **Abner J Salgado*** (asalgad1@utk.edu), Department of Mathematics, The University of Tennessee, Knoxville, TN 37996. *A PDE approach to the fractional obstacle problem.* Preliminary report.

We study solution techniques for the elliptic and parabolic obstacle problem with fractional diffusion. The fractional diffusion operator is realized as the Dirichlet-to-Neumann map of a nonuniformly elliptic problem posed on a semi-infinite cylinder. This allows us to localize the problem and consider instead a thin obstacle problem. We present, for the elliptic case, optimal error estimates based on recent regularity results. For the parabolic case we present an error analysis with minimal smoothness and one using the best regularity results available to date. (Received January 30, 2015)

1109-65-177 **Andreas Aristotelous*** (aaristot@temple.edu), **Ohannes Karakashian** and **Steven Wise**. *Discontinuous Galerkin Methods for Generalized Cahn-Hilliard Equations.*

Fully discrete discontinuous Galerkin methods with variable time steps and adaptive meshes in space are developed for fourth order generalized Cahn-Hilliard equations motivated from material science and biological applications. The methods are formulated and analyzed in both two and three dimensions. Convergence under mesh modification is demonstrated and simulation results in two dimensions are provided. (Received January 30, 2015)

1109-65-199 **Harish P Bhatt*** (hpb2e@mtmail.mtsu.edu), 2850 Middle Tennessee Blvd., Apt # D12, Murfreesboro, TN 37130, and **Abdul Q.M. Khaliq** (abdul.khaliq@mtsu.edu), 1301 East Main Street, Murfreesboro, TN 37132. *Numerical Simulation of System of Multidimensional Time Dependent PDEs with Locally Extrapolated ETD Scheme.*

The local extrapolation of first order locally one-dimensional exponential time differencing scheme is introduced for numerical solution of system of multidimensional time dependent PDEs. The stability, monotonocity, and convergence of the scheme have been examined. The performance of the novel scheme has been investigated by testing it on system of multidimensional nonlinear time dependent PDEs. The numerical experiments demonstrate that the present scheme provides better accuracy in comparison with the existing schemes. (Received February 01, 2015)

1109-65-227 **Yulong Xing*** (xingy@math.utk.edu), Knoxville, TN 37996. *Well-balanced discontinuous Galerkin methods for the Euler equations under gravitational fields.*

Hydrodynamical evolution in a gravitational field arises in many astrophysical problems. It is essential to correctly capture the effect of gravitational force in the simulations, especially if a long-time integration is involved, for example in modeling star and galaxy formation. Improper treatment of the gravitational force can lead to a solution which either oscillates around the equilibrium, or deviates from equilibrium after a long time run. In this presentation, we propose a recently developed well-balanced discontinuous Galerkin method for the Euler equations under gravitational fields. The hydrostatic equilibrium state for the Euler equations, such as zero flow velocity, can be precisely kept by the proposed scheme up to the machine error. Some numerical tests are performed to verify the well-balanced property, high-order accuracy, and good resolution for smooth and discontinuous solutions. (Received February 02, 2015)

1109-65-236 **Aycil Cexmelioglu*** (cesmelio@oakland.edu), **Bernardo Cockburn** and **Weifeng Qiu**. *Analysis of a Hybridizable Discontinuous Galerkin Method for the incompressible Navier-Stokes equations.* Preliminary report.

We present an a priori error analysis of a hybridizable discontinuous Galerkin method, for the approximation of the stationary incompressible Navier-Stokes equations. The method is defined on conforming triangulations providing piecewise polynomial approximations of fixed degree k to the velocity gradient, velocity and pressure. Under a small data assumption, we prove that the method is well defined and that the global L^2-norm of the error in each variable converges with optimal order of $k+1$, $k \geq 0$. Furthermore, the approximate velocity is shown to be superconvergent which is then elementwise postprocessed to obtain an H(div)-conforming, divergence-free approximate velocity which converges with an order of $k+2$, $k \geq 1$. (Received February 02, 2015)

1109-65-263 **Bobby Philip*** (philipb@ornl.gov) and **Rajeev Kumar** (kumarr@ornl.gov). *Iterative Methods for Nonlinear Systems Arising in Diblock CoPolymer Systems.*

Over the past four decades, extensive scientific research has been directed towards developing a molecular level understanding of micro-phase separation in diblock copolymers. Novel applications such as the development of advanced materials for thermoplastic elastomers, nano-lithography, fuel cells and supercapacitors have made these systems a major focus in soft matter research worldwide and field theoretic approaches such as the self-consistent field theory (SCFT) have been used to predict the thermodynamic stability of these polymers.

We describe the SCFT model for a diblock copolymer system posed in terms of field potentials. The resulting nonlinear SCFT equations are solved using a nonlinear Krylov accelerator solver. The outer nonlinear solver requires computing the nonlinear residual at each iteration. For the SCFT systems this is extremely expensive as it requires integration of a set of diffusion equations at each iteration. These equations are integrated using an implicit BDF4 method with multigrid solvers at each time step. We describe the full solution process and some initial results and conclude with a description of the challenges to be tackled in future. (Received February 02, 2015)

1109-65-293 **Yanzhao Cao*** (yzc0009@auburn.edu). *Finite element method for flows in poroelasstic media.*

We consider a system of partial differential equations which models flows through elastic porous media. This system consists of an elasticity equation describing the displacement of an elastic porous matrix and a quasilinear elliptic equation describing the pressure of the saturating fluid (flowing through its pores). In this model, the permeability depends nonlinearly on the dilatation (divergence of the displacement) of the medium. In this talk results well-posedness and regularity as well as finite element approximations of the PDE system will be presented. (Received February 03, 2015)

70 ► Mechanics of particles and systems

1109-70-9 **Kimberly E Stubbs*** (kstubbs@unca.edu). *Dynamics of Co-Orbital Moons Near Collision.*

This project is about celestial mechanics and dynamical systems. Specifically, the goal is to explore the techniques used in modern celestial mechanics to analyze near-collision dynamics and chaos. The model we're working with is a 3-body co-orbital system. Josep Cors and Glen Hall wrote a paper on 3-body co-orbital systems and determined when the moons will pass each other and/or change orbits. They were only interested in these two occurrences, and so they left out the dynamics of near-collision. We're interested in finding out what happens near collision of the two moons and have done the necessary change of variables to allow analysis of the dynamics and chaos. We'll look into the dynamics and what they mean for the entire system. (Received November 17, 2014)

76 ► Fluid mechanics

1109-76-66 **Guibo Li**, **Yongsheng Lian**, **Yisen Guo**, **Matthew Jemison** and **Mark Sussman*** (sussman@math.fsu.edu), Florida State University, Department of Math, Tallahassee, FL 32306, and **Trevor Helms** and **Marco Arienti**. *Multiphase flow and Encapsulation simulations using the moment of fluid method.*

A moment of fluid method is presented to study incompressible flows involving more than two materials. This work is an extension of Jemison et al (JCP, 2014) in which they presented a moment of fluid method for simulating two-phase flows. For the present method the interfaces between different phases are captured using the moment of fluid method, a directionally split cell integrated semi-Lagrangian method is used to calculate interface and momentum advection, a projection method is used to calculate pressure, and a block structured adaptive mesh refinement method is used to locally increase the resolution in the regions of interest. Various multiphase problems, including problems illustrating contact line dynamics, triple junctions, and encapsulation are studied using the new method in order to demonstrate its capabilities. Examples are given in 2D, 3D axisymmetric (R-Z), and 3D (X-Y-Z) coordinate systems. (Received January 20, 2015)

1109-76-165 **Jonathan Gustafsson*** (cjgustaf@nps.edu), Naval Postgraduate School, 1 University Circle, Herrmann Hall RM-413W, Monterey, CA 93943, and **Sivaguru S. Sritharan**. *Discrete and continuous spectra for the linearized Navier-Stokes equation in an exterior domain: A Computational simulation.*

Numerical approximations of the spectrum of the Oseen operator and the linearized Navier-Stokes operator for flow around a cylinder in two dimensions have been studied for Reynolds numbers between 2 and 40. By using a spectral method featuring basis functions covering the entire exterior domain, it is possible to obtain a numerical approximation to the continuous spectrum and the isolated eigenvalues (point spectrum). The numerical approximation of the spectra agrees with the previous rigorous results by Babenko (1982). That is a parabolic tongue containing the continuous spectra for the Oseen operator and a parabolic tongue containing the continuous spectrum plus a finite number of isolated eigenvalues for the linearized Navier–Stokes operator. The talk will describe spectral methods for unbounded domains and a way of approximating continuous spectrum of operators. By varying the so-called length parameter it is possible to classify an numerical calculated eigenvalue as part of the continuous spectrum or an isolated eigenvalue. (Received January 30, 2015)

1109-76-291 **Sarma L Rani*** (sarma.rani@uah.edu), Department of Mechanical and Aerospace Engr, Huntsville, AL 35899, and **Shreyas Bidadi** (sb0028@uah.edu), Department of Mechanical and Aerospace Engr, Huntsville, AL 35899. *On the stability and diffusive characteristics of Roe-MUSCL and Runge-Kutta schemes for Implicit LES.*

Monotonically integrated large-eddy simulation (MILES) approach utilizes the dissipation inherent to shock-capturing schemes to emulate the role played by explicit subgrid-scale eddy diffusivity at the high-wavenumber end of the turbulent energy spectrum. In the current study, a novel formulation is presented for quantifying the numerical viscosity inherent to Roe-based second-order TVD-MUSCL schemes for the Euler equations. Using this formulation, the effects of numerical viscosity and dissipation rate on implicit large-eddy simulations of turbulent flows are investigated. At first, the three-dimensional (3-D) finite-volume extension of the original Roe's flux, including Roe's Jacobian matrix, is presented. The fluxes are then extended to second-order using van Leer's MUSCL extrapolation technique. Starting from the 3-D Roe-MUSCL flux, an expression is derived for the numerical viscosity as a function of flux limiter and characteristic speed for each conserved variable, distance between adjacent cell centers, and a scaling parameter. A detailed investigation was performed of decaying homogeneous isotropic turbulence with varying degrees of compressibility. Spectra of numerical viscosity and dissipation rate are presented. (Received February 03, 2015)

1109-76-299 **Babak Shotorban*** (bs0002@uah.edu), University of Alabama in Huntsville, Huntsville, Alabama 35899. *An Eulerian Model for Particles Nonisothermally Carried by a Compressible Fluid.* Preliminary report.

An Eulerian model describing the transport of particles that nonisothermally interact with their carrying flow is developed in the general time-dependent, three-dimensional frame. The Eulerian model derives from the Lagrangian kinematic, momentum and energy particle equations based on a combination of the filtered Liouville equation and the method of moments. The filtered Liouville equation governs the filtered density function of the particle velocities and temperature in phase space. The equations are closed by expressing third order moments in terms of lower order moments based on the assumption that third-order correlations are negligible. The particle transport equations are two-way coupled with the inviscid, Euler equations governing compressible flows. Consistent with the hyperbolic conservation form of the Eulerian–Eulerian model, a flux-vector splitting and characteristics-based Roe averaging method discretizes the equations. Computations of a cloud of particles initially at rest in a uniform, subsonic flow and in an accelerated flow behind a normal shock in one dimension, show very good comparison with a recent higher order WENO based Eulerian–Lagrangian model. (Received February 03, 2015)

1109-76-304 **Nicholas Gewecke*** (ngewecke@daltonstate.edu), 650 College Drive, Dalton, GA 30720, and **Rich Braun** and **P. Ewen King-Smith**. *Tear Film Rippling During Blinks.* Preliminary report.

The human tear film is important in promoting ocular health and clear vision, but many dynamics of the film are not yet well-understood. Clinical observations indicate a rippling in the tear film during blinks, primarily when the lid is in motion. Our model incorporates a single-layer tear film with surfactant, lid motion, and a rough corneal surface to simulate these clinical observations, with good agreement. (Received February 03, 2015)

78 ► Optics, electromagnetic theory

1109-78-166 **Jonathan Gustafsson**, Naval Postgraduate School, 1 University Circle, Herrmann Hall RM-413W, Monterey, CA 93943, and **Sivaguru S. Sritharan*** (sssritha@nps.edu). *Computing the electromagnetic wave propagation in random media with thermal effects.*

The talk will focus on numerical techniques for solving problems arising from the heating of a medium due to electromagnetic radiation (EMR) propagation. The electromagnetic wave is continuous and monochromatic. The propagation of the EMR is governed by the Maxwell equation and the EMR beam will heat the air. The change in temperature will change the refractive index of the air and thereby change the EMR propagation. The two PDEs are of different type and will therefore be solved using different numerical methods. The temperature of the air is modeled by the convection-diffusion equation and the equation will be solved using standard finite difference method. The Maxwell equations which governing the EMR is more complicated. By neglecting polarization and backscattering, we arrive at the paraxial equation. The complex valued electromagnetic field can be expressed as two real valued field. The intensity of the beam and it's the phase. By the taking the gradient of the phase it is possible to get "fluid-like" equations. The refractive index acts as pressure and a new term called the quantum pressure is introduced. The similarities and differences to the Euler equations will be discussed. Since the equation are "almost" hyperbolic, Riemann solver has been implemented in CLAWPACK.
(Received January 30, 2015)

81 ► Quantum theory

1109-81-270 **Jerzy Szulga*** (szulgje@auburn.edu), Department of Mathematics and Statistics, Auburn, AL 36849. *Baby Fock spaces - commutative and noncommutative Rademacher systems.* Preliminary report.

Paul-Andre Meyer studied in 1990s the "baby Fock space", i.e., the space of operators on the algebra spanned by Rademacher random variables, with applications to noncommutative probability, or "quantum stochastic calculus", and further to the actual Fock spaces (essentially, algebras spanned by Brownian motion). The operators themselves form a noncommmutative multiplicative system, similar in structure to the underlying

Rademacher chaos but with different properties, as expected. In fact, they make an example of a "quantum probabilistic chaos", whose theory and formalism will be presented in the talk. (Received February 03, 2015)

82 ► Statistical mechanics, structure of matter

1109-82-246 **Lei Zhang***, 686 Cherry St., Atlanta, GA 30332, **Xifeng Su**, No. 19, Xinjiekouwai St., Haidian District, Beijing, 100875, Peoples Rep of China, and **Rafael de la Llave**, 686 Cherry St., Atlanta, GA 30332. *Equilibrium quasi-periodic configurations in quasi-periodic media.*

We consider an atomic model of deposition of materials over a quasi-periodic medium. The atoms of the deposited material interact with the medium (a quasi-periodic interaction) and with their nearest neighbors (a harmonic interaction). This is a quasi-periodic version of the well known Frenkel-Kontorova model.

We consider the problem of whether there are quasi-periodic equilibria with a frequency that resonates with the frequencies of the medium. We show that there are always perturbative expansions. We also prove a KAM theorem in a-posteriori form. We show that if there is an approximate solution of the equilibrium equation satisfying non-degeneracy conditions, we can adjust one parameter and obtain a true solution which is close to the approximate solution.

The proof is based on an iterative method of the KAM type. The iterative method is not based on transformation theory as the most usual KAM theory, but it is based on a novel technique of supplementing the invariance equation with another equation that factors the linearization of the equilibrium equation. (Received February 02, 2015)

92 ► Biology and other natural sciences

1109-92-5 **Jia Zhao*** (zhaojiachina@gmail.com), 1523 Greene Street, room 411, Columbia, SC 29205, and **Qi Wang**. *3D Mathematical Modeling and Simulations of Cell Mitosis by a Phase Field Approach.* Preliminary report.

During a cell cycle, mitosis is a process, in which a mother cell duplicates into two generically similar daughter cells. In the initial stage of mitosis, the mother cell, attached on a substrate, would undergo a dramatical shape change by detaching from the substance and forming a round surface. At the late stage of mitosis, a contractile ring would form in cell orbit and the mother cell would split into two daughter cells, which is known as cytokinesis for eukaryotic cells.

Recently, we have developed a series of three-dimensional hydrodynamic models by a phase field approach, studying cellular mitosis. Qualitatively patterns of cell rounding, blebbing and division process have been observed. In this talk, our preliminary study on the mechanism and controlling factors of cell mitosis would be present. 3D numerical simulations will be shown, as well. (Received September 10, 2014)

1109-92-6 **Evan M Milliken*** (evmilliken@ufl.edu), Department of Mathematics, PO BOX 11805, University of Florida, Gainesville, FL 32611-8105. *A Model of Infectious Salmon Anemia Virus with Viral Diffusion between Wild and Farmed Patches.* Preliminary report.

As the practice of aquaculture to provide farmed seafood has risen, the question of the effect large fish farms have on nearby wild fisheries has become ever more pressing. Infectious Salmon Anemia (ISA) is highly contagious disease with high accumulated mortality rates that has affected farmed salmon around the world. ISA is caused by Infectious Salmon Anemia virus (ISAv). Proposed is a model to examine the dynamics of a salmon farm and a wild fishery both on their own and when coupled via viral diffusion. The conditions for strong uniform persistence of the disease are given for the complete systems as well as for invariant subsystems. (Received October 27, 2014)

1109-92-11 **Yu Jin*** (yjin6@unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Population persistence in temporally varying river environments.*

We consider integrodifference models in temporally (periodically/randomly) varying river environments. Growth and dispersal functions are subjected to temporal variations. For the model with periodic (alternating) parameters, we obtain the principal eigenvalue of the linearization operator to determine population persistence and derive a boundary value problem to calculate persistence conditions. For the model with randomly varying parameters, we establish two persistence metrics: a generalized spectral radius and the asymptotic growth rate, which are mathematically equivalent but can be understood differently, to determine population persistence or extinction. The theoretical framework and methods for calculations are provided, and the framework is applied to calculating persistence in highly variable river environments. (Received December 07, 2014)

1109-92-23 **Jemal S Mohammed-Awel*** (jmohammedawel@valdosta.edu), **C. N. Ngonghala**, **S. Y. Del Valle** and **R. Zhao**. *Quantifying the impact of decay in bed-net efficacy on malaria transmission.*

Insecticide-treated nets (ITNs) are at the forefront of malaria control programs. The potential impact of ITNs on reducing malaria transmission is limited due to inconsistent or improper use, as well as decay in effectiveness. We develop a mathematical model for malaria spread that captures the decrease in ITN effectiveness. We perform uncertainty and sensitivity analyses to identify and rank parameters that play a critical role in malaria transmission. These analyses show that the basic reproduction number R0, and the infectious human population are most sensitive to bed-net coverage and the biting rate of mosquitoes. We consider the case in which ITN efficacy is constant over time as well as the case in which ITN efficacy decays over time. (Received December 27, 2014)

1109-92-50 **Sophia Jang*** (sophia.jang@ttu.edu), Lubbock, TX 79409, and **Edward Allen**, Lubbok, TX. *Deterministic and stochastic nutrient-phytoplankton-zooplankton models with periodic toxin producing phytoplankton.*

We present deterministic and stochastic models of nutrient-phytoplankton-zooplankton interaction to investigate the impact of periodic toxin producing phytoplankton upon persistence of the populations. The Itô differential equations are used to model variability in the environment. We conclude that the input nutrient concentration along with the toxin liberation rate play critical roles in the dynamics of the plankton interaction. In particular, toxin producing phytoplankton can terminate harmful plankton blooms and the plankton interaction is more stable if either the input nutrient concentration is smaller or if the toxin producing rate is larger. (Received January 17, 2015)

1109-92-57 **J M Cushing*** (cushing@math.arizona.edu), Department of Mathematics, 617 N Santa Rita, University of Arizona, Tucson, AZ 857191108, and **Amy Veprauskas**, **Shandelle M Henson** and **James L Hayward**. *Environmental change and life history strategies: cannibalism and reproductive synchrony II.* Preliminary report.

Environmental change (e.g., a reduction in food resources) can significantly alter the life history strategies of individuals in a population. For example, increased cannibalism has been widely documented in a large number of species, across from many taxa, in response to food shortages. In turn, individuals within a population will adapt their life history strategies in various ways in response to increased cannibalism. For example, recent observations made in glaucous-winged gull colonies on Protection Island National Wildlife Refuge have documented strong correlations among food shortages (caused by a rise in mean sea surface temperatures), adult cannibalism of eggs, and reproductive timing (egg laying) of females. We formulate and analyze a stage-structured matrix model for a cannibalistic population in order to investigate the complicated dynamics that can result from such a scenario, especially with regard to population extinction or persistence. Mathematically, the study involves the stability and bifurcations of equilibria and synchronous periodic cycles and the occurrence of multiple attractors and Allee effects. (Received January 29, 2015)

1109-92-69 **Shuguan Ji**, **Weishi Liu** and **Mingji Zhang*** (mzhang@math.msu.edu), 619 Red Cedar Road, Room C300, East Lansing, MI 48824. *Effects of (small) permanent charge and channel geometry on ionic flows via classical Poisson-Nernst-Planck models.*

We examine effects of permanent charges on ionic flows through ion channels via a quasi-one-dimensional classical Poisson-Nernst-Planck model. The geometry of the three-dimensional channel is presented in this model to a certain extent, which is crucial for the study. Two ion species, one positively charged and one negatively charged, are considered with a simple profile of permanent charges: zeros at the two end regions and a constant Q_0 over the middle region. The classical PNP model can be viewed as a boundary value problem (BVP) of a singularly perturbed system. The singular orbit of the BVP depends on Q_0 in a regular way. Assuming $|Q_0|$ is small, a regular perturbation analysis is carried out for the singular orbit. Our analysis indicates that effects of permanent charges depend on a rich interplay between boundary conditions and the channel geometry. Furthermore, interesting common features are revealed: for $Q_0 = 0$, only an average quantity of the channel geometry plays a role; however, for $Q_0 \neq 0$, details of the channel geometry matter, in particular, to optimize effects of a permanent charge, the channel should have a short and narrow neck within which the permanent charge is confined. The latter is consistent with structures of typical ion channels. (Received January 20, 2015)

1109-92-73 **Michael A. Saum*** (msaum@ggc.edu) and **James E. Russell**. *Mathematical Modeling of Parthenogenisis Induced* Wolbachia *Infections in a Population.* Preliminary report.

We develop population models based on estimated fitness parameters to predict the evolution of mutant alleles associated with female sexual function. These models describe possible mechanisms for the spread of Parthenogenisis Induced (PI) *Wolbachia* infection and the associated sex ratio distortion imposed on infected populations. Results obtained from experiments where *Wolbachia pipientis* infections occurred in a population of *Trichogramma kaykai* parasitic wasps are used to calculate estimates and confidence intervals of model parameters such as fecundity, mortality, and sex ratio. (Received January 21, 2015)

1109-92-75 **Azmy S. Ackleh** and **Keng Deng*** (deng@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504, and **Yixiang Wu**. *Competitive Exclusion and Coexistence in a Two-Strain Pathogen Model with Diffusion.*

We consider a two-strain pathogen model described by a system of reaction-diffusion equations. We define a basic reproduction number R_0 and show that when the model parameters are constant (spatially homogenous), if $R_0 > 1$ then one strain will outcompete the other strain and drive it to extinction, but if $R_0 \leq 1$ then the disease-free equilibrium is globally attractive. When we assume that the transmission and recovery rates are heterogenous, then there are two possible outcomes under the condition $R_0 > 1$: 1) Competitive exclusion where one strain dies out. 2) Coexistence between the two strains. Thus, spatial heterogeneity promotes coexistence. (Received January 21, 2015)

1109-92-84 **Glenn F Webb*** (glenn.f.webb@vanderbilt.edu), Mathematics Department, Vanderbilt University, Nashville, TN 37240, and **Cameron Browne**, Mathematics Department, Vanderbilt University, Nashville, TN 37240. *A Model of Ebola Incorporating Age of Infection.* Preliminary report.

A model of an Ebola epidemic is developed with infected individuals structured according to disease age. The transmission of the infection is tracked by disease age through an initial incubation (exposed) phase, followed by an infectious phase with variable transmission infectiousness. The removal of infected individuals is dependent on disease age, with three types of removal rates: (1) removal due to hospitalization (isolation), (2) removal due to reported mortality separate from hospitalization, and (3) removal due to unreported mortality or unreported recovery. The model is applied to the Ebola epidemics in Sierra Leone and Guinea. Model simulations indicate that successive stages of increased and earlier hospitalization of cases have resulted in mitigation of the epidemics. (Received January 23, 2015)

1109-92-85 **Necibe Tuncer** (ntuncer@fau.edu), Department of Mathematics, Florida Atlantic University, Boca Raton, FL 33431, FL 33431, **Juan Torres** (gatorcha@ufl.edu), Department of Mathematics, University of Florida, Gainesville, FL 32611, **Maia Martcheva*** (maia@ufl.edu), Department of Mahematics, University of Florida, Gainesville, FL 32611, **Mike Barfield** (mjb01@ufl.edu), Department of Biology, University of Florida, Gainesville, FL 32611, and **Robert D. Holt** (rdholt@ufl.edu), Department of Biology, University of Florida, Gainesville, FL 32611. *Dynamics of Low and High Pathogenic Avian Influenza in Wild and Domestic Bird Populations.*

We introduce a time-since-recovery structured, multi-strain, multi-population model of avian influenza. Influenza A viruses infect many species of wild and domestic birds and are classified into two groups based on their ability to cause disease: low pathogenic avian influenza (LPAI) and high pathogenic avian influenza (HPAI). Prior infection with LPAI provides partial immunity towards HPAI. The model structures LPAI-recovered birds (wild and domestic) with time-since-recovery and includes cross-immunity toward HPAI that can fade with time. We find a unique disease-free equilibrium (DFE), LPAI-only equilibrium and HPAI-only equilibrium and at least one coexistence equilibrium. LPAI and HPAI can coexist in sustained oscillations. Through simulations, we show that even if both populations (wild and domestic) are sinks; that is, have reproduction numbers and invasion numbers smaller than one, LPAI and HPAI can persist in both populations combined. (Received January 24, 2015)

1109-92-126 **Ronald E. Mickens*** (rmickens@cau.edu), Clark Atlanta University, Department of Physi, Atlanta, GA 30314. *A Comparative Analysis of Single Population Growth Models.*

Key Word: SIR models, population dynamics

Mathematical representations of SIR models for spread of disease often use for the growing susceptible population, S, the expression

$$\frac{dS}{dt} = \Pi - \mu S, \tag{1}$$

where Π is a constant production rate and $(1/\ \mu)$ is related to the "average" age of individuals of this population. For a variety of reasons, such a form is not suitable for actual use in trying to understand this type of disease spread. After stating several a priori conditions which should hold for any "valid" single population model, we examine in detail critical features of four single population growth models and compare the results they give for growth rates, estimates of times to population saturation, etc. All of these models, except for one, can be exactly solved in terms of the elementary functions. Conclusions are stated on the suitability of each single-population model, for S, for its incorporation into a full SIR type model. (Received January 28, 2015)

1109-92-128 **Shandelle M. Henson*** (henson@andrews.edu), Department of Mathematics, 4260 Administration Dr., Andrews University, Berrien Springs, MI 49104, and **J. M. Cushing** and **James L. Hayward**. *Environmental change and life history strategies: cannibalism and reproductive synchrony III.* Preliminary report.

Increased sea surface temperatures depress marine food webs and are associated with large increases in egg cannibalism in glaucous-winged gulls. The synchronization of gull ovulation cycles, observed in these birds, may be an adaptive response to increased egg cannibalism. We pose a general discrete-time model for ovulation dynamics during the breeding season and then extend it across multiple seasons. We show that in the presence of cannibalism ovulation synchrony can enhance total population size and allow the population to persist at lower birth rates than would be possible without synchrony. (Received January 29, 2015)

1109-92-133 **Eric S Numfor***, 1120 15th Street, Georgia Regents University, Augusta, GA 30912, and **Souvik Bhattacharya**, **Maia Martcheva** and **Suzanne Lenhart**. *Optimal Control in Multi-group Coupled Within-host and Between-host Models.*

Optimal control can be used to design intervention strategies for the control of infectious diseases, and has been applied in decoupled immunological and epidemiological models of HIV. We formulate a multi-group immuno-epidemiological model of coupled within-host model of ODEs and between-host model of ODE and PDEs, using HIV for illustration. Existence and uniqueness of solution to the immuno-epidemiological model are obtained by using Ekeland's principle. An explicit expression for the basic reproduction number of the linked model is derived, and local asymptotic and global stability results are obtained. An optimal control problem with drug-treatment control on the multi-group within-host system is formulated and analyzed. Numerical simulations based on a semi-implicit finite difference scheme and a forward-backward sweep method are obtained. (Received January 28, 2015)

1109-92-134 **Garrett Divens*** (garrett.divens@morehouse.edu), Department of Mathematics, Morehouse College, Atlanta, GA 30314, and **Ronald E. Mickens** (rmickens@cau.edu), Department of Physics, Clark Atlanta University, Atlanta, GA 30314. *Exact Solution to A SIR Model with Population Growth.*

AMS Classification Number: 92D25, 92D30

Key Words: SIR models, spread of disease, nonlinear analysis, exact solutions

A particular (nonstandard) representation, from the class of SIR models for spread of disease, is [1]

$$\frac{dS}{dt} = a\sqrt{S} - bS - \beta\sqrt{S}\sqrt{I}, \tag{1}$$

$$\frac{dI}{dt} = \beta\sqrt{S}\sqrt{I} - \gamma\sqrt{I}, \tag{2}$$

where the mathematical relation for dR/dt is not required. By means of a nonlinear transformation for the dependent variables, S and I, we can obtain a set of two, coupled, linear differential equations and for these an exact solution can be determined. An interesting and very important feature is that this system has finite time dynamics, i.e., $I(t)$ goes to zero in a finite time. We also show that (1) and (2) may be rewritten to equivalent forms such that the new parameters have direct epidemiological meanings.

Reference

1. R.E. Mickens, The College Mathematics Journal, Vol.437 (2012), 114-121. (Received January 28, 2015)

1109-92-135 **'Kale Oyedeji*** (kale.oyedeji@morehouse.edu), Department of Physics, Morehouse College, Atlanta, GA 30314-3773, and **Ronald E. Mickens** (rmickens@cau.edu), Department of Physics, Clark Atlanta University, Atlanta, 30314. *A New Phenomenological Law of Cooling.* Preliminary report.

AMS Classification Number: 80A20

Key Words: Law of cooling, heat transfer, Newton's law of cooling

If an object at temperature T is introduced into a uniform environment having temperature $T_e < T$, then the object cools to T_e. Likewise, if $T_e > T$, the object warms to T. Under the condition, $|T - Te|\ T_e$, these situations are usually modeled by the Newton cooling law,

$$\frac{dT}{dt} = -K\left(T - T_e\right), \tag{1}$$

where K is a constant parameter, having the physical units of inverse time. Since all the solutions of (1) approach T_e and do so asymptotically, I.e., as it cannot provide a dynamically consistent model for cooling/heating, because it is observed that the actual physical system achieves the equilibrium temperature, $_{Te}$, in a finite time. We present arguments to show that a correct, phenomenological law of cooling should have the structure [1]

$$\frac{dT}{dt} = -K\left(T - T_e\right)^{\alpha}, \tag{2}$$

where α is a parameter satisfying the restriction, $0 < \alpha < 1$.

Reference

1. R.E. Mickens, Georgia Journal of Science, Vol. 67 (2009), 55. (Received January 28, 2015)

1109-92-137 **James F Selgrade*** (selgrade@ncsu.edu), Box 8205, North Carolina State University, Raleigh, NC 27695. *Dynamics and Bifurcation in Models for Hormonal Regulation of the Menstrual Cycle.*

Systems of ordinary differential equations are presented which describe various aspects of hormonal regulation of the menstrual cycle of adult women. Differences in dynamical behavior occur depending on which hormones are included in the model and what data sets are used to estimate parameters. In some cases, bistability of periodic solutions may occur. We analyze the bifurcation diagrams with respect to sensitive parameters using XPPAUT. For example, two crucial model parameters are examined that modulate the effects of estradiol and of ovarian androgens on pituitary synthesis of luteinizing hormone, which is required for ovulation. We show that hysteresis may explain some model differences. Implications for hormonal regulation of the menstrual cycle are discussed. (Received January 28, 2015)

1109-92-155 **J. Wang*** (jin-wang02@utc.edu). *Modeling the spatial dynamics of cholera.* Preliminary report.

We present our recent work in modeling the spatial dynamics of cholera, a water-borne disease caused by the bacterium *Vibrio cholerae*, using a partial differential equation framework. An emphasis of this study is the interplay of different biological, environmental and physical factors, including the intrinsic bacterial growth, direct and indirect disease transmission pathways, host and bacterial diffusion, and bacterial convection, which shape the complex pattern of cholera epidemics. Traveling wave solutions and disease threshold dynamics will be discussed, and both analytical and numerical results will be presented. This is joint work with Xueying Wang and Drew Posny. (Received January 29, 2015)

1109-92-163 **H. T. Banks** and **Shuhua Hu***, Center for Research in Scientific Computation, North Carolina State University, Raleigh, NC 27695-8212. *Propagation of Growth Uncertainty in a Physiologically Structured Population.*

Classical physiologically structured population models have been widely studied and employed in the literature to model the dynamics of a wide variety of populations. However in a number of cases these have been found inadequate to describe some phenomena arising in certain real-world applications such as dispersion in the structure variables due to growth uncertainty/variability. Prompted by this, we described two recent approaches to describe this growth uncertainty/variability in a physiologically structured population. One involves formulating growth as a diffusion process while the other entails imposing a probabilistic structure on the set of possible growth rates across the entire population. Both approaches lead to physiologically structured population models with nontrivial dispersion. Even though these two approaches are conceptually quite different, we found that the resulting models, with appropriate boundary and initial conditions as well as properly chosen parameters, yield quite similar solutions. (Received January 30, 2015)

1109-92-168 **Jin Shang**, **Bingtuan Li** and **Michael Barnard*** (michael.barnard@louisville.edu). *Bifurcations in A Discrete Time Model Composed of Beverton-Holt Function and Ricker Function.*

This talk will discuss rigorous analysis for a two parameter discrete-time model composed of the Ricker function and Beverton-Holt function. This model was proposed by Lewis and Li [Bull. Math. Bio. 74 (2012), 2383-2402] in the study of a population in which reproduction occurs at a discrete instant of time whereas death and competition take place continuously during the season. We will present analytical results proving the existence of a period-doubling bifurcation curve in the model that divides the two-dimensional parameter space into a region of stability and a region of instability. We will demonstrate through numerical bifurcation diagrams that regions of periodic cycles are intermixed with the regions of chaos. We will also present an analytical result on the global stability of the model. (Received January 30, 2015)

1109-92-208 **Libin Rong*** (rong2@oakland.edu). *Modeling HIV persistence and slow CD4+ T cell decline.* Preliminary report.

HIV cannot be eliminated by current combination therapy because of latent infection. The reservoir consisting of latently infected CD4+ T cells is extremely stable. The progressive loss of CD4+ T cells is the hallmark of HIV infection. The mechanisms underlying these virus and T cell dynamics are not fully understood. In this talk, I will review some existing models and introduce a new one based on the establishment of HIV latency to probe HIV persistence and the latent reservoir stability. Both deterministic and stochastic simulations of the model will be performed to study the long-term dynamics of HIV and latently infected cells. I will also develop another model to test a new mechanism that may explain the slow time scale of CD4+ T cell decline. Modeling prediction will be compared with long-term CD4+ T cell data in untreated HIV patients. (Received February 01, 2015)

1109-92-216 **H. Thomas Banks*** (htbanks@ncsu.edu), Ctr for Research in Sci Computation, Raleigh, NC 27695-8212. *Structured Population Models for Daphnia magna.*

We use statistical validation techniques to verify density-dependent mechanisms hypothesized for populations of Daphnia magna. This species of water flea has been characterized by the National Institutes of Health as a model organism for biomedical research. D. magna is also widely used in ecotoxicology to assess the hazard of exogenous chemicals, e.g., pesticides, on ecosystems. These assessments, however, have mainly focused on endpoints below the population level of biological organization, i.e., at the molecular, cellular, or organism levels. Structured population models can be used to propagate organismal assessments to the population level, thereby enabling the causal association of organismal responses to ecosystem adversity. We develop structured population models that exemplify specific mechanisms, and use multi-scale experimental data from our laboratory in order to test their importance. We show that fecundity and survival rates are affected by both time-varying density-independent factors, such as age, and density-dependent factors, such as competition. We perform uncertainty analysis and show that our parameters are estimated with a high degree of confidence. (Received February 01, 2015)

1109-92-224 **James L. Hayward*** (hayward@andrews.edu), Department of Biology, Andrews University, 4280 Administration Dr, Berrien Springs, MI 49104-0410, **Shandelle M. Henson** (henson@andrews.edu), Department of Mathematics, Andrews University, 4260 Administration Dr, Berrien Springs, MI 49104-0350, and **J. M. Cushing** (cushing@math.arizona.edu), Program in Applied Mathematics, Department of Mathematics, University of Arizona, Tucson, AZ 85721-0089. *Environmental change and life history strategies: cannibalism and reproductive synchrony I.* Preliminary report.

Climate change brings a variety of expected and unexpected consequences. We found that egg cannibalism in marine gulls increases sharply when sea surface temperature rises as little as a half degree. This is because even slightly higher sea surface temperatures depress marine food webs, thus reducing the amount of food available to marine animals. Cannibalism provides an alternate source of food during such times. Indeed, an egg cannibal can obtain nearly half its daily energy requirement by stealing and eating a single neighbor's egg. But female gulls have developed a strategy to reduce the chance that one of their eggs will be cannibalized. They ovulate synchronously with other females, analogously to the way human females synchronize menstrual cycles when living or working in close proximity. When female gulls lay eggs at the same time, each egg has a smaller chance of being cannibalized. In short, cannibalism functions as an adaptive response to food scarcity associated with rising sea surface temperatures; reproductive synchrony, in turn, functions as an adaptive response to cannibalism. In this talk we consider the biological setting that motivates the mathematical models in the following two talks. (Received February 02, 2015)

1109-92-232 **Philip S Crooke*** (philip.s.crooke@vanderbilt.edu), Department of Mathematics, Vanderbilt University, Nashville, TN 37240, and **Derek Smith**, **Jeffrey D Blume**, **William D Dupont** and **Fritz F Parl**. *Models for Individual Breast Cancer Risk.*

Breast cancer is a leading cause of death among women in the United States. The American Cancer Society estimates that 295,240 new cases of breast cancer among women (2,360 among men) have been diagnosed and 40,430 deaths have occurred from the disease during 2014. In this talk, we proposed two models for individual breast cancer risk. The models are based on genetic and/or phenotypic information of the individual woman. The genetic component of the models involves information about genes that encode enzymes in the estrogen metabolism pathway. The phenotypic component includes information about the woman's use of hormone replacement therapy, BMI, family history, etc. (Received February 02, 2015)

1109-92-233 **Rene A. Salinas*** (salinasra@appstate.edu), Department of Mathematical Sciences, 121 Bodenheimer Drive, 242 Walker Hall, Boone, NC 28608. *An Individual-Based Model for Feral Hogs in Great Smoky Mountains National Park.*

The expansion of feral hog (Sus scrofa) populations in the United States has resulted in increased efforts to develop and implement control strategies designed to minimize their impact. We describe an individual-based model for feral hogs in Great Smoky Mountains National Park (GSMNP). The objectives of the model are to provide for an understanding of the population dynamics of the feral hog population and to determine the efficacy of the annual harvest as a population control method. Results suggest that the dynamics of the population are driven by fall hard mast production and the GSMNP harvests currently limit growth of the population, but these control efforts have not reduced the population. (Received February 02, 2015)

1109-92-239 **Gangaram S Ladde*** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, CMC 342, Tampa, FL 33620-5700. *Stochastic Dynamic Modeling, Method and Applications.* Preliminary report.

By outlining the development of stochastic dynamic modeling, a methods of finding solutions are exhibited. Moreover, a analytic and statical results are presented. Finally, applications are given to illustrate the presented work. (Received February 02, 2015)

1109-92-241 **James M Hyman*** (mhyman@tulane.edu). *Hybrid Multiscale Models for Forecasting and Mitigating an Outbreak of the Ebola Virus Disease.* Preliminary report.

We describe a mathematical model for the recent West African Ebola virus disease (EVD) epidemic that can be used to quantify the impact of mitigations on epidemic severity. While many infectious disease epidemics are initially characterized by an exponential growth in time, we observed that the district-level EVD outbreaks in West Africa follow slower polynomial-based growth kinetics over several generations of the disease. To better understand these unusual epidemic transmission patterns, our model combines a branching process for disease progression, a network diffusion model for the spatial spread, and two types of mitigation to assimilate county-level weekly incidence data and make predictions for the course of the epidemic. We model the disease progression (infection status, contact patterns, treatment) in each infected person with an agent-based. The communities of people in contact with the infected individual are modeled by a continuum group of people associated with the infected population. The slower than expected growth pattern of local EVD outbreaks could result from behavior changes, success of control interventions, or intrinsic features of the disease such as a high level of clustering. (Received February 02, 2015)

1109-92-247 **Sergei S. Pilyugin*** (pilyugin@ufl.edu), Department of Mathematics, University of Florida, Gainesville, FL 32611, and **Cameron J Browne** (cameron.j.browne@vanderbilt.edu), Department of Mathematics, Vanderbilt University, Nashville, TN 37240. *Within-host virus model with multidrug therapy: optimizing the treatment.*

In this talk, I will review the basic mathematical properties of within-host viral models starting with the classical model proposed by De Boer, Kirschner, and Perelson. I will discuss the general dynamics of the model, and some of the model modifications accounting for alternative routes of viral transmission. Then I will discuss the effect of antiviral treatments both time-independent and time-periodic and investigate the question of optimal timing for administering different components of perioidic multidrug therapy. (Received February 02, 2015)

1109-92-275 **Ahmed Abdelrazec*** (aabdelr@asu.edu), ASU - Tempe, Tempe, AZ 85282, and **Jacques Belair** and **Huaiping ZHU**. *Modeling the Spread and Control of Dengue with Limited Public Health Resources.*

A deterministic model for the transmission dynamics of a dengue disease, with a nonlinear recovery rate reflecting the public health resources, is formulated to study the impact of available resources of the health system on the spread and control of dengue fever. Model results indicate the existence of multiple endemic equilibria and coexistence of an endemic equilibrium and a periodic solution. Additionally, our model exhibits the phenomenon of backward bifurcation. The results of this study could be helpful for public health agency arrange a proper amount of health resources for the control of dengue transmission. (Received February 03, 2015)

1109-92-278 **Jia Li*** (li@math.uah.edu), Department of Mathematical Sciences, University of Alabama in Huntsville, Huntsville, AL 35899. *Stage-structured wild and sterile mosquito population models and their dynamics.*

The sterile insect technique (SIT), in which sterile mosquitoes are released to reduce or eradicate the wild mosquito population, is an effective weapon to prevent the transmission of mosquito-borne diseases. To study the impact of SIT on the disease transmissions, we formulate stage-structured, continuous- or discrete-time mathematical models, which include wild larvae and adult mosquitoes and sterile adult mosquitoes, for their interactive dynamics. We incorporate different strategies for releasing sterile mosquitoes, investigate the model dynamics, and compare the impact of the different release strategies. Numerical examples are also provided to demonstrate dynamical features of the models. (Received February 03, 2015)

1109-92-281 **M. Gregory Forest*** (forest@unc.edu), Department of Mathematics, CB 3250, Chapel Hill, NC 27599-3250. *Mathematics of Living Fluids.*

This talk will highlight several collaborations in biology where experimental advances, including microscopy, provide unprecedented insight into living fluids and other fluids fundamental to life. Yeast and mammalian cells are two living fluid examples, and mucus is a fluid fundamental to life that coats every organ in the human body not covered by skin. The mathematical challenges include analysis of the data but also the development of mechanistic models that could be of predictive value beyond experiments. The experiments, data, relevant biology, and our mathematical progress will be presented. My numerous collaborators will be recognized throughout the lecture. (Received February 03, 2015)

1109-92-288 **Anna Mummert*** (mummerta@marshall.edu), **Jessica Shiltz**, **Robert Hughes**, **Roger Estep** and **Marcia Harrison**. *Agent-based Modeling of Seasonal Influenza.* Preliminary report.

In this talk I will describe a suite of susceptible-exposed-infectious-recovered (SEIR) agent-based models for simulating an influenza outbreak developed in the Netlogo programmable environment. The models include a base seasonal model and the control strategies of isolation, quarantine, vaccination, and antivirals. Several models were created to explore the mechanism responsible for the second peak of infections seen in the 2009 H1N1 influenza pandemic, including a periodic transmission rate, waning immunity, and two interacting populations. Model assumptions will be specified, preliminary results will be given, and a corresponding classroom case study will be described. (Received February 03, 2015)

1109-92-290 **Nitin Krishna**, **Hannah Pennington**, **Caanan Coppola**, **Marisa Eisenberg** and **Richard Schugart***, richard.schugart@wku.edu. *A Mathematical Model for the Interactions of MMP-1, TIMP-1, and ECM in a Wound.*

In this talk, a mathematical model is presented describing interactions among matrix metalloproteinases (MMP-1), their inhibitors (TIMP-1), and extracellular matrix (ECM) in the healing of a neuropathic diabetic foot ulcer. De-identified patient data for modeling were taken from Muller et al. (2008) and classified into two patient subgroups of "good" and "bad" healers. Model parameters for both subgroups were estimated curve fitting the data for each subgroup. Multiple sensitivity analyses were conducted and compared, where we describe one parameter as being locally sensitive, but globally insensitive. Results, implications, and extensions of this work will be discussed. (Received February 03, 2015)

1109-92-305 **Jing Chen**, Department of Mathematics, University of Miami, Coral Gables, FL 33124-4250, **Lan Zou**, Department of Mathematics, Sichuan University, Chengdu, Sichuan 610064, Peoples Rep of China, **Zhen Jin**, Complex Systems Research Center, Shanxi University, Taiyuan, Shanxi 030006, Peoples Rep of China, and **Shigui Ruan*** (ruan@math.miami.edu), Department of Mathematics, University of Miami, Coral Gables, FL 33124-4250. *Modeling the Geographic Spread of Rabies in China.* Preliminary report.

Recent phylogeographical analyses of rabies virus clades indicate that the human rabies cases in different and geographically unconnected provinces in China are epidemiologically related. In order to investigate how the movement of dogs affects the geographically inter-provincial spread of rabies in Mainland China, we propose a multi-patch model for the transmission dynamics of rabies between dogs and humans, in which each province is regarded as a patch. In each patch the submodel consists of susceptible, exposed, infectious, and vaccinated subpopulations of both dogs and humans and describes the spread of rabies among dogs and from infectious dogs to humans. The two-patch model will be used to simulate the human rabies data to investigate the inter-provincial spread of rabies between Guizhou and Guangxi, Hebei and Fujian, and Sichuan and Shaanxi, respectively. It is found that the basic reproduction number of such a two patch model can be larger than 1 even the isolated basic reproduction numbers of these two patches are less than 1. In order to reduce and prevent geographical spread of rabies in China, our results suggest that the management of dog market and trade need to be regulated and transportation of dogs need to be better monitored and under constant surveillance. (Received February 03, 2015)

1109-92-311 **Zhisheng Shuai*** (shuai@ucf.edu), University of Central Florida, Orlando, FL 32816, **Marisa C. Eisenberg**, University of Michigan, **Joseph H. Tien**, Ohio State University, and **Pauline van den Driessche**, University of Victoria. *Mathematical Studies of Heterogeneous Cholera Models.*

Cholera was one of the most feared diseases in the 19th century, and remains a serious public health concern today. It can be transmitted to humans directly by person-to-person contact or indirectly through ingestion of contaminated water. Basic cholera models that include both direct and indirect transmission and assume homogeneous mixing in the host population will first be reviewed. Detailed models that incorporate spatial heterogeneity will be applied to understand cholera dynamics on community networks. New biological insights will be derived using results from matrix theory and graph theory. (Received February 03, 2015)

1109-92-314 **Jiaxu Li*** (jiaxu.li@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292. *Modeling impulsive subcutaneous insulin delivery with time delay and a frame work for artificial pancreas.*

An artificial pancreas is an integrated system consisting of an insulin pump (IP), a glucose monitoring system (GMS), and CLC algorithms, which mimics the physiological dynamical behaviors among glucose and insulin in an automated fashion. Although substantial progress in developing model-based CLC algorithms has been made over the past decade, effective approach is still lacking in handling the delayed effects in the insulin delivery mechanisms, GMS and the hepatic glucose production (HGP). We model the delayed effects explicitly in the metabolic feedback loop by delay differential equations with impulsive inputs. Analytically we show the existence of a periodic solution. Numerically we demonstrate the effectiveness of the control using our models. We expect that ideal tight control of blood sugar can be achieved by applying algorithms based on our models and integrated with IP and GMS. (Received February 03, 2015)

97 ► Mathematics education

1109-97-319 **Tyler L Turner*** (turnert@apsu.edu), Mathematics and Statistics, P.O. Box 4626, Clarksville, TN 37044. *Combining Flipped-Classroom and Traditional Techniques in Teaching Algebraic Concepts.*

Most students that enter our Math 1110 (Algebraic Problem Solving) course are unprepared for college–level mathematics; they have weak algebraic skills and minimal knowledge of graphing calculators. In many cases, their understanding of mathematics is not sufficient to relate mathematical content to real life. This course traditionally consists of teaching algebra from a problem-solving perspective by providing the students with handouts taken from various sources. For our pilot study, an interactive eBook was created to create more connections between the mathematical content and real life problems in order to help the students gain a better understanding of both. Conceptual questions were assigned as homework before each class. Links to other educational technologies, like Khan Academy, were provided to give students more support outside of the classroom. Additionally, a calculator tutorial was made to enhance student learning. (Received February 04, 2015)

LAS VEGAS, NV, April 18–19, 2015

Abstracts of the 1110th Meeting.

00 ► General

1110-00-37 **Pengcheng Xu*** (pengcheng.xu@okstate.edu), Department of Mathematics, Oklahoma State University, Stillwater, OK 74078. *P-moves between pants block decompositions of 3-manifolds.*

A pants block decomposition of a compact hyperbolic 3-manifold is a decomposition of the 3-manifold which cuts the manifold into fundamental pieces called pants blocks. This is similar to a triangulation, which cuts the 3-manifold into tetrahedra. In this talk we will discuss how to relate two pants block decompositions of a manifold with a sequences of P-moves, which are similar to Pachner moves between triangulations. (Received January 20, 2015)

1110-00-46 **Gezahagne Mulat Addis*** (gezy7271@gmail.com), Dilla University, 419 Dilla, Ethiopia. *Updated Fundamental Theorem of Homomorphisms.* Preliminary report.

From the fundamental theorem of homomorphisms, it is well known that any homomorphism of groups (or rings or modules or vector spaces and of general universal algebras) can be decomposed as a composition of a monomorphism and an epimorphism. This paper provides the uniqueness of such a decomposition up to the level of associates by introducing the notion of an associate of a homomorphism. (Received February 17, 2015)

1110-00-353 **Jennifer L Schei*** (jlschei@lanl.gov), MS: D454, Los Alamos National Laboratory, Los Alamos, NM 87544, and **James F Harsh** and **Christopher D Tomkins**. *Spot Size Characterization for Radiographic Image Reconstruction.*

Radiography provides a means to view the internal structure of objects that are opaque to visible light by illuminating with higher energy electromagnetic radiation, such as x-rays. Image reconstruction techniques rely on understanding the radiographic source input parameters. Accurately characterizing the source blur function size and shape aids in more accurate image reconstruction and permits comparison of different systems. We used a Bayesian Inference Engine (BIE) to model and reconstruct radiographic images obtained at Los Alamos radiographic facilities. We investigated five spot size definitions to characterize the source blur functions: the frequency at which the modulation transfer function is 50%, LANL spot size, ESF spot size, full-width-half-maximum, and limiting resolution. Since the blur functions may not be axially symmetric, we averaged these spot size definitions at 36 angles. Furthermore, the blur functions may be neither reflectively symmetric about a plane nor rotationally symmetric. To reconstruct such a blur function, we created an egg-shaped model, which allows for asymmetric scaling of the blur function in the x- and y-directions. These tools enhance our capability to characterize experimental blur functions and reconstruct radiographic images. (Received February 24, 2015)

1110-00-373 **Farzan Jafeh*** (farzanjafeh@gmail.com), Plano, TX 75093, and **Z. Balanov**, **M. Dabkowski** and **M. Muzychuk**. *Congruence Principle for Brouwer Degree of Equivariant Maps between Solvable Group Representations Sphere.*

Many problems related to qualitative investigation of nonlinear differential equations admitting certain group of symmetries can be reduced to the following question raised by J.F. Adams (see Seattle Conference on Differential and Algebraic Topology, Collection of Unsolved Problems, 1963): Let G be a compact Lie group, V and W orthogonal G-representations, and k a given integer. Does there exist a G-equivariant map $f : S(V) \to S(W)$ with $\deg(f, S(V)) = k$ (here "$\deg(f, S(V))$" stands for the Brouwer degree of f and "$S(V)$" denotes the unit sphere in V)? Since 1963, this problem was intensively studied using different methods and techniques (equivariant obstruction theory, Borel spectral sequence method, fundamental domain method, equivariant K-theory, to mention a few). Our focus in this talk will be the case when G is a finite solvable group. The essential technical tools include geometric equivariant topology, representation theory, invariant theory and multilinear algebra. This talk is based on our joint work with Z. Balanov, M. Dabkowski and M. Muzychuk. (Received February 24, 2015)

01 ► History and biography

1110-01-17 **Viktoria Savatorova***, viktoria.savatorova@unlv.edu. *Moscow school of mathematics: history of the origin, the heyday and the disintegration of the Legendary Lusitania.*

Shortly before the World War I, Lusin and Egorov initiated a seminar at Moscow University which gave rise to the Moscow School of Mathematics. The seminar quickly became known as Lusitania. It was extremely attractive for students passionate about mathematics whose works in the short run put Moscow on the mathematical map of the world. Among members of Lusitania were Aleksandrov, Kolmogorov, Khinchin, Lavrentiev, and many others. Disintegration of Lusitania began in the mid 30s as a result of natural mathematical development of its members who became distinguished mathematicians with creative aspirations and tasks of their own. However, political reasons also played a significant role in breaking Lusitania up. Stalin's government tried to establish ideological control upon all spheres of culture including science. The founders of Lusitania were suitable targets being known for their non-materialistic views. In 1931 Egorov was arrested and sent to prison on the basis of his religious beliefs. In 1936 Luzin was tried at a special hearing of the Commission of the Academy of Sciences of the USSR as an enemy under the mask of a Soviet citizen. Lusitania disintegrated bringing to life a number of new schools some of which had a considerable impact on the development of mathematics. (Received December 08, 2014)

1110-01-109 **David Fott*** (`david.fott@unlv.edu`), Box 455029, 4505 S. Maryland Pkwy., Las Vegas, NV 89154-5029. *Descartes's Political Philosophy for the Advancement of Mathematics and Science.* Preliminary report.

Descartes is known as the inventor of analytic geometry and of a universal method of deductive reasoning based on mathematics. In part because of that method, he is also known as the "father of modern philosophy." But he is not widely known as a political philosopher. Descartes teaches that the primary goal of society should be the advancement of science–and by implication mathematics–for the benefit of society. He is not completely neutral on the question of what political regime best accomplishes that goal, but the existence of tyrannies that have supported science suggests that a wide range of regimes may serve the purpose. He does insist on the free exchange of doctrines within and among societies, which societies should allow based on a belief in the benevolence of science. In my paper I will claim that the centuries subsequent to Descartes have done much to undermine that belief. I will also note an objection closer to the core of Descartes's teaching: His method of universal doubt, which would destroy our natural trust in the correspondence between image and thing, also undercuts our receptivity to mathematics and science and prepares the way for postmodern philosophy, in which any claim to supply an explanation of the workings of the universe is dogmatically rejected. (Received February 14, 2015)

1110-01-114 **Alok Kumar*** (`alok.kumar@oswego.edu`), Department of Physics, State University of New York, Oswego, NY 13126. *In Service to Nature and the Divine: The Role of Religion in Scientific Advances.* Preliminary report.

The contentions between science and religion are well publicized in history with examples of Galileo, Bruno, and others. As a result, it is commonly assumed that the sciences and religion are innately in conflict. The truth is that, for the great majority of our history, in most cultures, the religious beliefs and scientific work supported each other and no barrier existed between the "scientific" and the "sacred."

In India, Aryabhata, a fifth century scholar, in his book *Aryabhatiya*, suggests people to learn mathematics, geometry, and astronomy to achieve salvation. Elsewhere, in Europe, Roger Bacon, a thirteenth century scholar, considers mathematics essential to learn about the celestial world that controls the terrestrial events. In Islam, Muslims needed to establish the correct coordinates (latitude and longitude) of their cities so that they could determine the direction of Mecca (qibla) for prayer.

For many scientists, the mighty nature is a law abiding machine and the developments in science support this. This talk provides examples of such collaborations where religions guided sciences or vice versa for their mutual growth. (Received February 15, 2015)

1110-01-150 **Andrzej Lenard*** (`andrewlenard@attu.pl`), Andrzej Lenard, 3710 Alabama st. #3, San Diego, CA 92104. *Polish Math House of the Interwar Period, Volume I.*

After regaining its independence in 1918, Poland experiences an outburst of extraordinary mathematicians. Immediately they create several world-leading mathematical centers at Polish universities in Warszawa, Lvov, Krakow, Poznan and Vilnus, which compete in achievements and significant mathematical publications among themselves. Young, often self-taught mathematicians like Banach, Sierpinski, Ulam, Tarski, Knaster, Steinhaus and many more, practice mathematics in a most unorthodox, original way. Their work result in world-recognition and their minds are desired to help to win the World War II. Some migrate to the USA and contribute to the Manhattan Project; others are used in the Allied army to break the Enigma codes. Most of them, however, stay in Poland and face the slaughter of intellectual class by Germans and Russians. In the first volume I focus on Stefan Banach, Stanislaw Ulam and Bronislaw Knaster. Besides their lives and achievements, I also include examples of the education curricula they learned as students and taught as teachers. (Received February 17, 2015)

1110-01-210 **Satish C Bhatnagar*** (bhatnaga@unlv.nevada.edu), Department of Mathematical Sciences, Las Vegas, NV 89154. *Aryabhatt: The King of Diamonds.*

Historically, in the US academic institutions, the History of Mathematics (HOM) is like a no-man land, particularly, when it comes to its development as an area of instruction and its academic specialization. After my years of engagement in HOM, a 'theorem' in HOM is equivalent to finding the necessary and sufficient conditions for the mathematical development of an individual, institution, society, or a nation. Thus, this paper focuses on Aryabhatta (476-550 AD), as the first 'theorem' in HOM!

The name of Aryabhatta would make to the top four of every list of great mathematical minds of ancient India. Yet, little is known of his life beyond mathematics and astronomy. The paper has two broad parts. The first part, apart from providing a summary of his achievements, attempts to align the mathematical problems he tackled with social challenges of his period. After all, mathematics is neither pursued nor supported in an intellectual vacuum.

The second part sheds light on the social and political conditions of golden India (c 300-600 AD) under the dynasty of the Gupta kings, which encouraged the development of mathematical and scientific culture. However, its influence gradually spread for beyond the borders of India. (Received February 24, 2015)

1110-01-393 **Dieudonne D Phanord*** (dieudonne.phanord@unlv.edu), 4505 Maryland Parkway, BOX 454020, Las Vegas, NV 89154-4020. *Barriers to the flourishing of Mathematics in Haiti.* Preliminary report.

A historical perspective about existing barriers to the advancement of Mathematics in Haiti will be presented. In addition, a comparison will be made between Haiti and other former French colonies where Mathematics form a major segment of their undergraduate and graduate curricula. Moreover, it will demonstrated why many Haitians exiled oversees are being productive in Mathematics. (Received February 24, 2015)

03 ► Mathematical logic and foundations

1110-03-64 **Alexander S Kechris*** (kechris@caltech.edu), Department of Mathematics, California Institute of Technology, Pasadena, CA 91125. *Structurable equivalence relations.* Preliminary report.

An important aspect of the theory of countable Borel equivalence relations on Polish spaces is an understanding of the kind of countable (first-order) structures that can be assigned in a uniform Borel way to each equivalence class of a given equivalence relation. We will discuss some recent results and open problems in this area, especially concerning the notion of smoothness (concrete classifiability) of equivalence relations. (Received February 07, 2015)

1110-03-163 **Nam D Trang*** (namtrang@andrew.cmu.edu), 4922 Centre Ave., Apt 11, Pittsburgh, PA 15213. *Descriptive inner model theory and forcing axioms.*

We discuss discuss some recent developments in descriptive inner model theory, focusing on works on constructing canonical inner models of large cardinals and determinacy from combinatorial consequences of forcing axioms such as PFA. The upshot is the speaker's result, built on earlier works of Steel and Sargsyan, that PFA implies the existence of models of "$\mathsf{AD}_{\mathbb{R}} + \Theta$ is regular". The talk is mostly a survey talk and we aim to explain definitions and notions involved, hence should be accessible to general set theorists. (Received February 18, 2015)

1110-03-230 **Megumi Sano** and **Futoshi Takahashi*** (futoshi@sci.osaka-cu.ac.jp), 3-3-138, Sugimoto, Sumiyoshi-ku, Osaka, 558-8585, Japan. *Improved Hardy inequalities in a limiting case.*

Let Ω be a bounded domain in $\mathbb{R}^N$ $(N \geq 2)$ which contains a point a and put $R = \sup_{x\in\Omega} |x-a|$. We concern the following Hardy inequalities in a limiting case:

$$\int_\Omega |\nabla u(x)|^N dx \geq \left(\frac{N-1}{N}\right)^N \int_\Omega \frac{|u(x)|^N}{|x-a|^N (\log \frac{Re}{|x-a|})^N} dx,$$

$$\int_\Omega |\nabla u(x)|^N dx \geq \left(\frac{N-1}{N}\right)^N \int_\Omega \frac{|u(x)|^N}{|x-a|^N (\log \frac{R}{|x-a|})^N} dx$$

for $u \in W_0^{1,N}(\Omega)$. It is known that the constant $\left(\frac{N-1}{N}\right)^N$ is the best one when Ω is a ball B_R and $a = 0$, and is never attained on $W_0^{1,N}(B_R)$. In this talk, we improve the above inequalities by adding nonnegative remainder terms to the right hand sides. (Received February 22, 2015)

1110-03-232 **Valentina Harizanov*** (harizanv@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *Quasimaximal vector spaces.* Preliminary report.

A set of natural numbers is called cohesive if it is infinite but cannot be split into two infinite parts by an algorithmically generated set. Every infinite set of natural numbers has a cohesive subset. The complements of some cohesive sets are algorithmically generated and such complements are called maximal sets. A quasimaximal set is the intersection of finitely many maximal sets. Quasimaximal sets and quasimaximal vector spaces play an important role in computable mathematics. We will explore some interesting combinatorial properties of the filters of quasimaximal spaces in the lattice of algorithmically generated vector spaces modulo finite dimension. This is joint work with Rumen Dimitrov. (Received February 22, 2015)

1110-03-236 **Joao Marcos M Do O*** (jmbo.pq@gmail.com), Federal University of Paraiba, Department of Mathematics, Joao Pessoa, Paraiba 58051900, Brazil. *Scalar field equations with Trudinger-Moser critical nonlinearity.*

We investigate the existence of ground state solutions for a class of nonlinear scalar field equations involving nonlinearities with Trudinger-Moser critical growth. We have to handle the lack of compactness of the associated energy functional due to the unboundedness of the domain and the presence of limiting case of Sobolev embedding. (Received February 22, 2015)

1110-03-248 **Joao Marcos Do O*** (jmbo.pq@gmail.com), Federal University of Paraiba, Department of Mathematics, 58051-900, João Pessoa-PB, Brazil, Joao Pessoa, Paraiba 58051900, Brazil. *Trudinger-Moser type inequalities for weighted Sobolev spaces.*

We derive sharp Trudinger–Moser inequalities for weighted Sobolev spaces and we prove the existence of extremal functions. The inequalities we obtain here extend for fractional dimensions the classical results in radial case. The main ingredient used in our arguments reveals a new proof of a result due to J. Moser for which we give an improved version (Received February 22, 2015)

1110-03-299 **Sherwood J. Hachtman*** (shac@math.ucla.edu). *The strength of determinacy in levels of the Borel hierarchy.*

Borel determinacy, established by D. A. Martin in the theory ZF, states that in any infinite two-person game with Borel winning condition, one of the players has a winning strategy. Despite being a fundamental theorem of analysis, results of H. Friedman show that Borel determinacy cannot be proven without some appeal to the large uncountable infinities of set theory. In this talk, we present best-possible level-by-level refinements of the dual Friedman/Martin results. We will also explore some connections with reverse mathematics and measurable cardinals. (Received February 23, 2015)

1110-03-309 **Stephen C Jackson*** (jackson@unt.edu), Department of Mathematics, University of North Texas, Denton, TX 76203. *Applications of new marker techniques to Borel equivalence relations.*

We prove some new results in the theory of Borel equivalence relations using newly developed marker techniques. These results contrast with those obtained by forcing methods. This work is joint with S. Gao, E. Krohne, and B. Seward. (Received February 23, 2015)

1110-03-319 **Martin Zeman*** (mzeman@math.uci.edu), Department of Mathematics, University of California at Irvine, Irvine, CA 92697-3875. *A variant of the duality theorem for ideals.* Preliminary report.

The duality theorem is an important tool for studying ideals which yields the representation of the poset of positive sets as a quotient of certain naturally occurring forcing poset. I will present a variant of the theorem that can be used to establish several properties of the non-stationary ideal in generic extensions. This is a joint work with Sean Cox. (Received February 23, 2015)

1110-03-328 **Dima Sinapova***, Department of Mathematics, Statistics, and Co, 322 Science and Engineering Offices, 851 S. Morgan Street, Chicago, IL , and **Spencer Unger**. *A dichotomy theorem for Prikry type forcings and weak square.*

An old open question of Woodin is whether the volation of the singular cardinal hypothesis (SCH) at $\aleph_\omega$ implies weak square at $\aleph_\omega$. The standard way of violating SCH is with Prikry type forcing. We will analyze when Prikry type forcings add a weak square at a singular cardinal. (Received February 23, 2015)

1110-03-336 **Edward W. Krohne*** (edwardkrohne@my.unt.edu), General Academics Building 435, 1155 Union Circle #311430, Denton, TX 76201. *The Twelve Tiles Theorem and Consequences for $F(2^{\mathbb{Z}^2})$.*

We present a novel theorem of Borel Combinatorics that sheds light on the types of continuous functions that can be defined on the graph of $F(2^{\mathbb{Z}^2})$. The topological space $F(2^{\mathbb{Z}^2})$ embeds into the Cantor space 2^ω and has a natural free continuous $\mathbb{Z}^2$ action. Considering the graph induced by this action, we obtain a disjoint union of uncountably many Cayley graphs of $\mathbb{Z}^2$. It is folklore that no continuous (indeed, Borel) function provides a chromatic two-coloring of $F(2^{\mathbb{Z}^2})$, despite the fact that any finite part of $F(2^{\mathbb{Z}^2})$'s graph is bipartite. The Twelve Tiles Theorem offers a much more complete analysis of continuous functions on this space. That is, we construct a sequence of finite graphs $(\Gamma_n)_{n\in\omega}$, each consisting of twelve "tiles", such that for *any* property P (such as "chromatic two-coloring") that is locally recognizable in the proper sense, a continuous function with property P exists on $F(2^{\mathbb{Z}^2})$ iff a function with a corresponding property P' exists on some Γ_n. We present the theorem, and give several applications. (Received February 24, 2015)

1110-03-344 **Marion Scheepers*** (mscheepe@boisestate.edu), Department of Mathematics, Boise State University, 1910 University Drive, Boise, ID 83725. *Topological Ramsey spaces and Rothberger spaces.* Preliminary report.

Rothberger spaces arose in the context of the Borel Conjecture, while the notion of a topological Ramsey space arose from a theorem of Ellentuck. In this talk we describe how the classical Rothberger property fits into the framework of topological Ramsey spaces. (Received February 24, 2015)

1110-03-350 **Su Gao*** (sgao@unt.edu), Department of Mathematics, University of North Texas, 1155 Union Circle #311430, Denton, TX 76203, **Steve Jackson** (jackson@unt.edu), Department of Mathematics, University of North Texas, 1155 Union Circle #311430, Denton, TX 76203, **Edward Krohne** (edwardkrohne@my.unt.edu), Department of Mathematics, University of North Texas, 1155 Union Circle #311430, Denton, TX 76205, and **Brandon Seward** (b.m.seward@gmail.com), Department of Mathematics, University of Michigan, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *Forcing constructions and countable Borel equivalence relations.*

We present some results on the Borel combinatorics of equivalence relations induced by countable group actions that are proved using forcing constructions and arguments. These results reveal hidden regularity properties of Borel complete sections on certain orbits. As consequences they imply the nonexistence of Borel complete sections with certain features. (Received February 24, 2015)

1110-03-381 **John D. Clemens*** (johndclemens@gmail.com). *Treeable equivalence relations and essential countability.*

We establish a dichotomy theorem characterizing when a treeable Borel equivalence relation E is essentially countable. Under additional assumptions on the treeing, we show that E is essentially countable if and only if there is no continuous embedding of the relation E_1 into E. In particular, we generalize and provide a classical proof of the analogous result for hypersmooth equivalence relations due to Kechris and Louveau. By considering a special class of treeings, we use our dichotomy to deduce several results about the global structure of the Borel reducibility hierarchy on equivalence relations, namely: the collection of treeable Borel equivalence relations is unbounded in the Borel-reducibility hierarchy; for every Borel equivalence relation which is not essentially hyperfinite we may find equivalence relations of arbitrarily high descriptive complexity with which it is incomparable under Borel reducibility; and for a sufficiently complicated Borel Wadge class Γ there is no minimum non-potentially Γ equivalence relation. This is joint work with Dominique Lecomte and Ben Miller. (Received February 24, 2015)

05 ► Combinatorics

1110-05-19 **Spencer Backman*** (spencerbackman@gmail.com). *Riemann-Roch theory for graph orientations.*

We introduce an equivalence relation on the set of partial orientations of a graph, which generalizes Gioan's cycle-cocycle reversal system. We explain how this setup allows for a new interpretation of the linear equivalence of divisors on graphs (chip-firing), and a new proof of Baker and Norine's combinatorial Riemann-Roch formula. Fundamental connections to the max-flow min-cut theorem will be highlighted. (Received December 17, 2014)

1110-05-23 **Andrew Treglown*** (a.c.treglown@bham.ac.uk) and **Katherine Staden**. *On degree sequences forcing the square of a Hamilton cycle.*

Many famous results in extremal graph theory give minimum degree conditions that force some substructure. For example, Dirac's classical theorem characterises the minimum degree that ensures a Hamilton cycle in a graph. However, sometimes it is possible to obtain stronger results via degree sequence conditions. For example, Pósa gave a significant strengthening of Dirac's theorem: if $d_1 \leq \cdots \leq d_n$ is the degree sequence of G and $d_i \geq i+1$ for all $i < n/2$, then G contains a Hamilton cycle. A famous conjecture of Pósa gives a minimum degree condition that ensures a graph contains the square of a Hamilton cycle. This was proved for large graphs by Komlós, Sárközy and Szemerédi. In this talk we consider a degree sequence analogue of this theorem. (Received January 04, 2015)

1110-05-26 **Khandoker Mohammed Mominul Haque** (momin66@gmail.com), Department of Computer Science and Engineerin, Sylhet, Sylhet 3100, Bangladesh, and **Umme Nasreen Khanam*** (ummenasreen@gmail.com), Department Computer Science, Sylhet, Sylhet, Bangladesh. *On the prime cordial labeling of Möbius Ladder M_n.* Preliminary report.

A graph with vertex set V is said to have a prime cordial labeling if there is a bijection f from V to $\{1, 2, \ldots, |V|\}$ such that if each edge uv is assigned the label 1 for the greatest common divisor $gcd(f(u), f(v)) = 1$ and 0 for $gcd(f(u), f(v)) > 1$ then the number of edges labeled with 0 and the number of edges labeled with 1 differ by at most 1. In this paper, we show that Möbius Ladder M_n is prime cordial for all n except M_4. (Received January 09, 2015)

1110-05-28 **Ervin Györi**, **Alexandr Kostochka**, **Andrew McConvey*** (mcconve2@illinois.edu) and **Derrek Yager**. *Toward Żak's conjecture on graph packing.*

Two graphs $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$, each of order n, *pack* if there exists a bijection f from V_1 onto V_2 such that $uv \in E_1$ implies $f(u)f(v) \notin E_2$. In, 2014, Żak proved that if $\Delta(G_1), \Delta(G_2) \leq n-2$ and $|E_1| + |E_2| + \max\{\Delta(G_1), \Delta(G_2)\} \leq 3n - 96n^{3/4} - 65$, then G_1 and G_2 pack. In the same paper, he conjectured that if $\Delta(G_1), \Delta(G_2) \leq n-2$, then $|E_1| + |E_2| + \max\{\Delta(G_1), \Delta(G_2)\} \leq 3n - 7$ is sufficient for G_1 and G_2 to pack. We prove that, up to an additive constant, Żak's conjecture is correct. Namely, there is a constant C such that if $\Delta(G_1), \Delta(G_2) \leq n-2$ and $|E_1| + |E_2| + \max\{\Delta(G_1), \Delta(G_2)\} \leq 3n - C$, then G_1 and G_2 pack. In order to facilitate induction, we prove a stronger result on list packing. (Received January 14, 2015)

1110-05-32 **Tri Lai*** (tmlai@ima.umn.edu), 207 Church Street SE, 306 Lind Hall, Minneapolis, MN 55455. *Enumeration of lozenge tilings of a hexagon with holes on boundary.*

MacMahon's classical theorem on plane partitions fitting in a given box is equivalent to fact that the number of lozenge tilings of a centrally symmetric hexagon of side-lengths a, b, c, a, b, c (in cyclic order) on the triangular lattice is equal to

$$\frac{H(a)H(b)H(c)H(a+b+c)}{H(a+b)H(b+c)H(c+a)},$$

where the hyperfactorial function $H(n)$ is defined by $H(n) := 0!1! \ldots (n-1)!$.

We generalize MacMahon's theorem by giving an exact enumeration for the lozenge tilings of a hexagon with three holes on boundary. The result also solves (and generalizes) an open problem posed by James Propp (*New Perspectives in Geometric Combinatorics*, Cambridge University Press, 1999). In addition, we investigate a q-analog of the result and its connection to q-enumeration of plane partitions that fit in a connected union of several boxes. (Received February 12, 2015)

1110-05-43 **James M. Carraher*** (carraherjm2@unk.edu), **David Galvin**, **Stephen G. Hartke**, **A. J. Radcliffe** and **Derrick Stolee**. *Independence ratio of distance graphs.*

A distance graph is an infinite graph whose vertex set is the integers and two integers are adjacent if their distance is in a prescribed distance set. We investigate the density of independent sets in finitely-generated distance graphs. We search for periodic sets to provide lower bounds and use discharging arguments to find upper bounds. Using this method we are able to determine the exact density for many generator sets and present several conjectures. (Received January 28, 2015)

1110-05-50 **Fu Liu***, fuliu@math.ucdavis.edu, and **Federico Castillo**. *Ehrhart positivity for generalized permutohedra.*

The Ehrhart polynomial $i(P,m)$ of an integral polytope P counts the number of lattice points in dilations of P. It is well known that the leading, second, and last coefficients of $i(P,m)$ are the volume of P, one half of the volume of the boundary of P and 1, respectively, and thus are all positive. However, it is not true that all the coefficients of $i(P,m)$ are positive.

There are few families of polytopes that are known to have positive Ehrhart coefficients. De Loera et al conjectured that matroid polytopes have this property. In our work, we consider generalized permutohedra, which contain matroid polytopes, and conjecture they all have positive Ehrhart coefficients.

We first reduce our conjecture to another conjecture which only concerns regular permutohedra, a smaller family of polytopes. The key ingredients in the reduction are perturbation methods and a valuation on the algebra of rational pointed polyhedral cones constructed by Berline and Vergne. Then we are able to show that the third and fourth Ehrhart coefficients of regular permutohedra are always positive by explicitly computing Berline-Vergne's valuation for our polytopes. We also obtain partial results on the coefficients of the linear terms. (Received February 04, 2015)

1110-05-51 **Matthias Beck*** (mattbeck@sfsu.edu), **Ana Berrizbeitia**, **Michael Dairyko**, **Claudia Rodriguez**, **Amanda Ruiz** and **Schuyler Veeneman**. *Parking functions, Shi arrangements, and mixed graphs.*

The *Shi arrangement* is the set of all hyperplanes in $\mathbf{R}^n$ of the form $x_j - x_k = 0$ or 1 for $1 \leq j < k \leq n$. Shi observed in 1986 that the number of regions (i.e., connected components of the complement) of this arrangement is $(n+1)^{n-1}$. An unrelated combinatorial concept is that of a *parking function*, i.e., a sequence $(x_1, x_2, ..., x_n)$ of positive integers that, when rearranged from smallest to largest, satisfies $x_k \leq k$. (There is an illustrative reason for the term *parking function*.) It turns out that the number of parking functions of length n also equals $(n+1)^{n-1}$, a result due to Konheim and Weiss from 1966. A natural problem consists of finding a bijection between the n-dimensional Shi arragnement and the parking functions of length n. Pak and Stanley (1996) and Athanasiadis and Linusson (1999) gave such (quite different) bijections. We will shed new light on the former bijection by taking a scenic route through certain mixed graphs. (Received February 04, 2015)

1110-05-56 **Radmila Sazdanovic*** (rsazdanovic@math.ncsu.edu), Department of Mathematics NCSU, SAS Hall 2311 Stinson drive, POBox 8205, Raleigh, NC 27695, and **Martha Yip**. *Categorification of chromatic polynomials.* Preliminary report.

We will talk about Khovanov-type categorifications in graph theory. In particular, we analyze chromatic graph cohomology and describe Khovanov-Stanley homology, a categorification of the Stanley symmetric chromatic polynomial. (Received February 06, 2015)

1110-05-60 **Tewodros Amdeberhan** and **Emily Leven*** (esergel@ucsd.edu). *Multi-cores, posets, and lattice paths.*

A partition of a positive integer n has a Young diagram representation. To each cell in the diagram there is an associated statistic called the hook length, and if a number t is absent from the diagram then the partition is called a t-core. A partition is an (s,t)-core if it is both an s- and a t-core. Since the work of Anderson on (s,t)-cores, the topic has received growing attention. This talk discusses some recent work expands the discussion to multiple-cores, with an emphasis on $(s, s+1, \ldots, s+k)$-core partitions. Our results exploit connections between three combinatorial objects: multi-cores, posets and lattice paths (with a novel generalization of Dyck paths). (Received February 06, 2015)

1110-05-70 **Jozsef Balogh*** (jobal@math.uiuc.edu), **Shagnik Das**, **Michelle Delcourt**, **Hong Liu** and **Maryam Sharifzadeh**. *Intersecting families of discrete structures are typically trivial.*

The study of intersecting structures is central to extremal combinatorics. A family of permutations $F \subset S_n$ is *t-intersecting* if any two permutations in F agree on some t indices, and is *trivial* if all permutations in F agree on the same t indices. A k-uniform hypergraph is *t-intersecting* if any two of its edges have t vertices in common, and *trivial* if all its edges share the same t vertices. The fundamental problem is to determine how large an intersecting family can be. Ellis, Friedgut and Pilpel proved that for n sufficiently large with respect to t, the largest t-intersecting families in S_n are the trivial ones. The classic Erdős–Ko–Rado theorem shows that the largest t-intersecting k-uniform hypergraphs are also trivial when n is large. We determine the *typical* structure of t-intersecting families, extending these results to show that almost all intersecting families are trivial. We also obtain sparse analogues of these extremal results, showing that they hold in random settings. Our proofs use the Bollobás set-pairs inequality to bound the number of maximal intersecting families, which can then be combined with known stability theorems. (Received February 09, 2015)

1110-05-71 **Humberto Silva Naves*** (hnaves@ima.umn.edu), 1034 23rd Ave SE, Minneapolis, MN 55414. *Maximizing proper colorings on graphs.*

The number of proper q-colorings of a graph G, denoted by $P_G(q)$, is an important graph parameter that plays fundamental role in graph theory, computational complexity theory and other related fields. We study an old problem of Linial and Wilf to find the graphs with n vertices and m edges which maximize this parameter. This problem has attracted much research interest in recent years, however little is known for general m, n, q. Using analytic and combinatorial methods, we characterize the asymptotic structure of extremal graphs for fixed edge density and q. Moreover, we disprove a conjecture of Lazebnik, which states that the Turán graph $T_s(n)$ has more q-colorings than any other graph with the same number of vertices and edges. Indeed, we show that there are infinite many counterexamples in the range $q = O\left(s^2/\log s\right)$. On the other hand, when q is larger than some constant times $s^2/\log s$, we confirm that the Turán graph $T_s(n)$ asymptotically is the extremal graph achieving the maximum number of q-colorings. Furthermore, other (new and old) results on various instances of the Linial-Wilf problem are also established. (Received February 09, 2015)

1110-05-77 **Christian Stump**, **Hugh R. Thomas** and **Nathan F. Williams*** (nathan.f.williams@gmail.com), Nathan Williams, LaCIM, Pavillon Président-Kennedy, 201, Président-Kennedy, 4ème étage, Montréal, Québec H2X 3Y7, Canada. *Why the Fuss?*

We place the program of m-eralizing noncrossing Coxeter-Catalan combinatorics in the context of the corresponding positive Artin monoid. Both noncrossing partitions and cluster complexes have previously been successfully m-eralized, but no m-eralization of c-sortable elements has yet been given. We define m-c-sortable elements as certain elements of the corresponding Artin monoid, and relate these to the existing m-erlized Catalan objects. We define the m-eralized c-Cambrian lattice by naturally extending the construction of the c-Cambrian lattices as a restriction of the weak order to the c-sortable elements. We also construct these lattices using the m-eralized noncrossing partitions—using a construction that is new even for m=1—and the cluster complexes. (Received February 10, 2015)

1110-05-82 **James Haglund**, **Jeffrey B. Remmel** and **Andrew T. Wilson*** (atwilson@ucsd.edu). *Parking functions with undesirable spaces.* Preliminary report.

We consider an extension of parking functions in which some parking spaces are marked as "undesirable." These objects lead to a variety of enumerative, algebraic, and geometric questions. In this talk, we focus on a conjecture which connects parking functions with undesirable spaces to Macdonald polynomial operators, generalizing the Shuffle Conjecture of Haglund, Haiman, Loehr, Remmel, and Ulyanov. We also show how our conjecture brings together combinatorial objects such as ordered set partitions, LLT polynomials, and generalized Tesler matrices. (Received February 10, 2015)

1110-05-83 **Ronald J. Gould*** (rg@mathcs.emory.edu), Dept. Math and CS, Emory University, Atlanta, GA 30322, and **Ralph Faudree**, **Michael Jacobson** and **Douglas West**. *Minimum Degree and Dominating Paths.*

A *dominating path* in a graph is a path P such that every vertex outside P has a neighbor on P. A result of Broersma from 1988 implies that if G is an n-vertex k-connected graph and $\delta(G) > \frac{n-k}{k+2} - 1$, then G contains a dominating path. The lengths of dominating paths include all values from the shortest up to at least $\min\{n-1, 2\delta(G)\}$. For $\delta(G) > an$, where a is a constant greater than 1/3, the minimum length of a dominating path is at most logarithmic in n when n is sufficiently large (the base of the logarithm depends on a). The preceding results are sharp. For constant s and $c' < 1$, an s-vertex dominating path is guaranteed by $\delta(G) \geq n - 1 - c'n^{1-1/s}$ when n is sufficiently large, but $\delta(G) \geq n - c(s \ln n)^{1/s} n^{1-1/s}$ (where $c > 1$) does not even guarantee a dominating set of size s. We also obtain minimum degree conditions for the existence of a spanning tree obtained from a dominating path by giving the same number of leaf neighbors to each vertex. (Received February 10, 2015)

1110-05-87 **Chun-Hung Liu*** (chliu@math.princeton.edu) and **Sang-il Oum**. *Partitioning H-minor free graphs into three subgraphs with no large components.*

We prove that for every graph H, if a graph G does not contain H as a minor, then its vertex set $V(G)$ can be partitioned into 3 sets X_1, X_2, X_3 such that for each i, the subgraph induced by X_i has no component of size larger than a function of H and the maximum degree of G. This answers a question raised by Esperet and Joret, generalizes their result for partitioning $V(G)$ into 3 such sets for graphs G embeddable in a fixed surface, and improves a result of Alon, Ding, Oporowski and Vertigan for partitioning $V(G)$ into 4 such sets for H-minor free graphs G.

As a corollary, we prove that for every positive integer t, if a graph G has no K_{t+1} minor, then its vertex set $V(G)$ can be partitioned into $3t$ sets $X_1, \ldots, X_{3t}$ such that for each i, the subgraph induced by X_i has no component of size larger than a function of t. This corollary improves a result of Wood for partitioning $V(G)$ into $\lceil 3.5t+2 \rceil$ such sets.

This work is joint with Sang-il Oum. (Received February 10, 2015)

1110-05-96 **Jeremy M Aikin*** (jaikin@csusb.edu) and **Adam Bland**. *Monochromatic sinks in arc-colored tournaments.*

We give a brief overview of the work done regarding the existence of a monochromatic sink in an arc-colored tournament. In particular, we focus on the case involving three colors and prove that if we impose some restrictions on the number of times arc-colors are allowed to change along cycles or paths, a monochromatic sink exists. (Received February 12, 2015)

1110-05-108 **Younjin Kim*** (younjin@kaist.ac.kr), Department of Mathematical Sciences, KAIST, 291 Daehak-ro, Yuseong-gu, Daejeon, 305-338, South Korea. *On Extremal Combinatorial Problems of Noga Alon.*

In 1991, Alon, Babai and Suzuki conjectured that if $n \geq s + \max_{1 \leq i \leq r} k_i$, then $|\mathcal{F}| \leq \binom{n}{s} + \binom{n}{s-1} + \cdots + \binom{n}{s-r+1}$ when $\mathcal{F}$ is a family of subsets of $[n]$ such that $|F_i| \pmod{p} \in K = \{k_1, k_2, \cdots, k_r\}$ for all $F_i \in \mathcal{F}$ and $|F_i \cap F_j| \pmod{p} \in L = \{l_1, l_2, \cdots, l_s\}$ for $i \neq j$, where K and L are disjoint subsets of $\{0, 1, \cdots p-1\}$ and p is a prime. In this talk, we prove this conjecture by using the algebraic method.

A family $\mathcal{F}$ is t-intersecting if any two members have at least t common elements. In 1961, Erdős, Ko, and Rado proved that the maximum size of a t-intersecting family of subsets of size k is equal to $\binom{n-t}{k-t}$ if $n \geq n_0(k,t)$. In 2014, Alon, Aydinian, and Huang considered families generalizing intersecting families, and proved the same bound. In this talk, we give a strengthening of their result by considering families generalizing t-intersecting families for all $t \geq 1$. (Received February 14, 2015)

1110-05-110 **Vasu Tewari*** (vasu@math.ubc.ca), .. *A right Pieri rule for noncommutative Schur functions.*

The noncommutative Schur functions introduced by Bessenrodt, Luoto and van Willigenburg are a basis for the algebra of noncommutative symmetric functions. They are noncommutative lifts of the classical Schur functions and exhibit noncommutative analogues of many of their properties including a noncommutative Pieri rule, which due to the noncommutative product is a left noncommutative Pieri rule. In this talk, we will describe a right noncommutative Pieri rule for the noncommutative Schur functions. To do this, we will give a noncommutative analogue of the jeu de taquin slide that will be performed on semistandard reverse composition tableaux. These slides will give rise to an operator on composition shapes, that we call the jdt operator, which in turn can be used to endow the set of compositions with a new poset structure. We will enumerate the maximal chains in this poset, and see that the noncommutative Littlewood-Richardson coefficients turn up naturally in so doing. Finally we will use the jdt operator to give a right Pieri rule. (Received February 14, 2015)

1110-05-115 **John M Dusel*** (jmd@math.ucr.edu), University of California, Riverside, Department of Mathematics, Riverside, CA 92521. *Balanced parabolic quotients and branching rules for Demazure crystals.*

We study a subset of a parabolic quotient in a simply-laced Weyl group W—stable under an automorphism σ—which we call the balanced parabolic quotient. This subset relates the branching rule for a Levi subalgebra, Demazure modules, and σ-invariant weight spaces in σ-stable simple modules for the corresponding Lie algebra; and its Hasse diagram under the Bruhat order is a forest with a remarkable self-similarity property. We characterize an element of a balanced quotient on the level of the root system of W, and find that the subalgebras of the Borel associated with these elements decompose into the direct sum of two subalgebras: one contained in the Borel for a Levi subalgebra, and another consisting of σ-invariants. (Received February 15, 2015)

1110-05-117 **Shaohui Wang*** (swang4@go.olemiss.edu), 12 Couny Road 1106, oxford, MS 38655, and **Bing Wei**. *Multiplicative Zagreb indices of k-trees.*

Let G be a graph with vetex set $V(G)$ and edge set $E(G)$. The first generalized multiplicative Zagreb index of G is $\prod_{1,c}(G) = \prod_{v\in V(G)} d(v)^c$, for a real number $c > 0$, and the second multiplicative Zagreb index is $\prod_2(G) = \prod_{uv\in E(G)} d(u)d(v)$, where $d(u), d(v)$ are the degrees of the vertices of u, v. The multiplicative Zagreb indices have been the focus of considerable research in computational chemistry dating back to Narumi and Katayama in 1980s. In this paper, we generalize Narumi-Katayama index and the first multicative index, where $c = 1, 2$, respectively, and extend the results of Gutman to the generilized tree, the k-tree, where the results of Gutman are for $k = 1$. Additionally, we characterize the extremal graphs and determine the exact bounds of these indices of k-trees, which attain the lower and upper bounds. (Received February 16, 2015)

1110-05-121 **Matthew Yancey*** (mpyancey1@gmail.com). *Bipartite Communities.*

A recent trend in data-mining is to find communities in a graph. Generally speaking, a community of a graph is a vertex set such that the number of edges contained entirely inside the set is "significantly more than expected." These communities are then used to describe families of proteins in protein-protein interaction networks, among other applications. We present a new goal in community detection: to find good *bipartite communities*. A bipartite community is a pair of disjoint vertex sets S, S' such that the number of edges with one endpoint in S and the other endpoint in S' is "significantly more than expected." We claim that this additional structure is natural to some applications of community detection. We will present a new algorithm for finding many bipartite communities using spectral methods. Classical community detection is known to be **NP**-hard; our algorithm is an approximation method with rigorous bounds. Additionally, we will present how the algorithm performs on public-source data sets. (Received February 16, 2015)

1110-05-123 **Sarah Behrens** (s-sbehren7@math.unl.edu), **Catherine Erbes** (erbescc@hiram.edu), **Michael Santana*** (santana@illinois.edu), **Derrek Yager** (yager2@illinois.edu) and **Elyse Yeager** (yeager2@illinois.edu). *Induced Saturation of Graphs.* Preliminary report.

The saturation number of a graph is a well-known, and often difficult to calculate, graph parameter. In 2011, Martin and Smith introduced a new variant of the saturation number for induced subgraphs, known as the induced saturation number. In this paper they determine the induced saturation number for cliques, cliques minus an edge, and the path on four vertices. In particular, the only known examples of graphs with induced saturation number zero were cliques minus an edge.

In this talk we show that many other graphs, such as the paw, stars, odd cycles, and matchings, each have induced saturation number zero. The abundance of such graphs leads us to consider a new parameter, specifically defined for graphs H with induced saturation number zero, in which we look for the minimum number of edges in an H-induced-saturated graph. We present bounds on this new parameter for many of the graphs listed above, and in particular, we determine this value completely for the paw, as well as the order magnitude for stars. (Received February 16, 2015)

1110-05-134 **Lucas Kramer** and **Ryan R. Martin*** (rymartin@iastate.edu), 396 Carver Hall, Department of Mathematics, Iowa State University, Ames, IA 50011. *A new upper bound for the size of diamond-free families.*

In the Boolean lattice, we say that a family $\mathcal{F}$ has a diamond as a (weak) subposet if there are four distinct subsets A, B, C, D such that $A \subset B \subset D$ and $A \subset C \subset D$. There has been a great deal of recent activity on the size of families in the Boolean lattice with no (weak) copy of a fixed subposet. However, the maximum size of a diamond-free family is still unknown, even asymptotically.

Using a method due to Manske and Shen, we have obtained a new upper bound for the size of a diamond-free family in the n-dimensional Boolean lattice of $(2.2067 + o(1))\binom{n}{\lfloor n/2\rfloor}$. This improves the previous bound of 2.25, which was due to the authors and Michael Young. (Received February 24, 2015)

1110-05-140 **Xing Peng*** (x2peng@ucsd.edu), Department of Mathematics, University of California, San Diego, La Jolla, CA 92093, **Michael Tait**, Department of Mathematics, University of California, San Diego, La Jolla, CA 92093, and **Craig Timmons**, Department of Mathematics and Statistics, California State University, Sacramento., Sacramento, CA 95819. *On the chromatic number of the Erdős-Rényi orthogonal polarity graph.*

Let q be a prime power and $PG(2, q)$ be the projective plane of order two. The Erdős-Rényi orthogonal polarity graph, denoted ER_q, is the graph whose vertices are the points of $PG(2, q)$. Two distinct vertices (x_0, x_1, x_2) and (y_0, y_1, y_2) are adjacent if and only if $x_0y_0 + x_1y_1 + x_2y_2 = 0$. The graph ER_q has $q^2 + q + 1$ vertices and $\frac{1}{2}q(q+1)^2$

edges. Moreover, ER_q does not contain 4-cycle as a subgraph. These graphs were constructed independently by Brown, and Erdős, Rényi, and Sós. The graph ER_q has many applications to problems in extremal graph theory. The independence number of ER_q is well-studied. Mubayi and Williford showed $\alpha(ER_q) \geq Cq^{3/2}$ for some constant $C < 1$. Godsil and Newman proved $\alpha(ER_q) \leq q^{3/2} + q^{1/2} + 1$. Therefore, the chromatic number $\chi(ER_q)$ is at least $\frac{q^2+q+1}{\alpha(ER_q)} \geq \frac{q^2+q+1}{q^{3/2}+q^{1/2}+1} \geq q^{1/2}$. One may ask whether this lower bound actually gives the right order of magnitude of $\chi(ER_q)$. In this talk, I will discuss the recent progress on this problem and related questions. (Received February 17, 2015)

1110-05-158 **Brendon Rhoades*** (bprhoades@math.ucsd.edu). *Evaluating q-analogs in algebra and combinatorics.*

Let X be a finite set of combinatorial objects. After finding a formula for the cardinality $|X|$, it is typical to generalize by finding a formula for the generating function $X(q) = \sum_{x \in X} q^{\mathrm{stat}(x)}$ for some "natural" statistic stat on the set X. Evaluating $X(q)$ at $q = 1$ recovers the original enumerator $|X|$, but what about other roots of unity? This question leads to the $q = -1$ phenomenon of Stembridge and the more general cyclic sieving phenomenon of Reiner, Stanton, and White. We will give examples of this phenomenon when X consists of objects such as set partitions, tableaux, and polygon dissections. We will see that answering this enumerative question can predict new results in algebra and geometry. (Received February 18, 2015)

1110-05-159 **Jeremy L. Martin*** (jeremy.l.martin@gmail.com), 405 Snow Hall, 1460 Jayhawk Blvd, Lawrence, KS 66045. *The uniqueness problem for chromatic symmetric functions of trees.*

The chromatic polynomial of a graph is a well-known invariant with many wonderful properties, but unfortunately it contains no information about a tree except its number of vertices. A refinement due to Stanley is the *chromatic symmetric function*, which does distinguish between trees of the same size. It is an open question whether two nonisomorphic trees can have the same chromatic symmetric function. I will describe what is presently known about the problem, including my joint work with Matthew Morin and Jennifer Wagner, and a brute-force computation carried out by Keeler Russell to rule out small counterexamples. (Received February 18, 2015)

1110-05-160 **Art M. Duval**, **Bennet Goeckner**, **Caroline J. Klivans** and **Jeremy L. Martin*** (jlmartin@ku.edu), 405 Snow Hall, 1460 Jayhawk Blvd., Lawrence, KS 66045. *New approaches to conjectures on decompositions of simplicial complexes.* Preliminary report.

A simplicial complex Δ is *partitionable* if its face poset decomposes into the disjoint union of Boolean intervals, each headed by a facet. Partitionability can be seen as a weakening of shellability that provides a similar combinatorial interpretation for the h-vector of Δ. Garsia and Stanley (independently) conjectured that every Cohen-Macaulay simplicial complex is partitionable; a related question of Stanley's is whether a k-uply acyclic complex can be decomposed into Boolean intervals of rank k. We describe an approach to these problems from the point of view of simplicial trees, as well as some relevant examples and partial results. (Received February 18, 2015)

1110-05-162 **Zoltan Furedi** (z-furedi@illinois.edu) and **Zeinab Maleki*** (zmaleki@math.iut.ac.ir). *Zykov's Symmetrization for Multiple Graphs with an Application to Erdős' Conjecture on Pentagonal Edges.*

Erdős, Faudree, and Rousseau (1992) showed that a graph on n vertices and at least $\lfloor n^2/4 \rfloor + 1$ edges has at least $2\lfloor n/2 \rfloor + 1$ edges on triangles. This result is sharp, just add an extra edge to the complete bipartite graph. In this talk, we give an asymptotic formula for the minimum number of edges contained on triangles in a graph having n vertices and e edges. Also, we introduce the main tool of the proof which is a new generalization of Zykov's symmetrization that can be applied for several graphs simultaneously. Further, we show how our weighted symmetrization method can be applied to tackle Erdős' conjecture concerning the minimum number of edges on 5-cycles. This is a joint work with Zoltán Füredi. (Received February 18, 2015)

1110-05-164 **Po-Shen Loh*** (ploh@cmu.edu), Wean 6113, Dept of Math Sciences, Carnegie Mellon University, Pittsburgh, PA 15213, and **Jie Ma**. *Diameter Critical Graphs.*

A graph is called diameter-k-critical if its diameter is k, and the removal of any edge strictly increases the diameter. We prove several results related to a conjecture often attributed to Murty and Simon, regarding the maximum number of edges that any diameter-k-critical graph can have. In particular, we disprove a longstanding conjecture of Caccetta and Haggkvist (that in every diameter-2-critical graph, the average edge-degree is at most the number of vertices), which promised to completely solve the extremal problem for diameter-2-critical graphs.

On the other hand, we prove that the same claim holds for all higher diameters, and is asymptotically tight, resolving the average edge-degree question in all cases except diameter-2. We also apply our techniques to prove several bounds for the original extremal question, including the correct asymptotic bound for diameter-k-critical graphs, and an upper bound of $(1/6+o(1))n^2$ for the number of edges in a diameter-3-critical graph. (Received February 18, 2015)

1110-05-170 **Florian Pfender*** (florian.pfender@ucdenver.edu) and **Bernard Lidický**. *Semidefinite programming bounds for small Ramsey numbers.*

In this talk, we will show how to use the plain flag algebra method to prove and improve upper bounds on small Ramsey numbers with the help of semidefinite programming. Several new bounds will be discussed. (Received February 19, 2015)

1110-05-173 **Dawei He**, **Yan Wang** and **Xingxing Yu*** (yu@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Progress on the Kelmans-Seymour conjecture on K_5-subdivisions.* Preliminary report.

Kelmans and Seymour independently conjectured in the 1970s that every 5-connected nonplanar graph contains a subdivision of K_5. Ma and Yu proved that this conjecture holds for graphs containing K_4^-. In this talk, I will discuss recent progress we made on this conjecture. This is joint work with Dawei He and Yan Wang (Received February 19, 2015)

1110-05-185 **Chun-Hung Liu** and **Jie Ma*** (jiema@ustc.edu.cn). *A conjecture of Thomassen on cycles with length condition.*

It is proved that every graph of minimum degree at least k+1 contains at least (k-1)/2 cycles with consecutive even lengths. This implies, among other results, a conjecture of Thomassen for all even integers k that every graph of minimum degree at least k+1 contains cycles of length 2m modulo k for any integer m. For odd integers k, we provide the best known result that the bound k+4 will suffice. (Received February 20, 2015)

1110-05-188 **Michael Young***, 396 Carver Hall, Ames, IA 50010. *Coloring the Integers with Rainbow Arithmetic Progressions.*

A k-term arithmetic progression is a sequence of the form $a, a+d, a+2d, ..., a+(k-1)d$, where a and d are nonnegative integers. Van der Waerden's Theorem states that given a set of colors there exists an interval $[1,n]$ such that any coloring of the integers, using all the colors, will contain a k-term arithmetic progression with each term having the same color. Given a set of colors and $k>0$, actually determining n, called a *van der Waerden number* has proven to be a very challenging problem. In this talk, we will introduce and discuss results about anti-van der Waerden numbers. An *anti-van der Waerden number* is the number of colors needed to guarantee that any coloring of the interval $[1,n]$ with all the colors must contain a k-term arithmetic progression with each term having a distinct color. (Received February 20, 2015)

1110-05-191 **Luke Postle*** (lpostle@uwaterloo.ca). *The Minimum Edge Density of 5-Critical Triangle-Free Graphs.*

A graph G is k-critical if G is not $(k-1)$-colorable but every proper subgraph of G is $(k-1)$-colorable. A natural question is to determine asymptotically the minimum average degree possible in a k-critical graph. In the 1960's it was conjectured that a construction of Ore gives the best possible answer. Recently, Kostochka and Yancey proved this conjecture by showing that k-critical graphs have asymptotically average degree at least $k-2/(k-1)$. One may wonder if the lower bound can be improved if certain subgraphs are forbidden. We prove this is true for $k=5$ when forbidding triangles. (Received February 20, 2015)

1110-05-199 **Scott Andrews** and **Nathaniel Thiem*** (thiemn@colorado.edu). *Supercharacters and the combinatorics of GGG representations.* Preliminary report.

Kawanaka introduced the generalized Gelfand—Graev representations to find the cuspidal (aka. hard to find) representations of finite groups of Lie type. Their remarkably technical construction has led to a relative dearth of results about their structure. This talk examines the case of finite general linear groups; here, using basic supercharacter theoretic techniques we not only simplify their definition, but also recover a beautiful underlying combinatorics for these representations built on Kostka—Foulkes polynomials. The ultimate goal of this approach is to use these methods to expand this program to general type. (Received February 20, 2015)

1110-05-201 **Mykhaylo Tyomkyn** and **Andrew J Uzzell*** (andrew.uzzell@unl.edu). *Strong Turán stability.*

Turán's theorem says that the largest K_{r+1}-free graph of order n is the Turán graph, a complete r-partite graph with balanced classes. Let $t_{n,r}$ denote the number of edges of the Turán graph. How close must the number of edges in a K_{r+1}-free graph G be to $t_{n,r}$ in order to guarantee that G is "close" to the Turán graph in various ways? In other words, how large can $t_{n,r} - e(G)$ be if G is not "close" to the Turán graph in a given sense? We determine (up to constant factors) the minimum number of edges needed to guarantee that a K_{r+1}-free graph has each of several properties: being r-colorable; containing a large complete r-partite subgraph; being a blow-up of an r-partite graph of fixed size; and containing many "twins", that is, pairs of vertices with the same neighborhood. A consequence of our results is a new, shorter proof of a theorem of Simonovits on the size and structure of extremal K_{r+1}-free graphs of chromatic number k, for each fixed $k \geq r \geq 2$. (Received February 20, 2015)

1110-05-206 **Jozsef Balogh**, **Hong Liu** and **Maryam Sharifzadeh*** (sharifz2@illinois.edu).
Subdivisions of a large clique in C_6-free graphs.

Mader conjectured that every C_4-free graph has a subdivision of a clique of order linear in its average degree. We show that every C_6-free graph has such a subdivision of a large clique. We also prove the dense case of Mader's conjecture in a stronger sense, i.e., for every c, there is a c' such that every C_4-free graph with average degree $cn^{1/2}$ has a subdivision of a clique K_ℓ with $\ell = \lfloor c'n^{1/2} \rfloor$ where every edge is subdivided exactly 3 times. (Received February 20, 2015)

1110-05-216 **Xiangwen Li***, 152 Luoyu Road, Wuhan, Hubei 430079, Peoples Rep of China.
Z_3-connectivity and 2-neighborhoods of claw-free graphs.

Jaeger *et al.*'s Z_3-connected conjecture was reduced to consideration of 5-edge-connected claw-free graphs by Lovász *et al.* [J. Combin. Theory, (B) 103 (2013) 587–598], Lai *et al.* [Information Processing letters, 111 (2011) 1085–1088] and Ma and Li [Discrete Math., 336 (2014) 57–68]. Let G be a claw-free graph such that there are at least two common neighbors for every pair of 2-distance vertices. Then G is hamiltonian by Shi [J. Graph Theory, 16 (1992) 267–271]. In this paper, we show that G is not Z_3-connected if and only if G is one of seven specified graphs, or three families of well characterized graphs. (Received February 21, 2015)

1110-05-217 **J. Haglund*** (jhaglund@math.upenn.edu). *Some new interpretations for the q,t-Schröder polynomial.* Preliminary report.

The q,t-Schröder polynomial describes the hook coefficients in the character of the space of diagonal harmonics, as a sum of simple powers of q,t over lattice paths. In this talk we introduce two other parameters, z,w, into this model, and discuss some of the multiple interpretations of the resulting four parameter function. Some involve Macdonald polynomials, and others are connected to the f-vector to h-vector transformation of the type A_{n-1} associahedron. Part of this is joint work with Jeff Remmel and Andy WIlson. (Received February 21, 2015)

1110-05-218 **Guoli Ding***, Mathematics Department, Louisiana State University, Baton Rouge, LA 70803, and **Adam Ferguson**, Math Department, Louisiana State University, Baton Rouge, LA 70803. *Excluding two minors of the Petersen graph.* Preliminary report.

With respect to the minor relation $\preceq$, there are exactly four graphs between K_5 and the Petersen graph P, and these graphs form a chain $K_5 \preceq L \preceq M \preceq N \preceq O \preceq P$. A classical result of Wagner characterizes K_5-free graphs. Together with Splitter theorem, this result also easily implies a characterization of L-free graphs. In this talk, we discuss characterizations of M-free and N-free graphs. (Received February 21, 2015)

1110-05-225 **David Galvin*** (dgalvin1@nd.edu). *The extremal enumerative question for colouring.*

In the mid-1980's Linial and Wilf independent raised the question "which n-vertex, m-edge graph admits the most proper q-colourings?". This has proven to be a tough nut to crack, and has generated lovely work from Lazebnik, Loh, Norine, Pikhurko, Sudakov, Woldar and others.

A more restrictive question, "which n-vertex, d-regular graph admits the most proper q-colourings?" is also proving tough to answer, but at least here there is a very concrete conjecture. A similar "extremal enumerative' question can be asked for many family of graphs.

In this talk I'll survey some of the work that has been done on these questions, and highlight open problems. (Received February 23, 2015)

1110-05-227 **Csaba D Toth*** (csaba.toth@csun.edu), 18111 Nordhoff Street, Northridge, CA 91330.
On the number of plane graphs with polyline edges.

It is shown that every n-element point set in the plane admits at most $\exp(O(kn))$ labeled planar graphs using polyline edges with k bends per edge. This is the first exponential upper bound for the number of labeled plane graphs where the edges are polylines of constant size. Applications include exponential upper bounds for the number of maximal anchored rectangle packings for n-point set in the plane. (Received February 22, 2015)

1110-05-233 **Haidong Wu***, Department of Mathematics, University of Mississippi, University, MS 38677. *Binary matroids excluding certain minors.* Preliminary report.

In this talk, I will present some recent results on 3-connected binary matroids containing or excluding certain minors. (Received February 22, 2015)

1110-05-242 **Quang T. Bach*** (qtbach@ucsd.edu), Department of Mathematics, University of California, San Diego, La Jolla, CA 92093-0112, and **Jeffrey B. Remmel** (remmel@math.ucsd.edu), Department of Mathematics, University of California, San Diego, La Jolla, CA 92093-0112. *Computing generating functions for the number of descents in permutations avoiding a family of permutations that start with 1.*

Let Γ be a set of permutations and let $\mathcal{NM}_n(\Gamma)$ be the set of permutations σ in the symmetric group S_n which have no consecutive occurrences of any permutation in Γ. We let des(σ) be the number of descents of σ and LRmin(σ) be the number of left-to-right minima of σ. Jones and Remmel computed the generating function

$$M_\tau(x,y,t) = \sum_{n\geq 0} \frac{t^n}{n!} \sum_{\sigma\in\mathcal{NM}_n(\tau)} x^{\mathrm{LRmin}(\sigma)} y^{1+des(\sigma)}$$

for the cases where Γ is a single permutation that starts with 1 and has one descent. In this talk, we extend the methods of Jones and Remmel to permutations which avoid certain families of permutations and permutations with more than one descents. (Received February 22, 2015)

1110-05-243 **Andrzej Dudek*** (andrzej.dudek@wmich.edu), Department of Mathematics, Western Michigan University, Kalamazoo, MI 49008. *On Hamilton Cycles in Random Hypergraphs.*

In this talk, we present both old and new developments concerning the Hamiltonicity of random hypergraphs. First, we consider random k-uniform hypergraphs of order n (each possible k-tuple appears independently with probability p) and determine the thresholds for the existence of different types of Hamilton cycles (including loose and tight cycles). Next, we discuss some very recent results about Hamiltonicity of random regular hypergraphs (joint work with Alan Frieze, Andrzej Ruciński, and Matas Šileikis). (Received February 22, 2015)

1110-05-247 **Paul N. Balister*** (pbalistr@memphis.edu), Department of Math Sciences, University of Memphis, Memphis, TN 38152, and **Béla Bollobás** and **Karen Gunderson**. *Independence Densities of Graphs and Hypergraphs.*

The independence density of a finite hypergraph is the probability that a subset of vertices, chosen uniformly at random is independent; that is, contains no hyperedges. Independence densities can be generalized to countable hypergraphs using limits. We show that, in fact, every positive independence density of a countably infinite hypergraph with hyperedges of bounded size is equal to the independence density of some finite hypergraph whose hyperedges are no larger than those in the infinite hypergraph. This answers a question of Bonato, Brown, Kemkes, and Prałat about independence densities of graphs. Furthermore, we show that for any k, the set of independence densities of hypergraphs with hyperedges of size at most k is closed and contains no infinite increasing sequences. (Received February 22, 2015)

1110-05-249 **Hao Huang*** (huanghao@ima.umn.edu). *Biclique decomposition of random graphs.*

The biclique partition number bp(G) is the minimum number of complete bipartite graphs needed to partition the edges of a graph G. Erdos conjectured that for the random graph G=G(n, 0.5), bp(G)=n-$\alpha(G)$ with high probability, where $\alpha(G)$ is the independence number. In this talk I will discuss some recent progress and and remaining challenges in this area, and construct a counterexample to this conjecture. Joint work with Noga Alon and Tom Bohman. (Received February 22, 2015)

1110-05-254 **Andre Kundgen*** (akundgen@csusm.edu), California State University San Marcos, and **Tonya Reeves**, California State University San Marcos. *Repetition-free edge colorings of trees.* Preliminary report.

A *repetition* in an edge-colored graph is a path on an even number of edges in which the sequence of colors in the the first half of the path is identical to that in the second half. Alon, Grytczuk, Haluszczak, and Riordan showed that every k-ary tree has a repetition-free edge-coloring with at most $4k$ colors. We present a new method for finding repetition-free edge-colorings of k-ary trees that improves on their bound in some cases. (Received February 22, 2015)

1110-05-257 **E. Gorsky**, **M. Mazin** and **M. Vazirani*** (vazirani@math.ucdavis.edu), Math Department, One Shields Ave, Davis, CA 95616. *Affine permutations and rational slope parking functions.*

The Catalan numbers $1, 2, 5, 14\ldots$ is one of the most well-known sequences in combinatorics. It enumerates over 100 families of combinatorial objects. Some of these families include the set of non-decreasing parking functions on $[n]$, the "$(n+1)$-restricted" affine permutations $w \in \widehat{S}_n/S_n$, and a basis of the finite-dimensional representation $eL_{(n+1)/n}$ of the spherical Cherednik algebra eH_ne. The above families and the bijections between them all generalize from $(n+1, n)$ to (m, n) when $\gcd(m, n) = 1$. Further, we can move from Catalan numbers to m^{n-1} by considering all parking function $PF_{m/n}$, the "m-restricted" $w \in \widehat{S}_n$, or the H_n-representation $L_{m/n}$.

Parking functions carry interesting combinatorial statistics. I'll discuss some of these statistics, how we hope they interact with $L_{m/n}$, and how they do arise in the space of diagonal harmonics, and in the geometry of certain affine Springer fibres.

This is joint work with Eugene Gorsky and Mikhail Mazin. (Received February 23, 2015)

1110-05-273 **Mikhail Mazin*** (mmazin@math.ksu.edu), Mathematics Department, 138 Cardwell Hall, Manhattan, KS 66506-2602, and **Eugene Gorsky**. *Two formulas for the dinv statistic.*

There are two different formulas for the dinv statistic on rational Dyck paths. The first formula was formulated by Nick Loehr and Greg Warrington and is motivated by geometry of the Hilbert scheme of points on the complex plane. The second formula was formulated by Eugene Gorsky and Mikhail Mazin and is motivated by geometry of affine Springer fibers and Jacobi factors. The equivalence of these formulas is non-trivial from both geometric and combinatorial points of view.

In this talk, I will explain the geometric origins of both formulas and sketch a proof of their equivalence. (Received February 23, 2015)

1110-05-280 **Jozsef Balogh**, **Hong Liu*** (hliu36@illinois.edu), **Maryam Sharifzadeh** and **Andrew Treglown**. *The number of maximal sum-free subsets of integers.*

Cameron and Erdős raised the question of how many *maximal* sum-free sets there are in $\{1, \ldots, n\}$, giving a lower bound of $2^{\lfloor n/4 \rfloor}$. In this paper we prove that there are in fact at most $2^{(1/4+o(1))n}$ maximal sum-free sets in $\{1, \ldots, n\}$.

Our proof makes use of container and removal lemmas of Green as well as a result of Deshouillers, Freiman, Sós and Temkin on the structure of sum-free sets. (Received February 23, 2015)

1110-05-295 **Jacques Verstraete*** (jbaverstraete@gmail.com), 9500 Gilman Drive, La Jolla, CA 92037, and **Michael Tait** (jbaverstraete@gmail.com), 9500 Gilman Drive, La Jolla, CA 92037. *On injective labellings of graphs.*

For a symmetric function $f : \mathbb{N}^2 \to \mathbb{N}$, we say that a graph G is f-injectively labelled if for any two edges $\{a, b\}$ and $\{c, d\}$ of G, $f(a, b) \neq f(c, d)$. The case $f(a, b) = a + b$ has been considered by a number of authors. We discuss a number of new almost tight results for various functions f, including $f(a, b) = ab$, as well as a number of open problems.

Joint work with Mike Tait (Received February 23, 2015)

1110-05-296 **Rafael S. González D'León*** (rafaeldleon@uky.edu), University of Kentucky, Lexington, KY. *On the free Lie algebra with multiple brackets.*

It is a classical result that the multilinear component of the free Lie algebra is isomorphic (as a representation of the symmetric group) to the top (co)homology of the proper part of the poset of partitions Π_n tensored with the sign representation. We generalize this result in order to study the multilinear component of the free Lie algebra with multiple compatible Lie brackets. We introduce a new poset of weighted partitions Π_n^k that allows us to generalize the result. The new poset is a generalization of Π_n and of the poset of weighted partitions Π_n^w introduced by Dotsenko and Khoroshkin and studied by the author and Wachs for the case of two compatible brackets. We prove that the poset Π_n^k with a top element added is EL-shellable and hence Cohen-Macaulay. This and other properties of Π_n^k enable us to answer questions posed by Liu on free multibracketed Lie algebras. (Received February 23, 2015)

1110-05-298 **Axel Brandt** and **Jennifer Diemunsch*** (jennifer.diemunsch@ucdenver.edu), Campus Box 170, P.O. Box 173364, Denver, CO 80217, and **Sogol Jahanbekam**. *Lucky Choice Number for Planar Graphs.* Preliminary report.

Suppose the vertices of a graph G are labeled with real numbers. For each vertex $v \in G$, let $S(v)$ denote the sum of the labels of all vertices adjacent to v. A labeling is called *lucky* if $S(u) \neq S(v)$ for every pair u and

v of adjacent vertices in G. The least integer k for which a graph G has a lucky labeling from $\{1, 2, \ldots, k\}$ is called the *lucky number* of the graph, denoted $\eta(G)$. In 2009, Czerwiński, Grytczuk, and Żelazny conjectured that $\eta(G) \leq \chi(G)$, where $\chi(G)$ is the chromatic number of G. This talk discusses improvements on the current bounds for particular classes of planar graphs with a strengthening of the results through a list lucky labeling. The results rely on applying the discharging method and the Combinatorial Nullstellensatz to show that for a planar graph G of girth at least 26, $\eta(G) \leq 3$, which proves the conjecture for non-bipartite planar graphs of girth at least 26. (Received February 23, 2015)

1110-05-311 **David Perkinson*** (davidp@reed.edu), **Qiaoyu Yang** and **Kuai Yu**. *Parking functions and tree inversions.*

A bijection between the parking functions and the spanning trees of a labeled graph is described which relates the degree of a parking function with the number of inversions of its associated spanning tree. The special case of the complete graph solves a problem posed by Richard Stanley. (Received February 23, 2015)

1110-05-314 **Derrek Yager*** (yager2@illinois.edu), **Ervin Györi**, **Alexandr Kostochka** and **Andrew McConvey**. *A list version of graph packing.*

We consider the following generalization of graph packing. Let $G_1 = (V_1, E_1)$ and $G_2 = (V_2, E_2)$ be graphs of order n and $G_3 = (V_1 \cup V_2, E_3)$ a bipartite graph. A bijection f from V_1 onto V_2 is a *list packing* of the triple (G_1, G_2, G_3) if $uv \in E_1$ implies $f(u)f(v) \notin E_2$ and $vf(v) \notin E_3$ for all $v \in V_1$. We extend the classical results of Sauer and Spencer and Bollobás and Eldridge on packing of graphs with small sizes or maximum degrees to the setting of list packing. In particular, we extend the well-known Bollobás-Eldridge Theorem, proving that if $\Delta(G_1) \leq n-2, \Delta(G_2) \leq n-2, \Delta(G_3) \leq n-1$, and $|E_1| + |E_2| + |E_3| \leq 2n - 3$, then either (G_1, G_2, G_3) packs or is one of 7 possible exceptions. We have used the concept of list packing to solve some problems on ordinary graph packing, much as the concept of list coloring did for ordinary coloring. (Received February 23, 2015)

1110-05-316 **Xiangwen Li**, Hanzhong Normal University, **Runrun Liu**, Hanzhong Normal University, and **Gexin Yu*** (gyu@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23185. *A relaxation of the Bordeaux Conjecture.* Preliminary report.

A $(c_1, c_2, ..., c_k)$-coloring of a graph G is a mapping $\varphi : V(G) \mapsto \{1, 2, ..., k\}$ such that for every $i, 1 \leq i \leq k$, $G[V_i]$ has maximum degree at most c_i, where $G[V_i]$ denotes the subgraph induced by the vertices colored i. Borodin and Raspaud conjecture that every planar graph with neither 5-cycles nor intersecting triangles is 3-colorable. We prove that every planar graph with neither 5-cycles nor intersecting triangles is $(2, 0, 0)$-colorable and $(1, 1, 0)$-colorable. (Received February 23, 2015)

1110-05-317 **Janine LoBue Tiefenbruck*** (jlobue@ucsd.edu) and **Jeffrey B. Remmel**. *A Murnaghan-Nakayama Rule for Quasisymmetric Schur Functions.* Preliminary report.

The quasisymmetric Schur functions are a basis of the ring of quasisymmetric functions, indexed by weak compositions. They have been shown to refine the classical Schur functions in many nice ways. We present here a new combinatorial proof of the classical Murnaghan-Nakayama rule for Schur functions and generalize it to an analogous rule for the quasisymmetric Schur functions. That is, we show how to multiply a power symmetric function by a quasisymmetric Schur function and expand the result as a sum of quasisymmetric Schur functions, giving a combinatorial interpretation of the coefficients that arise in this sum. (Received February 23, 2015)

1110-05-337 **Patrik Norén*** (patrik.noren@ist.ac.at) and **Alexander Engström**. *Algebraic Graph Limits.*

The theory of graph limits associates random graph models to symmetric measurable functions on the unit square. We investigate what happens when these functions are polynomials. For low degree polynomials the models appearing are familiar and important, for example preferential attachment and Erdös-Rényi. The higher degree polynomials are also useful as any graph limit can be arbitrarily well approximated by a polynomial. We show that this setup is useful for in applications: To determine the parameters of a random graph model that fits the observed data best one can use numerical algebraic geometry efficiently. (Received February 24, 2015)

1110-05-341 **Alexander Engström*** (alexander.engstrom@aalto.fi). *Graph coloring and the total Betti number.*

The total Betti number of the independence complex of a graph is an intriguing graph invariant. Kalai and Meshulam have raised the question on its relation to cycles and the chromatic number of a graph, and a recent conjecture on that theme was proved by Bonamy, Charbit and Thomasse. We show an upper bound on the total Betti number in terms of the number of vertex disjoint cycles in a graph. The main technique is discrete Morse theory and building poset maps.

Ramanujan graphs with arbitrary chromatic number and girth $\log n$ is a classical construction. We show that any subgraph of them with less than $n^{0.003}$ vertices have smaller total Betti number than some planar graph of the same order, although it is part of a graph with high chromatic number. (Received February 24, 2015)

1110-05-342 **Michael Ferrara*** (`michael.ferrara@ucdenver.edu`). *Strong Chromatic Index of Subcubic Planar Graphs with Large Girth.*

The strong chromatic index of a graph G, denoted $\chi'_s(G)$, is the least number of colors needed to edge-color G so that edges at distance at most two receive distinct colors. The strong list chromatic index, denoted $\chi'_{\ell,s}(G)$, is the least integer k such that if arbitrary lists of size k are assigned to each edge then G can be edge colored from those lists where edges at distance at most two receive distinct colors. We use the discharging method, the Combinatorial Nullstellensatz, and computation to show that if G is a subcubic planar graph with $girth(G) \geq 47$ then $\chi'_{\ell,s}(G) \leq 5$, and if $girth(G) \geq 30$ then $\chi'_s(G) \leq 5$.

This project was started at the 2014 Rocky Mountain-Great Plains Graduate Research Workshop in Combinatorics (GRWC), and is joint with Philip DeOrsey, Jennifer Diemunsch, Nathan Graber, Stephen Harke, Sogol Jahanebkam, Bernard Lidický, Luke Nelsen, Derrick Stolee, and Eric Sullivan. As time permits, we will also give a brief overview of the GRWC, which provides a new and unique opportunity for graduate students to collaborate each summer. (Received February 24, 2015)

1110-05-346 **Andrew Berget*** (`andrew.berget@wwu.edu`), Department of Mathematics, Bellingham, WA 98225. *sl_2 and the critical group of the hypercube.* Preliminary report.

The critical group of a graph is a finite abelian group whose order is its number of spanning trees. There is a beautiful formula for the number of spanning trees of the hypercube, whose structure is only recently understood combinatorially. The structure of the 2-Sylow subgroup of the critical group of the hypercube remains unknown. In this talk I will present some connections between this group and sl_2. (Received February 24, 2015)

1110-05-347 **Susanna Fishel*** (`sfishel1@asu.edu`), School of Math. and Stat. Sciences, Arizona State University, PO Box 871804, Tempe, AZ 85287-1804, and **Stephen Griffeth**. *Unitary representations and abacus combinatorics.* Preliminary report.

Berkesch Zamaere, Griffeth, and Sam conjecture the existence of a BGG-style resolution of unitary modules of the type A Cherednik algebra. They are able to provide the resolution in some special cases, where the resolution has a particularly simple form. I will discuss recent work with Griffeth on the general case. (Received February 24, 2015)

1110-05-349 **Andrew Berget*** (`andrew.berget@wwu.edu`), Department of Mathematics, Bellingham, WA 98225. *Vector bundles associated to realizable matroids.*

Torus orbit closures in the Grassmannian are known to correspond to realizable matroids (over a fixed field). There is a large family of vector bundles over the Grassmannian whose cohomology is well understood and have deep connections to combinatorics. After reviewing this, I will present a result on how these vector bundles restrict to the torus orbit closures within the Grassmannian. (Received February 24, 2015)

1110-05-351 **Michael Barrus**, **Michael Ferrara**, **Jennifer Vandenbussche** and **Paul S Wenger*** (`pswsma@rit.edu`). *The Rainbow Saturation Number of Graphs.*

In 1987, Hanson and Toft introduced the following question drawing from both saturation numbers and Ramsey numbers:

Let $H_1, \ldots, H_k$ be graphs. What is the minimum number of edges in an n-vertex graph G such that 1) G has a k-edge-coloring what does not contain a monochromatic copy of H_i in color i for any i, and 2) for every edge $e \in E(\overline{G})$, every k-edge-coloring of $G + e$ contains a monochromatic coloring of H_i in color i for some i?

A *rainbow edge coloring* of a graph H is an edge coloring such that each edge receives a distinct color. In this talk we introduce an anti-Ramsey variation of the Hanson-Toft question: For a graph H, what is the minimum number of edges in an n-vertex t-edge-colored graph G that does not contain a rainbow copy of H, but the addition of any edge in any color to G completes a rainbow copy of H. We call this number the *t-rainbow saturation number* of H, denoted $\mathrm{sat}_t(n, H)$.

We present a variety of results demonstrating some surprising behavior of rainbow saturation numbers. In particular, we will show that for $t \geq \binom{k}{2}$, the t-rainbow saturation number $\mathrm{sat}_t(n, K_k)$ lies between $\frac{n \log n}{\log \log n}$ and $n \log n$. (Received February 24, 2015)

1110-05-352 **Joshua E Ducey*** (duceyje@jmu.edu) and **Peter Sin**. *The Critical Group of Skew Lines in $PG(3, q)$.*

The authors determine the critical group of the graph whose vertices are the lines of $PG(3, q)$, where two lines are adjacent when skew. (Received February 24, 2015)

1110-05-355 **Ghodratollah Aalipour*** (gaalipour@khu.ac.ir) and **Art Duval** (aduval@utep.edu). *Spanning tree enumerator for complete colorful compexes.*

In the recent years, combinatorial Laplacian of graphs and its eigenvalues have found many applications in several areas in Mathematics and Computer Sciences. An old application of Laplacian eigenvalues goes back to Kirchhoff's Matrix Tree Theorem. The Laplacian spectrum of a graph reflects the behavior of its structure in many ways. In this talk, we present the analogous definition of Laplacian eigenvalues for pure simplicial complexes as uniform hypergraphs. As an application of simplicial version of Matrix Tree Theorem, we obtain the weighted spanning tree enumerator for all dimensions of complete colorful complexes which are a generalization of complete multipartite graphs. This is joint work with Art Duval. (Received February 24, 2015)

1110-05-358 **Stephen G. Hartke*** (hartke@unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130. *Graph realizations with fixed number of edges between parts of a vertex partition.* Preliminary report.

Given a sequence $\pi = (d_1, \ldots, d_n)$, a graph G is a *realization* of π if π is the degree sequence of G. Motivated by questions about social and biological networks, we study realizations of a degree sequence that have the additional constraint that the number of edges between each pair of parts of a vertex partition is fixed. For partitions with two parts, we resolve the questions of how to test whether a given sequence has a compatible realization and whether the space of all such realizations is connected using small changes.

This is joint work with Péter Erdős, Leo van Iersel, and István Miklós. (Received February 24, 2015)

1110-05-363 **Christopher Cox*** (cocox@iastate.edu) and **Derrick Stolee**. *Ramsey numbers of ordered hypergraphs.*

For a k-uniform hypergraph G with vertex set $\{1, \ldots, n\}$, the ordered Ramsey number of G is the least integer N such that every t-coloring of the edges of the complete k-uniform graph on vertex set $\{1, \ldots, N\}$ contains a monochromatic copy of G whose vertices follow the prescribed order. We explore the connections between the ordered Ramsey numbers of monotone hyperpaths and Erdős-Szekeres-type problems. Furthermore, we determine that the ordered Ramsey number of a monotone loose hyperpath grows as a tower of height one less than its maximum degree and give an explicit formula when the maximum degree is either 1 or 2. (Received February 24, 2015)

1110-05-364 **Cory Palmer*** (cory.palmer@umontana.edu), University of Montana, Department of Mathematical Sciences, 32 Campus Drive, Missoula, MT 59812, and **Daniel Gerbner**. *Extremal results for Berge-hypergraphs.* Preliminary report.

Let H be a hypergraph and G be a graph. We say that H contains G if we can embed G into the vertex set of H such that each edge of G can be associated with a distinct edge of H containing it. We say H is G-free if it does not contain G. (When H is a graph this is the ordinary notion that H does not contain G as a subgraph).

We would like to determine the maximum possible size of the sum of the vertex degrees in an G-free hypergraph H on n vertices. (When H is a graph this maximum is twice the extremal number of G). Győri and Lemons showed that for 3-uniform hypergraphs, when G is an even cycle this maximum has the same order as the extremal number of an even cycle in graphs. Surprisingly, for cycles of length $2k + 1$ the parameter is the same order as for cycles of length $2k$ (this is significantly different from the extremal number of odd cycles in graphs).

We examine this question in a slightly more general setting and show that for any graph G, the maximum degree sum cannot behave too differently from the extremal number of G. We then focus on the particular case when G is a complete bipartite graph to get an analogue of the Kővari-Sós-Turán theorem. (Received February 24, 2015)

1110-05-367 **Anton Dochtermann*** (dochtermann@math.texas.edu). *Warmth and edge spaces of graphs.*

In recent years two novel approaches for finding lower bounds on the chromatic number of a graph have been introduced. One involves studying the connectivity of the 'edge space' of a graph, dating back to Lovász's celebrated proof of the Kneser conjecture. The other is motivated by constructions in statistical physics, and involves the notion of the 'warmth' of a graph introduced by Brightwell and Winkler.

We seek to relate these two constructions, and in particular we provide evidence for the conjecture that the warmth of a graph G is always less than three plus the connectivity of its edge space. We succeed in establishing the first nontrivial case of the conjecture, and calculate the warmth of a family of graphs with relevant edge space topology. We also demonstrate a connection between the warmth of a graph and the collection of complete bipartite subgraphs that it contains, providing an analogue for a similar result in the context of edge spaces. This is joint work with Ragnar Freij. (Received February 24, 2015)

1110-05-374 **Angela Hicks*** (ashicks@stanford.edu). *Generating the Frobenius Characteristic of the Diagonal Harmonics (Several Ways).*

The now decade old Shuffle Conjecture connects the Frobenius characteristic of the diagonal harmonics to parking functions. In particular, the parking function statistics area, dinv, and ides are used to generate a symmetric polynomial believed to be equal to this Frobenius characteristic. Refinements of the conjecture add an additional statistic, composition. We discuss several other ways of generating the same polynomials directly, using statistics on pairs of compatible objects, and discuss how these relate to symmetries in related areas of algebraic combinatorics. (Received February 24, 2015)

1110-05-376 **Olivier Bernardi** and **Alejandro H. Morales*** (ahmorales@math.ucla.edu), Los Angeles, CA. *Bijections and symmetries for factorizations of the long cycle.*

We study the factorizations of the permutation (1, 2, . . . , n) into k factors of given cycle types. Using the group algebra of the symmetric group, Jackson obtained for each k an elegant formula for counting these factorizations according to the number of cycles of each factor. In the cases k = 2, 3 Schaeffer and Vassilieva gave a combinatorial proof of Jackson's formula, and Morales and Vassilieva obtained more refined formulas exhibiting a surprising symmetry property. These counting results are indicative of a rich combinatorial theory which has remained elusive to this point, and it is the goal of this project to establish a series of bijections which unveil some of the combinatorial properties of these factorizations into k factors for all k. The first bijection is an instance of a correspondence of Bernardi between such factorizations and tree-rooted maps; certain graphs embedded on surfaces with a distinguished spanning tree. This is joint work with Olivier Bernardi. (Received February 24, 2015)

1110-05-387 **József Balogh** and **Šárka Petříčková*** (petrckv2@illinois.edu). *Number of maximal triangle-free graphs.*

Paul Erdős suggested the following problem: Determine or estimate the number of maximal triangle-free graphs on n vertices. Here we show that the number of maximal triangle-free graphs is at most $2^{n^2/8+o(n^2)}$, which matches the previously known lower bound. Our proof uses among others the Ruzsa-Szemerédi triangle removal lemma, and recent results on characterizing the structure of independent sets in hypergraphs. (Received February 24, 2015)

1110-05-399 **Benjamin J Young*** (bjy@uoregon.edu), 1222 University of Oregon, Eugene, OR 97403. *Macdonald's reduced word identity.* Preliminary report.

I will give a bijective proof of Macdonald's reduced word identity in Schubert calculus. The proof uses a variant of David Little's bumping algorithm. Joint work with Sara Billey and Alexander Holroyd. (Received February 24, 2015)

1110-05-404 **Jozsef Balogh**, **Frank Mousset** and **Jozef Skokan*** (jozef@member.ams.org). *An Extension of Dirac's Theorem.*

A classical result in graph theory, Dirac's Theorem, states that a= ny graph on $n > 2$ vertices with minimum degree at least $n/2$ contains a cy= cle through all of its vertices. One of possible generalizations is to decr= ease the minimum degree of the graph and ask how many cycles are needed to = cover its vertices. We answer this question and prove the following: For a = fixed integer $k > 1$ and n sufficiently large, if G is an n-vertex gra= ph with minimum degree at least n/k, then there are $k - 1$ cycles in G= covering its vertex set. This bound is best possible, as there are graphs = with minimum degree $n/k - 1$ that do not have this property. (Received February 27, 2015)

06 ► Order, lattices, ordered algebraic structures

1110-06-174 **Ivan Martino*** (ivan.martino@unifr.ch). *Subspaces arrangement of a finite group.*

We discuss the arrangements of subspaces arising naturally from a representation of a finite group. We show that they are useful to compute the class of the classifying stack of the group in a certain Grothendieck ring. (Received February 19, 2015)

11 ► Number theory

1110-11-39 **Irene Bouw**, **Jenny Cooley**, **Kristin Lauter**, **Elisa Lorenzo Garcia** and **Michelle Manes*** (mmanes@math.hawaii.edu), University of Hawaii, Department of Mathematics, 2565 McCarthy Mall, Keller 401A, Honolulu, HI 96822, and **Rachel Newton** and **Ekin Ozman**. *Bad reduction of genus 3 curves with complex multiplication.*

Let C be a smooth, absolutely irreducible genus 3 curve over a number field M. Suppose that the Jacobian of C has complex multiplication by a sextic CM-field K. Suppose further that K contains no imaginary quadratic subfield. We give a bound on the primes $\mathfrak{p}$ of M such that the stable reduction of C at $\mathfrak{p}$ contains three irreducible components of genus 1. (Received January 22, 2015)

1110-11-94 **Hao Chen*** (chenh123@uw.edu), Padelford C-543, University of Washington, Seattle, WA 98105. *Computing the rank of Mazur and Swinnerton-Dyer critical subgroup of elliptic curves.*

Let E be an optimal elliptic curve defined over $\mathbb{Q}$. The *critical subgroup* of E is defined by Mazur and Swinnerton-Dyer as the subgroup of $E(\mathbb{Q})$ generated by traces of branch points under a modular parametrization of E. We prove that for all rank two elliptic curves with conductor smaller than 1000, the critical subgroup has rank zero. First, we define a family of critical polynomials attached to E and describe how to compute such polynomials. We then give conditions for the critical subgroup to be torsion in terms of the factorization of critical polynomials. Finally, a table of critical polynomials is obtained for all elliptic curves of rank two and conductor smaller than 1000, from which we deduce our result. (Received February 12, 2015)

1110-11-95 **Arthur Baragar*** (baragar@unlv.nevada.edu). *The Neron-Tate pairing and elliptic K3 surfaces.* Preliminary report.

In this talk, we describe a connection between the Neron-Tate pairing on the elliptic curves in an elliptic fibration of a K3 surface with section, and the structure of the ample cone for the K3 surface. (Received February 12, 2015)

1110-11-141 **Ekin Ozman** and **Rachel Pries*** (pries@math.colostate.edu). *On the existence of ordinary and almost ordinary Pryms.*

We study the relationship between the p-rank of a curve and the p-ranks of the Prym varieties of its cyclic covers in characteristic p > 0. For all p and g, we generalize a result of Nakajima by proving that the Prym varieties of all unramified cyclic degree L covers of a generic curve X of genus g > 2 and p-rank f are ordinary. When p > 3, we prove that there exists a curve of genus g and p-rank f having an unramified degree 2 cover whose Prym is almost ordinary. Using work of Raynaud, we use these two theorems to prove results about the (non)-intersection of the L-torsion group scheme with the theta divisor of the Jacobian of a generic curve X of genus g and p-rank f. (Received February 17, 2015)

1110-11-145 **Igor Szczyrba*** (igor.szczyrba@unco.edu), University of Northern Colorado, School of Mathematical Sciences, Ross hall, Greeley, CO 80639, and **Rafal Szczyrba** and **Martin Burtscher**. *Analytic representation of the generalized Fibonacci constants.*

We study generalizations of the sequence of the n-anacci constants that consist of the ratio limits generated by linear recurrences of an arbitrary order n with equal integer weights m. We derive the continuous representation of these ratio limits and prove that, for a fixed m, the ratio limits form a strictly increasing sequence converging to $m+1$. We also show that the generalized n-anacci constants form a totally ordered set. (Received February 17, 2015)

1110-11-168 **Jennifer Berg*** (jberg@math.utexas.edu), **Francesca Balestrieri** (balestrieri@maths.ox.ac.uk), **Michelle Manes** (mmanes@math.hawaii.edu), **Jennifer Park** (jennifer.park2@mcgill.ca) and **Bianca Viray** (bviray@math.washington.edu). *Insufficiency of the Brauer-Manin obstruction for Enriques surfaces.*

Let X be a smooth projective variety over a global field k. In 1970, Manin showed the the Brauer group of X could obstruct the existence of k-rational points. In this talk, we discuss results that show that the Brauer-Manin obstruction is insufficient to explain all failures of the Hasse principle for Enriques surfaces. This extends work of Varilly-Alvarado and Viray from 2011, in which the authors constructed an Enriques surface X over the rationals with an etale-Brauer obstruction to the Hasse principle, but no algebraic Brauer-Manin obstruction. (Received February 19, 2015)

1110-11-186 **Nils Bruin*** (nbruin@sfu.ca), Department of Mathematics, Simon Fraser University, Burnaby, BC V5A1S6, Canada, and **Tom Fisher**. *Twists of Shioda modular surfaces of level 4.* Preliminary report.

One of the most mysterious objects associated to an elliptic curve E is its Tate-Shafarevich group. Its elements can be represented by classes in the Galois-cohomology group $H^1(\mathbb{Q}, E[n])$, for various n. Mazur defines a class $\xi \in H^1(\mathbb{Q}, E[n])$ to be *visible* if there exists another elliptic curve E' with $E'[n] \simeq E[n]$ such that the homogeneous space under E' corresponding to ξ has a rational point. Visibility provides information about the image of ξ in $\mathrm{Sha}(E)$.

Mazur showed that any ξ representing an element in $\mathrm{Sha}(E)[3]$ can be made visible. His proof uses that the elliptic surface obtained from the universal elliptic curve over $X(3)$ is rational. The visibility follows from the fact that a certain twist of this surface has a rational point.

The case $\xi \in H^1(\mathbb{Q}, E[4])$ is particularly interesting. The curve $X(4)$ is rational, but the relevant elliptic surface is not. It is a K3 surface. Further complications in determining the correct surface arise from the fact that 4 is even. We will discuss how to compute a model of the relevant surface given ξ and give some examples of the various obstructions to rational points that can arise on these surfaces. (Received February 20, 2015)

1110-11-198 **David Krumm*** (dkrumm@cmc.edu). *A local-global principle in the dynamics of polynomial maps.* Preliminary report.

Let K be a number field and let $f \in K[x]$ be a polynomial. For any nonnegative integer n, let f^n denote the n-fold composition of f with itself. If $\tilde{K}$ is a field containing K, we say that an element $\alpha \in \tilde{K}$ is *periodic* for f if there exists a positive integer n such that $f^n(\alpha) = \alpha$. In that case, the least such n is called the *period* of α. It is clear that if f has a point of period n in K, then it has a point of period n in any extension of K; in particular, for every finite place v of K, f has a point of period n in the completion K_v. In this talk we will discuss whether the converse holds: if f has a point of period n in every nonarchimedean completion of K, must it then have a point of period n in K? (Received February 20, 2015)

1110-11-246 **Jamie Juul*** (jrahr@ur.rochester.edu). *Galois groups of iterated rational maps and their applications.*

Given a rational map defined over a field, one can consider the Galois groups of the field extensions generated by adjoining the pre-images of an algebraic point under iterates of the map. The study of these Galois groups has seen a recent increase in interest due to its many applications to number theory and dynamics. The Chebotarev density theorem allows us to translate statements about the densities of certain significant sets in number theory and dynamics to statements about these Galois groups. In this talk we will discuss some cases in which the structure of these Galois groups are known as well as some of the applications of these results. (Received February 22, 2015)

1110-11-250 **Aaron Levin*** (adlevin@math.msu.edu) and **Yu Yasufuku**. *Integral points and orbits in the projective plane.* Preliminary report.

We will discuss the problem of classifying the behavior of integral points on affine subsets of the projective plane. As an application, we will examine the problem of classifying endomorphisms of the projective plane with an orbit containing a Zariski dense set of integral points (with respect to some plane curve). This is joint work with Yu Yasufuku. (Received February 22, 2015)

1110-11-255 **Shabnam Akhtari***, akhtari@uoregon.edu. *Thue equations with few coefficients.* Preliminary report.

Suppose that $F(x, y) \in \mathbb{Z}[x, y]$ is an irreducible form of degree at least 3 and has no more than s nonzero coefficients, where s is an integer greater than 1. A conjecture of Siegel's implies that for every integers m, the number of solutions of the Thue equation $F(x, y) = m$ may be bounded in terms of s and m only. I will talk about some old and new results related to this conjecture. (Received February 23, 2015)

1110-11-276 **Patrick Ingram***, Department of Mathematics, Colorado State University, Fort Collins, CO 80523. *Arithmetic dynamics of correspondences.*

Arithmetic dynamics typically studies the iteration of functions (usually endomorphisms of an algebraic variety) from a number theoretic perspective. The more general case of the iteration of finite-to-finite relations has been less extensively considered. In this talk, we will introduce some of the basic notions, with an emphasis on the theory of heights, and pose a few problems for further study. (Received February 23, 2015)

1110-11-318 **T Alden Gassert*** (thomas.gassert@colorado.edu). *On discriminants of iterated quadratic fields.*
Let $f(x) = x^2 + c \in \mathbb{Z}[x]$, and let K be a number field generated by a root of $f^n(x)$ (assuming $f^n(x)$ is irreducible). The purpose of this talk is to determine the multiplicities of primes dividing the discriminant of K. As a consequence of our result, we identify a sufficient condition for K to be monogenic. Namely, K is monogenic if $f(0)$, $f^2(0)$, $f^3(0), \ldots, f^n(0)$ are all square-free. (Received February 23, 2015)

1110-11-322 **Alyson Deines*** (aly.deines@gmail.com). *Shimura Degrees and Congruence Primes.*
Almost 20 years ago, Wiles proved modularity of elliptic curves over $\mathbb{Q}$; for an elliptic curve E over $\mathbb{Q}$ of conductor N, there is a non-constant map from the modular curve $X_0(N)$ to E. For some curve isogenous to E, the degree of this map will be minimal; this is the modular degree. The Jacquet-Langlands correspondence allows us to similarly parameterize elliptic curves by Shimura curves. In this case we have several different Shimura curve parameterizations for a given isogeny class. Further, this generalizes to elliptic curves over totally real number fields. In this talk I will discuss these degrees and how to compute them. Further, I compare these degrees with D-new modular degrees and D-new congruence primes. The data indicates that there is a strong relationship between Shimura degrees, new modular degrees and congruence primes. (Received February 23, 2015)

1110-11-360 **Bianca Viray*** (bviray@math.washington.edu). *Reciprocity laws and rational points on varieties.*
Determining whether a system of polynomial equations has a rational solution is a long-studied problem. A first step is to determine whether the polynomial system has a solution over the real numbers and modulo N, for every positive integer N. However, this so-called local solubility is often not sufficient to guarantee the existence of a rational solution. Indeed, quadratic reciprocity and higher reciprocity laws can give nontrivial compatibility conditions among the real solutions and solutions modulo N in order for them to arise from a common rational solution. These conditions are known as the Brauer-Manin obstruction and are encoded by the Brauer group. In this talk, I will describe recent work on computing the Brauer group with a view towards these arithmetic applications. (Received February 24, 2015)

14 ► Algebraic geometry

1110-14-21 **Mao-Ting Chien*** (mtchien@scu.edu.tw), Department of Mathematics, Soochow University, Taiwan. *Singular points of the algebraic curve defined by a hyperbolic form.*
A point (t_0, x_0, y_0) on a curve $F(t, x, y) = 0$ is called a singular point if the gradient $\nabla F(t_0, x_0, y_0) = 0$. A singular point is called a node if there are two distinct tangents at the point. We investigate singular points of the algebraic curve defined by a hyperbolic form satisfying some symmetric properties. We show that all singular points of such a curve are real nodes. (Jointly with Hiroshi Nakazato) (Received December 27, 2014)

1110-14-99 **Vivek Shende*** (vivek@math.berkeley.edu). *Knotty character varieties.* Preliminary report.
I will describe how contact geometry gives rise to cluster algebras. (Received February 13, 2015)

1110-14-192 **Jeffrey D Achter***, Department of Mathematics, Colorado State University, Fort Collins, CO 80523-1874, and **Sebastian Casalaina-Martin**. *On descending cohomology geometrically.* Preliminary report.
I'll discuss the problem of determining when the cohomology of a smooth projective variety over the rational numbers can be modeled by an abelian variety. The primary motivation is a problem posed by Barry Mazur; we provide an answer to Mazur's question in two situations. First, we show that the third cohomology group can be modeled by the cohomology of an abelian variety over the rationals provided the Chow group of points is supported on a surface. (Conjecturally, this answers Mazur's question for all threefolds.) Second, we show how a result of Beauville establishes that the middle cohomology of a fibration in quadrics over the rational numbers can be modeled by an abelian variety (Received February 20, 2015)

1110-14-213 **Christopher Lyons***, clyons@fullerton.edu, and **Paul Lewis**. *The Tate Conjecture for surfaces with $p_g = q = 1$ and $K^2 = 2$.* Preliminary report.
Smooth projective surfaces with the invariants $p_g = 1$, $q = 1$, and $K^2 = 2$ were classified over $\mathbb{C}$ by Bombieri—Catanese and Horikawa. Although they are of general type, these surfaces possess attractive special features. For instance, via the Albanese map, they fiber into genus 2 curves over an elliptic curve. They may also be expressed

as branched double covers of the symmetric square of an elliptic curve. Finally, the Kuga-Satake construction relates them to abelian varieties.

Using these features, we identify a certain dense open subset of the moduli space of these surfaces for which one may prove the Tate Conjecture in characteristic zero. (Specifically, we prove the conjecture for those surfaces whose canonical bundle is very ample.) This is accomplished by establishing a big monodromy theorem, and then exploiting the Kuga-Satake construction and Faltings' results on abelian varieties. One key ingredient along the way is to find such a surface with minimal Picard number, and this is done by reducing modulo p and counting points. (Received February 21, 2015)

1110-14-223 **Craig Costello*** (craigco@microsoft.com), Microsoft Research, One Microsoft Way, Redmond, WA 98052. *Genus 2 curves in cryptography: successes and challenges.*

In recent years genus 2 curves have been showed to offer several advantages over their elliptic curve counterparts. This talk will give a very brief overview of the state-of-the-art in genus 2 cryptography, before discussing some interesting open challenges facing its potential adoption in the real world. (Received February 21, 2015)

1110-14-321 **Sho Tanimoto** (st26@rice.edu), Department of Mathematics MS 136, Rice University, 6100 S. Main St., Houston, TX 77005, and **Anthony Várilly-Alvarado*** (av15@rice.edu), Department of Mathematics MS 136, Rice University, 6100 S. Main St., Houston, TX 77005. *Kodaira dimension of moduli of special cubic fourfolds.* Preliminary report.

Cubic fourfolds containing a surface not homologous to a complete intersection often have nonspecial cohomology isomorphic to the primitive cohomology of a K3 surface "twisted" by an element of the Brauer group. This isomorphism is usually a manifestation of a geometric correspondence, which has consequences for the distribution of rational points on K3 surfaces over number fields. We will discuss this circle of ideas, including some recent developments in joint work with McKinnie, Sawon and Tanimoto on p-torsion Brauer classes of K3 surfaces and with Tanimoto on the Kodaira dimension of the moduli space of special cubic fourfolds of fixed discriminant. (Received February 23, 2015)

15 ► Linear and multilinear algebra; matrix theory

1110-15-272 **Emily Herzig*** (elh042000@utdallas.edu), UTD, Dept of Mathematical Sciences, FO 35, 800 W Campbell Rd, Ste FO 2.406, Richardson, TX 75080, and **V Ramakrishna** and **M Dabkowski**. *The Covering Map in Dimensions Five and Six, Revisited.*

The exponential of a matrix, while often very useful, is generally difficult to find in its exact form. Here we present an algorithm for computing the exact exponential of a 5×5 or 6×6 skew-symmetric matrix. The process utilizes a double covering map from $Spin(n)$ to $SO(n)$ (for $n = 5$ or 6), and relies on novel representations of $spin(n)$ along with a complete characterization of the exponentials of matrices in $su(4)$, and of matrices in a 4×4 symplectic-type Lie algebra. (Received February 24, 2015)

16 ► Associative rings and algebras

1110-16-12 **Xin Tang*** (xtang@uncfsu.edu), 1200 Murchison Road, Fayetteville, NC 28301. *Isomorphism Classes and Automorphisms of Some Polynomial Based Quantum Weyl Algebras.* Preliminary report.

In this talk, we will present some preliminary results on the isomorphism classes and automorphisms of some quantum Weyl algebras defined over a polynomial base ring. (Received November 25, 2014)

1110-16-18 **Malik Bataineh*** (msbataineh@just.edu.jo), Irbid, 22110, Jordan, and **bdarneh**. *On Almost 2-absorbing submodules.*

Let R be a commutative ring with identity and let M be a unitary R-module. A proper submodule N of an R-module M will be called almost 2-absorbing submodule if $a, b \in R$ and $m \in M$ with $abm \in N - (N : M)N$ implies that $ab \in (N : M)$ or $am \in N$, or $bm \in N$. Also a proper ideal I of R will be called almost 2-absorbing ideal if $a, b, c \in R$ with $abc \in I - I^2$ implies that $ab \in I$ or $ac \in I$, or $bc \in I$. These concepts are generalizations of the notions of 2-absorbing submodules and ideals respectively, which have been studied by A. Yousefian Darani and A. Badawi. In this paper we will study almost 2-absorbing submodules by investigating their properties and classifying modules for which every submodule is an almost 2-absorbing submodule. (Received December 10, 2014)

1110-16-25 **Fred Van Oystaeyen**, **Xiaolan Yu** and **Yinhuo Zhang*** (yinhuo.zhang@uhasselt.be). *Cleft extensions of Koszul twisted Calabi-Yau algebras.* Preliminary report.

Let H be a twisted Calabi-Yau (CY) algebra and σ a 2-cocycle on H. Let A be an N-Koszul twisted CY algebra such that A is a graded H^σ-module algebra. We show that the cleft extension $A\#_\sigma H$ is also a twisted CY algebra. This result has two consequences. Firstly, the smash product of an N-Koszul twisted CY algebra with a twisted CY Hopf algebra is still a twisted CY algebra. Secondly, the cleft objects of a twisted CY Hopf algebra are all twisted CY algebras. As an application of this property, we determine which cleft objects of $U(\mathcal{D}, \lambda)$, a class of pointed Hopf algebras introduced by Andruskiewitsch and Schneider, are Calabi-Yau algebras.
(Received January 07, 2015)

1110-16-42 **Lauren Grimley**, Texas A&M University, **Van C. Nguyen*** (v.nguyen@neu.edu), Northeastern University, and **Sarah Witherspoon**, Texas A&M University. *On the Hochschild cohomology ring of twisted tensor products.*

The Hochschild cohomology of an associative algebra over a field k has a cup product and a bracket product which satisfy some compatibility conditions, making it a Gerstenhaber algebra. Let R and S be associative graded k-algebras and consider their twisted tensor product $R \otimes_k^t S$. In this talk, we investigate the Gerstenhaber structure of the Hochschild cohomology ring, $\mathrm{HH}^*(R \otimes_k^t S)$, of this twisted tensor product. This study allows us to compute the Gerstenhaber brackets for some quantum complete intersections. Moreover, given R or S is finite dimensional, we are able to "break down" the Gerstenhaber algebra structure of a particular subalgebra of $\mathrm{HH}^*(R \otimes_k^t S)$. (Received January 29, 2015)

1110-16-66 **Richard Gene Chandler*** (richard.chandler@mavs.uta.edu), Department of Mathematics, University of Texas at Arlington, P.O. Box 19408, Arlington, TX 76019-0408, and **Michaela Vancliff** (vancliff@uta.edu), Department of Mathematics, University of Texas at Arlington, P.O. Box 19408, Arlington, TX 76019-0408. *The One-Dimensional Line Scheme of a Certain Family of Quantum $\mathbb{P}^3$s.*

A quantum $\mathbb{P}^3$ is a noncommutative analogue of a polynomial ring on four variables, and, in this talk, it is taken to be a regular algebra of global dimension four. It is well known that if a generic quadratic quantum $\mathbb{P}^3$ exists, then it has a point scheme consisting of exactly twenty distinct points and a one-dimensional line scheme. We will discuss the line scheme of a family of algebras whose generic member is a candidate for a generic quadratic quantum $\mathbb{P}^3$. We find that the line scheme of the generic member is the union of seven curves; namely, an elliptic curve in a $\mathbb{P}^3$, four planar elliptic curves and two nonsingular conics. (Received February 08, 2015)

1110-16-69 **Pavel Etingof**, 77 Massachusetts Ave, Cambridge, MA 02139, and **Chelsea Walton*** (notlaw@math.mit.edu), 77 Massachusetts Ave., E17-331, Cambridge, MA 02139. *Semisimple Hopf actions on quantizations.* Preliminary report.

We study actions of semisimple Hopf algebras H on filtered deformations B of commutative domains such as algebras of differential operators on a smooth affine irreducible variety, universal enveloping algebras of a finite dimensional Lie algebra, symplectic reflection algebras, and quantized quiver varieties. We show that the action of H on B must factor through a group algebra, or in other words, if H acts inner faithfully on B, then H is cocommutative. The techniques used include reduction modulo p and the study of semisimple cosemisimple Hopf actions on division algebras.

(The title, authors, and abstract of the talk are subject to change.) (Received February 09, 2015)

1110-16-72 **Edward L. Green*** (green@math.vt.edu) and **Sibylle Schroll** (ss489@leicester.ac.uk). *Brauer Configuration Algebras.* Preliminary report.

I report on joint work with Sibylle Schroll. We introduce Brauer configurations and algebras which generalize Brauer graphs and algebras. I will give the definition of this new class of algebras and some of its properties. In particular, Brauer configuration algebras are finite dimensional, symmetric algebras. We show that these algebras are multiserial and for radical cubed zero, the converse holds. We also define special multiserial algebras, generalizing special biserial algebras and show that an algebra is a Brauer configuration algebra if and only if it is a special multiserial algebra. (Received February 09, 2015)

1110-16-75 **Jason Gaddis*** (gaddisjd@wfu.edu) and **Kenneth L. Price**. *Some Algebras Similar to the 2×2 Jordanian Matrix Algebra.*

The impetus for this study is the work of Dumas and Rigal on the Jordanian deformation of the coordinate ring of functions on 2×2 matrices, denoted $M_J(2)$. This algebra presents an interesting automorphism group and representation theory, and so we are motivated to find other examples of algebras exhibiting similar behavior.

In this talk, I will discuss the construction of a family of algebras containing $M_J(2)$ along with results on their structure. (Received February 09, 2015)

1110-16-137 **Padmini P Veerapen*** (pveerapen@tntech.edu). *Graded skew Clifford algebras and μ-rank on noncommutative quadratic forms in four generators.* Preliminary report.

We seek to determine when the number of point modules over an Artin-Schelter regular graded skew Clifford algebra of global dimension four [CV, CVc] is finite. In [SV], the authors construct Artin-Schelter regular graded Clifford algebras of global dimension four with a certain number of point modules. Our goal is to generalize these results to Artin-Schelter regular graded *skew* Clifford algebras. To do so, we first extend the notion of μ-rank defined in [VV1] on noncommutative quadratic forms on two and three generators to quadratic forms on four generators. This work is being done in collaboration with Leah Frauendienst. (Received February 17, 2015)

1110-16-183 **William Chin*** (wchin@condor.depaul.edu). *Coverings of pointed Hopf algebras.*

We discuss coverings of graded pointed Hopf algebras, which arise as coalgebra coverings of the underlying pointed coalgebras. When there are enough quadratic relations, the universal covering Hopf algebra of a bosonization of a Nichols algebra is given by the enveloping group of the underlying rack. This provides a range of finite-dimensional pointed noncocommutative Hopf algebras with various nonabelian groups of group-like elements. We discuss some cases where Hopf algebra coverings lift to nongraded Hopf algebras. (Received February 20, 2015)

1110-16-195 **Kenneth Chan*** (kenhchan@math.washington.edu), University of Washington, Department of Mathematics, Box 354350, Seattle, WA 98195-4350, **Alexander Young** (aayoung0@uw.edu), University of Washington, Department of Mathematics, Box 354350, Seattle, WA 98195-4350, and **James Zhang** (zhang@math.washington.edu), University of Washington, Department of Mathematics, Box 354350, Seattle, WA 98195-4350.
Discriminants of Clifford algebras.

The discriminant of an algebra A was recently shown to be useful in determining the full automorphism group of A. We prove a discriminant formula for Clifford algebras over a commutative domain, and discuss the ramifications for computing the automorphism groups for these algebras. This is joint work with Alexander Young and James Zhang. (Received February 20, 2015)

1110-16-208 **Jiafeng Lv**, **Xingting Wang** and **Guangbin Zhuang*** (gbzhuang@usc.edu), 3620 S. Vermont Ave., KAP 104, Los Angeles, CA 90089-2532. *A note on the duality between Poisson homology and cohomology.*

For a Poisson algebra A, by studying its universal enveloping algebra A^{pe}, we prove a duality theorem between Poisson homology and cohomology of A. (Received February 20, 2015)

1110-16-320 **Anne V Shepler*** (ashepler@unt.edu), University of North Texas, Department of Mathematics, 1155 Union Circle #311430, Denton, TX 76203-5017. *Deformations of quadratic algebras and group actions.*

Generators of many noncommutative algebras satisfy quadratic relations. Often, a noncommutative algebra arises as a deformation of a well-behaved algebra together with a group acting on it. Braverman and Gaitsgory, along with Polishchuk and Positselski, investigated the Poincaré-Birkhoff-Witt property for quadratic algebras. We show how to extend these ideas to fields of arbitrary characteristic using Hochschild cohomology in the modular setting, giving Poincaré-Birkhoff-Witt theorems for algebras over group rings which are not necessarily semisimple. New analogues of symplectic reflection algebras, Drinfeld orbifold algebras, and graded affine Hecke algebras emerge in the modular setting. (Received February 23, 2015)

1110-16-329 **Andrew Conner*** (abc12@stmarys-ca.edu) and **Peter Goetz**. *Homological properties of twisted tensor products.* Preliminary report.

Let C be a connected $\mathbb{N}$-graded algebra over a field k and let A and B be graded subalgebras of C. We say C is a twisted tensor product of A and B if the natural linear map $A \otimes B \to C$ is an isomorphism. Examples of twisted tensor products include graded Ore extensions and smash products of graded Hopf algebras. In this talk we examine the extent to which homological properties of C - in particular the Koszul property - can be inferred from those of A and B. (Received February 24, 2015)

1110-16-332 **Jingcheng Dong**, Nanjing, Peoples Rep of China, and **Henry J. Tucker*** (htucker@usc.edu), Los Angeles, CA. *Integral modular categories of Frobenius-Perron dimension pq^n.*

We generalize and apply a criteria for integral modular categories to be group-theoretical, i.e. Morita dual to a category of G-graded vector spaces with associativity given by a 3-cocycle. Integral modular categories of Frobenius-Perron dimension pq^n, where p and q are primes, are considered. It is already known that such categories are group-theoretical in the cases of $0 \leq n \leq 4$. In the general case we determine that these categories are either group theoretical or contain a Tannakian subcategory of dimension q^i for $i > 1$. We then show that all integral modular categories $\mathcal{C}$ with $\mathrm{FPdim}(\mathcal{C}) = pq^5$ are group-theoretical, and, if in addition $p < q$, all with $\mathrm{FPdim}(\mathcal{C}) = pq^6$ or pq^7 are group-theoretical. (Received February 24, 2015)

1110-16-348 **Ragnar Buchweitz**, **Eleonore Faber** and **Colin Ingalls***, cingalls@unb.ca. *Noncommutative resolutions of discriminants of reflection groups.* Preliminary report.

Let W be subgroup of $\mathrm{GL}(V)$ generated by reflections. Let $S = k[V]$ be the polynomial ring and let $z \in S$ cut out the hyperplane arrangement of mirrors in V. The discriminant is the image of the hyperplane arrangement in the quotient V/W which is cut out by z^2. Let A be the skew group algebra $W \rtimes k[V]$. Let e be the idempotent of kG corresponding to the trivial representation. Our main result is that

$$\mathrm{End}_{S^W}(S/zS) = A/AeA$$

forms a noncommutative resolution of the discriminant since it is Koszul, has global dimension $\mathrm{dimV} - 1$, and its centre $S^W/(z^2)$ is polynomial functions on the discriminant. (Received February 24, 2015)

1110-16-380 **Cris Negron*** (negron@uw.edu). *Braided structures and the Gerstenhaber bracket on Hochschild cohomology.* Preliminary report.

Given a finite dimensional Hopf algebra H acting on an algebra A, we can form an intermediate cohomology $H^\bullet(H, A)$ which comes equipped with a natural right H-action, and recovers the Hochschild cohomology of the smash product $A\#H$ after taking invariants. In fact, the cohomology $H^\bullet(H, A)$ is a Yetter-Drinfeld module over H and is a braided commutative algebra under the natural braiding induced by the Yetter-Drinfeld structure. This multiplicative structure has proved useful in verifying finite generation of Hopf cohomology, and has been studied extensively by Forest-Greenwood, Shepler, and Witherspoon. Supposing H has finite exponent, I will discuss how one can produce a braided antisymmetric bracket on $H^\bullet(H, A)$ which lifts the Gerstenhaber bracket to this braided setting, in the sense that it recovers the Gerstenhaber bracket after taking invariants. (Received February 24, 2015)

17 ► Nonassociative rings and algebras

1110-17-204 **Susan Elle*** (selle@ucsd.edu). *Ore extensions of global dimension 5.* Preliminary report.

We consider Artin Schelter regular algebras of dimension 5 which are also iterated Ore extensions. We review the findings of Floystad and Vatne that there is no enveloping algebra with Hilbert series $h(x) = \frac{1}{(1-x)^2(1-x^2)(1-x^3)(1-x^5)}$, although there is an AS-regular algebra with this series. We provide an example of an Ore extension with this Hilbert series and discuss the possible resolution types of some other Ore extensions of dimension 5. (Received February 20, 2015)

1110-17-220 **Gregory P Wene*** (gpwene2011@hotmail.com), 12513 Elm Country Lane, San Antonio, TX 78230. *S-3 Permutations of Real Division Algebras.*

The structure constants of an n-dimensional algebra A over a field F determine an nxnxn cube called the cubical array associated with the algebra A. Knuth, J. Algebra 2: 182-217, permuted the indices of the cubical array associated with a finite division algebra to generate (possibly) new division algebras. This series of algebras is called a Knuth orbit. We investigate the possible Knuth orbits of finite dimensional real division algebras (Received February 21, 2015)

1110-17-326 **Jesse S Levitt*** (jlevit3@lsu.edu) and **Milen Yakimov**. *Connected Hopf Algebras and Drinfeld's Quantization of Triangular R-matrices.* Preliminary report.

The classification problem for Hopf algebras of finite GK-dimension has attracted a lot of interest in recent years. Recently advancing to the point where Wang, Zhang and Zhuang were able to classify all such Hopf algebras of GK-dimension 4. In a previously unrelated development, in 1983, Drinfeld constructed quantizations of all triangular R-matrices. They produce non-cocommutative Hopf algebra structures on completions of universal enveloping algebras. When the quantizations are finite we obtain actual connected Hopf algebras of finite

GK-dimension. We will show how previous examples of these are special cases of the Drinfeld construction. (Received February 24, 2015)

18 ► Category theory; homological algebra

1110-18-147 **Yin Tian*** (ytian@scgp.stonybrook.edu), Simons Center for Geometry and Physics, State University of New York, Stony Brook, NY 11794. *A categorification of quantum sl(1,1) via contact topology.* Preliminary report.

The Alexander polynomial of knots can be recovered as Witten-Reshetikhin-Turaev invariant associated to quantum sl(1,1). Knot Floer homology categorifies the Alexander polynomial. In this talk, we present a categorification of quantum sl(1,1). Our construction is motivated from contact categories introduced by Ko Honda, which study 3-dimensional contact strucutures on thickened surfaces. (Received February 17, 2015)

20 ► Group theory and generalizations

1110-20-259 **Liudmila Sabinina*** (liudmila@uaem.mx), av.Universidad 1001, Facultad de Ciencias, 62209 Cuernavaca, Morelos, Mexico. *Code loops and their half-automorphisms.* Preliminary report.

We study half-automorphisms of Moufang loops. For a group according to Scott's theorem any such mapping is an automorphism or an anti-automorphism. Without the associative law this is not necessarily true. In particular, we compute the group of half-automorphisms of a code loop. (Received February 23, 2015)

1110-20-391 **Jerzy Kocik*** (jkocik@siu.edu), Department of Mathematics, SIU, Mail Code 4408, Carbondale, IL 62901. *Geometry of the spinor action on the celestial sphere and relativistic addition of velocities.*

Homomorphism between a Lorenz group and its projective spinor representation is extended to a geometric group of "reversions" of a sphere. This results in a visualization of Penrose's spinor action on celestial sphere, a remarkably simple formula for relativistic composition of velocities as well as its new geometric construction. (Received February 24, 2015)

28 ► Measure and integration

1110-28-53 **Kevin R Vixie*** (vixie@speakeasy.net). *Geometric Measure Theory and Data.*

The interface between analysis and geometry is rich with insights, many of which are under-exploited when it comes to their potential for data analysis problems. After a big picture look at the opportunities presented by this analysis/data interface, I will give concrete examples of recent work involving geometric measure theory and data, and then comment on the additional challenges encountered when uncertainty is added to the picture. (Received February 05, 2015)

34 ► Ordinary differential equations

1110-34-73 **Kwang C Shin*** (kshin@westga.edu), 1601 Maple St, Carrollton, GA 30110. *A Necessary and Sufficient Condition for Reality of Eigenvalues of Anharmonic Oscillators in the complex plane and $\mathcal{PT}$-symmetry.* Preliminary report.

All self-adjoint anharmonic oscillators have real eigenvalues only. However, self-adjointness is a sufficient condition for real eigenvalues but not a necessary condition. A large class of non-self-adjoint $\mathcal{PT}$-symmetric anharmonic oscillators have real eigenvalues only. In this talk, we examine a necessary and sufficient condition for reality of eigenvalues of a large class of anharmonic oscillators in the complex plane. (Received February 09, 2015)

1110-34-221 **Boniface Otieno Kwach*** (bkwach@kibabiiuniversity.ac.ke), Kibabii University College, P. O. Box 1699, Bungoma, Bungoma, Western 50200, Kenya, **Naphtali Omolo Ongati**, Jaramogi Oginga Odinga University of Science, P. O. Box 210, Bondo, **Michael Oduor Okoya**, Jaramogi Oginga Odinga University of Science, P. O. Box 210, Bondo, and **Amos E. Otedo**, Kisumu East District Hospital, P.O.Box 4685-40103, Kisumu. *Mathematical Modeling of Insulin Therapy in Patients with Diabetes Mellitus.* Preliminary report.

This study presents a Mathematical Model of Insulin Therapy in Patients with Diabetes Mellitus which includes external rate at which blood glucose, insulin and epinephrine are being increased in the form, $\dot{Y} = AY + \vec{r}(t)$ and whose solution was analyzed to provide the systems natural frequency, ω_0, which is the basic descriptor of saturation level of the drug. It was established that the resonance period for the final model, that is, $T_0 = 3.76912$ hrs, is in the acceptable therapeutic range and agrees well with the data for the existing insulin therapy. By employing the model, it is shown that, the peak, which is the time period for insulin to be most effective in lowering blood sugar, is shorter than $T_0 = 5.3199$ hrs, for the existing model. This model would help the medical practitioners to predict drug therapy in patients with Diabetes Mellitus, in such a way that the concentration of the drug remains in the therapeutic range.

Mathematics Subject Classification: Primary 93A30; Secondary 91B74, 93C05
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1110-34-285 **Stephen B Robinson*** (sbr@wfu.edu), P.O. Box 7388, Wake Forest University, Winston Salem, NC 27109, and **Sarah Parsons**. *On the discrete analog of a theorem of Schaaf and Schmitt.*

We consider a discrete version of the boundary value problem

$$-u'' = u + c\sin(u),$$
$$u(0) = u(\pi) = 0,$$

where $c \in \mathbb{R}$. A well-known result of Schaaf and Schmitt in 1988 shows that this problem has infinitely many positive solutions. Since then this problem and its generalizations have been studied extensively using a variety of methods such as bifurcation from infinity, shooting, and variational arguments. All of these arguments, to our knowledge, reduce to careful estimates of an integral which is closely related to Bessel functions. We prove an analogous result for the discrete problem using variational techniques. The argument does not rely on an adaptation of the integral estimates mentioned above, but on a well-known elementary theorem about the density of points in the unit circle generated by rotations that are an irrational multiple of 2π. (Received February 23, 2015)

1110-34-305 **Osei Kofi Tweneboah*** (oktweneboah@miners.utep.edu), 500 West University Avenue, El Paso, TX 79968, and **Maria Christina Mariani** (mcmariani@utep.edu), 500 West University Avenue, El Paso, TX 79968. *Stochastic Differential Equation Applied To Geophysics.* Preliminary report.

This work is devoted to the study of modeling geophysical data. We propose a stochastic differential equation arising on the superposition of independent Ornstein-Uhlenbeck processes driven by a Levy non-Gaussian process. Superposition of independent Ornstein-Uhlenbeck processes offer analytic flexibility and provide a class of continuous time processes capable of exhibiting long memory behavior. The stochastic differential equation is applied to geophysics by fitting the model with real earthquake data series. (Received February 23, 2015)

35 ► Partial differential equations

1110-35-8 **Michael Sever*** (sever@math.huji.ac.il), Department of Mathematics, The Hebrew University, Givat Ram, Jerusalem, Israel. *Linear stability of weak solutions of multidimensional systems of conservation laws.*

Linear stability of discontinuous, weak solutions of multidimensional systems of conservation laws, with respect to perturbation of initial-boundary data, is exceptional. We prove stability for a nontrivial class of self-similar weak solutions of the symmetric p-system in two dimensions. The decisive step is judicious choice of the test space used in the weak form of the linearized system, made possible by exceptional structure of this system. We obtain definitions of stability and admissibility applicable generally, and suitable for computational investigation.
(Received October 27, 2014)

1110-35-9 **Viktoria Savatorova*** (viktoria.savatorova@unlv.edu), **Yalchin Efendiev** (efendiev@math.tamu.edu) and **I. Yucel Akkutlu** (akkutlu@pe.tamu.edu). *Multiscale Modeling of Gas Transport in Organic-Rich Resource Shales.*

Organic-rich resource shales play an important role in global natural gas production. Shale gas transport is an active area of research due to growing interest in producing natural gas from source rocks. Shale is a sedimentary rock made of fine scale inorganic sediments. The pore volume is small relative to the other conventional rocks (e.g., sandstone) consisting of irregularly shaped pores and micro-cracks. In this work, we introduced a new set of governing equations to describe the nanoporous nature of the resource shale matrix and applied a homogenization approach using asymptotic expansions in multiple scales. We studied scaled up gas transport in shales, consisting of microporous inorganic material and nanoporous organic material (kerogen). We came to the conclusion that both gas amount distribution in reservoir and production rates are dependent on the amount of kerogen in the shale matrix. Adsorbed-phase transport by the organic pore walls and its release were responsible for the increased amounts and rates. Both increase with the percentage of kerogen amount. We performed simulation study investigating cases of Henry (linear) and Langmuir (nonlinear) models for the gas release as well as different values of micro-macro scale length ratio, and diffusion coefficients. (Received November 01, 2014)

1110-35-22 **Jonathan J Wylie*** (mawylie@cityu.edu.hk), Dept of Mathematics, City University of Hong Kong, Kowloon Tong, Hong Kong. *Coupled reaction-diffusion models with degenerate sources.*

We consider a general system of coupled nonlinear diffusion equations that are characterized by having degenerate source terms and thereby not having isolated rest states. Such equations arise naturally in the study of ion propagation through biological cells and fluid transport through porous media with evaporation and condensation. Using a general form of physically relevant source terms, we derive conditions that are required to trigger traveling waves when a stable uniform steady-state solution is perturbed by a highly localized disturbance. We also discuss the implications for biological systems. (Received December 29, 2014)

1110-35-24 **Humberto Ramos Quoirin***, Universidad de Santiago de Chile, Departamento de Matematicas y C.C., Casilla 307, Correo 2, Santiago, Chile. *Indefinite slightly superlinear problems.* Preliminary report.

We consider the semilinear elliptic problem

$$\begin{cases} -\Delta u = a(x)f(u) & \text{in } \Omega \\ u = 0 & \text{on } \partial\Omega \end{cases}$$

where Ω is a bounded domain of $\mathbb{R}^N$, $N \geq 3$, a is a continuous function which may change sign and f is superlinear but does not satisfy the standard Ambrosetti-Rabinowitz condition. We analyze the model case $f(s) = s\ln(s+1)$ as well as a more general class of nonlinearities for which we obtain a mountain-pass solution. The main difficulty is related with the boundedness of Palais-Smale sequences of the associated functional. (Received January 05, 2015)

1110-35-30 **Marian Bocea*** (mbocea@luc.edu), Department of Mathematics & Statistics, Loyola University Chicago, 1032 W. Sheridan Road, Chicago, IL 60660. *Eigenvalue Problems for Rapidly Growing Operators in Divergence Form.*

The spectrum of an exponential type perturbation of the Laplace operator is completely characterized in an Orlicz-Sobolev setting by means of an asymptotic analysis of a class of eigenvalue problems involving the p-Laplacian. This talk is based on joint work with Mihai Mihăilescu (University of Craiova and "Simion Stoilow" Institute of Mathematics of the Romanian Academy, Bucharest, Romania). (Received January 15, 2015)

1110-35-35 **Byungjae Son*** (b_son@uncg.edu), 1723 Walker Avenue, Apt 307, Greensboro, NC 27403, and **Ratnasingham Shivaji**. *Bifurcation and multiplicity results for classes of p, q Laplacian systems.*

We study positive solutions to boundary value problems of the form:

$$\begin{cases} -\Delta_p u = \lambda\{u^{p-1-\alpha} + f(v)\} \text{ in } \Omega, \\ -\Delta_q v = \lambda\{v^{q-1-\beta} + g(u)\} \text{ in } \Omega, \\ u = 0 = v \text{ on } \partial\Omega, \end{cases}$$

where $\Delta_m u := \mathrm{div}(|\nabla u|^{m-2}\nabla u)$; $m > 1$ is the m-Laplacian operator of u, $\lambda > 0$, $p > 1$, $q > 1$, $\alpha \in (0, p-1)$, $\beta \in (0, q-1)$ and Ω is a bounded domain in $\mathbb{R}^N; N \geq 1$ with smooth boundary $\partial\Omega$. Here $f, g : [0, \infty) \to \mathbb{R}$ are nondecreasing C^1 functions with $f(0) = 0 = g(0)$. We first establish that for $\lambda \approx 0$ there exist positive solutions bifurcating from the trivial branch $(\lambda, u \equiv 0, v \equiv 0)$ at $(0, 0, 0)$. We further discuss an existence result for all

$\lambda > 0$ and a multiplicity result for a certain range of λ under additional assumptions of f and g. We employ the method of sub-super solutions to establish our results. (Received January 20, 2015)

1110-35-36 **Quinn A Morris*** (qamorris@uncg.edu), **R Shivaji** and **R Dhanya**. *Existence of positive radial solutions for superlinear, semipositone problems on the exterior of a ball.*

We study positive radial solutions to $-\Delta u = \lambda K(|x|)f(u)$; $x \in \Omega_e$ where $\lambda > 0$ is a parameter, $\Omega_e = \left\{x \in \mathbb{R}^N \mid |x| > r_0, r_0 > 0, N > 2\right\}$, Δ is the Laplacian operator, $K \in C\left([r_0, \infty), (0, \infty)\right)$ satisfies $K(r) \leq \frac{1}{r^{N+\mu}}$; $\mu > 0$ for $r >> 1$, and $f \in C^1\left([0, \infty), \mathbb{R}\right)$ is a class of non-decreasing functions satisfying $\lim_{s\to\infty} \frac{f(s)}{s} = \infty$ (superlinear) and $f(0) < 0$ (semipositone). We will be interested in solutions, u, such that $u \to 0$ as $|x| \to \infty$, and which also satisfy the nonlinear boundary conditon $\frac{\partial u}{\partial \eta} + \tilde{c}(u)u = 0$ when $|x| = r_0$, where $\frac{\partial}{\partial \eta}$ is the outward normal derivative, and $\tilde{c} \in C\left([0, \infty), (0, \infty)\right)$. We will establish the existence of a positive radial solution for small values of the parameter λ. We also establish a similar result for the case when u satisfies the Dirichlet boundary conditon ($u = 0$) for $|x| = r_0$. We establish our results via variational methods, namely using the Mountain Pass Lemma. (Received January 20, 2015)

1110-35-38 **David G. Costa** and **Cyril Tintarev*** (tintarev@math.uu.se), Lägerhyddsv. 1, 751 06 Uppsala, Uppland, Sweden. *Concentration profiles for Moser-Trudinger functional look like toy pyramids.*

We study concentration phenomena of critical sequences for semilinear elliptic functionals of Moser-Trudinger type. We show, that, up to a remainder vanishing in the Sobolev norm, any such sequence is a sum of elementary concentrations of the form $j_k^{1/2} w(|x - x_0|^{j_k})$, with $j_k \to \infty$, and the radial "concentration profiles" w have a peculiar shape reminding of a toy pyramid for toddlers.

Unlike their counterpart in higher dimensions, the Talenti solution, which is unique up to rescaling transformations, the set of "toy pyramids" is essentially uncountable. Since, unlike the higher dimensions, an elementary concentration of a critical sequence is not necessarily a critical sequence (See e.g. the paper of Adimurthi and Prashanth), we show that every rescaling sequence of a toy pyramid defines a critical sequence up to a remainder vanishing in the energy norm. (Received January 21, 2015)

1110-35-40 **Monica Clapp** (monica.clapp@im.unam.mx), Instituto de Matematicas, UNAM, Circuito Exterior, Ciudad Universitaria, 04510 Mexico, D.F., Mexico, and **Sweta Tiwari*** (swetatiwari@im.unam.mx), Instituto de Matematicas, UNAM, Circuito Exterior, Ciudad Universitaria, 04510 Mexico, D.F., Mexico. *Multiple solutions to the pure super-critical problem for the p-Laplacian.*

We present some existence and multiplicity results of positive and sign changing solutions to the problem

$$-\Delta_p v = |v|^{q-2}\, v \quad \text{in } \Omega, \qquad v = 0 \quad \text{on } \partial\Omega,$$

in some bounded smooth domain Ω in $\mathbb{R}^N$, where $\Delta_p v := \operatorname{div}(|\nabla v|^{p-2}\, \nabla v)$ is the p-Laplace operator, $1 < p < N$ and $q > p^* := \frac{Np}{N-p}$ is super-critical.

As far as we know, these are the first existence results for the pure supercritical quasilinear problem. (Received January 27, 2015)

1110-35-48 **Alberto Bressan** and **Tao Huang*** (txh35@psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802. *Representation of Dissipative Solutions to a Nonlinear Variational Wave Equation.*

We introduces a new way to construct dissipative solutions to a second order variational wave equation. By a variable transformation, from the nonlinear PDE one obtains a semilinear hyperbolic system with sources. In contrast with the conservative case, here the source terms are discontinuous and the discontinuities are not always crossed transversally. Solutions to the semilinear system are obtained by an approximation argument, relying on Kolmogorov's compactness theorem. Reverting to the original variables, one recovers a solution to the nonlinear wave equation where the total energy is a monotone decreasing function of time. (Received February 03, 2015)

1110-35-65 **Ting-Hao Hsu*** (hsu.296@osu.edu), Department of Mathematics, The Ohio State University, Columbus, OH 43210. *Viscous singular shock profiles for some systems of conservation laws.*

We consider the viscous regularization $u_t + f(u)_x = \epsilon t u_{xx}$ for systems of conservation laws. One of our examples is a model for incompressible two-phase flow in one space dimension, for which we prove existence of viscous profiles for singular shocks, which by definition are distributions containing delta measures that are weak limits of approximate solutions. The main tool in this study is the geometric singular perturbation theory for singularly perturbed equations. Another example is the so-called Keyfitz-Kranzer model, for which the existence of viscous profiles for singular shocks has been proved by Schecter in 2004. In this talk we improve that result by describing the convergence and growth rates of the unbounded family of solutions. (Received February 23, 2015)

1110-35-80 **Andrea Cianchi*** (cianchi@unifi.it), Piazza Ghiberti 27, 50122 Firenze, Italy.
Mountain pass type solutions to fully anisotropic elliptic problems.

The existence of a nontrivial bounded solution to the Dirichlet problem, for a class of fully anisotropic nonlinear partial differential elliptic equations, is established. The relevant solution is obtained as a critical point of a non-coercive functional, associated with an energy integral whose dependence on the gradient is through a general convex function. This function need not be radial, nor have a polynomial type growth. Besides providing genuinely new conclusions, our result recovers and embraces, in a unified framework, several contributions in the existing literature, and augments them in various special instances. This is a joint work with G.Barletta. (Received February 10, 2015)

1110-35-84 **Alfonso Castro*** (castro@g.hmc.edu), Mathematics, Harvey Mudd College, Claremont, CA 91711, and **Jose Caicedo** and **Arturo Sajuan**. *Bifurcation from infinity for a semilinear wave equation with non-monotone nonliearity.*

We consider a one-dimensional wave equation and depending on a parameter λ. We give sufficient conditions on the nonlinear term for the equations to have solutions converging to (λ_k, ∞) even when the nonlinearity is not monotone. The main difficulty in this problem is given by the interaction of the infinite dimensional kernel of D'Alembert's operator with sign-changing derivative of the nonlinearity. (Received February 10, 2015)

1110-35-86 **Xiaoqian Xu*** (xxu@math.wisc.edu). *Fast growth of the vorticity gradient in symmetric smooth domains for 2D incompressible ideal flow.*

We will construct an initial data for the two-dimensional Euler equation in a bounded smooth symmetric domain, such that the gradient of vorticity in L^∞ grows as a double exponential in time for all time. Our construction is based on the recent result by Kiselev and Šverák. (Received February 10, 2015)

1110-35-93 **Alexander Pankov*** (alexander.pankov@morgan.edu), Mathematics Department, Morgan State University, 1700 E Cold Spring Lane, Baltimore, MD 21251. *Gap Solitons in Almost Periodic One-Dimensional Structures.*

We consider almost periodic stationary nonlinear Schrödinger equations in dimension 1. Under certain assumptions we prove the existence of nontrivial finite energy solutions in the strongly indefinite case. The proof is based on a carefull analysis of the energy functional restricted to the so-called generalized Nehari manifold, and the existence and fine properties of special Palais-Smale sequences. As an application, we show that certain one dimensional almost periodic photonic crystals possess gap solitons for all prohibited frequencies. (Received February 12, 2015)

1110-35-101 **Emine Celik*** (emine.celik@ttu.edu), 6302 Elgin Ave Apt 277, lubbock, TX 79413, and **Luan Hoang**. *Estimates for generalized Forchheimer flows in heterogeneous porous media.*

We study the generalized Forchheimer flows for slightly compressible fluids in heterogeneous porous media. The coefficients in the Forchheimer equations depend on the spatial variables. This results in singular/degenerate parabolic equations for the pressure. We estimate the pressure, its time derivative and gradient in terms of the initial and boundary data. Asymptotic estimates in time are also established. We utilize weighted Sobolev inequalities with specific weights defined by the Forchheimer equation's coefficient functions, De Giorgi's iteration, and uniform Gronwall inequality. This is a joint work with Luan Hoang. (Received February 13, 2015)

1110-35-107 **Jiahong Wu*** (jiahong.wu@okstate.edu), 401 Mathematical Sciences, Department of Mathematics, Stillwater, OK 74078. *The two-dimensional Boussinesq equations with fractional dissipation.*

The Boussinesq equations concerned here model geophysical flows such as atmospheric fronts and ocean circulations. Mathematically the 2D Boussinesq equations serve as a lower-dimensional model of the 3D hydrodynamics equations. In fact, the 2D Boussinesq equations retain some key features of the 3D Euler and the Navier-Stokes equations such as the vortex stretching mechanism. The global regularity problem on the 2D Boussinesq equations with partial or fractional dissipation has attracted considerable attention in the last few years. This talk presents recent developments in this direction. In particular, we detail the global regularity result on the 2D Boussinesq equations with vertical dissipation as well as the result for the 2D Boussinesq equations with general critical dissipation. (Received February 14, 2015)

1110-35-111 **Monica Visan*** (visan@math.ucla.edu), 520 Portola Plaza, Math Sciences Building 6363, Los Angeles, CA 90095. *The cubic-quintic NLS with non-vanishing boundary conditions.*

I will report on recent joint work with R. Killip and J. Murphy on the cubic-quintic NLS with non-vanishing boundary conditions at infinity. (Received February 15, 2015)

1110-35-112 **Liliane A Maia*** (lilimaia@unb.br), Departamento de Matemática, Campus Universitário Darcy Ribeiro, Asa Norte, Brasília, Brazil, and **Benedetta Pellacci** (benedetta.pellacci@uniparthenope.it), Dipartimento di Scienze e Tecnologie, Università degli Studi di Napoli Parthenope, Centro Direzionale Isola C4, 80143, Napoli, Italy. *Positive Solutions for Asymptotically Linear Problems in Exterior Domains.*

We will present some recent results on the existence of a positive solution for the following class of elliptic problems

$$-\Delta u + \lambda u = f(u), \quad \text{in} \quad \Omega, \quad u \in H_0^1(\Omega),$$

where Ω is an unbounded domain in $\mathbb{R}^N$ not necessarily symmetric, $N \geq 3$, with smooth boundary $\partial\Omega \neq \emptyset$ bounded, and such that $\mathbb{R}^N \setminus \Omega$ is bounded. The non-linearity f is super-linear at zero and asymptotically linear at infinity. This result is established via a linking argument on the Nehari manifold and by means of a barycenter function. This is a work in collaboration with Benedetta Pellacci from Università degli Studi di Napoli *Parthenope*, Italy. (Received February 15, 2015)

1110-35-120 **Djairo G. deFigueiredo*** (djairo@ime.unicamp.br), UNICAMP, IMECC, Depto Matematica, Campinas, Sao Paulo 13085-140, Brazil. *On Trudinger-Moser type inequalities.*

In analogy with the results in dimension N lager than 3, where weights increase the critical Sobolev powers, we discuss the role of weights in imbeddings in dimension 2, increasing the exponents of Trudinger-Moser. (Received February 16, 2015)

1110-35-126 **Geng Chen*** (gchen73@math.gatech.edu), 686 Cherry Street, School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Well-posedenss of nonlinear variational wave equations.*

In this talk, we will discuss the existence, uniqueness, Lipschitz continuous dependence on the initial data under some Finsler type optimal transport metric and the generic structure of solutions for nonlinear variational wave equation

$$u_{tt} - c(u)(c(u)u_x)_x = 0$$

in one space dimension. This talk includes a series of research works with Alberto Bressan and Qingtian Zhang. (Received February 16, 2015)

1110-35-127 **Eunkyung Ko**, **Mythily Ramaswamy** and **Ratnasingham Shivaji*** (r_shivaj@uncg.edu), Dept of Mathematics & Statistics, University of North Carolina at Greensboro, Greensboro, NC 27455. *Uniqueness of positive radial solutions for a class of semipositione problems on the exterior of a ball.*

We study positive radial solutions to: $-\Delta u = \lambda K(|x|)f(u);\ x \in \Omega_e$, where $\lambda > 0$ is a parameter, $\Omega_e = \{x \in \mathbb{R}^N : |x| > r_0,\ r_0 > 0, N > 2\}, \Delta$ is the Laplacian operator, $K \in C([r_0,\infty),(0,\infty))$ satisfies $K(r) \leq \frac{1}{r^{N+\mu}}; \mu > 0$ for $r \gg 1$ and $f \in C^2([0,\infty),\mathbb{R})$ is a concave increasing function satisfying $\lim_{s\to\infty} \frac{f(s)}{s} = 0$ and $f(0) < 0$ (semipositone). We are interested in solutions u such that $u \to 0$ as $|x| \to \infty$ and satisfy the nonlinear boundary condition $\frac{\partial u}{\partial \eta} + \tilde{c}(u)u = 0$ if $|x| = r_0$ where $\frac{\partial}{\partial \eta}$ is the outward normal derivative and $\tilde{c} \in C([0,\infty),(0,\infty))$ is an increasing function. We will establish the uniqueness of positive radial solutions for large values of the parameter λ. (Received February 16, 2015)

1110-35-128 **Charis Tsikkou*** (chtsikkou@mail.wvu.edu), West Virginia University, Department of Mathematics. *Analysis of 2+1 Diffusive-Dispersive PDE Arising in River Braiding.*

In the context of a weakly nonlinear study of bar instabilities in a river carrying sediment, P. Hall introduced an evolution equation for the deposited depth which is dispersive in one spatial direction, while being diffusive in the other. In this talk, we present local existence and uniqueness results using a contraction mapping argument in a Bourgain-type space. We also show that the energy and cumulative dissipation are globally controlled in time. (Received February 16, 2015)

1110-35-130 **Changhui Tan*** (ctan@cscamm.umd.edu), 4123 CSIC Building, University of Maryland, College Park, MD 20742. *Eulerian dynamics with nonlocal interactions.*

In this talk, I will discuss compressible Euler equations with interaction forces, including attraction, repulsion and alignment. The system arises as the hydrodynamic limit of the mean-field description for models on collective behaviors, such as flocks of birds, school of fishes, colonies of bacteria, etc. We outline the derivation of the system, and study its global well-posedness and large time behavior. In the case of alignment force, we obtain a sharp threshold on initial data, where subcritical initials converges to a flocking solution, and supercritical initials blows up in finite time. This is a joint work with J.A. Carrillo, Y.-P. Choi and E. Tadmor. (Received February 17, 2015)

1110-35-131 **Nathan Glatt-Holtz**, **Roger Temam** and **Chuntian Wang*** (wang211@umail.iu.edu), Rawles Hall, 831 East 3rd St, Bloomington, IN 47405. *Numerical Analysis of the Stochastic Navier-Stokes Equations: Stability and Convergence of Invariant Measures.*

When studying turbulence of the fluids, many outstanding problems are concerned with the long-term behaviors. This motivates us to design schemes that justify the long-term simulations of chaotic and complex systems. Working towards this final goal, in this article, we propose a class of space-time discretization numerical schemes that preserve certain statistical features for the stochastic Navier-Stokes equations (NSE) subject to a nonlinear state dependent white noise forcing. We first demonstrate the stability criteria and convergence of schemes. Then we establish existence and convergence of an invariant measure for each step of the schemes to the ergodic measure of the limit system, provided that the associated semigroup of the limit system has a strict contraction property. It is also verified that this is the case in many meaningful settings of the stochastic NSE. (Received February 17, 2015)

1110-35-132 **Patrick Guidotti*** (gpatrick@math.uci.edu), Department of Mathematics, 340 Rowland Hall, Irvine, CA 92697. *Some Nonlinear Diffusions of Image Processing.*

Two regularizations of the well-known Perona-Malik equation of Image Processing will be presented and analyzed. Particular emphasis will be given to theoretical explanations for numerical observations concerning the behavior of solutions. (Received February 17, 2015)

1110-35-149 **Luis Silvestre** and **Vlad Vicol*** (vvicol@math.princeton.edu), Fine Hall, Washington Road, Princeton, NJ 08544. *On a transport equation with nonlocal drift.*

Cordoba, Cordoba, and Fontelos proved that for some initial data, the following nonlocal-drift variant of the 1D Burgers equation does not have global classical solutions

$$\partial_t \theta + u \partial_x \theta = 0, u = H\theta,$$

where H is the Hilbert transform. We provide four essentially different proofs of this fact. Moreover, we study possible Holder regularization effects and conjecture that solutions which arise as limits from vanishing viscosity approximations are bounded in the Holder class in $C^{1/2}$ for all positive time. (Received February 17, 2015)

1110-35-166 **Anthony Suen*** (acksuen@ied.edu.hk), Department of Mathematics and I.T., The Hong Kong Institute of Education, 10, Lo Ping Road, Tai Po, New Territories, Hong Kong, Hong Kong, and **Tong Li**. *Existence of intermediate weak solution to the equations of multidimensional chemotaxis systems.*

We prove the global-in-time existence of intermediate weak solutions of the equations of chemotaxis system in a bounded domain of $\mathbb{R}^2$ or $\mathbb{R}^3$ with initial chemical concentration small in H^1. No smallness assumption is imposed on the initial cell density which is in L^2. We first show that when the initial chemical concentration c_0 is small only in H^1 and $(n_0 - n_\infty, c_0)$ is smooth, the classical solution exists for all time. Then we construct weak solutions as limits of smooth solutions corresponding to mollified initial data. Finally we determine the asymptotic behavior of the global solutions. (Received February 23, 2015)

1110-35-171 **Yongki Lee*** (yongki.lee@ucr.edu), Department of Mathematics, University of California, Riverside, Riverside, CA 92521. *A class of non-local conservation laws: sub-thresholds for finite time shock formation.*

We investigate a class of non-local conservation laws with the nonlinear advection coupling both local and non-local mechanisms, which arise in several applications such as traffic flows and the collective motion of cells. We identify sub-thresholds for finite time shock formation in traffic flow models and the hyperbolic Keller-Segel model. This is a joint work with Hailiang Liu. (Received February 19, 2015)

1110-35-172 **Hidemitsu Wadade*** (wadade@se.kanazawa-u.ac.jp), Kakuma-machi, Kanazawa-shi, Ishikawa, 920-119, Kanazawa, Ishikawa 920-119, Japan. *The limiting case of Sobolev embeddings on critical Sobolev-Lorentz-Zygmund spaces.*

In this talk, we consider the limiting case of Sobolev embeddings on the critical Sobolev-Lorentz-Zygmund spaces. Especially, we establish the corresponding Trudinger-Moser inequality and Brezis-Gallouet-Wainger inequality of double logarithmic type. Also we investigate the almost Lipschitz continuity for functions in the higher order Sobolev-Lorentz-Zygmund spaces. (Received February 19, 2015)

1110-35-179 **Farhod Abdullayev*** (fabdullayev@wpi.edu), 100 Institute Road, Worcester, MA 01609. *On quasi-static limits of one-dimensional dynamic cohesive fracture.*

Quasi-static models are based on the assumption that whatever is driving the motion, for example loading or Dirichlet conditions, varies slowly in time compared to the elastic wave speed of the material. We analyze a one-dimensional model of dynamic cohesive fracture with varying Dirichlet condition, and take the limit as the speed with which the condition changes goes to zero. We then study the question of whether the usual model for quasi-static cohesive fracture is the limit of dynamic cohesive fracture. (Received February 19, 2015)

1110-35-207 **Nguyen Lam*** (nhlam@pitt.edu), Department of Mathematics, 301 Thackeray Hall, Pittsburgh, PA 15260, **Guozhen Lu** (gzlu@wayne.edu), Department of Mathematic, 1150 FAB, 656 W Kirby, Detroit, MI 48202, and **Lu Zhang** (eu4347@wayne.edu), Department of Mathematic, 1150 FAB, 656 W Kirby, Detroit, MI 48202. *Equivalence of critical and subcritical sharp Moser-Trudinger-Adams inequalities.*

In this talk, we will report our recent work on sharp Moser-Trudinger-Adams inequalities. More precisely, we will show the equivalence of critical and subcritical sharp Moser-Trudinger-Adams inequalities. This proposes a new approach to the study of critical sharp Moser-Trudinger-Adams inequalities. This is joint work with Guozhen Lu and Lu Zhang. (Received February 20, 2015)

1110-35-224 **Matthew D Blair*** (blair@math.unm.edu). *Strichartz and localized energy estimates for the wave equation in strictly concave domains.*

In this talk, we will introduce a family of energy estimates for solutions to the wave equation in domains with a strictly concave boundary satisfying homogeneous boundary conditions. They can be thought of as refinements of the classical local energy and local smoothing estimates. The estimates show that for frequency localized solutions, taking the square integral of the solution over small frequency-dependent collars of the boundary results in a stronger gain in regularity than would be expected for collars of a uniform size. We will also discuss the consequences for the development of Strichartz estimates with subcritical exponents in such domains, in particular providing an avenue for treating Neumann conditions. (Received February 21, 2015)

1110-35-226 **Hanli Tang*** (hltang@bnu.edu.cn), Beijing, Beijing 100875, Peoples Rep of China. *Sharp singular Moser-Trudinger inequalities in Lorentz-Sobolev space.*

In this report, we establish best constants for several types of singular Moser-Trudinger inequalities in Lorentz-Sobolev spaces. These include sharp constants for singular Moser-Trudinger inequality on both bounded and unbounded domains with the Lorentz norm restrictions. And we also set up best constants for subcritical and singular subcritical Moser-Trudinger inequalities in Lorentz-Sobolev space. This is a joint work with Professor Guozhen Lu. (Received February 22, 2015)

1110-35-228 **Maxence Cassier*** (cassier@math.utah.edu), **Christophe Hazard** (christophe.hazard@ensta-paristech.fr) and **Patrick Joly** (patrick.joly@inria.fr). *On the limiting amplitude principle for a transmission problem between a dielectric and a metamaterial.*

In this talk, we study a transmission problem between a dielectric and a metamaterial. The question we consider is the following: does the limiting amplitude principle hold in such a medium? This principle defines the stationary regime as the large time asymptotic behavior of a system subject to a periodic excitation.

An answer is proposed here in the case of a two-layered medium composed of a dielectric and a particular metamaterial (Drude model). In this context, we reformulate the time-dependent Maxwell's equations as a Schrödinger equation and perform its complete spectral analysis. This permits a quasi-explicit representation of its solution via the "generalized diagonalization" of its associated unbounded self-adjoint operator. As an application of this study, we show finally that the limiting amplitude principle holds except for a particular fequency, called the plasmonic frequency, characterised by a ratio of permittivities and permeabilities equal to -1 across the interface. This frequency constitutes an unusual example of resonance in an unbounded medium and the response of the system to this excitation blows up linearly in time. (Received February 24, 2015)

1110-35-229 **Paolo Salani*** (paolo.salani@unifi.it), Dipartimento di Matematica e Informatica "U., Viale Morgagni 67/A, 50131 Firenze, FI, Italy. *Mean width rearrangements for fully nonlinear elliptic equations.*

I introduce a method to compare solutions of different equations in different domains. As a consequence, it is possible to define a new kind of rearrangement, which applies to solutions of fully non linear equations $F(x, u, Du, D^2u) = 0$ (not necessarily in divergence form), and to obtain related Talenti's type results. (Received February 22, 2015)

1110-35-231 **Maochun Zhu*** (zhumaochun2006@126.com), School of Mathematical Sciences, Beijing Norm University, Beijing, 100875, Peoples Rep of China. *A sharp Moser-Trudinger type inequality involving L^n norm on $\mathbb{R}^n$.*

In this talk, I will present an improved Moser-Trudinger inequality on unbounded domains, and show that the supremum is attained under suitable assumptions. The method we used is the blow-up analysis. This is joint work with Guozhen Lu. (Received February 22, 2015)

1110-35-234 **M. Ignatova*** (ignatova@math.princeton.edu) and **V. Vicol**. *Almost global existence for the Prandtl boundary layer equations.*

We address the Prandtl boundary layer equations on the half space with real-analytic initial datum with respect to the tangential variable. The boundary traces of the horizontal Euler flow and pressure are taken to be constants. We establish that if the initial datum lies within ϵ of a stable profile, then the time of existence for the solution is at least $\exp(\epsilon^{-1}/\log(\epsilon^{-1}))$. This is a joint work with V. Vicol. (Received February 22, 2015)

1110-35-240 **Luan T Hoang***, Department of Mathematics and Statistics, Texas Tech University, Box 41042, Lubbock, TX 79409-1042, and **Vincent Martinez**. *On the normal form of Navier-Stokes equations in Gevrey spaces.*

We study the 3-D incompressible Navier-Stokes equations on periodic domains with potential body forces. The normal form associated with the solution's asymptotic expansion was previously proved to be a Poincaré-Dulac normal form in the space of smooth functions. Here, we derive Gevrey estimates for the homogeneous polynomials of this normal form. This is a step in establishing the normal form in the Gevrey spaces. The presentation is based on a joint work with Vincent Martinez. (Received February 22, 2015)

1110-35-241 **Ronghua Pan*** (panrh@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30332, **Geng Chen**, 686 Cherry Street, Atlanta, GA 30332, and **Shengguo Zhu** (zhushengguo@sjtu.edu.cn), 80 Dongchuan Road, Minhang District, Shanghai. *Shock formation in compressible Euler equations.*

It is well-known that shock will form in finite time for hyperbolic conservation laws from initial compression no matter how small and smooth the data are. Classical results, including P. D. Lax, T. Liu, Li-Zhou-Kong, confirms that when initial data are small near constant states, nonlinear compression does lead to finite time shock formation. A natural puzzleis how this phenomena could be proved for large data. Joint with G. Chen and S. Zhu, we justify this expectation under some reasonable conditions for compressible Euler equations, in both isentropic and adiabatic cases. (Received February 22, 2015)

1110-35-253 **Alina Chertock*** (chertock@math.ncsu.edu), **Alexander Kurganov**, **Anthony Polizzi** and **Ilya Timofeyev**. *Pedestrian flow models with slowdown interactions.*

In this talk, I will discuss one-dimensional models for the behavior of pedestrians in a narrow street or corridor. I will first formulate a stochastic cellular automata model with explicit rules for pedestrians moving in two opposite directions. Coarse-grained mesoscopic and macroscopic analogs will then be carefully derived leading to the coupled system of PDEs for the density of the pedestrian traffic. The obtained first-order system of conservation laws is only conditionally hyperbolic and thus higher-order nonlinear diffusive corrections resulting in a parabolic macroscopic PDE model will be introduced. Finally, I will present a number of numerical experiments comparing and contrasting the behavior of the microscopic stochastic model and the resulting coarse-grained PDEs for various parameter settings and initial conditions. These numerical experiments demonstrate that the nonlinear diffusion is essential for reproducing the behavior of the stochastic system in the nonhyperbolic regime. (Received February 22, 2015)

1110-35-258 **John K Hunter*** (jkhunter@ucdavis.edu), Department of Mathematics, University of California, 1 Shields Avenue, Davis, CA 95616. *Nonlinear, nondispersive surface waves.*

An asymptotic analysis of weakly nonlinear, nondispersive waves on boundaries and interfaces leads to spatially nonlocal equations that describe the nonlinear mixing of the spectral components of the wave. Solutions of these equations typically form singularities which correspond to a loss of smoothness on the boundary or an overturning of the interface. We will give examples of such surface waves in MHD, incompressible fluids, and electromagnetism. (Received February 23, 2015)

1110-35-261 **Daniele Cassani*** (daniele.cassani@uninsubria.it), Università degli Studi dell'Insubria, Dipartimento di Scienza e Alta Tecnologia, Via Valleggio 11, 22100 Como, Italy. *Pohozaev-Trudinger-Moser type inequalities via Zygmund spaces.*

New insights in limiting cases of Sobolev embeddings can be achieved by using Zygmund quasi-norms which, from one side throw light on classical inequalities, improving previous results such as optimal regularity for borderline PDE, attainability issues of sharp inequalities, on the other side within this framework new inequalities are established towards a better understanding of critical phenomena. (Received February 23, 2015)

1110-35-262 **Michael S. Jolly*** (msjolly@indiana.edu), Department of Mathematics, 831 E. 3rd Street, Bloomington, IN 47405. *Data Assimilation by Feedback Control and Kalman Filters.* Preliminary report.

We present recent rigorous estimates for data assimilation via feedback control for dissipative systems. The relaxation of the solution to the feedback control system to a reference solution enables the evolution of a determining form, an ordinary differential equation in a space of trajectories. Every solution of the determining form evolves toward a steady state which is a trajectory on the global attractor of the original system. The determining form is employed to synchronize, i.e., remove noise from trajectories. Numerical computations compare the effectiveness of this approach is compared to the method of Kalman filters. (Received February 23, 2015)

1110-35-267 **Maya Chhetri*** (maya@uncg.edu) and **Petr Girg**. *Asymptotically linear system of three equations.*

We will discuss some bifurcation results for asymptotically linear system of three semilinear equations satisfying Dirichlet boundary conditions. The associated linear part of the system has only two simple eigenvalues whose corresponding eigenfunctions are componentwise *nonnegative*. We will discuss bifurcation of positive solutions from infinity from these simple eigenvalues. In particular, we will discuss sufficient conditions under which the system has bifurcation from infinity of componentwise *positive* solutions from both, one, or none of the simple eigenvalues. (Received February 23, 2015)

1110-35-275 **Fernando Guevara Vasquez***, 1400 E 155 S RM 233, Salt Lake City, UT 84112, and **Leonid A Kunyansky**. *Directional Active Cloaking for the 2D Helmholtz equation.* Preliminary report.

One way of cloaking or hiding objects from probing waves is to use active sources to cancel out the incident field while radiating little waves. For the 2D Helmholtz equation, this could be achieved by e.g. a few multipolar sources that reproduce (in certain regions) the fields produced by the single and double layer potentials from Green's identities applied to the region inside a closed curve. We show progress towards understanding how restricting the incident fields to plane waves removes the need to consider the whole closed curve. One possible application is to remove the need for having multipolar sources completely surrounding the region to be cloaked. (Received February 23, 2015)

1110-35-279 **Nguyen Lam**, **Guozhen Lu** and **Lu Zhang*** (eu4347@wayne.edu). *Sharp singular Trudinger-Moser inequality with exact growth and its extremals.*

Sharp singular Trudinger-Moser inequality with exact growth and its extremals

In our work, we study a sharp version of the Trudinger-Moser inequality of Adachi-Tanaka type with exact growth on $D^{1,N}(\mathbb{R}^N) \cap L^q(\mathbb{R}^N)$. We establish the inequalities with a polynomial decay and show actually we are able to get a critical equality without using the restriction of full norm. Moreover, we will see that decay allowed is the best possible. In addition, we study the existence of the extremal functions for the inequality in a subcritical case. (Received February 23, 2015)

1110-35-282 **Qi Han*** (qhan@wpi.edu), Department of Mathematical Sciences, Worcester Polytechnic Institute, Worcester, MA 01609. *Compact embedding results of Sobolev spaces and positive solutions to an elliptic equation in R^N.* Preliminary report.

Using a regular Borel measure $\mu \geq 0$ that vanishes on each set of capacity zero, we derive a proper subspace $D^1_\mu(R^N)$ of $D^1(R^N)$ when $N \geq 3$. This space $D^1_\mu(R^N)$ is compactly embedded into $L^1(R^N)$. An equivalence characterization and an example are provided that guarantee such a property. An example is also given if one is only interested in the compact embedding to $L^r(R^N)$ for $1 \leq r < 2$. Moreover, similar results can be derived for general $D^{1,p}_{\mu}(R^N)$ when $1 < p < N$, while when $p = N$, we need to use the space $W^{1,N}_{\mu}(R^N)$. As an application, we prove an existence result of positive solutions to

$$-\Delta u + Vu = \lambda u^r + f(x,u)$$

in $H^1_{\mu}(R^N)$ or $D^1_{\mu}(R^N)$ when $N \geq 2$ without the Ambrosetti-Rabinowitz condition on $f(x,u)$. Results for the N-Laplacian problem can be discussed similarly when we have exponentially subcritical growth. (Received February 23, 2015)

1110-35-283 **Rafael Granero Belinchon*** (rgranero@math.ucdavis.edu), Department of Mathematics, University of California, Davis, One Shields Avenue, Davis, CA 95616. *The Muskat and Hele-Shaw cell problem with H^2 initial data.*

We study the dynamics of the interface between two incompressible fluids in a two-dimensional porous medium or in a Hele-Shaw cell. For this problem, we establish global well-posedness and decay to equilibrium for small H^2 perturbations of the rest state. For the one-phase Muskat problem, we prove local well-posedness for H^2 initial data of arbitrary size. Finally, we show that solutions to the Muskat equations instantaneously become infinitely smooth. (Received February 23, 2015)

1110-35-286 **Ning Ju*** (ning.ju@okstate.edu), 401 Mathematical Sciences, Department of Mathematics, Stillwater, OK 74078. *Some New Results about Solutions of Primitive Equations.*

The Primitive equations are a set of nonlinear evolutionary partial differential equations in Geophysics modeling large scale ocean and atmosphere dynamics. Existence of global-in-time strong solutions to this system was obtained independently by Cao-Titi, Kobelkov and Kukavica-Ziane. However, some other related problems about the solutions remain not completely resolved. Some results recently obtained by the speaker about existence, uniqueness and regularity of solutions of Primitive Equations will be reported. (Received February 23, 2015)

1110-35-290 **Allen M. Tesdall*** (allen.tesdall@csi.cuny.edu) and **Richard Sanders**. *Further results on irregular weak reflection.*

Recent numerical solutions and physical experiments have shown the existence of a complex reflection pattern known as GMR which provides a resolution of the triple point paradox. This pattern is characterized by a discontinuous transition from supersonic to subsonic flow at the rear of each patch in a sequence of tiny supersonic patches. We study numerically the possibility of an alternate structure in which the transition from supersonic to subsonic flow is smooth. (Received February 23, 2015)

1110-35-291 **Luigi Fontana** and **Carlo Morpurgo*** (morpurgoc@missouri.edu). *Adams and Moser-Trudinger inequalities on spaces of infinite measure. Part I.*

We first present a sharp Adams inequality for the Riesz potential $|x|^{\alpha-n} * f$ ($0 < \alpha < n$), for functions f with arbitrary compact support on $\mathbb{R}^n$. The same result also holds for more general convolution kernels, which are homogeneous of order $\alpha - n$. Up to now such results were only known for a class of f whose supports have uniformly bounded measure.

Next, we present sharp Adams inequalities for general integral operators on spaces of arbitrary measure, whose integral kernel satisfies suitable growth and decay conditions. These results extend the ones obtained earlier by the authors, in the context of finite measure spaces. (Received February 23, 2015)

1110-35-292 **Luigi Fontana*** (luigi.fontana@unimib.it) and **Carlo Morpurgo**. *Adams and Moser-Trudinger inequalities on spaces of infinite measure. Part II.*

We present several sharp Moser-Trudinger inequalities for the critical Sobolev space $W^{k,n/k}$ on $\mathbb{R}^n$ and on the hyperbolic space $\mathbb{H}^n$. Up to now, results are only known for $k = 1$, both on $\mathbb{R}^n$ and $\mathbb{H}^n$, and for $k = 2$ on $\mathbb{R}^4$.

These new results are obtained as applications of the Adams inequalities described in Part I. (Received February 23, 2015)

1110-35-301 **Cristina Tarsi*** (cristina.tarsi@unimi.it), Via Saldini 50, 20133 Milan, MI, Italy. *Limiting Sobolev inequalities and the 1-biharmonic operator.*

In this talk we present recent results, obtained in collaboration with E. Parini (Univ. Marseille) and B. Ruf (Univ. Milano), on optimal embeddings of the space of functions whose distributional Laplacian belongs to $L^1(\Omega)$, where Ω is a bounded domain. This function space turns out to be strictly larger than the Sobolev space $W^{2,1}$, in which the whole set of second order derivatives is considered. In particular, we discuss sharp embedding inequalities which allow to improve the optimal summability results for solutions of Poisson equations with L^1-data by Maz'ya ($N \geq 3$) and Brezis-Merle ($N = 2$). We then consider optimal embeddings of the mentioned space into L^1, which yields the corresponding eigenvalue problems for the 1-*biharmonic operator* (a higher order analogue of the 1-Laplacian). We finally discuss possible applications of this operator to the image processing. (Received February 23, 2015)

1110-35-307 **Mihaela Ifrim** and **Daniel Tataru*** (tataru@math.berkeley.edu). *Global nonlinear dispersive waves and the wave packet method.*

The aim of this talk is to provide a brief introduction to the method of wave packet testing, which has proved very useful in recent work on global well-posedness for various water wave models. (Received February 23, 2015)

1110-35-313 **Eun Heui Kim***, 1250 Bellflower Blvd, Department of Mathematics, California State University, Long Beach, Long Beach, CA 90840. *Global solutions for transonic self-similar two-dimensional Riemann problems.*

We discuss the recent development of multi-dimensional transonic Riemann problems. Specifically, we discuss existence results and regularity results on configurations that give rise to transonic problems for a model system – the nonlinear wave system. (Received February 23, 2015)

1110-35-315 **Mengxia Dong*** (eu8879@wayne.edu) and **Guozhen Lu**. *A general sharp weight Moser-Trudinger inequality.*

In this article, our main purpose is to establish the weighted Moser-Trudinger type inequality with its sharp constant and consider the existence of a maximizer associated with the weighted Moser-Trudinger type inequality. Recently Ishiwata, Nakamura and Wadade have shown the singular Moser-Trudinger type inequality for all radially symmetric functions. We improve this result by showing such weighted inequalities also hold for arbitrary functions which are not necessarily radially symmetric. Moreover, we also prove a more general inequality and establish the existence of maximizer could be attained. This is joint work with Guozhen Lu. (Received February 23, 2015)

1110-35-323 **Zhen Lei**, **Adam Navas** and **Qi S Zhang***, Math. Dept. UCR, Riverside, CA 92521. *A priori bounds for axially symmetric Navier-Stokes equations.*

Let v be the velocity of Leray-Hopf solutions to the axially symmetric three-dimensional Navier-Stokes equations. Under suitable conditions for initial values, it is proven that the modulus of v is bounded by the constant multiple of the inverse square of the distance to the axis, modulo a log term. Similar bound is proven for the angular stream function. A critical regularity condition for the vertical speed is also given. This result gives a mathematical explanation of the folklore belief that singularity can happen only if the vertical convection is high enough. This is a joint work with Zhen Lei and Adam Navas. (Received February 23, 2015)

1110-35-324 **Benjamin Harrop-Griffiths*** (benhg@math.berkeley.edu), **Mihaela Ifrim** and **Daniel Tataru**. *Asymptotic behavior via testing against wave packets.*

We discuss some recent progress on the asymptotic behavior of dispersive PDE using the the method of testing by wave packets, originally developed by Ifrim and Tataru in the context of the 1d NLS and 2d water waves. (Received February 23, 2015)

1110-35-325 **Chongsheng Cao**, **Jinkai Li** and **Edriss S Titi*** (titi@math.tamu.edu), Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77843. *Recent advances concerning the primitive equations of oceanic and atmospheric dynamics.*

In this talk we will survey some of the recent advances concerning the global regularity of the primitive equations of oceanic and atmospheric dynamics. In particular, we will discuss the case of anisotropic viscosity and heat diffusion. Moreover, we will show that in the absence of viscosity the solutions develop a finite time singularity whenever they exist. (Received February 23, 2015)

1110-35-330 **Jungang Li*** (fl6532@wayne.edu), Wayne State University, 656 W. Kirby, Detriot, MI 48202. *Sharp Moser-Trudinger Inequality on Complete Noncompact Riemannian Manifolds*

We will consider the sharp Li-Ruf type critical Moser-Trudinger inequality on complete noncompact Riemannian manifolds. Namely,

$$\sup_{u\in W^{1,n}(M),||u||_{1,\tau}\leq 1}\int_M \phi(\alpha_n|u|^{\frac{n}{n-1}})dV_g \leq C(n,\tau) \tag{1}$$

Where $\phi(t)=\sum_{k=n-1}^{\infty}\frac{t^k}{k!}$, α_n is the Moser's constant, $||u||_{1,\tau}=(\int_M \tau|u|^n+|\nabla u|^n)^{\frac{1}{n}}$. The inequality is sharp. Our method is motivated by an earlier symmetrization-free argument due to Lam and Lu in the Heisenberg group (Adv. Math. (2012)) or high order Sobolev spaces (J. Diff. Equ. (2013)) where they develop a general method to derive global Moser-Trudinger inequalities on domains of infinite measure from local ones on domains of finite measure. This method works in more general settings.

Moreover, we prove the Adachi-Tanaka's version of sharp subcritical Moser-Trudinger inequality on complete noncompact Riemannian manifolds. Namely,

$$\frac{1}{||u||_n^n}\int_M \phi(\alpha|u|^{\frac{n}{n-1}})dV_g \le C \tag{2}$$

holds for all $u \in W^{1,n}(M)$ such that $||\nabla u||_n \le 1$, $\alpha < \alpha_n$. This is a joint work with Prof. Guozhen Lu. (Received February 24, 2015)

1110-35-339 **MIkyoung Lim*** (mklim@kaist.ac.kr), , South Korea. *Conductivity problem in the presence of two circular inclusions and the anomalous resonance.*

The plasmonic concentric structure exhibits the cloaking due to the anomalous localized resonance. In this talk I present the anomalous resonance in superlens with eccentric core. I also consider the conductivity problem in the presence of adjacent circular inclusions with constant conductivities. When two inclusions get closer and their conductivities degenerate to zero or infinity, the gradient of the solution can be arbitrary large. I present an asymptotic formula of the solution, which characterizes the gradient blow-up of the solution in terms of conductivities of inclusions as well as the distance between inclusions. (Received February 24, 2015)

1110-35-345 **Peter Constantin*** (const@math.princeton.edu), Department of Mathematics, Princeton University, Fine Hall, Washington Road, Princeton, NJ 08544, and **Tarek Elgindi**, Department of Mathematics, Princeton University, Fine Hall, Washington Road, Princeton, NJ. *Nonlocal equations: electroconvection.* Preliminary report.

I will describe a system of equations arising in electroconvection in which nonlocal effects are due to the electric potential. I will prove some results of well-posedness and describe some open problems. This is joint work with Tarek Elgindi. (Received February 24, 2015)

1110-35-356 **Alex Ionescu** and **Victor D Lie*** (vlie@purdue.edu), 2435 A Kestral Blvd, West Lafayette, IN 47906. *Quasilinear Systems of Klein-Gordon Equations in 3D with vorticity.*

We show that for small enough initial data, the solution for the 3D quasilinear systems of Klein-Gordon equations with vorticity (and different speeds) exists for a time T which is inverse proportional relative to the size (properly measured) of the vorticity. In particular, for zero vorticity, we recover the corresponding small data global existence result of A. Ionescu and B. Pausader. Our analysis relies on a carrefully designed bootstrap (in time) algorithm which further relates with the structure of the nonlinearity. To take advantage of this structure, one is led to the study of biliniear operators of the form

$$\widehat{T[f,g]}(\xi) = \int_R \int_{R^3} e^{it\Phi(\xi,\eta)}\, m(\xi,\eta)\, \hat{f}(\xi-\eta,t)\, \hat{g}(\eta,t)\, d\eta\, dt\,.$$

This study involves Fourier transform methods adapted to the properties of the phase Φ.

This is a joint work with A. Ionescu. (Received February 24, 2015)

1110-35-365 **Angel Castro**, **Diego Cordoba** and **Javier Gomez-Serrano***, 610 Fine Hall, Washington Road, Princeton, NJ 08544. *Existence and regularity of rotating global solutions for the generalized surface quasi-geostrophic patches.*

In this talk we will discuss the existence of C^∞ convex global rotating solutions for the generalized surface quasi-geostrophic patch equation. Joint work with Angel Castro and Diego Cordoba. (Received February 24, 2015)

1110-35-366 **Mihaela Ifrim*** (ifrim@berkeley.edu) and **Daniel Ioan Tataru** (tataru@berkeley.edu). *The lifespan of small data solutions in two dimensional water waves.*

We consider water wave equations in two space dimensions expressed in position-velocity potential holomorphic coordinates, and prove that small data solutions have at least cubic lifespan. (Received February 24, 2015)

1110-35-370 **A. Vasseur** and **C. Yu*** (yucheng@math.utexas.edu). *Existence of Global Weak Solutions for the Degenerate Compressible Navier-Stokes Equations.*

In this paper, we prove the existence of global weak solutions for the 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 shallow water equations, for any $\gamma > 1$, with large initial data possibly vanishing on the vacuum. This solves an open problem proposed by Lions. (Received February 24, 2015)

1110-35-372 **Igor Kukavica** (ikukavica@gmail.com) and **Fei Wang*** (wang828@usc.edu). *Weighted Decay for the Surface Quasi-Geostrophic Equation.*

We address the weighted decay for the solution of the surface quasi-geostrophic (SQG) equation which is given by

$$\theta_t + u \cdot \nabla\theta + \Lambda^{2\alpha}\theta = 0, \tag{1}$$

where $\Lambda = (-\Delta)^{1/2}$. The first moment decay $\| |x|\theta\|_{L^2}$ was obtained by M. and T. Schonbek in their paper "Moments and lower bounds in the far-field of solutions to quasi-geostrophic flows". Here we obtain the decay rates of $\||x|^b\theta\|_{L^2}$ for any $b \in (0,1)$ and the rate of increase of this quantity for $b \in [1, 1+\alpha)$ under natural assumptions on the initial data. (Received February 24, 2015)

1110-35-378 **Anna L Mazzucato*** (alm24@psu.edu). *On helically-symmetric incompressible flows.*

We present a symmetry-reduced form of the Navier-Stokes and Euler equations under helical symmetry, and study certain distinguished geometric limits, under which the flows become close to planar flows. This is joint work with Milton Lopes, Dongjuan Niu, Helena Nussenzveig Lopes, and Edriss Titi (Received February 24, 2015)

1110-35-384 **Weiwei Hu*** (weiweihu@usc.edu), 3620 S. Vermont Ave., KAP 244B, Los Angeles, CA 90089-2532, and **Igor Kukavica** and **Mohammed Ziane**. *Stabilization of the Boussinesq Equations with Zero Diffusivity.*

In this talk, we address the stabilization problem of the 2D Boussinesq equations with zero diffusivity on a open bounded domain. The goal is to stabilize the steady-state $(0, ky)$, for $k > 0$, by employing the internal feedback control for velocity. The control only acts on a finite number of open subsets of the domain. (Received February 24, 2015)

1110-35-392 **Mihaela Ignatova**, **Igor Kukavica*** (kukavica@usc.edu), **Irena Lasiecka** and **Amjad Tuffaha**. *On the well-posedness of a fluid-structure interaction system.*

We consider a fluid-structure system which consists of the incompressible Navier-Stokes equations and a damped linear wave equation defined on two dynamic domains. We will review the local and global well-posedness results. (Received February 24, 2015)

1110-35-397 **Suncica Canic***, 4800 Calhoun Rd., Houston, TX 77204, and **Boris Muha** and **Martina Bukac**. *Existence of a weak solution to a fluid-composite structure interaction problem.*

Composite materials appear in virtually all areas of engineering and in nature. No mathematical results exist so far that analyze solutions to fluid-structure interaction problems with composite structures. In this talk we make a first step in this direction. We present an existence result for a weak solution to a fluid-structure interaction problem between an incompressible, viscous fluid flowing in a cylinder with elastic walls composed of two layers: a thin layer modeled by the linearly elastic membrane shell, and the thick layer modeled by the equations of linear elasticity. This set up was motivated by blood flow in human arteries whose walls are composed of several different layers. The coupling between the three different models is accomplished at a deformed fluid-structure and structure-structure interface, via two sets of coupling conditions: continuity of velocity (no-slip) and balance of contact forces. The resulting mathematical model is a time-dependent, nonlinear moving-boundary problem of hyperbolic-parabolic type. Our theoretical and numerical results reveal a new physical regularizing mechanism for this class of problems: the inertia of the fluid-structure interface with mass regularizes the evolution of the entire solution. (Received February 24, 2015)

1110-35-398 **Steve Shkoller*** (shkoller@math.ucdavis.edu), Department of Mathematics, University of California at Davis, Davis, CA 95616. *Finite-time splash singularity for the Navier-Stokes equations.*

We prove that there exist solutions to the free-boundary Navier-Stokes equations which propagate a locally smooth fluid interface, which self-intersects in finite time. This is joint work with D. Coutand. (Received February 24, 2015)

1110-35-400 **Hanli Tang*** (hltang@bnu.edu.cn), Beijing, Beijing 100875, Peoples Rep of China. *Moser-Trudinger inequalities in Lorentz-Sobolev spaces and hyperbolic spaces and Adams inequalities with exact growth condition.*

In this talk, we will report some works on both critical singular and subcritical singular and non-singular Moser-Trudinger inequalities in unbounded domains with Lorentz-Sobolev norms. We will also describe sharp Moser-Trudinger on hyperbolic spaces of any dimension with exact growth condition. Finally, we will present sharp

Adams inequalities of second order with exact growth condition in all dimensions greater than two. (Received February 24, 2015)

1110-35-407 **Pooriya Beyhaghi** (pbeyhagh@ucsd.edu<mailto:pbeyhagh@ucsd.edu>), **Huan Yu** (huy015@emg.ucsd.edu) and **Thomas Bewley*** (bewley@ucsd.edu). *Contractive control design for three coupled Burgers equations, and its implications for Navier-Stokes systems.*

One approach to the linear stabilization of near-wall transitional= flow (i.e., of slightly-perturbed laminar flow) is via consideration of th= e Orr-Sommerfeld/Squire equations. This formulation is delicate, as it redu= ces the three momentum equations and the divergence-free constraint of the = incompressible NSE down to a highly non-normal set of two equations, one fo= r the wall-normal velocity and one for the wall-normal vorticity, and invol= ves inverting a Laplacian with boundary conditions embedded. A simpler formulation for the purpose of control design may be found by sim= ply dropping the divergence-free constraint from the problem considered alt= ogether, and at the same time dropping the pressure gradient from the momen= tum equations, which acts to enforce this constraint. What remains is three= coupled Burgers equations. The present talk will describe under what conditions a controller designed = in this simpler, unconstrained, higher- dimensional setting is also guarant= eed to work when the divergence-free constraint is reintroduced to the prob= lem formulation; namely, the trajectories of the controlled unconstrained s= ystem must be contractive. We then demonstrate this control design approach= with a few illustrative examples. (Received March 03, 2015)

37 ► Dynamical systems and ergodic theory

1110-37-142 **Erik M Bollt*** (bolltem@clarkson.edu), Clarkson University, Mathematics, Potsdam, NY 13699, and **Ranil Basnayake**, Clarkson University, Mathematics, Potsdam, NY 13699. *Data Mining Remotely Sensed Image Sequences and Transport Analysis of Spatiotemporal Dynamical Systems.*

Scientific fields, such as climatology, and oceanography produce large data sets from spatiotemporal video data as remotely sensed hyperspectral satellite data. Variational methods for image processing suited to complex dynamical systems typical of fluid dynamics, and the tools of dynamical systems such as transfer operators have not been brought to bear on data inferred directly from movies. We discuss modeling and transport analysis for remotely sensed oceanographic systems. We also include discussion of systematic sensor error corrections. (Received February 17, 2015)

41 ► Approximations and expansions

1110-41-10 **George A Anastassiou*** (ganastss@memphis.edu), George Anastassiou, Dept. of Mathematical Sciences, U. Memphis, Memphis, TN 38152. *Approximation and Interpolation by Neural Network Operators.*

Here we introduce some general interpolating neural network operators in the univariate and multivariate cases. Initially we establish the interpolation property of the operators on functions. Then we derive the approximation properties of these operators on functions. We prove first the ordinary real quantitative pointwise and uniform convergences of these operators to the unit. Smoothness of functions is taken into consideration and speed of convergence improves dramatically. As extensions we consider also the fractional, fuzzy, fuzzy-fractional, fuzzy-random, complex and iterated cases. Furthermore we give Voronovskaya type asymptotic-expansions at all studied settings for the errors of related approximations. (Received November 20, 2014)

1110-41-383 **Eric A Machorro*** (machorea@nv.doe.gov), P.O. Box 98521, North Las Vegas, NV 89193-8521, **Aaron Luttman**, M/S NLV 070, North Las Vegas, NV 89193-8521, and **Jerry Blair** (machorea@nv.doe.gov), P.O. Box 98521, M/S NLV 070, North Las Vegas, NV 89193-8521. *Peano Kernel Theorem for Distributions : A Generalized Peano Kernel Theorem for Distributions of Exponential Decay.*

The Peano Kernel Theorem (PKT) is a classical representation theorem in numerical quadrature. The idea is that if T is a quadrature rule that exactly integrates polynomials of degree $n-1$ on a bounded interval $[a,b]$, then there exists a kernel K, depending only on T, such that

$$E(f) = T(f) - \int_a^b f(t)\,dt = \int_a^b K(t) f^{(n)}(t)\,dt,$$

whenever $f \in C^n([a,b])$. In this work, we generalize the PKT from the class of linear functionals on $C^n([a,b])$ to the class of Laplace transformable tempered distributions of exponential decay. In particular, it is not necessary that the functionals being approximated have compact support. The generalized result is proven using an approach that provides a formula for computing K in the Fourier domain, which can be more computationally tractable and efficient in many cases. We conclude with examples of how the generalized Peano Kernel Theorem can be used for error analysis in signal processing.
(Received February 24, 2015)

42 ► Fourier analysis

1110-42-197 **William Beckner*** (beckner@math.utexas.edu), Department of Mathematics, University of Texas at Austin, Austin, TX 78712. *Kunze-Stein Phenomena and Riesz Potentials.*

Sharp forms of Kunze-Stein phenomena on SL(2,R) are obtained by using symmetrization and Stein-Weiss potentials. Our methods extend to include the Lorentz groups and n-dimensional hyperbolic space through application of the Riesz-Sobolev rearrangement inequality. (Received February 20, 2015)

1110-42-375 **Huan Chen*** (fd7628@wayne.edu), Detroit, MI 48202. *Moser-Trudinger inequalities for certain subelliptic operators.* Preliminary report.

This is a preliminary talk on some recent work on Moser-Trudinger inequalities on the Heisenberg group. (Received February 24, 2015)

44 ► Integral transforms, operational calculus

1110-44-67 **Gaik Ambartsoumian*** (gambarts@uta.edu), Department of Mathematics, University of Texas at Arlington, P.O. Box 19408, Arlington, TX 76019-0408. *Broken-ray and conical Radon transforms in imaging.*

Broken-ray and conical Radon transforms appear in mathematical models of various novel imaging modalities, including single scattering optical tomography and some imaging techniques based on Compton scattering effect. The talk will discuss the known results and recent developments in the study of these integrals transforms, their applications and the open problems. (Received February 09, 2015)

45 ► Integral equations

1110-45-252 **Daniel Toader Onofrei*** (onofrei@math.uh.edu), 5227 Fountainbrook Ln, Sufar Land, TX 77479. *Active manipulation of fields.*

In this talk we will present our new results regarding the near field active manipulation for acoustic and electromagnetic fields. In the first part of the talk we will discuss our results in the setting of the scalar Helmholtz equation. In this context, through a detailed sensitivity study, a qualitative comparison between existent far field schemes and the proposed near field scheme will be offered which will prove the feasibility of the latter approach. Then, in the second part of the talk we will present our theoretical approach for the active manipulation of electromagnetic fields in homogeneous isotropic linear media. Numerical results will be shown in the context of tuning normal modes in a cylindrical open waveguide. (Received February 22, 2015)

46 ► Functional analysis

1110-46-47 **Sergio Solimini** and **Cyril Tintarev*** (tintarev@math.uu.se). *Functional-analytic theory of concentration compactness.* Preliminary report.

Concentration-compactness method allows a functional-analytic formulation in terms of a profile decomposition. Given a group D of linear isometries on a Banach space E, profile decomposition of a sequence in E is its representation as a sum of (1) asymptotically decoupled elementary concentrations and (2) of a D-weakly vanishing remainder. The notions involved are defined as follows. (1) An elementary concentration is a sequence of the form $g_k w$, $g_k \in D$. Two elementary concentrations $g_k v$ and $g_k w$ are called asymptotically decoupled if $g_k^{-1} h_k$ converges weakly to zero. (2) A sequence $(v_k) \subset E$ is called D-weakly vanishing if for any sequence $(g_k) \subset D$, $g_k v_k$ converges weakly to zero.

A non-compact imbedding of E into a topological vector space Y is called cocompact (relative to D) if every D-weakly vanishing sequence in E vanishes in the topology of Y. Imbeddings of homogeneous Besov and Triebel-Lizorkin (including Sobolev) spaces into L^p are cocompact relative to translations to dilations.

We state a general result for existence of profile decomposition in Banach spaces which extends previously known results for Hilbert spaces and spaces of Sobolev type. (Received February 02, 2015)

1110-46-304 **Federica Sani*** (federica.sani@unimi.it), via Cesare Saldini 50, 20133 Milano, Italy, and **Daniele Cassani** and **Cristina Tarsi**. *On Trudinger-Moser type inequalities in the whole space.*

The Trudinger-Moser inequality is a substitute for the well known Sobolev embedding theorem when the limiting case is considered. We discuss equivalent Moser type inequalities in the whole space which involve complete and reduced Sobolev norm. Then we introduce an optimal Lorentz-Zygmund type inequality from which can be derived classical inequalities in $H^1(\mathbb{R}^2)$. (Received February 23, 2015)

47 ► Operator theory

1110-47-15 **Ayse Guven*** (a.guven@qmul.ac.uk), London, E1 4NS, United Kingdom. *Explicit upper bounds for the spectral distance of two trace class operators.*

Given two trace class operators A and B on a separable Hilbert space we provide an upper bound for the Hausdorff distance of their spectra involving only the distance of A and B in operator norm and the singular values of A and B. By specifying particular asymptotics of the singular values our bound reproduces or improves existing bounds for the spectral distance. The proof is based on lower and upper bounds for determinants of trace class operators of independent interest. (Received December 03, 2014)

1110-47-238 **Waleed K. Al-Rawashdeh*** (walrawashdeh@mtech.edu), Montana Tech, Department of Mathematical Sciences, 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 February 22, 2015)

49 ► Calculus of variations and optimal control; optimization

1110-49-122 **Aaron Benjamin Luttman***, P.O. Box 98521, Las Vegas, NV 89193-8521. *A Tomographic Approach to Fusion Neutron Spectroscopy with Uncertainty Quantification.*

Two of the most important properties for characterizing controlled nuclear fusion reactors are the time profile and energy spectrum of the fusion neutrons. It is possible to model the signals from neutron detectors at different distances from the fusion source as tomographic projections of the time-energy spectrum, and, in this work, we present a model for neutron creation as a function of time and energy, its Radon transform as a model for the detector signals, and a Markov Chain Monte Carlo method for estimating the model parameters through Radon inversion of the detector signals. The formulation is demonstrated on real data from a U.S. Department of Energy Dense Plasma Focus fusion reactor.

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1110-49-338 **Michinori Ishiwata*** (ishiwata@sigmath.es.osaka-u.ac.jp), 1-3, Machikaneyama, Toyonaka, Osaka, 560-8531, Japan. *On the existence and nonexistence of maximizers for variational problems associated with Sobolev type embeddings in $\mathbb{R}^N$.*

In this talk, we consider the attainability of a maximizing problem

$$D := \sup_{\|u\|_{H^{1,N}_\gamma}=1} \left(\|u\|_N^N + \alpha \|u\|_p^p \right),$$

where $N \geq 2$, $N < p < \infty$, $\alpha > 0$, $\gamma > 0$ and $\|u\|_{H^{1,N}_\gamma} = \left(\|u\|_N^\gamma + \|\nabla u\|_N^\gamma \right)^{\frac{1}{\gamma}}$. The existence of a maximizer for D is closely related to the exponent γ. In fact, we show that the value

$$\alpha = \alpha_* := \inf_{\|u\|_{H^{1,N}_\gamma}=1} \left(\frac{1 - \|u\|_N^N}{\|u\|_p^p} \right)$$

is a threshold in terms of the attainability of D.

This is a joint work with H. Wadade, Kanazawa university. (Received February 24, 2015)

51 ► Geometry

1110-51-175 **Tom Mark** (bt5t@virginia.edu), 141 Cabell Drive Kerchof Hall, Charlottesville, VA 22904, and **Bulent Tosun*** (bt5t@virginia.edu), 141 Cabell Drive Kerchof Hall, Charlottesville, VA 22904. *Tightness of positive rational contact surgeries.*

We want to understand existence of a tight contact structure on a closed three manifold that is obtained by a smooth rational surgery along a knot in the three-sphere. Our main tool is a generalization of a theorem of Baldwin on the effect on the Ozsvath-Szabo contact invariant of capping off of binding components of open book decompositions. We will describe this result and outline the applications to positive rational contact surgeries. (Received February 19, 2015)

1110-51-235 **F. R. Cohen** and **R. Komendarczyk*** (rako@tulane.edu), Tulane University, 6823 St. Charles Ave, New Orleans, LA 70118, and **R. Koytcheff** and **C. Shonkwiler**. *The κ-invariant separates homotopy string links.* Preliminary report.

The κ-invariant is an induced map on the π_0 of the space of n–component link maps to the π_0 of the space of maps from the n–torus to n–configurations in $\mathbb{R}^3$. It is conjectured that the κ-invariant is strong enough to separate homotopy links, i.e. it is a complete invariant of homotopy links. In this talk, I will discuss an analog of the κ-invariant in the setting of homotopy string links and show that the invariant is a complete invariant in this setting. This is a joint work with F. R. Cohen, R. Koytcheff and C. Shonkwiler. (Received February 22, 2015)

1110-51-264 **Garrett D Alston*** (galston@math.ou.edu). *Legendrian DGA as Immersed Floer Theory.* Preliminary report.

I will explain the relationship between the Legendrian dga of a Legendrian in PxR and the Floer theory of the corresponding Lagrangian in P. Here P is an exact symplectic manifold and R is the real line. (Received February 23, 2015)

1110-51-385 **M K Dabkowski*** (mdab@utdallas.edu), Richardson, TX 75080. *Twisted Equivariant $\Gamma \times \mathbb{T}^n$-Degree with n-Parameters: Computational Formulae.* Preliminary report.

We introduce a new notion of the generalized twisted $\Gamma \times \mathbb{T}^n$-equivariant degree with n free parameters, present algorithmic computational formulae based on the reduction techniques to $\mathbb{T}^n$-equivariant maps and by applying reduction of parameters techniques. (Received February 24, 2015)

1110-51-388 **Alexander Coward*** (alexander.coward@gmail.com), University of California, Berkeley, CA 94720, and **Alvin Jin** and **Moor Xu**. *Topological unknots can be physically unknotted with a polynomial amount of stretching.*

A major open problem in physical knot theory is whether there exists a Gordian unknot - that is a physical knot that is topologically unknotted but that cannot be physically unknotted keeping its width and length fixed. In this talk we will outline a proof that all topologically unknotted physical knots may be unknotted via a physical isotopy that preserves width and only allows the length to grow to a polynomial function of the starting length. (Received February 24, 2015)

1110-51-389 **W Z Krawcewicz*** (wieslaw@utdallas.edu), Richardson, TX 75080. *Advances in Recent Development of the Equivariant Degree Theory: Theoretical, Computational and Applied Aspects.* Preliminary report.

Different versions of the equivariant degree were constructed to study symmetric variational problems, existence and multiplicity results in symmetric differential equations, bifurcation and Hopf bifurcation problems in equivariant dynamical systems etc. The developed methods, based on the most recent advances in the equivariant degree theory allow computerization of the symbolic computations, even for large symmetry groups, and consequently effective applications of these methods in applied models. Although these methods are still peaceful, there is a clear potential for applications in drone technology and robotics. (Received February 24, 2015)

1110-51-390 **Yanli Lv*** (yxl103720@utdallas.edu), Richardson, TX 75080. *Multiple Periodic Solutions for Symmetric Second Order Newtonian Systems with Even Potentials: Equivariant Degree Approach.* Preliminary report.

We present the equivariant gradient degree techniques developed to study the existence of multiple p-periodic solutions to the Γ-equivariant Newtonian system of the type

$$\ddot{x} = -\nabla f(x), \tag{1}$$

where $f : \mathbb{R}^n \to \mathbb{R}$ is a C^2 Γ-invariant function. The system (1) leads to finding critical points of the variational functional $J : \mathbb{H} \to \mathbb{R}$, where $\mathbb{H} := H^1(S^1_p; V)$, $V := \mathbb{R}^n$ and $S^1_p := \mathbb{R}/(p/2\pi)\mathbb{Z}$, is given by

$$J(x) := \int_0^p \left(\frac{1}{2}|\dot{x}(t)|^2 - f(x(t))\right) dt, \tag{2}$$

The functional (2) is $\Gamma \times O(2)$-equivariant, it is possible to apply the gradient $\Gamma \times O(2)$-equivariant theory to investigate the multiple p-periodic solutions with with various symmetric properties. Our work provides theoretical advances for the application of such gradient equivariant degree, computational algorithms and their implementations, in order to compute the compete equivariant invariant for the functional (2), which contains full topological classification of the p-periodic solution set. (Received February 24, 2015)

53 ► Differential geometry

1110-53-61 **Joel Hass*** (hass@math.ucdavis.edu), Department of Mathematics, 1 Shields Ave., Davis, CA 95616. *Optimal diffeomorphisms of surfaces and some applications.*

The problem of comparing the shape of two surfaces arises in many areas, including facial recognition, brain cortex analysis and computer vision. It is referred to by names such as surface registration, surface warping, best fit, shape analysis and optimal diffeomorphism. We will review some past work in this area and discuss two approaches to constructing an optimal map between a pair of surfaces. The goal is to find a good alignment of two surfaces, if they are nearly isometric, and to indicate their geometric distance if not. The first approach is based on finding an optimal conformal map between two genus-zero surfaces. A second approach is based on constructing hyperbolic orbifold metrics on surfaces and finding an energy minimizing map between them. We will then examine what these alignments reveal about the geometric similarity of shapes such as polyhedra, spheres and ellipsoids, and between shapes arising in biology, such as brain cortices, the surfaces of proteins and bones. (Received February 06, 2015)

1110-53-74 **Bahar Acu*** (bacu@usc.edu), Department of Mathematics, University of Southern California, Los Angeles, CA 90089, and **Russell Avdek**, CA. *Symplectic Mapping Class Group Relations Generalizing the Chain Relation.*

In this paper, we examine mapping class group relations of some symplectic manifolds. For each $n \geq 1$ and $k \geq 1$, we show that the $2n$-dimensional Weinstein domain $W = \{f = \delta\} \cap B^{2n+2}$, determined by the degree k homogeneous polynomial $f \in \mathbb{C}[z_0, \ldots, z_n]$, has a Boothby-Wang type boundary and a right-handed fibered Dehn twist along the boundary that is symplectically isotopic to a product of right-handed Dehn twists along Lagrangian spheres. We also present explicit descriptions of the symplectomorphisms in the case $n = 2$ recovering the classical chain relation for the torus with two boundary components. (Received February 09, 2015)

1110-53-90 **Erkao Bao*** (baoerkao@gmail.com) and **Ko Honda** (honda@math.ucla.edu). *Definition of Cylindrical Contact Homology in Dimension 3.*

In this talk I will give a rigorous definition of cylindrical contact homology for contact 3-manifolds that admit nondegenerate contact forms with no contractible Reeb orbits. By "defining contact homology" we mean the following: To a contact 3-manifold (M, ξ) we assign an isomorphism class $\{HC(\mathcal{D})\}_{\mathcal{D}}$ of groups, where each group $HC(\mathcal{D})$ is defined using some auxiliary data $\mathcal{D}$ and any two groups $HC(\mathcal{D}^1)$ and $HC(\mathcal{D}^2)$ for the same (M,ξ) are naturally isomorphic. It is based on a joint work with Ko Honda. (Received February 11, 2015)

1110-53-119 **James I Conway*** (conway@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30332.
Tight Surgeries on Knots in Overtwisted Contact Manifolds.

Most work on surgeries in contact manifolds has focused upon determining the situations where tightness is preserved. We will discuss an approach to this problem from the reverse angle: when negative surgery on a fibred knot in an overtwisted contact 3-manifold produces a tight one. We will examine the various phenomena that occur, and discuss an approach to characterising them via Heegaard Floer homology. (Received February 16, 2015)

1110-53-157 **Caitlin Leverson*** (cleverso@math.duke.edu). *Legendrian Knots, Augmentations, and Rulings.*

A Legendrian knot in $\mathbb{R}^3$ with the standard contact structure is a knot for which $dz - ydx = 0$. Given a Legendrian knot, one can associate the Chekanov- Eliashberg differential graded algebra (DGA) over $\mathbb{Z}/2$. Fuchs and Sabloff showed there is a correspondence between augmentations to $\mathbb{Z}/2$ of the DGA and rulings of the knot diagram. Etnyre, Ng, and Sabloff showed that one can define a lift of the Chekanov-Eliashberg DGA over $\mathbb{Z}/2$ to a DGA over $\mathbb{Z}[t,t^{-1}]$. This talk will give an extension of the relationship between rulings and augmentations to $\mathbb{Z}/2$ for the DGA over $\mathbb{Z}/2$, to a relationship between rulings and augmentations to a field of the DGA over $\mathbb{Z}[t,t^{-1}]$. No knowledge of the Chekanov-Eliashberg DGA will be assumed. (Received February 18, 2015)

1110-53-386 **Handan Yildirim*** (handanyildirim@istanbul.edu.tr), Istanbul University Mathematics Department, (Current address: Michigan State University), Wells Hall 619 Red Cedar Road, East Lansing, MI 48824-1027. *A note on conformally flat almost contact metric manifolds.* Preliminary report.

It is known that there is a $*$-Ricci tensor in almost contact metric geometry. In this regard, we have notions of (weakly) $*$-Einstein and $*$-η-Einstein for almost contact metric manifolds.

In this talk which is based on a joint work with David E. Blair, we focus on conformally flat almost contact metric manifolds which are (weakly) $*$-Einstein and $*$-η-Einstein.

(The speaker expresses her appreciation to TUBITAK-BAYG for their financial support during her researches at Mathematics Department of Michigan State University.) (Received February 24, 2015)

1110-53-401 **P. P. Yu***, University of Maine at Presque Isle, Presque Isle, ME 04769. *On the equivalence of a pair of differential two-forms.* Preliminary report.

Cartan's method of equivalence is used to study the equivalence of a pair of differential two-forms, one of which is non-integrable and may have rank deficiency, on a four-dimension manifold. Invariants and the symmetry (pseudo)group are found for each of the algebraically distinct cases. As the pair of two-forms satisfying Maxwell's equations may be used to describe the electromagnetic field in linear material medium, this investigation is expected to shed light on the realizability of general-relativistic optical transformations in four-dimensional space-times from a theoretical perspective. (Received February 24, 2015)

54 ► General topology

1110-54-54 **Heather A Dye** and **Aaron Kaestner*** (akaestne@gmail.com), North Park University, 3225 W Foster Ave, Campus Box 57, Chicago, IL 60625, and **Louis H Kauffman**. *A Rasmussen Invariant for Virtual Knot Cobordisms.*

We derived a generalization of the Rasmussen invariant for virtual knot cobordisms and furthermore generalize Rasmussen's result on the slice genus for positive knots to the case of positive virtual knots. This generalization of the Rasmussen invariant provides an obstruction to knot cobordisms in $S_g \times I \times I$ in the sense of Turaev. (Received February 05, 2015)

1110-54-287 **Marithania Silvero*** (marithania@us.es). *Conway polynomial of strongly quasipositive links.*

Strongly quasipositive links were introduced by Lee Rudolph in 1990 as the boundaries of what he called quasi-positive surfaces. Quasipositive surfaces are basically orientable surfaces consisting in a finite number of parallel discs joined by some bands twisted in a positive way. There are not many invariants which help to determine whether a link is strongly quasipositive or not.

We give a necessary condition on the coefficients of the Conway polynomial of links with braid index 3 to be strongly quasipositive. We also show that, however, this condition cannot be generalized to every strongly quasipositive link. (Received February 23, 2015)

1110-54-333 **Liljana Babinkostova*** (liljanababinkostova@boisestate.edu), Department of Mathematics, Boise State University, 1910 University Drive, Boise, ID 83725, and **Marion Scheepers** (mscheepe@boisestate.edu), Department of Mathematics, Boise State University, 1910 University Drive, Boise, ID 83725. *The selective strong screenability game.*
Selective screenability, introduced in a 1978 paper, and selective strong screenability, coincide in a wide class of topological spaces. The two corresponding games, however, are vastly different from each other. In this talk we describe results that illustrate this remark, and indicate that a deeper investigation of the selective strong screenability game is necessary. (Received February 24, 2015)

1110-54-405 **Alexander Shumakovitch*** (shurik@gwu.edu), Department of Mathematics, The George Washington University, 2115 G St. NW, Monroe Hall, room 240, Washington, DC 20052, and **Robert Ullman**. *On Khovanov Homology for Knots of Slalom Divides.*
Presentation of recurrent patterns for Khovanov homology of knots = associated with families of divides obtained by performing slalom on planar= rooted trees. (Received March 01, 2015)

55 ► Algebraic topology

1110-55-49 **Yongju Bae*** (ybae@knu.ac.kr), Department of Mathematics, College of Natural Sciences, Kyungpook National University, Daegu, 702-701, South Korea. *On properties of partition functions for Alexander quandles.*
For a given quandle cocycle, to calculate the partition function of a knot K, we need to find all possible quandle colorings of a diagram D of K. In that context, finite quandles are the only concerned to treat the partition function. In this talk, I will consider a method to treat the partition function for the Alexander quandle $\Lambda/(\Delta_L(t))$ even though $\Lambda/(\Delta_L(t))$ is infinite. Here $\Delta_L(t)$ denotes the reduced Alexander polynomial of L. (Received February 04, 2015)

1110-55-379 **Changsong Li*** (changsong.li@utdallas.edu), 17708 Dickerson St. Apt 312, Dallas, TX 75252. *Temperley-Lieb Algebra Approach to Catalan States of Generalized Crossing.* Preliminary report.
Using combinatorial approach, we show which elements of a basis (in the reduced form) of Temperley-Lieb algebra can be obtained as Kauffman states of lattice crossing and generalized crossing. In addition, we give an algorithm for finding them and we obtain further results concerning coefficients of the Catalan states that can be obtained as Kauffman states of $m \times 2$ lattice crossing. Finally, we discuss some further application of our method. (Received February 24, 2015)

57 ► Manifolds and cell complexes

1110-57-29 **Charles Frohman*** (charles-frohman@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242. *The Localized Skein Algebra of a Closed Surface is Frobenius.*
If $K_N(F)$ is the Kauffman bracket skein algebra of a closed surface F where the N denotes the fact that $A = e^{\pi \mathbf{i}/N}$,N an odd counting number, then it is a ring extension of the coordinate ring of the $SL_2\mathbb{C}$-character variety of the fundamental group of F. Extending work of Abdiel and Frohman, we localize $K_N(F)$ by inverting the nonzero characters to get an algebra over the function field of the character variety of F. We prove this algebra is Frobenius. The technique of proof is to lift the problem to a punctured surface, and show that the results there imply the result for a closed surface. The proof requires defining a refinement of the trace appearing in Abdiel-Frohman, arXiv:1501.02631 . (Received January 14, 2015)

1110-57-31 **Heather Ann Dye*** (heatheranndye@gmail.com), McKendree University, 701 College Road, Lebanon, IL 62254. *A bracket polynomial for pseudoknots.*
In this talk, I construct a bracket polynomial for pseudoknots and discuss some applications. (Received January 16, 2015)

1110-57-58 **Ko Honda*** (honda@math.ucla.edu). *An invitation to Floer homology.*

This is a gentle introduction to Floer homology. "Floer homology" is a generic term for various homology theories of knots, 3- and 4-dimensional manifolds (aka spaces), symplectic manifolds, contact manifolds, etc., and has had an enormous impact in geometry/topology since its introduction by Floer more than twenty years ago. In this talk we start with a baby version of this theory called Morse homology, which gives a way to distinguish topological spaces (e.g., a sphere from the surface of a donut). We then build our way up to more recent theories such as contact homology and embedded contact homology. (Received February 06, 2015)

1110-57-63 **John Etnyre*** (etnyre@math.gatech.edu). *Embeddings of contact 3-manifolds.* Preliminary report.

In this talk I will discuss some preliminary results and observations about embedding contact 3-manifolds in Euclidean 5-space with the standard contact structure, in addition to other contact 5-manifolds. These results come from discussions with Yanki Lekili and Ryo Furukawa and will joint results between various combinations of them and myself. (Received February 07, 2015)

1110-57-81 **Erica Flapan*** (eflapan@pomona.edu), Department of Mathematics, Pomona College, 640 N. College Ave., Claremont, CA 91711, and **Hugh Howards** (howards@wfu.edu), Department of Mathematics, Wake Forest University, 127 Manchester Hall, Winston-Salem, NC 27109. *Intrinsic chirality of graphs in 3-manifolds.* Preliminary report.

We say that an embedding Γ of a graph γ in a 3-manifold M is *achiral* if there is an orientation reversing homeomorphism of (M,Γ). If a graph γ has no such embedding in M we say γ is *intrinsically chiral* in M.

We prove that for any closed, connected, orientable, irreducible 3-manifold M, there is an integer n_M such that every 3-connected graph γ with genus$(\gamma) > n_M$ and no involution is intrinsically chiral in M. On the other hand, we prove that every graph has achiral embeddings in infinitely many closed, connected, orientable, irreducible 3-manifolds. (Received February 10, 2015)

1110-57-88 **Francis Bonahon*** (fbonahon@math.usc.edu), Department of Mathematics, University of Southern California, Los Angeles, CA 90089-2532, and **Qingtao Chen** (chenqtao@gmail.com), International Centre for Theoretical Physics, Strada Costiera, 11, 34151 Trieste, Italy. *The quantum trace homomorphism between the Kauffman skein algebra and the quantum Teichmüller space.* Preliminary report.

The quantum trace homomorphism relates two different quantizations of the character variety consisting of all homomorphisms from the fundamental group of a surface S to $\mathrm{SL}_2(\mathbb{C})$. One is the Kauffman skein algebra considered by Turaev, Bullock-Frohman-Kania-Bartoszyńska and Przytycki-Sikora. The other is the quantum Teichmüller space introduced by Chekhov-Fock and Kashaev. The original construction of the quantum trace homomorphism, by Helen Wong and the first author, was based on trial and error to guess the appropriate formulas, followed by brute force computations to check invariance under many choices. We present a more conceptual definition of the quantum trace homomorphism, which is more deeply grounded in the fundamental representation of the quantum group $\mathrm{U}_q(\mathfrak{sl}_2)$. (Received February 10, 2015)

1110-57-97 **Seiich Kamada** (skamada@sci.osaka-cu.ac.jp), Department of Mathematics, Osaka City Univerisity, Osaka, 558-8585, Japan, **Jieon Kim** (jieonkim@pusan.ac.kr), Department of Mathematics, Pusan National University, Busan, 609-735, South Korea, and **Sang Youl Lee*** (sangyoul@pusan.ac.kr), Department of Mathematics, Pusan National University, Busan, 609-735, South Korea. *Quandle cocycle invariants of surface-links via marked graph diagrams.*

By using the cohomology theory of quandles, quandle cocycle invariants and shadow quandle cocycle invariants are defined for oriented links and surface-links via broken surface diagrams. By using symmetric quandles, symmetric quandle cocycle invariants are also defined for unoriented links and surface-links via broken surface diagrams. A marked graph diagram is a link diagram possibly with 4-valent vertices equipped with markers. S. J. Lomonaco, Jr. and K. Yoshikawa introduced a method of describing surface-links by using marked graph diagrams. In this talk, we would like to present interpretations of these quandle cocycle invariants in terms of marked graph diagrams, and introduce a method of computing them from marked graph diagrams. (Received February 13, 2015)

1110-57-98 **Louis H Kauffman*** (kauffman@uic.edu), Math UIC, 851 South Morgan Street, Chicago, IL 60607-7045. *Khovanov Homology and Virtual Knot Theory.* Preliminary report.

This talk will discuss some applications of Khovanov Homology to virtual knot theory. In particular we will discuss joint work with Heather Dye and Aaron Kaestner where we generalize the Rasmussen Invariant to virtual knots and apply it to positive virtual knots. We also discuss a proof that virtual knots of unit Jones polynomial, obtained from classical non-trivial knots by virtualization are both non-trivial and non-classical. A remaining problem is to determine virtual genus of such knots. (Received February 13, 2015)

1110-57-100 **Louis H Kauffman*** (kauffman@uic.edu), Math UIC, 851 South Morgan Street, Chicago, IL 60607-7045. *Majorana Particles.* Preliminary report.

This talk will discuss how, mathematically, a standard Fermion can be regarded as a combination of two Majorana particles. Majorana particles have operator algebras that are Clifford algebras with one element of square 1 associated to each particle, and distinct particles anti-commuting. We will concentrate on the relationship of this structure with the Dirac equation and will discuss braiding representations associated with Majorana particles. (Received February 13, 2015)

1110-57-103 **Hugh N Howards*** (howards@wfu.edu), Department of Mathematics, Wake Forest University, Winston Salem, NC 27109, and **Andrew Kobin**. *The dual of a mosaic.* Preliminary report.

Lomonaco and Kauffman introduce a standard system of knot mosaics as a model of physical quantum states. The mosaic number of a knot is the smallest integer m such that the knot can be represented on an $m \times m$-mosaic. Although thin position does not translate directly into mosaics we develop a related concept called the dual of a mosaic and use it to bound mosaic number. (Received February 13, 2015)

1110-57-116 **Jennifer Schultens*** (jcs@math.ucdavis.edu), 2900 Ponteverde Ln, Davis, CA 95618. *The Kakimizu complex of a surface.* Preliminary report.

The Kakimizu complex, named after Osamu Kakimizu, is usually defined in the context of knots. Several recent results describe the geometric structure of this complex. In particular, Johnson, Pelayo and Wilson showed that the Kakimizu complex of a knot is quasi-Euclidean. Prior to this, Przytycki and the author extended the definition of the Kakimizu complex to the context of 3-manifolds and showed that, even in this broader context, the Kakimizu complex is contractible.

The definition of the Kakimizu complex can be adapted to the setting of 2-manifolds. The resulting complex is closely related to the homology curve complexes defined by Hatcher, Irmer, Hatcher-Margalit and Bestvina-Bux-Margalit. Their insights translate into a geometric picture of the Kakimizu complex of a 2-manifold. Most importantly, these insights can be promoted to the setting of the Kakimizu complex of 3-manifolds via product constructions. (Received February 15, 2015)

1110-57-124 **Seung Yeop Yang*** (syyang@gwu.edu) and **Jozef H. Przytycki**. *Annihilation of the torsion subgroup of rack homology of R_{2k} and some other finite quandles.*

It is a classical result in reduced homology of finite groups that the order of a group annihilates its homology. Niebrzydowski and Przytycki conjectured that for a finite quasigroup quandle the torsion of its rack homology is annihilated by the order of the quandle. Additionally, they conjectured that for nonconnected dihedral quandles R_{2k}, k annihilates the torsion subgroup of rack homology if k is odd. In this talk, we prove the both conjectures. The method can be taught as the analogue of presimplicial homotopy in precubic theory (See the talk by J. H. Przytycki). (Received February 16, 2015)

1110-57-125 **Jozef H. Przytycki*** (przytyck@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052, and **Seung Yeop Yang**. *Precubic homotopy: knot theory motivated "abstract nonsense".*

While working on annihilation of torsion of rack homology of finite quandles (see presentation by S.Y. Yang) we came upon an object similar to presimplicial homotopy but related to structures being precubic sets. We define precubic homotopy h between precubic morphisms f and g as a collection of morphisms h_i^{ϵ} such that: (1) $d_i^{\delta} h_j^{\varepsilon} = h_{j-1}^{\varepsilon} d_i^{\delta}$ for $i < j$, (2) $d_i^{\varepsilon} h_i^0 = d_{i+1}^{\varepsilon} h_i^1$, $d_i^0 h_i^1 = d_{i+1}^0 h_i^0$, $d_i^1 h_i^1 = d_i^1 h_{i-1}^0$, (3) $d_i^{\delta} h_j^{\varepsilon} = h_j^{\varepsilon} d_{i-1}^{\delta}$ for $i > j+1$, (4) $d_1^1 h_1^1 = f$ and $d_{n+1}^1 h_n^0 = g$ where $\varepsilon, \delta = 0, 1$. We show that if h is a precubic homotopy from f to g in the category of modules then $h = \sum_{i=1}^{n} (-1)^i (h_i^0 + h_i^1)$ is a chain homotopy from f to g. (Received February 16, 2015)

1110-57-129 **Colin Adams*** (cadams@williams.edu), Bronfman Science Center, Williams College, Williamstown, MA 01267. *Volumes of hyperbolic links.* Preliminary report.

Using a generalization of augmented alternating links, we find volumes of hyperbolic links in terms of simpler constituent links. We also discuss improvements to upper bounds for hyperbolic volume coming from link diagrams. (Received February 17, 2015)

1110-57-133 **Abhijit Champanerkar**, **Ilya Kofman** and **Jessica S Purcell*** (jpurcell@mathematics.byu.edu). *Geometrically maximal knots.*

We consider the ratio of volumes of hyperbolic knots to their crossing numbers. This ratio is known to have maximum value less than the volume of a regular ideal octahedron. This motivates several questions, such as, for which knots is the ratio very near the maximum? For fixed crossing number, what links maximize this ratio? We say that a sequence of hyperbolic knots is geometrically maximal if these ratios limit to the maximum value. In this talk, we describe several sequences of geometrically maximal knots, and present several conjectures. (Received February 17, 2015)

1110-57-135 **Adam Lowrance*** (adlowrance@vassar.edu) and **Radmila Sazdanovic**. *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 February 17, 2015)

1110-57-136 **Susan M Abernathy*** (susan.abernathy@angelo.edu) and **Patrick M Gilmer**. *Even and odd Kauffman bracket ideals for genus-1 tangles.* Preliminary report.

A genus-1 tangle is a 1-manifold with two boundary components properly embedded in the solid torus. We discuss genus-1 tangle embedding and define an even and odd version of the Kauffman bracket ideal for genus-1 tangles. Using skein theory techniques, we outline a method for computing a finite list of generators for these ideals. This includes adapting a basis of Habiro's for the even Kauffman bracket skein module of the solid torus to define bases for the even and odd skein modules of the solid torus relative to two points. We compute the even and odd ideals for some specific examples, including an example which is obstructed from embedding in the unknot by the even and odd Kauffman bracket ideals together but not by the ordinary Kauffman bracket ideal. (Received February 17, 2015)

1110-57-138 **Lenhard Ng**, **Dan Rutherford**, **Vivek Shende** and **Steven Sivek***, Fine Hall, Washington Road, Princeton, NJ 08544-1000, and **Eric Zaslow**. *Augmentations are sheaves.*

In this talk I will outline the proof that the augmentation category of a Legendrian knot in $\mathbb{R}^3$, which was introduced in Lenny Ng's talk, is equivalent to a category of constructible sheaves on $\mathbb{R}^2$ introduced by Shende–Treumann–Zaslow. The main idea is to localize these categories, by breaking a front projection into "bordered" vertical strips and associating versions of each category to these strips. When the pieces are particularly simple, consisting of a single interesting feature such as a crossing, then we will compute the local versions of each, compare them directly, and glue the pieces back together to yield the desired equivalence. This result establishes that augmentations of a Legendrian knot, which are defined algebraically, are nevertheless geometric objects even when they do not come directly from a Lagrangian filling. (Received February 17, 2015)

1110-57-139 **Lenhard Ng*** (ng@math.duke.edu), **Dan Rutherford**, **Vivek Shende**, **Steven Sivek** and **Eric Zaslow**. *The augmentation category of a Legendrian knot.*

I will introduce the augmentation category, an A_∞ category associated to a Legendrian knot or link in $\mathbb{R}^3$. The objects of this category are the augmentations of the contact homology differential graded algebra of the knot. The idea of constructing such a category was first carried out by Bourgeois and Chantraine, and our construction is very similar but different in some crucial aspects. I will discuss some properties of the augmentation category, including relations to Lagrangian fillings, but not including its equivalence to the Shende–Treumann–Zaslow category of constructible sheaves, which will be addressed in Steven Sivek's talk. (Received February 17, 2015)

1110-57-143 **Kenneth C. Millett*** (millett@math.ucsb.edu), Department of Mathematics, UCSB, Santa Barbara, CA 93106. *Leonardo's Knots.*

In much of Leonardo da Vinci's work, one finds curves that are twisted, entangled, and often knotted. Part history, part art, part geometry and part topology, this talk will explore some new facets of Leonardo's representation of form and structure with a focus on etchings achieved during his time in Milan in the late 15th centaury. In addition to an analysis of the characteristic knotting found in these, we will also analyze the character of the dihedral symmetry they exhibit. By considering the mathematical foundations of the forms visible in this body of work, one gains understanding of how and why these forms were constructed in this specific manner and can speculate on the meaning that is encoded within their forms. (Received February 17, 2015)

1110-57-148 **Mark C. Hughes*** (hughes@mathematics.byu.edu). *Braiding knot cobordisms.*
Alexander's theorem states that any oriented link can be represented as the closure of a braid, and allows us to study knots via the algebraic and geometric properties of closed braids. Various authors have defined similar notions of braiding for surfaces in 3 and 4-space, and have used them to answer numerous questions, from finding bounds on the Seifert and slice genera of a knot K, to characterizing which 3-manifolds arise as the boundaries of compact Stein surfaces. We extend these braidings to cobordisms between knots, and show that any oriented knot cobordism can be arranged in this form. We also discuss how these braided cobordisms can be used to provide information about their boundary knots. (Received February 17, 2015)

1110-57-152 **Ayaka Shimizu*** (shimizu@nat.gunma-ct.ac.jp), Gunma National College of Technology, 580 Toriba-cho, Maebashi-shi, Gunma 371-8530, Japan. *The warping matrix for knots.*
Let D be an oriented knot diagram on the 2-sphere, and let b be a base point of D. A *warping crossing point* of D with b is a crossing point of D such that we meet the crossing point as an under-crossing first when we travel D from b. The *warping degree* of D with b is the number of the warping crossing points of D with b. In this talk we define the *warping matrix* of D by using warping degrees. We show that we can recreate D from the warping matrix of D, and investigate the property of warping matrix. (Received February 18, 2015)

1110-57-167 **J. Elisenda Grigsby*** (grigsbyj@bc.edu), **Anthony M. Licata** and **Stephan M. Wehrli**. *(Sutured) Khovanov homology and representation theory.*
I will discuss some of the representation theory underlying sutured annular Khovanov homology, a variant of Khovanov homology particularly well-suited to studying braid closures. This is joint work with Tony Licata and Stephan Wehrli. (Received February 19, 2015)

1110-57-178 **Robin Wilson*** (robinwilson@csupomona.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 February 19, 2015)

1110-57-180 **Carmen Caprau***, Department of Mathematics, California State University, Fresno, 5245 N. Backer Ave. M/S PB 108, Fresno, CA 93740, and **Andrew De la Pena** and **Sarah McGahan**. *Virtual singular braids and links.* Preliminary report.
The set of virtual singular braids contains as a subset classical braids, singular braids, and virtual braids. The set of isotopy classes of n-stranded virtual singular braids forms a monoid that can be described via generators and relations. The closure of a virtual singular braid yields a virtual singular link diagram. This talk will be centered on Alexander- and Markov-type theorems for virtual singular links and braids. (Received February 19, 2015)

1110-57-182 **Carl Hammarsten*** (chammar@gwu.edu). *Decorated Heegaard diagrams and combinatorial Heegaard Floer homology.*
A 3-dimensional closed manifold Y represented by its branched spine has a canonical Heegaard decomposition. We present this decomposition graphically in the form of a strip diagram. We show that strip diagrams have nice properties which greatly simplify the calculation of Heegaard Floer homology. Motivated by this work, we introduce the idea of a decorated Heegaard diagram. That is, a Heegaard diagram together with a collection of embedded paths satisfying certain criteria. Using this decorated Heegaard diagram, we present a combinatorial definition of a chain complex which is homotopically equivalent to the Heegaard Floer one, yet significantly smaller. Finally, we consider the presentation of a branched spine by its O-graph and show how to reformulate our definition in these terms. (Received February 19, 2015)

1110-57-187 **Yoshiro Yaguchi*** (yaguchi-y@nat.gunma-ct.ac.jp), Gunma National College of Technology, 580 Toriba-cho, Maebashi-shi, Gunma 371-8530, Japan. *Hurwitz action on tuples of permutations.*
Hurwitz equivalence is an equivalent relationship in a direct product of a group (or a quandle), which is defined by using an natural action by a braid group on the direct product. In 1891, Hurwitz gave a system of representatives of Hurwitz equivalence on tuples of transpositions of a symmetric group. In this talk we will give a system of

representatives of Hurwitz equivalence on tuples of permutations of the symmetric group of degree 3. (Received February 20, 2015)

1110-57-189 **J. Scott Carter***, Department of Mathematics and Statistics, ILB 325, Mobile, AL 36688.
Braiding Forests, Products of Simplices, and Cocycles. Preliminary report.

This is based on joint work with Atsushi Ishii, Kokomo Tanaka, and Masahico Saito. We start by considering the dual structure to an $(n+1)$-dimensional simplex. This is called an n-dimensional foam. When an $(m+1)$-dimensional ball is decomposed into the product of simplices, such foams and their products are overlain in a structure that contains a unique 0-dimensional singularity. The structure is lifted into one higher dimension and an analogue of a codimension 2 knotting results. We show how to quantify crossing relations in a quandle-like structure, and describe the homology generators for this structure. (Received February 20, 2015)

1110-57-196 **Andreas V Michaelides*** (amichae@tulane.edu), 2206 Valmont St, Apt.B, New Orleans, LA 70115. *Lower bounds for ropelength of links via higher linking numbers and other finite type invariants.* Preliminary report.

Based on the arrow diagram formulas for finite type invariants due to Goussarov, Polyak and Viro, we obtain lower bounds for the ropelength of links and knots. In this talk, I will specifically present ropelength and crossing number bounds for Brunnian links, in terms of Milnor triple linking numbers. Further, I will sketch how to obtain generalizations to the n-component case. (Received February 20, 2015)

1110-57-209 **George Mossessian*** (gmoss@math.ucdavis.edu). *A classification of minimal tunnel systems for high-distance knots.* Preliminary report.

Let K be an n-bridge knot, $n \geq 3$, with bridge distance greater than $2n$. It follows that the tunnel number of K is $n-1$, and there are at most $\binom{2n}{n}$ distinct tunnel systems for K, which we explicitly construct. Further, we show that, if the bridge distance of K is at least $4n$, certain pairs of Heegaard splittings corresponding to these tunnel systems have stable genus at least $2n-1$, while all others have stable genus at most $n+1$. Although, at the time of submission, it remains open whether the upper bound on the number of distinct tunnel systems can be realized, some partial results in this direction can be shown as well. (Received February 20, 2015)

1110-57-214 **Louis H Kauffman*** (kauffman@uic.edu), Mathematics Department, University of Illinois at Chicago, 851 South Morgan Street, Chicago, IL 60607-7045. *Non-Commuative Worlds, Discrete Physics and Differential Geometry.* Preliminary report.

By formulating calculus in terms of commutators, we create non-commutative worlds that represent models of dynamics with discrete time, space and discrete derivatives. These worlds can be compared with classical worlds, as with quantum mechanics where Poisson brackets are replaced by commutators. In making such comparisons, we demand constraints in the sense that derivative formulas in advanced calculus should match corresponding formulas in the non-commutative world. Quadratic Hamiltonians satisfy the first constraint. Higher order constraints appear to be related to General Relativity. We will explain the state of the art in this form of exploration. (Received February 21, 2015)

1110-57-215 **Yewon Joung*** (yewon112@pusan.ac.kr), Busan. *On an invariant of surface-links via marked graph diagrams.*

A surface-link of n components is n mutually disjoint connected and closed (possibly orientable or non-orientable) 2-manifolds smoothly (or piecewise linearly and locally flatly) embedded in $\mathbb{R}^4$. A marked graph diagram is a link diagram on $\mathbb{R}^2$ possibly with some 4-valent vertices equipped with markers. In this talk, I would like to introduce an invariant of surface-links via marked graph diagrams by using a classical link invariant. (Received February 21, 2015)

1110-57-219 **Jim E Hoste*** (jhoste@pitzer.edu), 1050 N Mills Ave, Claremont, CA 91711, and **Patrick D Shanahan**. *Links with finite n-quandles.* Preliminary report.

Associated to every link L in the 3-sphere is its fundamental quandle, as well as quotients of this quandle for every integer $n > 1$, known as n-quandles. We will discuss progress on our goals to: 1) classify all links L and all integers n such that the n-quandle of L is finite, and 2) classify all finite quandles that appear as n-quandles of some link. (Received February 21, 2015)

1110-57-222 **Robion Kirby*** (kirby@math.berkeley.edu), Math. Dept., University of California, Berkeley, CA 94720, and **David Gay**. *Trisections and monodromy of 4-manifolds.* Preliminary report.

Every smooth, closed 4-manifold has a trisection (analogous to a bisection=Heegaard splitting of a 3-manifold) which is unique up to stabilization. A monodromy of a trisection is defined, and examples will be given. (Received February 21, 2015)

1110-57-260 **Radmila Sazdanovic*** (rsazdanovic@math.ncsu.edu), Department of Mathematics NCSU, SAS Hall 2311 Stinson drive, PO Box 8095, Raleigh, NC 27695, and **Uroš Tkalec**, **Jozef Przytycki**, **Bryan Gin-ge Chen** and **Simon Čopar**. *Knotting particle defect lines.* Preliminary report.

Recently, physicists have developed experimental techniques to produce knots and links in the form of defect fillaments in liquid crystals. We will talk about classifying these knots and links using billiard projections in a regular rectangular grid. Our goal is showing that the defect lines can be manipulated with laser tweezers to create any arbitrarily complex knot or link. (Received February 23, 2015)

1110-57-270 **Jason Cantarella** and **Harrison Chapman*** (hchaps@gmail.com), UGA Mathematics Department, Athens, GA 30602, and **Matt Mastin**. *Random Knot Diagrams and the Knot Diagram Distance Graph.* Preliminary report.

There are a finite number of smooth n-crossing immersions of the circle into the sphere with transverse self-intersections (up to diffeomorphism of the sphere). So a natural way to define a random knot is to choose randomly from this set of n-crossing diagrams and then assign over and under information to the crossings randomly.

This model is closer to the techniques of classical knot theory than other random knot models such as random closed polygons or random self-avoiding lattice walks, giving us the hope that it will serve as a bridge between those models and knot theory. In this talk, we discuss experimental results on the frequency of knots obtained by tabulating all the n-crossing diagrams (for small n) and computing knot type.

Using our data set, we can also build a graph of connections between knot types where two knot types K_1 and K_2 are connected by an edge if there is a diagram of K_1 where changing a single crossing transforms the knot to type K_2. This graph allows us to test some conjectures on unknotting numbers and knot distances. (Received February 23, 2015)

1110-57-281 **Oliver Dasbach** and **Anastasiia Tsvietkova***, tsvietkova@math.ucdavis.edu. *Hyperbolic volume of links and the colored Jones polynomial.*

Since quantum invariants were introduced into knot theory, there has been a strong interest in relating them to the intrinsic geometry of a link complement. This is for example reflected in the Volume Conjecture, which claims that the hyperbolic volume of a link complement in S^3 is determined by the colored Jones polynomial.

In the work of M. Lackenby, and of I. Agol and D. Thurston, an upper bound for volume of a hyperbolic link complement in terms of the number of twists of a link diagram is obtained. We will discuss how to refine this bound. We will also show how to express the refined bound in terms of the three first and three last coefficients of the colored Jones polynomial for alternating links. The talk is based on joint work with O. Dasbach. (Received February 23, 2015)

1110-57-289 **Jozef H. Przytycki*** (przytyck@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *From quantum plane to q-polynomial of rooted trees.*

e describe here a new invariant of rooted trees and following up state sum invariant of pointed graphs. We argue that the invariant is interesting on it own, and that it has connections to knot theory and homological algebra. Another reason that we propose this invariant is that we deal here with an elementary, interesting new mathematics and after the talk everybody can take part in developing the topic, inventing new results and connections to other disciplines of mathematics (and likely statistical mechanics and combinatorial biology). The staring point of the talk is the well known formula for $(x+y)^n$ in the quantum plane ($yx = qxy$). (Received February 23, 2015)

1110-57-302 **Cameron McA. Gordon***, gordon@math.utexas.edu, and **Tye Lidman**, tlid@math.utexas.edu. *Left-orderability, taut foliations and cyclic branched covers.*

It is conceivable that for a closed 3-manifold M the following are equivalent: (1) $\pi_1(M)$ is left-orderable, (2) M supports a co-orientable taut foliation, and (3) M is not a Heegaard Floer homology L-space. We will discuss these properties in the case where M is the n-fold cyclic branched cover of a knot. (Received February 23, 2015)

1110-57-327 **Alexander Zupan*** (zupan@math.utexas.edu), Department of Mathematics, University of Texas at Austin, 1 University Station C1200, Austin, TX 78712, and **Jeffrey Meier**.
Cosmetic surgeries on tunnel number one links.

A nontrivial Dehn surgery on a knot or link in a 3-manifold M which again yields M is called a cosmetic surgery. Gordon and Luecke demonstrated that knots in S^3 are determined by their complements, and thus knots in S^3 have no cosmetic surgeries. In contrast, there are infinitely many two component links in S^3 which admit cosmetic surgeries. In this talk, we classify all tunnel number one links in S^3 admitting a cosmetic surgery with integral surgery slope. (Received February 23, 2015)

1110-57-340 **Kanako Oshiro*** (oshirok@sophia.ac.jp). *On quandles which give a non-trivial coloring for twist-spun trefoils.*

Let F_q be a finite field with $\mathrm{char}(F_q) = p$ for a prime p. In this talk, I show some properties of a conjugation quandle obtained from $\mathrm{SL}_2(F_q)$. Especially, the quandle gives a non-trivial coloring for the p-twist-spun trefoils. (Received February 24, 2015)

1110-57-343 **Matthew Hedden**, **Christopher M. Herald*** (herald@unr.edu) and **Paul Kirk**.
Traceless tangle character varieties and a Lagrangian-Floer theory in the pillowcase. Preliminary report.

Abstract: The traceless SU(2) character variety of the 4-punctured sphere is a 2D surface with singularities, known as the pillowcase. The traceless character varieties of the tangle complements give rise to Lagrangian submanifolds in the pillowcase. We define a relatively Z/4 graded Lagrangian-Floer homology in this context. In this setting, the intersections that generate it correspond to the generators of Kronheimer-Mrowka singular instanton chain complex for the knot. We discuss the Atiyah-Floer conjecture relating these two Floer homology theories. (Received February 24, 2015)

1110-57-357 **Carson S. Rogers*** (csrogers@math.ucdavis.edu), One Shields Avenue, Davis, CA 95616. *Bridge index, link genus, and bridge position for Seifert surfaces.*

In this talk, we will define and examine a notion of bridge position for Seifert surfaces of links in 3-manifolds, which extends the classical notion of bridge position for links. After describing the basic properties of these bridge presentations, we will show that bridge surfaces of links which yield such presentations of a Seifert surface can have Hempel distance no greater than two in a wide range of cases. Motivated by this result, we will then discuss the potential to use this fact to establish new upper bounds on bridge index in terms of Seifert genus for links of distance at least 3. This is work in progress. (Received February 24, 2015)

1110-57-359 **Kate Petersen*** (petersen@math.fsu.edu). *(P)SL(2,C) Representations of Knot Groups.* Preliminary report.

I'll discuss a diagrammatic method to determine all geometric (P)SL(2,C) representations of a knot group. (Received February 24, 2015)

1110-57-362 **Mohamed Elhamdadi***, 4202 E. Fowler Ave., Tampa, FL 33620, and **Elkaioum Moutuou**, , United Kingdom. *Continuous cohomology of topological quandles.* Preliminary report.

After extending the notions of ideals and normal subgroups etc to the context of topological quandles, we outline a continuous cohomology of topological quandles. (Received February 24, 2015)

1110-57-368 **Hao Chen** and **Jason Parsley*** (parslerj@wfu.edu). *Petal Links.* Preliminary report.

A petal diagram of a knot or link consists of a center point surrounded by n non-nested loops; it represents n strands of the link at various heights which all project onto the same center point. Though every knot has a petal diagram, as shown recently by Adams, extremely few links have petal diagrams. We tabulate all petal links of 2-7 components and examine the connection between petal links and simple graphs. (Received February 24, 2015)

1110-57-369 **Marc Culler***, Mathematics, Statistics, and Computer Science, 851 S Morgan St, MC 249, University of Illinois at Chicago, Chicago, IL 60607-7045. *Computation of A-polynomials and the PE-character variety.*

I will introduce the PE-character variety of a knot manifold, which consists of characters that restrict to elliptic characters on the peripheral subgroup. Techniques for computing it, which arise from related methods for computing A-polynomials, will be described. The PE-character variety contains the $SU(2)$ character variety as well as parts of the $SL(2,\mathbb{R})$ character variety. Unlike the $SU(2)$ character variety, it is a union of immersed closed curves in the Clifford torus in $\mathbb{C}^* \times \mathbb{C}^*$. This fact clarifies some of the connections with classical knot invariants. (Received February 24, 2015)

1110-57-377 **Nicholas Jackson**, **Colin G. Johnson** and **Matt Rathbun*** (mrathbun@fullerton.edu). *Evolution of simplification strategies for knot diagrams.* Preliminary report.

We are adapting evolutionary computation methods to investigate the landscapes of sequences of moves that operate on a diagram for a knot, with various aims in mind. One avenue is investigation of efficient unknotting operations for knots. Another is to explore the space of Reidemeister move sequences on diagrams of the unknot to understand so-called 'hard' unknots, which are diagrams that require significant complication in order to subsequently simplify further. We will discuss the general methods employed, and report on preliminary results of this work-in-progress. (Received February 24, 2015)

1110-57-382 **Oliver Dasbach*** (kasten@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70808, and **Mustafa Hajij**. *Natural operations on knot diagrams, and the colored Jones polynomial.*

The connected sum for knots has natural generalizations, and we explain the implications for the colored Jones polynomial. (Received February 24, 2015)

1110-57-395 **Patricia Cahn*** (pcahn@math.upenn.edu) and **Vladimir Chernov**. *Knots Transverse to a Vector Field.*

We study knots transverse to a fixed vector field V on a 3-manifold M up to the corresponding isotopy relation. We show this classification is particularly simple when V is the co-orienting vector field of a tight contact structure, or when M is irreducible and atoroidal. We also apply our results to study loose Legendrian knots in overtwisted contact manifolds, and generalize results of Dymara and Ding-Geiges. (Received February 24, 2015)

1110-57-396 **Jing Wang*** (gwjwang@gwu.edu) and **Jozef H Przytycki** (przytyck@gwu.edu). *Introduction to Yang-Baxter Homology.*

Yang-Baxter operators have been used to construct link invariants such as Jones polynomial, HOMFLYPT polynomial, etc. In this talk, I will give an introduction on general Yang-Baxter homology motivated from distributive homology and homology of set-theoretic Yang-Baxter operators. (Received February 24, 2015)

1110-57-402 **Kei Nakamura*** (knakamura@math.ucavis.edu). *New Examples Related to Thurston's Congruence Link.*

Sometime in 90's, Bill Thurston found an 8-component hyperbolic link whose complement exhibits 336-fold PGL(2,7)-symmetry; the link complement coincides with an abstract polytope found independently by Schulte and Weiss. In this talk, we describe the standard triangulation and the combinatorics of this link complement as well as a few other known/new examples with similar properties. (Received February 24, 2015)

60 ► Probability theory and stochastic processes

1110-60-11 **Carl Mueller*** (carl.2015@outlook.com), Dept. of Mathematics, University of Rochester, Rochester, NY 14627, and **Robert Dalang**, **Yimin Xiao** and **Samy Tindel**. *Do stochastic PDE hit points or have double points in the critical dimensions?*

This talk will describe work in progress. The stochastic heat equation is often used as a basic model for a moving polymer:

$$\partial_t u = \Delta u + \dot{W}(t,x). \tag{1}$$

Here, $u = u(t,x) \in \mathbf{R}^d$ is the position of the polymer, $x \in \mathbf{R}$ is the length along the polymer, and t is time. $\dot{W}(t,x)$ is two-parameter vector-valued white noise.

We say that the solution hits a point z if there is positive probability that $u(t,x) = z$ for some (random) parameters (t,x). Multiple points have a similar definition. Some time ago the speaker and R. Tribe proved that in the critical dimensions, $u(t,x)$ does not hit points and does not have double points. The critical dimensions are different for these two phenomena. The proof only applies to the above equation.

The goal of our work is to adapt an argument of Talagrand to study this question for equations similar to the above, but which

(1) have colored noise in place of white noise.

(2) have nonlinearities in front of the noise term.

As usual, the critical case is by far the hardest. In fact, there are a number of results about the situation away from criticality, but they are not sharp enough to give the results we seek. (Received November 22, 2014)

1110-60-27 **Yaozhong Hu** and **Khoa Le*** (khoa.le.n@gmail.com). *Nonlinear integrations and related differential equations.*

We introduce nonlinear integrals of the form $\int_0^t W(ds, \varphi_s)$ where $W(t,x)$ and φ_t are possibly the sample path of some stochastic processes. This type of integrals appear naturally when dealing with SPDEs. The first example is the transport equation

$$\partial_t u(t,x) + \partial_t W(t,x)\nabla u(t,x) = 0, \quad u(0,x) = u_0(x)\,,$$

where W is Hölder continuous in time and space of order τ and λ respectively. The initial condition u_0 is assumed to be sufficient regular. Assuming $(1+\lambda)\tau > 1$, existence in the space of Hölder continuous functions is obtained by characteristic method to give $u(t,x) = u_0(\varphi_t^{-1}(x))$ where $\varphi_t(x)$ is the flow of the ODE

$$\varphi_t(x) = x + \int_0^t W(ds, \varphi_s(x))ds.$$

If W has more regularity in space, e.g. $C^{1+\lambda}$, then the solution is unique.

The second example is a pararbolic equation of the type

$$\partial_t u(t,x) = Lu(t,x) + \partial_t W(t,x)u(t,x), \quad u(T,x) = u_T(x)$$

for $0 \le t \le T$. Here L is the generator of an elliptic diffusion and W is only continuous in time and $C^{1+\alpha}$ in space. Existence and uniqueness are obtained by Feynman-Kac formula

$$u(t,x) = \mathbb{E}\left[u_T(X_T^{t,x}) \exp\left(\int_t^T W(ds, X_s^{t,x})\right)\right].$$

(Received January 10, 2015)

1110-60-45 **Qi Feng*** (feng71@purdue.edu) and **Xuejing Zhang**. *Taylor expansions for solutions of stochastic differential equations driven by rough paths.* Preliminary report.

We study the Taylor expansion for the solution of a differential equation driven by p-rough paths with $p > 2$. We will prove a general theorem concerning the convergence of the Taylor expansion on a nonempty interval provided that the vector fields are analytic on a ball centered at the initial point. We will also derive criteria that enable us to study the rate of convergence of the Taylor expansion. Our deterministic results can be applied to stochastic differential equations driven by fractional Brownian motions with Hurst parameter $1/4 < H < 1/2$ and continuous Gaussian process with finite $2D$ $\rho-$variation. At last, we give a Castell expansion and a tail estimate with exponential decay for the remainder terms of the solutions of the differential equations driven by continuous centered Gaussian process with finite $2D$ $\rho-$variation and fractional Brownian motion with Hurst parameter $H > 1/4$. (Received January 31, 2015)

1110-60-55 **Eulalia Nualart*** (eulalia@nualart.es), C/ Ramón Trias Fargas, 08005 Barcelona, Spain. *Noise excitability of the stochastic heat equation.*

We consider the following stochastic heat equation on an interval with Dirichlet boundary conditions driven by a space-time white noise

$$\partial_t u_t(x) = \frac{1}{2}\partial_{xx} u_t(x) + \lambda\sigma(u_t(x))\dot{W}(t,\,x)$$

We show that in the long run, the second moment of the solution grows exponentially fast if λ is large enough. But if λ is small, then the second moment eventually decays exponentially. If we replace the Dirichlet boundary condition by the Neumann one, then the second moment grows exponentially fast no matter what λ is. We also provide various extensions. This talk is based on a joint work with M. Foondun. (Received February 05, 2015)

1110-60-91 **Davar Khoshnevisan*** (davar@math.utah.edu), 155 South 1400 East, Salt Lake City, UT 84112. *Local Behavior of the Solution to a Stochastic PDE.*

We describe various local properties of the solution to a stochastic PDE. Special emphasis is put on sample-function properties. Properties of the parabolic Anderson model, and the associated KPZ equation, are highlighted. This is based on joint works with M. Foondun and P. Mahboubi on one hand, and J. Swanson, Y. Xiao, and L. Zhang on another. (Received February 12, 2015)

1110-60-102 **Yaozhong Hu** and **Jingyu Huang*** (huangjy@ku.edu), 1712 Anna Dr. Apt 04, Lawrence, KS 66044, and **David Nualart** and **Samy Tindel**. *Stochastic heat equation with general multiplicative Gaussian noises: Hölder continuity and intermittency.*

We study the stochastic heat equation with multiplicative noises: $\frac{\partial u}{\partial t} = \frac{1}{2}\Delta u + u\dot{W}$, where $\dot{W}$ is a mean zero Gaussian noise and $u\dot{W}$ is interpreted both in the sense of Skorohod and Stratonovich. The existence and uniqueness of the solution are studied for noises with general time and spatial covariance structure. Feynman-Kac formulas for the solutions and for the moments of the solutions are obtained under general and different conditions. These formulas are applied to obtain the Hölder continuity of the solutions. They are also applied to obtain the intermittency bounds for the moments of the solutions. (Received February 13, 2015)

1110-60-105 **Thomas R. Cass*** (thomas.cass@imperial.ac.uk), Department of Mathematics, Imperial College London, 180 Queen's Gate, London, SW7 2AZ, United Kingdom, and **Marcel Ogrodnik**, Department of Mathematics, Imperial College London, 180 Queen's Gate, London, United Kingdom. *Tail estimates for Markovian rough paths.*

The accumulated p-variation $M(\mathbf{x})$ of a p-rough path $\mathbf{x}$ over $[0,t]$ is given by

$$\sup_{\substack{D=\{0=t_0<t_1<\ldots t_r=t\} \\ ||\mathbf{x}||_{p\text{-}var,[t_i,t_{i+1}]}\leq 1}} \sum_{i=1}^{r} ||\mathbf{x}||^p_{p\text{-}var,[t_i,t_{i+1}]}.$$

This functional arises naturally as an optimal pathwise growth estimate to solutions to rough differential equations, and to higher order terms in the signature of $\mathbf{x}$ (i.e. the canonical Lyons lift). This has implications when $\mathbf{x} = \mathbf{x}(\omega)$ is random when some important applications demand precise tail estimates for the random variable $M(\mathbf{x}(\omega))$. In this talk we work with a general class of Markovian rough paths and prove an almost-Gaussian tail estimate for $M(\mathbf{x}(\omega))$. We comment on the relevance of these estimates for some of the applications mentioned above. (Received February 13, 2015)

1110-60-106 **Christian Litterer*** (christian.litterer@polytechnique.edu). *Rough paths on manifolds.*

We introduce a notion of rough paths on embedded submanifolds and demonstrate that this class of rough paths is natural. As a consequence we obtain a rough path analogue of Cartan's development map developed by Eeels, Elworthy and Malliavin in the stochastic setting. Finally, we show equivalence of existing notions of rough paths on manifolds under their respective geometric assumptions. Joint work with T. Cass and B. Driver. (Received February 14, 2015)

1110-60-153 **Daniel J Kelleher***, Purdue University, Department of Mathematics, West Lafayette, IN 47907. *Differential forms on Dirichlet spaces and analysis on fractals.*

We will discuss techniques of defining intrinsic metrics and vector analysis for measurable Dirichlet forms (quadratic forms on scalar functions) and resistance forms. This vector analysis has applications in constructing a Dirac operator and a space of one forms. This construction combines ideas from classical and non-commutative functional analysis. We will discuss the spectral properties of these ideas, as well as how they relate to analytic ideas such as heat kernel estimates and other functional inequalities. (Received February 18, 2015)

1110-60-169 **David Nualart*** (nualart@ku.edu). *Quantitative stable limit theorems for multiple Skorohod integrals.*

The purpose of this talk is to present some results on quantitative stable limit theorems for multiple Skorohod integrals, where the limit distribution is a mixture of Gaussian distributions, obtained in collaboration with Ivan Nourdin and Giovanni Peccati. The proofs are based on an interpolation procedure and the techniques of Malliavin calculus. We will discuss the applications of these results to the case of weighted quadratic variations of the fractional Brownian motion. (Received February 19, 2015)

1110-60-184 **Andrey Sarantsev*** (ansa1989@math.washington.edu), Padelford Hall C138, Seattle, WA 98195, and **Cameron Bruggeman** (bruggeman@math.columbia.edu), MC 4406, 2990 Broadway, New York, NY 10027. *Diffusion Approximation of Reflected Brownian Motion.* Preliminary report.

Consider a reflected Brownian motion on the positive half-line. This is not a diffusion process, but we can weakly approximate it by diffusion processes. Essentially, we approximate the local time term by drift terms. Similar results are obtained for many dimensions, including the case of oblique reflection. (Received February 20, 2015)

1110-60-193 **Le Chen*** (chenle@ku.edu), Department of Mathematics, 405 Snow Hall, 1460 Jayhawk Blvd, Lawrence, KS 66045-7594, and **Kunwoo Kim**. *On comparison principle and strict positivity of solutions to the nonlinear stochastic fractional heat equation.*

We study the following nonlinear stochastic heat equation:

$$\left(\frac{\partial}{\partial t} - {}_xD^a_\delta\right) u(t,x) = \rho\left(u(t,x)\right) \dot{W}(t,x), \quad t>0,\ x\in\mathbb{R},$$

where ${}_xD^a_\delta$ is the fractional differential operator of order $a \in]1,2]$ and skewness δ ($|\delta| \le 2-a$), $\dot{W}$ is the space-time white noise, and $\rho : \mathbb{R} \mapsto \mathbb{R}$ is Lipschitz continuous with $\rho(0) = 0$. I will show that if u_1 and u_2 are two solutions starting from two measures μ_1 and μ_2, respectively, and if $\mu_1 < \mu_2$, then

$$P(u_1(t,x) < u_2(t,x) \quad \text{for all } t > 0 \text{ and } x \in \mathbb{R}) = 1.$$

For the Laplacian case ($a = 2$), this result generalizes the comparison principle by Mueller by allowing measure-valued initial data. This talk is based on a joint-work with K. Kim (arXiv:1410.0604). (Received February 20, 2015)

1110-60-212 **Samy Tindel*** (samy.tindel@univ-lorraine.fr), Institut Elie Cartan Lorraine, BP 239, 54000 Nancy, Lorraine, France. *Noisy differential equations with power type coefficients.*

We are interested in this talk in ordinary differential equations with a noisy term and a diffusion type coefficient of the form $\sigma(x) = \|x\|^\alpha$, with a constant α smaller than 1.

This kind of equation has a long story in stochastic analysis. We will first review some of the efforts made by Yamada and Watanabe in this direction (when the equation is driven by a Brownian motion), as well as more some recent developments concerning stochastic PDEs.

We will then introduce an extension of Young's integral which allows to handle the case of equations driven by a Gaussian signal whose paths are Hölder continuous with Hölder exponent greater than 1/2. Notice that only existence results are obtained, the uniqueness part being still widely open. (Received February 21, 2015)

1110-60-244 **Steven A Bleiler*** (bleilers@pdx.edu), F.M. Dept. of Math and Stat, P.O. Box 751, Portland State University, Portland, OR 97207-0751, and **Tom Fielden** (tom@tomfielden.com), 615 SW Rustica Terrace, Portland, OR 97225. *Modeling with computational probability I.*

In this talk the appropriate background for the development of a programmatic modeling environment that includes natural programming objects such as arrays, matrices and random variables all compatible with direct symbolic-numeric random variable calculation will be presented. (Received February 22, 2015)

1110-60-245 **Tom Fielden*** (tom@tomfielden.com), 615 SW Rustica Terrace, Portland, OR 97225, and **Steven A Bleiler** (bleilers@pdx.edu), F.M. Dept. of Math and Stat, P.O. Box 751, Portland State Unversity, Portland, OR 97202-0751. *Modeling with computational probability II.*

Building on and in the context of the mathematical foundations established in talk I, a specific spreadsheet based model developed by the Federal EPA to demonstrate the benefit to rate payers and power producers of the promotion of energy efficiency is discussed. The EPA model is taken from spreadsheet form into the Rico environment where an uncertainty, risk and sensitivity analyses is performed. (Received February 22, 2015)

1110-60-271 **Bruce K. Driver** and **Nathaniel Eldredge*** (neldredge@unco.edu), School of Mathematical Sciences, University of Northern Colorado, 501 20th St., Campus Box 122, Greeley, CO 80639, and **Tai Melcher**. *Regularity of hypoelliptic heat kernels on infinite-dimensional Heisenberg groups.*

A prototypical example of a hypoelliptic diffusion is Brownian motion on the 3-dimensional real Heisenberg group; it is a process driven by a 2-dimensional classical Brownian motion, which nonetheless manages to diffuse smoothly throughout the 3-dimensional state space. Specifically, its endpoint distribution (heat kernel measure) has a C^∞ smooth density with respect to Lebesgue measure. We study an analogue of this process on an infinite-dimensional Heisenberg-like Lie group modeled on abstract Wiener space, as introduced by B. Driver and M. Gordina. Using pure stochastic calculus methods, we are able to show an analogous result: the heat kernel measure of this process is smooth in an appropriate sense (infinitely Malliavin differentiable), and we have L^p bounds for its derivatives. Our work reproduces and improves upon results of F. Baudoin, M. Gordina, and T. Melcher, which were obtained via a more geometric approach (generalized curvature-dimension inequalities). (Received February 23, 2015)

1110-60-293 **Kanadpriya Basu*** (kbasu@utep.edu), 500 West University Avenue, El Paso, TX 79968, and **Maria Christina Mariani** (mcmariani@utep.edu), 500 West University Avenue, El Paso, TX 79968. *Stochastic models applied to seismic data.* Preliminary report.

The classical Ising model was used to re-create the ferromagnetic phenomenon in statistical mechanics. The model describes the behavior of atoms in a lattice. Each atom may interact only with its neighbors, and has two states called spins. When the temperature in the system passes a critical value the system exhibits a polarization of spins (phase transition) and spontaneous magnetization. In this work we consider mayor earthquakes as phase transitions and apply an extension of the Ising type models and the Levy type models to investigate the statistical behavior of the temporal distribution of earthquakes. We show that a pattern arises from the scale invariance property and that Lévy flight models may be used to estimate parameters related to some major event - major earthquake. We finally investigates the underlying volatility processes in earthquake series: we study the applicability of a range of GARCH specifications for modeling volatility of these series in order to identify similarities and differences in the volatility structures. (Received February 23, 2015)

1110-60-303 **Shuwen Lou** and **Cheng Ouyang*** (couyang@math.uic.edu), Department of Math, Stat, and Computer Sci., University of Illinois at Chicago, 851 S. Morgan Street, Chicago, IL 60607. *Fractal dimensions of rough differential equations driven by fractional Brownian motions.*

We study fractal properties of rough differential equations driven by fractional Brownian motions with Hurst parameter $H > \frac{1}{4}$. In particular, we show that the Hausdorff dimension of the sample paths of the solution is $\min\{d, \frac{1}{H}\}$ almost surely and that the Hausdorff dimension of the level set $L_x = \{t \in [\epsilon, 1] : X_t = x\}$ is $1 - dH$ with positive probability when $d < \frac{1}{H}$. (Received February 23, 2015)

1110-60-354 **Zhenan Wang*** (zn_wang@math.northwestern.edu) and **Elton Pei Hsu** (ehsu@math.northwestern.edu). *Bismut's gradient formula for vector bundles.*

We prove a general Bismut's formula for the gradient of a class of smooth Wiener functionals over vector bundles of a compact Riemannian manifold. This general formula can be used repeatedly for obtaining probabilistic representation of higher order covariant derivatives of solutions of the heat equation similar to the classical Bismut's representation for the covariant gradient of the heat kernel. (Received February 24, 2015)

62 ► Statistics

1110-62-176 **Marylesa Howard*** (howardmm@nv.doe.gov), **Aaron Luttman**, **Stephen Mitchell**, **Michael Fowler** and **Margaret Hock**. *Bayesian Sampling for Error Estimation in Image Reconstruction of X-Ray Radiographs.*

The inverse Abel transform is used to reconstruct material densities of a radially symmetric object from an X-ray radiograph. A common approach to solving this ill-posed problem is through variational methods; however, they lack a natural method by which uncertainty in the reconstruction may be quantified. To address error estimation, we developed a hierarchical Bayesian sampling approach with a Gaussian likelihood and priors for the unknown density profile, the data precision matrix, and two scale parameters. The data presented were obtained from high-energy X-ray radiography facilities. (Received February 19, 2015)

65 ► Numerical analysis

1110-65-16 **Samir Kumar Bhowmik*** (bhowmiksk@gmail.com), Department of Mathematics and Statistics, Al Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia. *Piecewise Polynomial Approximation of a Nonlocal Phase Transitions Model.* Preliminary report.

Piecewise collocation-finite element and Galerkin-finite element methods are proposed and analysed for a non-linear partial integro-differential equation that arises in the modeling of phase transitions. We compute solutions in both methods using some standard quadrature rules. We present the order of accuracy of such semidiscrete time dependent problem with full integral and quadrature for the Galerkin inner product considering both the real solutions and the approximate solutions are sufficiently smooth in whole domain Ω. We also find an upper bound considering the approximate solutions are L_2 in Ω and H^s in each subdomain w_i such that $\Omega = \cup_i w_i$. (Received December 04, 2014)

1110-65-34 **Thinh T Kieu*** (thinh.kieu@ung.edu), 3820 Mundy Mill Rd., Oakwood, GA 30503. *Expanded mixed finite element methods for the generalized Forchheimer flows of slightly compressible fluid in porous media.*

The nonlinear Forchheimer equations are used to describe the dynamics of fluid flows in porous media when Darcy's law is not applicable. In this article, we consider the generalized Forchheimer flows for slightly compressible fluids, and then study the expanded mixed finite element method applied to the initial boundary value problem for the resulting degenerate parabolic equation for pressure. The bounds for the solutions, time derivative and gradient of solutions are established. Utilizing the monotonicity properties of Forchheimer equation and boundedness of solutions, a priori error estimates for solution are obtained in L^2-norm, L^∞-norm as well as for its gradient in L^{2-a}-norm for all $a \in (0,1)$. Optimal L^2-error estimates are shown for solutions under some additional regularity assumptions. Numerical results using the lowest order Raviart-Thomas mixed element confirm the theoretical analysis regarding convergence rates. (Received January 19, 2015)

1110-65-59 **Timo Heister**, **Maxim Olshanskii** and **Leo Rebholz*** (rebholz@clemson.edu). *Natural vorticity boundary conditions for solid walls and application to velocity-vorticity methods for Navier-Stokes equations.* Preliminary report.

We derive boundary conditions for the vorticity equation with solid wall boundaries. The formulation uses a Dirichlet condition for the normal component of vorticity, and Neumann type conditions for the tangential components. In a Galerkin (integral) formulation the tangential condition is natural, i.e. it is enforced by a right-hand side functional and does not impose a boundary constraint on trial and test spaces. The functional involves the pressure variable, and we discuss several velocity-vorticity formulations where the proposed condition is appropriate. Several numerical experiments are given that illustrate the validity of the approach. (Received February 06, 2015)

1110-65-62 **Daozhi Han** (dhan@math.fsu.edu), Tallahassee, FL 32306, and **Xiaoming Wang*** (wxm@math.fsu.edu), Tallahassee, FL 32306. *A second order in time accurate, long time stable and efficient scheme for the Cahn-Hilliard-Navier-Stokes system.*

We present a second order in time accurate efficient numerical scheme for the Cahn-Hilliard-Navier-Stokes system that models two phase flows. Our efficient algorithm is based on the Chorin-Temam projection method for the velocity equation and the convex-splitting method for the phase-field (Cahn-Hilliard) equation. The scheme inherits the energy law of the original system and is uniquely solvable at each time step. (Received February 07, 2015)

1110-65-76 **Vincent J Ervin*** (vjervin@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634-0975. *Generalized Newtonian Fluid Flow through a Porous Medium.*

We present a model for generalized Newtonian fluid flow through a porous medium. In the model the dependence of the fluid viscosity on the velocity is replaced by a dependence on a smoothed (locally averaged) velocity. With appropriate assumptions on the smoothed velocity, existence of a solution to the model is shown. Two examples of smoothing operators are discussed. A numerical approximation scheme is presented and an a priori error estimate derived. A numerical example is given illustrating the approximation scheme and the a priori error estimate. (Received February 10, 2015)

1110-65-89 **Leo Rebholz** and **Mengying Xiao*** (mengyix@clemson.edu), SC 29630. *On reducing the splitting error in Yosida methods for the Navier-Stokes equations with grad-div stabilization.*

This paper analyzes the accuracy of the 'discretize-then-split' Yosida solver for incompressible flow problems, when divergence-free elements are used together with grad-div stabilization (with parameter γ). The Yosida method uses an inexact block LU factorization to create linear algebraic systems that are easier to solve, but at the expense of accuracy. We prove the difference between solutions of the exact and approximated linear algebraic systems is $O(\gamma^{-2})$ in the natural norms of the associated finite element problem, and thus that full accuracy can be obtained by the Yosida method if large γ is used ($\gamma \geq 10$ is sufficient in our numerical examples). The proof is based on transforming the Yosida inexact linear algebraic system into finite element problems, and analyzing these problems with finite element techniques based on poitnwise divergence-free subspaces and their orthogonal complements. (Received February 11, 2015)

1110-65-92 **Yuzhou Sun**, **Pengtao Sun**, **Bin Zheng*** (bin.zheng@pnnl.gov) and **Guang Lin**. *Error analysis of finite element method for Poisson-Nernst-Planck equations.*

A priori error estimates of finite element method for time-dependent Poisson-Nernst-Planck equations are studied in this work. We obtain the optimal error estimates in $L^\infty(H^1)$ and $L^2(H^1)$ norms, and suboptimal error estimates in $L^\infty(L^2)$ norm, with linear element, and optimal error estimates in $L^\infty(L^2)$ norm with quadratic or higher-order element, for both semi- and fully discrete finite element approximations. Numerical experiments are also given to validate the theoretical results. (Received February 12, 2015)

1110-65-113 **Michael Neilan*** (neilan@pitt.edu), 301 Thackeray Hall, 139 University Place, Pittsburgh, PA 15260. *Finite element methods for elliptic problems in non–divergence form.*

The finite element method is a powerful and ubiquitous tool in numerical analysis and scientific computing to compute approximate solutions to partial differential equations (PDEs). A contributing factor of the method's success is that it naturally fits into the functional analysis framework of variational models. In this talk I will discuss two classes of finite element methods for problems that do not conform to the usual variational framework, namely, elliptic PDEs in non–divergence form. I will first present the derivation of the schemes and give a brief outline of the convergence analysis. Finally, I will present several challenging numerical examples showing the robustness of the method as well as verifying the theoretical results. (Received February 15, 2015)

1110-65-118 **Hyesuk Lee*** (hklee@clemson.edu). *Numerical analysis and approximation of fluid-structure interaction problems.*

Simulating fluid-structure interactions is challenging due to the tight coupling between the solid and fluid substructures in a moving domain. Explicit and implicit decoupling methods often either fail or require relaxation when densities of the two materials are close. In this talk both monolithic and decoupling approaches are considered for analytical and numerical studies of fluid-structure interaction problems where a fluid is governed by a Newtonian or non-Newtonian model. An optimization based method which allows the problems to be stably decoupled is discussed and numerical results are presented. (Received February 16, 2015)

1110-65-144 **Sean Ryan Breckling*** (brecklin@unlv.nevada.edu). *The Numerical Analysis of the Navier-Stokes Alpha Model Using Scott-Vogelius Elements in Space and Crank-Nicholson in Time.*

We present a numerical study of the Navier Stokes-α (NS-α) model, a regularization of the Navier Stokes Equations (NSE) that resolve only motions above certain critical scales. Next, an unconditionally stable finite-element implementation of NS-α is proposed, followed by proofs for the stability and convergence. Lastly, the results from two numerical experiments are presented. (Received February 17, 2015)

1110-65-146 **Yingda Cheng**, **Ching-Shan Chou** and **Fengyan Li*** (lif@rpi.edu), 110 8th Street, Troy, NY 12180, and **Yulong Xing**. *L^2 Stable Discontinuous Galerkin Methods for 1d Two-way Wave Equations.*

In this work, a family of L^2 stable discontinuous Galerkin methods are investigated to solve one-dimensional two-way wave equations for their stability, accuracy, and dispersion property. We particularly identify a subfamily of the methods which is optimal in L^2 errors and has superconvergence. New insight is provided into some known observations when discontinuous Galerkin methods are applied to wave equations. (Received February 17, 2015)

1110-65-151 **Maxim A Olshanskii***, Department of Mathematics, University of Houston, 4800 Calhoun St, Houston, TX 77204. *ILU preconditioners for the incompressible Navier–Stokes equations with applications to haemodynamics simulations.*

In the talk we discuss several variants of threshold incomplete LU factorizations for linearized discrete incompressible Navier–Stokes equations. The resulting preconditioners are used to accelerate the convergence of a Krylov subspace method applied to finite element discretizations of fluid dynamics problems in three space dimensions. The performance of the ILU preconditioners is demonstrated for a wide range of flow and discretization parameters. It is shown that in numerically challenging cases of higher Reynolds number flows one benefits from using a two-parameter modification of a standard ILUT preconditioner. We shall give a semi-empirical explanation of this observation based on an estimates for the ellipticity and the symmetric part dominance of arising matrices. Numerical experiments will demonstrate the effectiveness of the proposed preconditioners if threshold parameters are chosen suitably. The approach is further applied to simulate a flow in a right coronary artery. This is a joint work with Igor N. Konshin and Yuri V. Vassilevski from the Institute of Numerical Mathematics, Russian Academy of Sciences. (Received February 18, 2015)

1110-65-154 **Chiu-Yen Kao**, **Alexander Kurganov**, **Zhuolin Qu** and **Ying Wang***, wang@math.ou.edu. *A Fast Explicit Operator Splitting Method for Modified Buckley-Leverett Equations.*

In this talk, I will discuss a fast explicit operator splitting method to solve the modified Buckley-Leverett equations which include a third-order mixed derivatives term resulting from the dynamic effects in the pressure difference between the two phases. The method splits the original equation into two equations, one with a nonlinear convective term and the other one with high-order linear terms so that appropriate numerical methods can be applied to each of the split equations: The high-order linear equation is numerically solved using a pseudo-spectral method, while the nonlinear convective equation is integrated using the Godunov-type central-upwind scheme. A variety of numerical examples in both one and two space dimensions show that the solutions may have many different saturation profiles depending on the initial conditions, diffusion parameter, and the third-order mixed derivatives parameter. The results are consistent with the study of traveling wave solutions and their bifurcation diagrams. This is a joint work with C.-Y. Kao, A. Kurganov, and Z.-L. Qu. (Received February 18, 2015)

1110-65-155 **Hong Wang***, Department of Mathematics, University of South Carolina, Columbia, SC 29208. *An accuracy-preserving spectral method for fractional differential equations.*

Fractional differential equations (FDEs) provide an adequate description of anomalously diffusive transport processes. Recent study shows that FDEs with smooth coefficients may generate solutions with strongly local behavior and poor regularity. Consequently, a traditional spectral method need not generate high-order accuracy for FDEs with smooth coefficients. We present an accuracy-preserving spectral method for a variable-coefficient FDE, which has a proved high-order accuracy as long as the problem has smooth coefficients. Numerical results are presented to show the utility of the method. (Received February 18, 2015)

1110-65-156 **Jay Gopalakrishnan*** (`gjay@pdx.edu`), Portland, OR 97207-0751, **Peter Monk** (`monk@udel.edu`), Newark, DE 19716, and **Paulina Sepulveda** (`spaulina@pdx.edu`), Portland, OR 97212-0751. *A tent pitching scheme motivated by Friedrichs theory.*

This talk presents a new explicit space time finite element method for the time-dependent wave equation. The method is motivated by the modern theory of Friedrichs systems. Certain Friedrichs systems can be posed on Hilbert spaces normed with a graph norm. Functions in such spaces arising from advective problems are found to have traces with a weak continuity property at points where the inflow and outflow boundaries meet. Motivated by this continuity property, an explicit space-time finite element scheme of the tent pitching type, with spaces that conform to the continuity property, is designed. The presentation includes numerical results for a model one-dimensional wave propagation problem. (Received February 18, 2015)

1110-65-161 **Susanne C. Brenner** (`brenner@math.lsu.edu`), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803, **Jiguang Sun** (`jiguangs@mtu.edu`), Department of Mathematical Sciences, Michigan Technological University, Houghton, MI 49931, and **Li-yeng Sung*** (`sung@math.lsu.edu`), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Finite Element Methods for a Fourth Order Curl Operator on Planar Domains.* Preliminary report.

We present theoretical and numerical results for new finite element methods for a fourth order curl operator on planar domains. Both the source problem and the eigenvalue problem will be considered. These finite element methods, which are based on standard Lagrange finite elements for second order scalar problems, are derived through the Hodge decomposition of divergence free vector fields. (Received February 18, 2015)

1110-65-177 **Wenyuan Liao*** (`wliao@ucalgary.ca`), 2500 University Drive NW, Calgary, Alberta T2N1N4, Canada. *Helmholtz decomposition based numerical method for solving 3D Elastic wave equation.*

Elastic wave equation is a coupled system of partial differential equations (PDE) that has been widely used in modeling wave propagation through an elastic medium such as the earth. Numerical solution of such model is of great interests to both Mathematicians and Geophysicists working on a variety of applications, geophysical exploration for instance. In particular numerical modeling of Elastic wave equation is an integral part of full waveform inversion and other wave equation based seismic inversion methods.However, given that the Elastic wave equation is a coupled PDE system, and the large size of the physical domain, it is a challenging task to develop efficient and accurate numerical method for it. Here we first use the Helmholtz decomposition to decouple the Elastic wave equation system into four scalar acoustic wave equations, which are then efficiently solved by compact higher-order finite difference method. Some novel boundary treatments have been developed for the new equations. The numerical solution of the Elastic wave equation is reconstructed from the previously obtained numerical solutions of the four scalar PDEs. Finally numerical examples are solved to demonstrate the efficiency and effectiveness of the newly proposed numerical method. (Received February 19, 2015)

1110-65-181 **Jinchao Xu** and **Lu Wang*** (wanglupku@gmail.com), 65 Rio Robles East, #3423, San Jose, CA 95134, and **Xiaozhe Hu**. *Discretizations and Solvers for Coupled PDEs.* Preliminary report.

In this talk, I will report some theoretical and numerical results on the integrated study of robust discretization and efficient solvers for discretized partial differential equations. Using the framework of fast auxiliary space preconditioning (FASP) method, I will provide some examples to show briefly how to develop optimal iterative algorithms for solving finite element systems on unstructured grids for PDEs. (Received February 19, 2015)

1110-65-190 **Maximilian S Metti***, Pennsylvania State University, Mathematics Department, State College, PA 16802, and **Jinchao Xu**, **Chun Liu** and **Xiaozhe Hu**. *Applications and Discretizations of the Poisson-Nernst-Planck Equations.*

Electrostatic systems are a subclass of electromagnetic systems, where several charge carriers interact with one another through an electric field and the magnetic field is assumed to be static in time. Such systems are of significant interest in the study and design of modern electronic devices, electrochemistry, and biology. Electrostatics are often described by the Poisson-Nernst-Plank (PNP) equations, which are a strongly-coupled system of nonlinear equations. In this talk, we present several applications of the PNP equations to electronic devices and discuss some possible modifications to this mathematical model. Furthermore, a discretization of the PNP equations is proposed and analyzed, establishing stability of the discrete problem by leveraging the nonlinear nature of the equations. A numerical solver for these equations is then described along with some numerical results. (Received February 20, 2015)

1110-65-203 **Pushkin Kachroo**, **Puneet Lakhanpal** and **Monika Neda***, monika.neda@unlv.edu. *Numerical Study of Traffic Flow Models.*

Traffic flow has been considered to be a continuum flow of a compressible liquid having a certain density profile and an associated velocity, depending upon density, position and time. Herein, the Lighthill Witham and Richards (LWR) model combined with the Greenshield's model, is studied. Numerical solutions of several numerical experiments are computed using the Godunov Method and the Finite Element Method, and a comparison is given too. Furthermore, the finite element time relaxation method is introduced for the treatment of the shocks. (Received February 20, 2015)

1110-65-211 **Jiajia Waters*** (wangj16@unlv.nevada.edu), Department of Mechanical Engineering, University of Nevada Las Vegas, Las Vegas, Las Vegas, NV 89154. *A comparison between global and localized RBF meshless methods in solving incompressible Naiver-Stokes equations.*

The term "meshless method" refers to the class of numerical techniques that rely on either global or localized interpolation on non-ordered spatial point distributions. We have developed both a global and localized radial basis function (RBF) collocation framework to solve the incompressible Navier-Stokes equations. Here we make a comparison between these two meshless methods after establishing the accuracy of each one based on the solution to benchmark fluid flow problems. Global RBF-based methods have some well-known drawbacks, including poor conditioning of the ensuing algebraic set of equations. While these drawbacks can be addressed, to some extent, by domain decomposition and appropriate pre-conditioning.

The attractive feature of the localized RBF method is that it allows field variable derivatives of any order to be estimated by simple inner products of vectors that can be pre-built and stored. In addition, the memory demands of the localized approach approach are minimal, as no global collocation matrix needs to be allocated; only small vectors are stored for every one of the data centers. We conclude that localized methods offer tremendous advantages over global RBF-based meshless methods in terms of data preparation, parallelizability. (Received February 21, 2015)

1110-65-239 **Junping Wang*** (jwang@nsf.gov), 4210 Wilson Boulevard, MPS/DMS, National Science Foundation, Arlington, VA 22230. *New Developments in Weak Galerkin Finite Element Methods.*

This talk shall discuss some new developments of the weak Galerkin finite element method (WG) for partial differential equations. The talk will start with the second order elliptic equation, for which WG shall be applied and explained in detail. In particular, the concept of weak gradient will be introduced and discussed for its role in the design of weak Galerkin finite element schemes. The speaker will then introduce a general notion of weak differential operators, such as weak Hessian, weak divergence, and weak curl etc. These weak differential operators shall serve as building blocks for WG finite element methods for other class of partial differential equations, such as the Stokes equation, the biharmonic equation for thin plate bending, the Maxwell equations in electron magnetics theory, and the div-curl problems. The speaker will further discuss the WG for partitions with curved elements. A mathematical convergence theory shall be briefly given for some applications. The talk should be accessible to graduate students with adequate training in computational methods. (Received February 22, 2015)

1110-65-251 **Alexander Kurganov*** (kurganov@math.tulane.edu), Mathematics Department, 6823 St. Charles Ave., New Orleans, LA 70118. *Well-Balanced Positivity Preserving Central-Upwind Scheme for the Shallow Water System with Friction Terms.*

Shallow water models are widely used to describe and study free-surface water flow. While in some practical applications the bottom friction does not have much influence on the solutions, there are still many applications, where the bottom friction is important. In particular, the friction terms will play a significant role when the depth of the water is very small.

We study shallow water equations with friction terms and develop a semi-discrete second-order central-upwind scheme that is capable of exactly preserving physically relevant steady states and maintaining the positivity of the water depth. The presence of the friction terms increases the level of complexity in numerical simulations as the underlying semi-discrete system becomes stiff when the water depth is small. We therefore implement an efficient semi-implicit Runge-Kutta time integration method that sustains the well-balanced and sign preserving properties of the semi-discrete scheme. We test the designed method on a number of one- and two-dimensional examples that demonstrate robustness and high resolution of the proposed numerical approach. (Received February 22, 2015)

1110-65-256 **Anthony D LaFleur*** (alafleur@unr.nevada.edu). *A fast characteristic finite difference method for fractional advection-diffusion equations with non-linear reaction.*

Contaminant transport in porous media can be modeled with fractional differential equations. This approach results in early arrival of contaminants and heavy-tail distributions observed in field experiments. The fractional advection-diffusion equation discretized by the implicit finite difference scheme and with the shifted Grunwald approximation is unconditionally stable. We add an additional non-linear, Lipschitz continuous term to account for reactions and we solve the advection-diffusion equation utilizing fast Toeplitz matrix-vector multiplication. We then extend the method to the two-dimensional case. Numerical results are provided to compare performance of the methods proposed. (Received February 23, 2015)

1110-65-266 **Yong Li*** (yakaqi@gmail.com), Mathematics, 301 Thackeray Hall, Pittsburgh, PA 15260, and **Catalin Trenchea** (trenchea@pitt.edu), Mathematics, 301 Thackeray Hall, Pittsburgh, PA 15260. *Partitioned second-order method for magnetohydrodynamics in Elsässer fields.* Preliminary report.

In this address we propose a partitioned, two step, second-order method for magnetohydrodynamics in Els\'{a}sser variables, which treats implicitly the subproblem terms and explicitly the coupling terms. The stability analysis shows that the method is unconditionally stable for the magnetic Prandtl number in the interval (0.5,2). In a large number of laboratory simulations, the magnetic Prandtl number is taken to be unity. The algorithm is shown to be long-time stable, and the finite element error analysis is presented with a numerical test supporting the theory. (Received February 23, 2015)

1110-65-277 **S.C. Brenner** and **J. Gedicke*** (jgedicke@math.lsu.edu), Department of Mathematics, and Center for Computation and Technology, Louisiana State University, Baton Rouge, LA 70803, and **L.-Y. Sung**. *Hodge decomposition for two-dimensional time harmonic Maxwell's equations: impedance boundary condition.*

We extend the Hodge decomposition approach for the cavity problem of two-dimensional time harmonic Maxwell's equations to include the impedance boundary condition, with anisotropic electric permittivity and sign changing magnetic permeability. We derive error estimates for a P_1 finite element method based on the Hodge decomposition approach and present results of numerical experiments that involve metamaterials and electromagnetic cloaking. The well-posedness of the cavity problem when both electric permittivity and magnetic permeability can change sign is also discussed. (Received February 23, 2015)

1110-65-288 **Aziz Takhirov*** (aziz.takhirov@math.tamu.edu), Department of Mathematics, Mail stop 3368, Texas A&M University, College Station, TX 77843-3368. *Fourier Finite Element(FFE) based algorithm for the numerical study of plasma detachment in the plasma propulsion systems.* Preliminary report.

Magneto-plasma devices can achieve very high specific impulse, which makes them suitable for interplanetary space flight missions. However, they can fully function in a vacuum and it is very difficult to test them in ground-based experiments. Therefore, computational analysis is an important part of development for these devices. In this short talk, we discuss ongoing, FFE based approximation to compressible, Hall MHD equation modelling the plasma detachment in the exhaust plume of such devices. (Received February 23, 2015)

1110-65-308 **Tzanio V. Kolev** (kolev1@llnl.gov), P.O. Box 808, L-561, Livermore, CA 94551, **Jinchao Xu** (xu@math.psu.edu), Department of Mathematics, Penn. State University, University Park, PA 16802, and **Yunrong Zhu*** (zhuyunr@isu.edu), 921 S. 8th Ave., Stop 8085, Pocatello, ID 83209-8085. *Multilevel Preconditioners for Reaction-Diffusion Problems with Discontinuous Coefficients.*

We consider multilevel preconditioners for solving the linear systems arising from the linear finite element approximation of the reaction-diffusion problems, where both diffusion and reaction coefficients are piecewise constant functions. We discuss in detail the influence of both the discontinuous reaction and diffusion coefficients to the performance of the classical BPX and multigrid V-cycle preconditioner. (Received February 23, 2015)

1110-65-335 **Jichun Li***, Dept of Mathematical Sciences, University of Nevada, Las Vegas, NV 89154-4020. *mathematical analysis and time-domain finite element simulation of carpet cloak.*

In this talk,we will present the mathematical analysis of a popular carpet cloak proposed recently by physicists. The well-posedness of the model is first proved, then a finite element time-domain (FETD) method is proposed for solving this model. Stability and error analysis are proved for the FETD method. Finally, numerical simulation of the carpet cloak is realized by our FETD method. (Received February 24, 2015)

1110-65-361 **Jeffrey M Connors*** (jeffrey.connors@uconn.edu), University of Connecticut, Department of Mathematics, 196 Auditorium Road, Storrs, CT 06269, and **Jeffrey W Banks** and **Jeffrey A Hittinger**. *Nonlinear Error Transport for ALE Hydrodynamics.*

Arbitrary Lagrangian-Eulerian (ALE) schemes are often used to model large-deformation hydrodynamics. In general, numerical errors are not negligible due to insufficient grid resolution imposed by computational resource limitations. It can be useful to employ a posteriori error estimates to help to undertand the results of ALE simulations. We discuss the application of the nonlinear error transport (NET) method in order to resolve fields of error directly in both the Lagrangian and remapping steps of ALE schemes.

The application of NET to ALE schemes is new and poses interesting challenges. First, we discuss the formulation of the error equations within the Lagrangian reference frame, including both the errors in particle positions and in state values. Then we explain the meaning of remapping error in the context of the overall discretization error budget. Subsequently, the methodology is introduced to discretize the error equations for both the Lagrangian and remapping steps, which requires special consideration of the role of errors in particle positions. Finally, computational examples are discussed.

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68 ► Computer science

1110-68-294 **Michael I Ham*** (mikeh@lanl.gov), MST 080, LANL, Los Alamos, NM 87544. *Exploring Sparse Reconstruction of Single Objects Within Imagery.* Preliminary report.

In computer vision, object detection using sparse representation has proven to be one of the most robust methods for locating and identifying a wide range of object categories. Year after year, detection accuracy is improving in tests like the Image Net Large Scale Visual Recognition Challenge, but some fundamental concepts of image reconstruction through sparse representation have not been fully explored. In this presentation we examine to what degree the same sparse elements are used to represent the entirety of the same object within an image and whether the change in the composition of those representative groups can be used to detect the edges of an object within an image. It is hoped this work can produce insights that increase the accuracy of sparse detection methods. (Received February 23, 2015)

76 ► Fluid mechanics

1110-76-104 **Susan Friedlander***, susanfri@usc.edu, and **Anthony Suen**, acksuen@ied.edu.hk.
Well-posedness results for the viscous MG equation.

We discuss the 3D active scalar equation called the magnetogeostrophic equation which was proposed by Moffatt and Loper as a model for the geodynamo process in the Earth's fluid core. When the fluid viscosity is nonzero the constitutive law that relates the drift velocity and the scalar temperature produces two orders of smoothing. We will describe the consequences of this property . (Received February 13, 2015)

1110-76-165 **Aleksey S Telyakovskiy*** (alekseyt@unr.edu), Department of Mathematics and Statistics, University of Nevada, Reno, NV 89557. *Modeling of groundwater flows with the Boussinesq equation.* Preliminary report.

Groundwater flows in unconfined aquifers are commonly modeled by the Boussinesq equation. This nonlinear diffusion equation relies on the Dupuit assumption of essentially horizontal flows, when the vertical component of the velocity vector is neglected. We analyze the recharge of an initially dry aquifer. In this case solutions to the Boussinesq equation propagate with a finite speed. For certain pumping regimes one can introduce similarity variables and reduce this initial-boundary value problem for partial differential equation to a boundary-value problem for a nonlinear ordinary differential equation. We construct an approximate analytical solution to this problem. (Received February 18, 2015)

1110-76-200 **Jiangguo Liu*** (liu@math.colostate.edu), Department of Mathematics, Colorado State University, Fort Collins, CO 80523. *Application of the Weak Galerkin Finite Element Method to Two-phase Flow Problems.*

Coupled flow and transport problems arise from modeling petroleum reservoir, magma movement in Earth crust, and drug delivery, among other real-world applications. Computer simulations of these problems require accurate and efficient numerical methods for the governing partial differential equations. In this talk, we present new numerical methods for two-phase flow problems that couple the Darcy equation for pressure and a transport equation for saturation in a nonlinear manner. The coupled problem is solved in the framework of operator decomposition. Specifically, the Darcy equation is solved by the weak Galerkin finite element method (WGFEM), whereas the saturation equation is solved by a finite volume method. The numerical velocity obtained from solving the Darcy equation by the WGFEM is locally conservative and has continuous normal components across element interfaces. This ensures accuracy and robustness of the finite volume solver for the saturation equation. Numerical experiments on benchmarks demonstrate that the combined methods can handle very well two-phase flow problems in high-contrast heterogeneous porous media. This is a joint work with Victor Ginting at University of Wyoming and Guang Lin at Purdue University. (Received February 20, 2015)

1110-76-202 **Jiangguo Liu*** (liu@math.colostate.edu), Department of Mathematics, Colorado State University, Fort Collins, CO 80523. *A Comparative Study of Finite Element Methods for Darcy Flow Computation.*

The Darcy equation is a fundamental equation for flow and transport problems in porous media. There exist plenty of finite element methods for solving the Darcy equation: the continuous Galerkin methods, the discontinuous Galerkin methods, the mixed methods, and the newly developed weak Galerkin methods. In this talk, we present a comparative study of these methods on Darcy flow computation, particularly on their scheme formulation, accuracy, properties, and Matlab implementation. It is demonstrated that the weak Galerkin methods are locally conservative by design, produce continuous normal fluxes across element interfaces, need no penalty factors, and result in symmetric positive-definite linear systems that are easier to solve, compared to the saddle-point problems. Moreover, we will show that the novel weak Galerkin methods are somehow equivalent to the classical mixed methods. This talk is based on the joint work with Guang Lin (Purdue), Lin Mu (Michigan State), Farrah Sadre-Marandi (ColoState), and Xiu Ye (UALR). (Received February 20, 2015)

1110-76-297 **Svetlana V. Poroseva*** (poroseva@unm.edu), Department of Mechanical Engineering, University of New Mexico, Albuquerque, NM 87131-0001. *On Validation of High-Order Statistical Closures with DNS Data in Turbulent Boundary Layers.*

Numerical simulations of engineering turbulent flows are usually conducted with first-order statistical closures of the Reynolds-Averaged Navier-Stokes (RANS) equations. However, all turbulence effects are modeled in such closures that has a negative impact on the accuracy of simulation results. To improve the performance of RANS turbulence models, higher-order closures should be considered. Three physical processes – turbulent diffusion, interaction of turbulent pressure and velocity fluctuation fields, and dissipative processes –need to be modeled in high-order closures. In the presentation, the modeling of turbulent diffusion based on the Gram-Charlier series expansions will be discussed. Direct numerical simulation (DNS) data in the boundary layer over a flat plate at different pressure gradients and in the channel flow will be used to validate the Gram-Charlier series expansions as a closing procedure. New linear models for the second- and higher-order velocity/pressure gradient correlations will also be presented. The proposed velocity/pressure-gradient models are applicable to two-dimensional incompressible boundary layers and are based on the analysis of DNS data. (Received February 23, 2015)

1110-76-300 **Eric J Olson*** (ejolson@unr.edu), University of Nevada Reno, Dept of Mathematic, Mail Stop 084, Reno, NV 89557. *Statistical Properties of the Residual Error in Turbulence Models.* Preliminary report.

In the analysis of 3DVAR and 4DVAR data assimilation algorithms it is assumed that model error can be represented by a stochastic forcing term. We compute the actual model error in the LANS-alpha model by plugging in a solution obtained from direct numerical simulation and computing the residual error. Our focus is on how well the statistical properties of this residual error may be characterized by a stochastic force. (Received February 23, 2015)

1110-76-310 **James P Kelliher*** (kelliher@math.ucr.edu) and **Hantaek Bae**. *Conservation of striated regularity for Eulerian velocities.*

That vorticity having Hölder regularity in the direction of a “sufficient” family of vector fields (striated regularity) continues to have such regularity for all time under the evolution of the 2D Euler equations was first shown by Chemin in 1991. A partial extension of this result for short time was made in 3D by Gamblin and Saint Raymond in 1995 and in full generality by Danchin in 1999. These results were all obtained with an extensive use of paradifferential calculus. We describe how both the 2D and 3D results can be obtained following an elementary approach of Ph. Serfati 1994, and how the solutions can be viewed as preserving striated regularity of the velocity rather than of the vorticity. (Received February 23, 2015)

1110-76-371 **Robert Owczarek*** (urzedowe@hughes.net), 59 Coryphodon Ln, Jemez Springs, NM 87025. *Statistical physics of superfluid helium.*

Statistical physics of vortices in superfluid helium as a model of the phase transition will be discussed. (Received February 24, 2015)

1110-76-394 **Anthony Suen**, The Hong Kong Institute of Education, and **Matthias L Youngs*** (youngsml@iupuc.edu), Division of Science, IUPUC, 4601 Central Avenue, Columbus, IN 47203. *A Free Boundary Problem for the Spherically Symmetric Compressible Navier-Stokes Equations.*

From the compressible Navier-Stokes equations, a model is constructed for a symmetric baratropic flow. The support of the density is tracked in positive time. We will discuss the physical significance of the free boundary and the *a priori* estimates involved in this model that rely on fundamental, natural bounds. (Received February 24, 2015)

78 ► Optics, electromagnetic theory

1110-78-68 **Taoufik Meklachi**, **Graeme W Milton**, **Daniel Onofrei**, **Andrew E Thaler*** (andythaler05@gmail.com) and **Gregory Funchess**. *New insights on cloaking due to anomalous localized resonance.*

We present recent results on cloaking due to anomalous localized resonance for general charge density distributions. We prove that the power dissipated in a superlens diverges as certain dissipation parameters in the superlens tend to zero and when certain charge density distributions are located within a critical distance of the superlens. The critical distance strongly depends on the rate at which the dissipation parameters in the materials surrounding the superlens tend to zero. (Received February 09, 2015)

1110-78-237 **Habib Ammari**, **Giulio Ciraolo**, **Hyeonbae Kang**, **Hyundae Lee*** (hdlee@inha.ac.kr) and **Graeme W. Milton**. *Spectral analysis of Neumann-Poincaré-type operator and cloaking due to anomalous localized resonance.*

If a body of dielectric material is coated by a plasmonic structure of negative dielectric constant with nonzero loss parameter, then cloaking by anomalous localized resonance (CALR) may occur as the loss parameter tends to zero. The aim of this paper is to investigate this phenomenon in two and three dimensions when the core, shell and matrix are isotropic materials. The analysis of this paper reveals that occurrence of CALR is determined by the eigenvalue distribution of the Neumann-Poincaré- type operator associated with the structure. (Received February 22, 2015)

81 ► Quantum theory

1110-81-312 **Blake Temple*** (temple@math.ucdavis.edu), Department of Mathematics, University of California, One Shields Drive, Davis, CA 95616-8633, and **J Smoller** and **Z Vogler**. *Applied Mathematics vs Dark Energy.*

The 1999 observations of redshift v luminosity for supernovae in nearby galaxies won the Nobel Prize because it demonstrated that the universe is expanding faster than the Standard Model of Cosmology (SM) allows. The only way to preserve the Cosmological Principle, that on the largest length scale the universe is a Friedmann space-time which holds no special place, is to add the Cosmological Constant to Einstein's equations as a source term. Its interpretation is Dark Energy. A best fit among Friedmann space-times with Dark Energy leads to the conclusion that the universe is a critical Friedmann space-time, with 70% Dark Energy. In this talk I present an alternative explanation based on the discovery of a new asymptotic ansatz for perturbations of SM which create an instability. The instability is triggered by a one parameter family of self-similar perturbations of SM from the Radiation epoch, and creates a large, central region of uniform under-density which expands faster than the SM, and induces precisely the same range of corrections to redshift vs luminosity as are produced by the theory of Dark Energy. The result is a testable mathematical explanation for the anomalous acceleration of the galaxies wholly within Einstein's original theory, without the need for Dark Energy. (Received February 23, 2015)

82 ► Statistical mechanics, structure of matter

1110-82-274 **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** and **Kenneth Millett**. *Writhe and mutual entanglement combine to give the entanglement length.*

We propose a method to estimate N_e, the entanglement length, that incorporates both local and global topological characteristics of chains in a melt under equilibrium conditions. This estimate uses the writhe of the chains, the writhe of the primitive paths and the number of kinks in the chains in a melt. An advantage of this method is that it works for both linear and ring chains, works under all periodic boundary conditions, does not require knowing the contour length of the primitive paths and it does not rely on a smooth set of data. We apply this method to linear finitely extendable non-linear elastic chains and we observe that our estimates are consistent with those from other studies. (Received February 23, 2015)

85 ► Astronomy and astrophysics

1110-85-265 **Chad T. Olinger***, colinger@lanl.gov, and **Carlos Biaou**. *Simulation-Aided Data Analysis to Understand Solar Wind.*

Simulation of solar wind ion implanted into collection materials is improving the interpretation of laboratory measurements from the NASA's Genesis solar wind sample return mission. The mission collected solar wind on some of the cleanest materials ever created; subsequent laboratory measurements were planned to characterize the composition of the returned solar wind. Solar wind composition constrains the elemental and isotopic evolution pathways of solar system materials measured in meteorites. The mission planned to correct laboratory measurements for backscatter loss through simulation. These corrections are developed using the open source software Stopping and Range of Ions in Matter (SRIM-2003, Ziegler 2004). The Genesis spacecraft's "hard landing" resulted in significant collector contamination. Surface contamination elevated the need for ion implantation modeling to also characterize implantation depth profiles to decompose experimental results between implanted ions and surface contamination. Through this synergy between simulation and laboratory measurements, most of the original Genesis goals for improving constraints on the average isotopic and elemental composition of the solar system are being realized. LA-UR-15-21259 (Received February 23, 2015)

86 ► Geophysics

1110-86-44 **Kanadpriya Basu*** (kbasu@utep.edu), 500 West University Avenue, El Paso, TX 79968, and **Maria Christina Mariani** (mcmariani@utep.edu), 500 West University Avenue, El Paso, TX 79968. *Investigation of Statistical Behavior of Very Large Seismic Time Series Data Sets by applying different Stochastic Models.* Preliminary report.

This work is devoted to the study of the ASARCO demolition seismic data. In April 2013 two old smoke stacks leftover by the ASARCO Company were demolished in the City of El Paso. The University of Texas at El Paso deployed a series of vertical-component seismometers in downtown El Paso between 0.5 and 5.5 km from the stacks with the objective to record the seismic waves generated by the demolition. In the present study we use some of the seismograms recorded during the demolition. A seismogram is a time series that records the displacement of the ground caused by passing seismic waves. We applied Levy models, DFA and Hurst methods to study the presence of memory effects in these time series. We conclude that the three models may be used to estimate characteristic parameters of the propagation medium for seismic waves,and that the data presents long range correlations and memory effects. (Received January 28, 2015)

1110-86-269 **Kyle T Mandli*** (kyle.mandli@columbia.edu), 500 W. 120th St, Mudd 200, MC 4701, New York, NY 10027, and **Ihab Sraj**, **Omar M Knio**, **Clint N Dawson** and **Ibrahim Hoteit**. *Uncertainty Quantification and Inference for Tsunami Modeling.* Preliminary report.

Tsunamis in the past decade have been responsible for some of the most deadly and costly natural disasters ever recorded. Coastal communities have faced this hazard by assessing the risk they pose, attempting to make informed decisions about the likelihood that such an event would occur with cost to life and property. To do this, computational models of tsunami events are often employed to explore multiple different scenarios. Unfortunately, since tsunami events are relatively rare, there is an abundance of uncertainty in the input data for these computational models ranging from effects of the domain such as bathymetry and friction parameterizations, to the earthquake source. In this talk we present an approach to quantifying the uncertainty in the friction field and source mechanism and a method to find the best parameterized values of these fields using the Tōhoku tsunami as a case study. (Received February 23, 2015)

91 ► Game theory, economics, social and behavioral sciences

1110-91-7 **Irinel C. Dragan*** (dragan@uta.edu), 411 S.Nedderman Dr., Arlington, TX 76019-0408. *On the coalitional rationality of the Banzhaf Value and other non efficient Semivalues.*

In an earlier work,[1], a new problem for efficient values of TU games was solved by means of the Inverse problem: find out a new game for which the value is coalitional rational, that is belongs to the Core. In the present work, the same problem is solved for Semivalues, for which a definition of coalitional rationality should be introduced. A Semivalue is coalitional rational if it belongs to the Core of the Power Game of a game in the Inverse Set relative to the Semivalue, (this was found in another recent work, [2]). It is shown how such a game may be found and the technique is applied to the Banzhaf Value, itself a Semivalue,for some examples. [1] I.Dragan (2014), On the coalitional rationality of the Shapley Value and other efficient values, AJOR, 4, 4, 228-234; presented at AMS Meeting 2014, Albuquerque, New Mexico. [2] I.Dragan (2005), On the Inverse problem for Semivalues of Cooperative TU games, IJPAM, 4, 545-561. (Received October 11, 2014)

92 ► Biology and other natural sciences

1110-92-52 **Javier Arsuaga*** (jarsuaga@ucdavis.edu), One Shields Avenue (149 Briggs Hall), Davis, CA 95616. *Modelling the topological structure of the mitochondrial DNA in trypanosomes.* Preliminary report.

Trypanosomes are parasites that cause fatal diseases in humans in many developing countries. A distinctive feature of these organisms is the organization of their mitochondrial DNA, also known as Kinetoplast DNA (kDNA) into thousands of minicircles that are topologically linked. Minicircles form a gigantic chainmail like network with each minicircle linked to three other minicircles (i.e. has valence 3); The origin and biological significance of these complex structures remain to be understood.

We hypothesized that volume confinement is the driving force determining the topological structure of kDNA. To test this hypothesis we developed a mathematical model that quantifies the growth of the topological properties of minicircles as a function of their density and size. Our results show that (1) there is a percolation pathway of network formation (2) the probability that a giant minicircle network forms grows as 1- O(exp(aD)) with D the density of minicircles and a>0 (3) the valence of the giant network grows linearly with the density and can be kept at a low value by the local orientation of minicircles. (Received February 05, 2015)

93 ► Systems theory; control

1110-93-20 **Paul A Fuhrmann*** (fuhrmannbgu@gmail.com), Prof. Paul A. Fuhrmann, Department of Mathematics, Ben Gurion University, 84105 Beer Sheva, Israel. *The Beurling-Lax theorem and control of some infinite dimensional systems.* Preliminary report.

The purpose of this paper is to outline a, seemingly new, approach to a wide variety of optimal control problems for linear, causal, time-invariant systems. This approach has the advantages of not being restricted to finite-dimensional systems, and has extensions to optimization problems for various classes of transfer functions, including positive real and bounded real functions. The technique used is based on translation semigroups and their Fourier transforms, invariant subspaces, intertwining maps and realizations based on model operators. In the rational case, the Beurling-Lax theorem is used to derive state space formulas based on solutions to various Riccati equations. (Received December 21, 2014)

94 ► Information and communication, circuits

1110-94-268 **Lixin Shen*** (lshen03@syr.edu), Syracuse, NY 13244. *Wavelet Inpainting with Sparse Regularization.* Preliminary report.

In this talk we proposed a constrained inpainting model to recover an image from its incomplete and/or inaccurate wavelet coefficients. The objective function of the proposed model uses the ℓ_0 norm to promote the sparsity of the resulting image in a tight framelet system. A fixed-point proximity algorithm was developed to solve the model. Our numerical experiments show that the proposed model and the related fixed-point algorithm can recover images with much higher quality in terms of the PSNR values and visual quality of the restored images than the models based on the ℓ_1 norm and the total variation. (Received February 23, 2015)

1110-94-331 **Christopher M Brislawn*** (cbrislawn@yahoo.com), 55 Paseo Encantado NE, Santa Fe, NM 87506. *A Theory of Causal Lifting Factorization for Perfect Reconstruction Filter Banks.* Preliminary report.

Wavelet transforms and perfect reconstruction filter banks share a relationship like that enjoyed by continuous and discrete Fourier transforms. Sweldens' theory of lifting factorization for wavelet transforms was reinterpreted by Daubechies and Sweldens in terms of the polyphase matrix representation of filter banks. The key to such factorizations was the Euclidean algorithm for finding greatest common divisors of the Laurent polynomials in unimodular polyphase matrices. Lifting has subsequently proven to be a powerful tool in applications like the ISO JPEG 2000 image coding standard. Unfortunately, the unimodular theory of lifting represents signal processing algorithms in terms of noncausal structures. The lack of a precise definition allows, e.g., a given perfect reconstruction filter bank to be lifted from any other perfect reconstruction filter bank in infinitely many different ways, almost all of them useless. The author presents recent work on an intrinsically causal approach to lifting factorization, based on commutative ring theory, that produces well-defined, well-behaved "degree-lifting" matrix factorizations. This dispenses with the Euclidean algorithm in favor of techniques based on linear Diophantine equations and a simple generalization of polynomial division. (Received February 24, 2015)

1110-94-406 **Sergey Plis*** (s.m.plis@gmail.com), The Mind Research Network, 1101 Yale Blvd. NE, Albuquerque, NM 87106, and **Jianyu Yang** (zhurisheep@gmail.com) and **David Danks** (ddanks@cmu.edu). *Structure learning from undersampled graphs: the theory and an algorithm.*

Presentation of the theory and an algorithm for structure learning= from undersampled graphs. (Received March 02, 2015)

97 ► Mathematics education

1110-97-205 **Treena Basu*** (basu@oxy.edu), 1600 Campus Road, Los Angeles, CA 90041, and
Lokenath Debnath (debnathl@utpa.edu), 1201 W University Drive, Edinburg, TX 78539.
A Short History of Statistics. Preliminary report.

This paper deals with a short history of statistics and its applications. Included are mean, median, mode, midrange, errors of observations, Bernoulli's law of large numbers, principle of least squares, standard deviation and variance of data. Special attention is given to Gauss' derivation of the method of least squares with the formula for the variance of the continuous probability distribution. Fisher's celebrated maximum likelihood method for estimation of parameters is presented with examples of the unknown parameters in binomial, Poisson, and normal distributions. This is followed by a brief historical introduction to regression and correlation with regression curves,correlation coeffcients and their properties. Some examples of applications are mentioned. Included is also some modern information that puts students, teachers, and statisticians at the forefront of current advanced studyand research in analytical and computational aspects of statistics. (Received February 20, 2015)

2010 MATHEMATICS SUBJECT CLASSIFICATION

Compiled in the Editorial Offices of MATHEMATICAL REVIEWS and ZENTRALBLATT MATH

00 General
01 History and biography
03 Mathematical logic and foundations
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General algebraic systems
11 Number theory
12 Field theory and polynomials
13 Commutative rings and algebras
14 Algebraic geometry
15 Linear and multilinear algebra; matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory; homological algebra
19 *K*-theory
20 Group theory and generalizations
22 Topological groups, Lie groups
26 Real functions
28 Measure and integration
30 Functions of a complex variable
31 Potential theory
32 Several complex variables and analytic spaces
33 Special functions
34 Ordinary differential equations
35 Partial differential equations
37 Dynamical systems and ergodic theory
39 Difference and functional equations
40 Sequences, series, summability
41 Approximations and expansions
42 Fourier analysis
43 Abstract harmonic analysis
44 Integral transforms, operational calculus
45 Integral equations
46 Functional analysis
47 Operator theory
49 Calculus of variations and optimal control; optimization
51 Geometry
52 Convex and discrete geometry
53 Differential geometry
54 General topology
55 Algebraic topology
57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
65 Numerical analysis
68 Computer science
70 Mechanics of particles and systems
74 Mechanics of deformable solids
76 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
85 Astronomy and astrophysics
86 Geophysics
90 Operations research, mathematical programming
91 Game theory, economics, social and behavioral sciences
92 Biology and other natural sciences
93 Systems theory; control
94 Information and communication, circuits
97 Mathematics education

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