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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
1059	April 17–18, 2010	Albuquerque, NM	February 23	Vol 31, No. 3
1060	May 22–23, 2010	Newark, NJ	March 30	Vol 31, No. 3
1061	June 2–4, 2010	Berkeley, CA	April 13	Vol 31, No. 3
1062	October 2–3, 2010	Syracuse, NY	August 10	Vol 31, No. 4
1063	October 9–10, 2010	Los Angeles, CA	August 17	Vol 31, No. 4
1064	November 5–7, 2010	Notre Dame, IN	September 14	Vol 31, No. 4
1065	November 6–7, 2010	Richmond, VA	September 14	Vol 31, No. 4
1066	December 15–18, 2010	Pucon, Chile	TBA	TBA
1067	January 5–8, 2011	New Orleans, LA	September 22	Vol 32, No. 1
1068	March 12–13, 2011	Statesboro, GA	TBA	TBA
1069	March 18–20, 2011	Iowa City, IA	January 25	TBA
1071	April 30–May 1, 2011	Las Vegas, NV	March 8	TBA
1074	October 14–16, 2011	Lincoln, NE	August 23	TBA
1075	October 22–23, 2011	Salt Lake City, UT	August 30	TBA

LEXINGTON, KY, March 27–28, 2010

Abstracts of the 1057th Meeting.

00 ► General

1057-00-441 **Paola Sztahn*** (paola_sztajn@ncsu.edu), Elementary Education Department, 317 J Poe Hall, North Carolina State University, Raleigh, NC 27695-7801. *Perspectives on Mathematics Outreach - Elementary Mathematics.* Preliminary report.

We will discuss opportunities and examples of outreach to and with elementary teachers and schools. (Received January 26, 2010)

1057-00-444 **M. Kathleen Heid*** (mkh2@email.psu.edu), Department of Curriculum and Instruction, Penn State University, University Park, PA 16802. *Developing a Framework for the Mathematical Knowledge for Teaching Secondary Mathematics.*

We will discuss our work in developing a framework for the Mathematical Knowledge for Teaching Secondary Mathematics. This is a practice-based attempt to think about the ways that a secondary teacher needs to understand mathematics. We see this work as important to the dialogue between mathematicians and mathematics educators regarding how teachers could draw on their mathematical knowledge in the course of their practice. (Received January 26, 2010)

1057-00-453 **Marshall Williams*** (mcwill@uic.edu). *Geometric and analytic quasiconformality in metric measure spaces.*

In this talk, we will discuss the equivalence between the analytic definition and a one-sided geometric definition of quasiconformality for homeomorphisms between metric measure spaces. Our results partially generalized what is already known for two extreme cases, where the domain has either many rectifiable curves (the Loewner condition) or no rectifiable curves (the trivial case). (Received January 26, 2010)

03 ► Mathematical logic and foundations

1057-03-55 **Takashi Gyoshin Nitta*** (nitta@edu.mie-u.ac.jp), Kurimamachiya 1577, Tsu, Mie 514-8507, Japan, **Ives Peraire**, Aubere, 62177 Clermomd-Ferrond, France, and **Dapeng Cai**, Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8601. *Divergent Fourier Analysis Using Degrees Of Observality and Solving Undiscounted Infinite Horizon Optimization.*

(1)The aim of this work is to generalize the methods of Fourier Analysis in order to apply them to a wide class of possibly non integrable functions, with infinitely many variables. The method consists in distinguishing several levels of observability, with a natural meaning. Mathematical coherence is ensured by the fact that these natural concepts are represented within a sure mathematical framework, that of the relative set theory . This work is also a step for an other approach of the Fourier transform of functionnals. It can be related to the one, which use double extensions of standard real numbers, performed by T. Nitta and T.Okada. (2)Undiscounted infinite horizon optimization problems are intrinsically difficult because (i) the objective functional may not converge; (ii) boundary conditions at the infinite terminal time cannot be rigorously expressed in the real number field. We demonstrate that under a hyper-real terminal time, there exists a unique optimal solution in the hyper-real number field. We show that under fairly general conditions, the standard part of the hyper-real optimal path is the optimum among all feasible paths in the standard real number field, in the sense of two modified overtaking criteria. (Received December 25, 2009)

1057-03-330 **Stephen G Simpson*** (simpson@math.psu.edu), Department of Mathematics, McAllister Building, Pollock Road, Pennsylvania State University, State College, PA 16802. *The Reverse Mathematics of General Topology.*

In reverse mathematics, specific mathematical theorems are classified up to logical equivalence over a weak base theory, according to the strength of the set-existence axioms which are needed to prove them. An empirical phenomenon confirmed by many case studies is that many theorems fall into one of the "big five" equivalence classes: RCA_0, WKL_0, ACA_0, ATR_0, Π^1_1-CA_0. However, Mummert and Simpson have found that a certain metrization theorem in general topology falls into an equivalence class Π^1_2-CA_0 which is much, much stronger than any of the big five. For any countable partially ordered set P, let MF(P) be the space of maximal filters on P. This class of spaces is known to include all complete separable metric spaces as well as many nonmetrizable spaces. The metrization theorem in question states that MF(P) is completely metrizable if and only if it is regular. (Received January 25, 2010)

1057-03-448 **Jana Marikova*** (J-Marikova@wiu.edu). *Valuations on o-minimal fields.*

The prototypical example of an o-minimal structure is formed by the semialgebraic sets. In the 1980's, van den Dries observed that many properties of semialgebraic sets follow from a few axioms. Since then the investigation of o-minimal structures, i.e. structures satisfying these axioms, has been a flourishing subject, with many applications to other areas of mathematics. Here we shall focus on o-minimal expansions of fields and their valuations. In particular, we show that whenever R is an o-minimal expansion of a field and V a proper convex subring then the o-minimality of the corresponding residue field with structure induced from R via the residue map is equivalent to (R,V) satisfying a first order axiom scheme. (Received January 26, 2010)

05 ► Combinatorics

1057-05-6 **Doron Zeilberger*** (zeilberg@math.rutgers.edu), Department of Mathematics, Rutgers University, 110 Frelinghuysen Rd, Piscataway, NJ 08854-8019. *3x+1.*

Paul Erdős once said that mathematics is not yet ready to tackle the notorious Collatz $3x+1$ problem, and he was probably right, as far as purely human attempts are concerned. But I believe that a creative collaboration with machinekind may increase the chance of a proof from epsilon squared to epsilon, and even if we don't find a proof, trying it out should be fun. (Received July 22, 2009)

1057-05-18 **Eran Nevo*** (en87@cornell.edu). *Title: Face enumeration: from spheres to flag spheres.*

Two well known conjectures in f-vector theory are the following: 1. McMullen's generalized lower bound conjecture: the g-vector of a (homology-) sphere is nonnegative. 2. Gal's conjecute: the gamma-vector of a flag (homology-) sphere in nonnegative.

By introducing new "g-vectors", we will present new conjectured lower bounds on face-vectors of spheres with bounded dimension of minimal non-faces. These interpolate between conjectures 1 & 2 above.

Further conjecture and results joint with Kyle Petersen, on upper bounds on face numbers of flag spheres, will be presented. (Received January 20, 2010)

1057-05-22 **Joseph E. Bonin*** (jbonin@gwu.edu), Department of Mathematics, The George Washington University, Washington, DC 20052. *A Construction of Infinite Sets of Intertwines for Pairs of Matroids.*

An intertwine of a pair of matroids is a matroid such that it, but none of its proper minors, has minors that are isomorphic to each matroid in the pair. One motivation for studying intertwines is their role in problems concerning the excluded minors for the union of two minor-closed classes of matroids. Brylawski, Robertson, and Welsh independently asked whether two matroids can have infinitely many intertwines. This problem was settled in the affirmative in unpublished work by Vertigan in the mid-1990's. We give a new construction of infinite sets of intertwines for a broad class of pairs of matroids. We also treat some of the properties of these intertwines. Several open problems will be posed. (Received November 29, 2009)

1057-05-37 **Aaron Lauve*** (lauve@math.tamu.edu), Department of Mathematics, Texas A&M University, MailStop 3368, College Station, TX 77843-3368, and **Sarah K Mason** (sarahkmason@gmail.com). *QSym over Sym has a stable basis.*

We prove that the subset of quasisymmetric polynomials conjectured by Bergeron and Reutenauer to be a basis for the coinvariant space of quasisymmetric polynomials is indeed a basis. This provides the first constructive proof of the Garsia–Wallach result stating that quasisymmetric polynomials form a free module over symmetric polynomials and that the dimension of this module is $n!$. (Received December 09, 2009)

1057-05-40 **Anton Dochtermann***, anton.dochtermann@gmail.com, and **Alex Engstrom**. *Cellular resolutions of hypergraph edge ideals.*

Given an ideal I in the polynomial ring $S = k[x_1, ..., x_n]$, a basic problem in commutative algebra is to describe a (minimal) free resolution of I. One particularly geometric method is through the construction of a 'cellular resolution', where the syzygies of I are encoded by the faces of a polyhedral (or more generally CW) complex. For a (hyper)graph G on n vertices, the edge ideal I_G is defined to be the monomial ideal in S generated by the edges of G. We show how certain 'mixed subdivisions' of dilated simplices naturally support minimal cellular resolutions of the edge ideals of complete graphs, and then consider labeled subcomplexes to obtain resolutions of edge ideals of a large class of hypergraphs. In particular we obtain explicit cellular resolutions of the edge ideals of (complements of) 'interval' graphs, generalizing results of Nagel and Reiner. (Received December 10, 2009)

1057-05-72 **Ionut Ciocan-Fontanine** and **Matjaz Konvalinka*** (matjaz.konvalinka@vanderbilt.edu), 1326 Stevenson Center, Nashville, TN 37240, and **Igor Pak**. *Weighted branching formulas for the hook lengths.*

The famous hook-length formula is a simple consequence of the branching rule for the hook lengths. While the Greene-Nijenhuis-Wilf probabilistic proof is the most famous proof of the rule, it is not completely combinatorial, and a simple bijection was an open problem for a long time. In this talk, we will see an elegant bijective argument that proves a stronger, weighted analogue of the branching rule. Variants of the bijection prove seven other interesting formulas. Another important approach to the formulas is via weighted hook walks; some results in this area will also be discussed. (Received January 05, 2010)

1057-05-74 **Joanna Ellis-Monaghan** (jellis-monaghan@smcvt.edu), Dept. of Mathematics, St. Michael's College, Colchester, VT 05439, and **Thomas Zaslavsky*** (zaslav@math.binghamton.edu), Dept. of Mathematical Sciences, Binghamton University (SUNY), Binghamton, NY 13902-6000. *Tutte functions of matroids.* Preliminary report.

A *Tutte function* of matroids is a function $F : \mathcal{M} \to L$, from an arbitrary minor-closed class $\mathcal{M}$ of matroids to a module L over a commutative ring B, that satisfies the *parametrized deletion-contraction law* $F(M) = \gamma_e F(M\backslash e) + \delta_e F(M/e)$ for every matroid $M \in \mathcal{M}$ and every point e in M that is neither a loop nor a coloop. Here γ_e and δ_e are arbitrary but fixed values in B. F is *multiplicative* if L is a commutative B-algebra and F also satisfies $F(M_1 \oplus M_2) = F(M_1)F(M_2)$. We are classifying all Tutte functions, following up previous work of Zaslavsky (1992) and Ellis-Monaghan–Traldi (2006) on multiplicative Tutte functions on relatively "large" classes $\mathcal{M}$ of matroids, and Bollobás and Riordan (1999) on slightly restricted Tutte functions of graphic matroids with relatively "large" domain $\mathcal{M}$. (Received January 06, 2010)

1057-05-75 **Thomas Zaslavsky*** (zaslav@math.binghamton.edu), Dept. of Mathematical Sciences, Binghamton University (SUNY), Binghamton, NY 13902-6000. *Signed graphs, lattice points, and social psychology.*

Some people like, dislike, or are indifferent to some objects. Construct a signed bipartite graph Σ with vertex sets U for persons and W for objects and edges labelled $+$ for liking and $-$ for disliking. Theories in social psychology due to Abelson & Rosenberg (1958) and to Mrvar & Doreian (2009) say there is stress measured by partitioning the people and objects.

(A&R) Partition $U \cup W$ into two sets; count negative edges within a set and positive edges between sets; minimize over all bipartitions. This *frustration index* l measures stress.

(M&D) Partition U and W into k_U sets U_i and k_W sets W_j. Count the U_iW_j-edges of the minority sign amongst all U_iW_j-edges; sum over i, j; minimize over all partition pairs. This (k_U, k_W)-*biclusterability index* $Q(k_U, k_W)$ measures stress.

How do these indices compare? The critical value is $Q(2, 2)$, because $Q \geq l$ if $k_U = 1$ or $k_W = 1$, while $Q \leq l$ if $k_U, k_W \geq 2$. When Σ is $K_{2,n}$ with signs, the comparison of Q with l reduces to counting lattice points in the standard simplex in $\mathbb{R}^4$. This extends to an asymptotic treatment of general signed graphs. (Received January 07, 2010)

1057-05-77 **Gary Gordon*** (gordong@lafayette.edu), Math Dept, Lafayette College, Easton, PA 18042. *Matroids and root systems.*

We survey some recent work on the matroids derived from root systems considered as collections of vectors in $\mathbb{R}^n$. We concentrate on one specific matroid: The vector matroid corresponding to the 600 cell. The corresponding matroid has rank 4, and the high degree of symmetry displayed by the vectors gives rise to some very symmetric flat incidence data in the matroid. We also compute the symmetry group of the matroid. This is joint work with the Lafayette College REU team from the summer of 2009. (Received January 07, 2010)

1057-05-78 **Dillon Mayhew*** (dillon.mayhew@msor.vuw.ac.nz), Wellington, New Zealand, **Geoff Whittle**, Wellington, New Zealand, and **Stefan van Zwam**, Waterloo, Canada. *Obstacles to matroid decomposition theorems.*

A decade ago, Whittle introduced some fundamental classes of ternary matroids, including those of near-regular and sixth-root-of-unity matroids. Whereas a matroid is regular if and only if it is representable over GF(2) and GF(3), a matroid is near-regular if and only if it is representable over GF(3), GF(4), and GF(5), and is sixth-root-of-unity if and only if it is representable over GF(3) and GF(4).

Seymour's decomposition theorem splits every regular matroid into components that are graphic, cographic, or isomorphic to R_{10}, using 1-, 2-, and 3-sums. One would hope that similar results might hold for Whittle's classes. Indeed, it was conjectured that near-regular matroids can be decomposed into components that are signed-graphic, co-signed-graphic, or isomorphic to one of a finite number of sporadic matroids, using 1-, 2-, and 3-sums. It was also though that every 3-connected matroid that is sixth-root-of-unity without being near-regular can be decomposed into regular components and a copy of $\mathrm{AG}(2, 3)\backslash e$, using 3-sums.

In this rather upsetting talk, we show that these beliefs are false, and point the way to some results that may be somewhat more true. (Received January 07, 2010)

1057-05-83 **Jeremy Aikin*** (jeremy.aikin@maconstate.edu), **Carolyn Chun**, **Rhiannon Hall** and **Dillon Mayhew**. *Cyclically sequential internally 4-connected binary matroids.*

We give a characterization for internally 4-connected binary matroids with the property that their ground set can be cyclically ordered so that any consecutive collection of elements in this cyclic ordering is 4-separating. (Received January 15, 2010)

1057-05-85 **Geoffrey P Whittle*** (geoff.whittle@vuw.ac.nz), PO Box 600, Wellington, New Zealand, and **Jim Geelen** and **Bert Gerards**. *Binary matroid minors.*

In this talk I will attempt to give a global perspective on work with Jim Geelen and Bert Gerards on binary matroid minors. (Received January 09, 2010)

1057-05-88 **Alexander Yong***, 1409 W. Green Street, Urbana, IL 61801, and **Li Li** (llpku@uiuc.edu), 1409 W. Green Street, Urbana, IL 61801. *Some Gröbner degenerations of Kazhdan-Lusztig ideals and multiplicities of Schubert varieties.*

We study Hilbert-Samuel multiplicity for points of Schubert varieties in the complete flag variety, by Gröbner degenerations of the Kazhdan-Lusztig ideal. In the covexillary case, we give a positive combinatorial rule for multiplicity by establishing (with a Gröbner basis) a reduced and equidimensional limit whose Stanley-Reisner simplicial complex is homeomorphic to a shellable ball or sphere. We show that multiplicity counts the number

of facets of this complex. In particular, our result gives a multiplicity rule for Grassmannian Schubert varieties, providing alternative statements and proofs to formulae of [Lakshmibai-Weyman '90], [Rosenthal-Zelevinsky '01], [Krattenthaler '01], [Kreiman-Lakshmibai '04], [Woo-Yong '09] and others. We suggest extensions of our methodology to the general case. (Received January 10, 2010)

1057-05-95 **Kurt W. Luoto*** (kwluoto@math.ubc.ca), University of British Columbia, Department of Mathematics, 1984 Mathematics Road, Vancouver, BC V6T 1Z2, Canada. *Quasisymmetric and noncommutative Schur functions.*

In recent work, Haglund, Mason, van Willigenburg, and this author introduced a family of quasisymmetric functions which we call quasisymmetric Schur (QS) functions. These naturally refine the (symmetric) Schur functions and form a Z-basis of QSym, the quasisymmetric function algebra. We showed that this basis has interesting properties such as a Littlewood-Richardson rule for the product of a symmetric Schur with a QS function.

We extend the definition of QS functions to skew QS functions, which are counterparts to the classical skew Schur functions. Intimately related to these are the duals of the QS functions, which form a Z-basis of NSym, the graded Hopf algebra which is dual to QSym. The dual QS functions are noncommutative analogs of the classical Schur functions, having analogous properties such as a Littlewood-Richardson rule and relationship to a poset of compositions which is analogous to Young's lattice of partitions. We discuss how the dual QS functions arise in the study of the Poirier-Reutenauer tableaux algebra, known in some circles as FSym, the algebra of free symmetric functions.

This is joint work with Christine Bessenrodt and Stephanie van Willigenburg. (Received January 13, 2010)

1057-05-98 **Tom A. Enkosky*** (tenkosky@math.ku.edu). *Slope Varieties and Series Parallel Networks.* Preliminary report.

The slope variety of a graph G is an algebraic variety whose points are slope configurations of drawings of G in the plane. We consider the variety for the complete graph on n vertices over the field of size 2. We show that the number of points in this variety equals the number of series parallel networks with n labeled edges. (Received January 13, 2010)

1057-05-107 **Xiangqian ZHOU*** (xiangqian.zhou@wright.edu), Dept of Math and Stat, Wright State University, 3640 Col. Glenn Hwy, Dayton, OH 45434. *On clones in GF(q)-representable matroids.*

Two elements of a matroid are clones if the map that interchanges the two elements and fixes all other elements is an automorphism of the matroid. In this talk, we present some recent results that relate clones and matroid representability over a finite field. (Received January 14, 2010)

1057-05-138 **Catherine Yan*** (cyan@math.tamu.edu), Department of Mathematics, Texas A&M University, MS 3368, College Station, TX 77843-3368, and **William Chen**, **Andrew Wang** and **Alina Zhao**. *Mixed Statistics on* 01*-Fillings of Moon Polyominoes.*

We establish a stronger symmetry between the numbers of northeast and southeast chains in the context of 01-fillings of moon polyominoes. We introduce four pairs of mixed statistics on 01-filings of moon polyominoes, each of them being a combination of northeast and southeast chains with respect to a bipartition of rows or columns of the moon polyomino. We show that they share the same symmetric distribution as (ne, se), the numbers of northeast chains and southeast chains, respectively. (Received January 19, 2010)

1057-05-150 **Rudi Pendavingh** (rudi@win.tue.nl), Technische Universiteit Eindhoven, Postbus 513, 5600MB Eindhoven, Netherlands, and **Stefan van Zwam*** (Stefan.van.Zwam@cwi.nl), Combinatorics and Optimization, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada. *Representing some non-representable matroids.* Preliminary report.

Most research on representable matroids has focused on matroids representable over a (commutative) field. In particular, in 1996 Semple and Whittle introduced *partial fields* to study matroids that can be represented over several distinct fields. An important result here is Whittle's classification of the representations of ternary matroids.

In this talk we introduce *skew partial fields*. These generalize partial fields by dropping the requirement that multiplication is commutative. The construction of matroid representations over commutative partial fields relies heavily on determinants, for which there is no straightforward generalization to the noncommutative case. To get around this, we will fall back on the way Tutte treated matroid representation, namely by something he called a *chain group*.

One feature of partial fields is that, whenever a matroid is representable over a partial field, it is also representable over a field. Not so for skew partial fields: we will construct a matroid that is representable over a skew partial field but not over any skew field! Hence skew partial fields provide a proper extension of the notion of representability, while preserving most traditional properties. (Received January 19, 2010)

1057-05-151 **Sandra Kingan*** (skingan@brooklyn.cuny.edu), Department of Mathematics, Brooklyn College, City University of New York, 2900 Bedford Avenue, Brooklyn, NY 11210. *Inequivalence in Representable Matroids. Preliminary Report.* Preliminary report.

The study of matroids representable over finite fields is complicated by the presence of inequivalent representations. Two F-representations of a matroid are algebraically equivalent if one can be obtained from the other by elementary row operations, column scaling, and field automorphisms. If we don't allow field automorphisms, then we say the representations are projectively equivalent. We introduce another type of equivalence where we allow column permutations and relate it to geometric properties of the matroid. (Received January 19, 2010)

1057-05-154 **Rhiannon Hall*** (rhiannon.hall@brunel.ac.uk), Mathematics Department, Brunel University, Uxbridge, Middlesex UB83PH, England, and **Jeremy Aikin** (jeremy.aikin@maconstate.edu), **Carolyn Chun** (Carolyn.Chun@msor.vuw.ac.nz) and **Dillon Mayhew** (Dillon.Mayhew@msor.vuw.ac.nz). *Fan-like 4-separating structures in binary matroids.*

In 3-connected matroids, the relationship between fans and wheels and whirls is well understood, as are the highly symmetrical structures involved. We consider an analogous question for **internally 4-connected binary matroids**. If such a matroid has an exactly 4-separating "fan-like" set of elements X that can be ordered $(x_1, \ldots, x_k)$ such that for all $1 \leq i \leq j \leq k$, $\{x_i, x_{i+1}, \ldots, x_j\}$ is 4-separating, then what structures might X have? We begin by considering those "wheel-like" matroids whose groundset has a cyclic ordering $(x_0, \ldots, x_{n-1})$ such that for all $0 \leq i, j \leq n-1$ the set $\{x_i, x_{i+1}, \ldots, x_{i+j}\}$ is 4-separating (all subscripts are read modulo n). We then think about the structures when only part of the matroid in question, a "fan-like" part, has this property. Just as the wheels, whirls and fans have nice symmetric structures, we find that for internally 4-connected binary matroids, the cyclically sequential matroids and the fan-like structures have aesthetically pleasing, symmetrical structures. (Received January 20, 2010)

1057-05-155 **Mathias Drton** and **Caroline J Klivans*** (cjk@math.uchicago.edu), 1100 E. 58th St., Chicago, IL 60637, and **Ed Swartz**. *A Geometric Interpretation of the Characteristic Polynomial of a Hyperplane Arrangement.*

We consider projections of points in R^n onto chambers of real linear hyperplane arrangements. We show that the coefficients of the characteristic polynomial are proportional to the average spherical volumes of the sets of points that are projected onto faces of a given dimension. As a corollary we obtain that for real finite reflection arrangements the coefficients of the characteristic polynomial precisely give the spherical volumes of points projected onto faces of a fixed dimension of the fundamental chamber. The connection between projection volumes and the characteristic polynomial is established by considering angle sums of the associated zonotope.

This talk reflects joint work with Mathias Drton and Ed Swartz. (Received January 20, 2010)

1057-05-167 **Lucas J. Rusnak*** (rusnak@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902. *Oriented Incidence and a Generalization of Hypergraphs.*

I will introduce an incidence-based orientation scheme for hypergraphs that combinatorially model {0, +1, -1}-matrices. Topics discussed will include the introduction of new hypergraphic structures and operations, the decomposition of oriented hypergraphs into three families of varying degrees of "balance", and their relevance to the classification of the circuits of {0, +1, -1}-matrices. Additionally I will discuss extensions of the theory related to circuit classifications of representable matroids. (Received January 20, 2010)

1057-05-177 **Gábor Hetyei*** (ghetyei@uncc.edu), Department of Mathematics and Statictics, University of North Carolina at Charlotte, Charlotte, NC 28223-0001. *Tridiagonal operators and Viennot's combinatorial theory of orthogonal polynomials.*

In their recent work on modeling a quantum oscillator, Sukumar and Hodges observed that the matrix entries in powers of certain operators in a representation of the Lie algebra $su(1,1)$ have a combinatorial interpretation. We will show that Viennot's combinatorial theory of orthogonal polynomials may be used to generalize these results. Our approach links the questions raised by Sukumar and Hodges to finding the moments and inverse polynomial coefficients of certain Laguerre polynomials and Meixner polynomials of the second kind. As an immediate consequence of results by Koelink, Groenevelt and Van Der Jeugt, for the same operators, substitutions into

essentially the same Laguerre polynomials and Meixner polynomials of the second kind may be used to express their eigenvectors. Using Viennot's theory we will explain and generalize this "coincidence". (Received January 21, 2010)

1057-05-200 **David W. Cook II*** (dcook@ms.uky.edu), Department of Mathematics, University of Kentucky, 715 Patterson Office Tower, Lexington, KY 40504. *Clique-whiskered graphs and face vectors.* Preliminary report.

The concept of whiskering a graph at every vertex in order to produce a Cohen-Macaulay graph was introduced by Villarreal. This result was strengthened to show that a fully whiskered graph is vertex-decomposable and pure by Doctermann and Engström.

We introduce a generalisation of whiskering which we call *clique-whiskering*. We show that a fully clique-whiskered graph is vertex-decomposable and has a surprising relation between its h-vector and the face vector of the independence complex of the base graph. (Received January 22, 2010)

1057-05-203 **Eric L Clark*** (eclark@ms.uky.edu), 715 Patterson Office Tower, Department of Mathematics, University of Kentucky, Lexington, KY 40506-0027, and **Richard Ehrenborg**. *The Frobenius Poset.*

Motivated by the classical Frobenius problem, we introduce the Frobenius poset on the integers, that is, for a sub-semigroup Λ of the non-negative integers, we define the order by $n \leq_\Lambda m$ if $m - n \in \Lambda$. When Λ is generated by two relatively prime integers, we show that the order complex of an interval in the Frobenius poset is either contractible or homotopy equivalent to a sphere. We also show that when Λ is generated by the arithmetic sequence $\{a, a+d, a+2d, \ldots, a+(a-1)d\}$ where a and d are relatively prime, the order complex is homotopy equivalent to a wedge of spheres. (Received January 22, 2010)

1057-05-208 **Loni Delaplane*** (ldelapla@bsc.edu) and **Haidong Wu**. *Bounding Coefficients of Characteristic Polynomials of Binary Matroids.*

The *characteristic polynomial* of a matroid M with ground set E is defined as

$$\chi(M, x) = \sum_{X \subseteq E} (-1)^{|X|} x^{r(M)-r(X)}.$$

For a graphic matroid, $M(G)$, the characteristic polynomial is related to $P_G(x)$, the chromatic polynomial of the graph G, by the equation

$$P_G(x) = x^{\omega(G)} \chi(M(G), x)$$

where $\omega(G)$ is the number of components of G. We give several upper and lower bounds on the coefficients of the characteristic polynomial of a binary matroid. This generalizes the corresponding bounds for graphic matroids of Li and Tian, as well as Björner's bound for binary matroids. It also gives new bounds on the coefficients of the flow polynomial of a graph. (Received January 22, 2010)

1057-05-220 **Rigoberto Florez*** (florezr@uscsumter.edu), 200 Miller Rd., University of South Carolina Sumter, Room: 140 Schwartz Building, Sumter, SC 29150. *A construction of a projective rectangle in a full algebraic matroid.* Preliminary report.

A projective rectangle is a generalization of a projective plane, where not every two lines intercept. In this talk we define a projective rectangle. We discuss how to construct a projective rectangle in a full algebraic matroid. (Received January 23, 2010)

1057-05-221 **Thomas Lam** and **Pavlo Pylyavskyy*** (pavlo@umich.edu). *Total positivity in loop groups: Chevalley generators.*

We study infinite products of Chevalley generators in the formal loop group. I will describe the formalism of infinite sequences of braid moves, called a braid limit. I will explain what are the equivalence classes of infinite reduced words, and how a partial order on them called the limit weak order arises. (Received January 23, 2010)

1057-05-222 **Andrew D Frohmader*** (adf2@cornell.edu), 190 Pleasant Grove Rd Apt D2, Ithaca, NY 14850. *Flag f-vectors of colored complexes.*

One can construct a simplicial complex on a set of colored vertices with the restriction that no two vertices of the same color can be in the same face. The flag f-numbers of the complex are the numbers of faces whose vertices are precisely a given color set, e.g., edges with exactly one red vertex and one blue vertex. It then makes sense to ask what possible collections of flag f-numbers a complex could have. More than twenty years ago, it was shown that three other characterization problems are equivalent to this one, but none of the problems have a known solution. We explain why this problem cannot have a "nice" solution of a certain type analogous

to known solutions of some similar problems, and then give a solution to the case of three colors. (Received January 23, 2010)

1057-05-240 **Carolyn Chun** (Carolyn.Chun@msor.vuw.ac.nz), **Dillon Mayhew** (dillon.mayhew@msor.vuw.ac.nz) and **James Oxley*** (oxley@math.LSU.edu). *A Chain Theorem for Internally* 4*-connected Binary Matroids.*

When M is 3-connected matroid, Tutte's Wheels-and-Whirls Theorem proves that M has a 3-connected proper minor N with $|E(M) - E(N)| = 1$ unless M is a wheel or a whirl. This talk will discuss a corresponding result for internally 4-connected binary matroids. (Received January 24, 2010)

1057-05-253 **Ed Swartz*** (ebs22@cornell.edu), Malott Hall, Ithaca, NY 14853. *f-vectors, descent sets and the weak order.* Preliminary report.

In the last few years Chari's convex ear decomposition has been applied to several apparently unrelated order complexes of posets to derive new insight into their f-vectors. An unexpected consequence of these investigations is that their flag f-vectors are closely related to a specific interaction between descent sets and the weak order of finite Coxeter groups. The goal of this talk is to explain how face enumeration on these posets and other complexes naturally leads to a zoo of open problems involving descent sets and the weak order. (Received January 24, 2010)

1057-05-281 **Talmage James Reid*** (mmreid@gmail.com), Hume 314, University, MS 38677, and **Joshua Adam Gray** (jagray@olemiss.edu), Hume 305, University, MS 38677. *Matroids and k-arcs in Projective Geometries.*

This talk discusses the relationship between certain well-known substructures of projective space called k-arcs and clone-sets in matroids. Let $d, k \in \mathbb{Z}^+$ and q be a prime power. A k-arc of $PG(d, q)$ is a subset S such that $PG(d, q)|S \cong U_{d+1,k}$. A pair of elements in a matroid are clones if the map that interchanges the two elements and fixes all other elements is an automorphism. For representable matroids, we relate these two substructures by using a result of Reid and Zhou. This research is joint with J. A. Gray. (Received January 25, 2010)

1057-05-302 **Mike Newman*** (mnewman@uottawa.ca), Department of Mathematics and Statistics, 585 King Edward, Ottawa, Ontario K1N 6N5, Canada. *Random Matroids.* Preliminary report.

We consider the properties of a 'random' matroid, that is, a matroid chosen uniformly at random from the set of n-element matroids. Much is obvious about this object, but very little is actually known. For instance, it is known that asymptotically at least half of all n-elements matroids are connected. We describe some of our progress as well as what we hope to achieve. This is joint work with Dillon Mayhew, Dominic Welsh and Geoff Whittle. (Received January 25, 2010)

1057-05-325 **Jesus De Loera** and **David Haws*** (dchaws@gmail.com), UNIVERSITY OF KENTUCKY, Department of Statistics, 817 PATTERSON OFFICE TOWER, Lexington, KY 40506-0027, and **Jon Lee** and **Allison O'Hair**. *Computation in Multicriteria Matroid Optimization.*

Optimizing over a matroid has applications to experimental design, data mining (minimal variance clustering), and the problem of finding minimum norm spanning trees. Motivated by recent work on algorithmic theory for nonlinear and multicriteria matroid optimization, we have developed algorithms and heuristics aimed at practical solutions of large instances of some of these difficult problems. Our methods primarily use the local adjacency structure inherent in matroid polytopes to pivot to feasible solutions which may or may not be optimal. We also present a modified breadth-first-search heuristic that uses adjacency to enumerate a subset of feasible solutions. We present other heuristics, and provide computational evidence supporting our techniques. We implemented all of our algorithms in the software package MOCHA. (Received January 25, 2010)

1057-05-337 **Russ Woodroofe*** (russw@math.wustl.edu), Department of Mathematics, Campus Box 1146, One Brookings Drive, St. Louis, MO 63130. *Erdős-Ko-Rado theorems for simplicial complexes.*

A well-known result of Erdős, Ko, and Rado states that the largest intersecting uniform family of sufficiently small sets is the family of all sets containing a fixed vertex. More recently Holroyd, Talbot, and Borg have conjectured an extension of the Erdős-Ko-Rado Theorem for intersecting families of faces in a simplicial complex. In this talk, I will show how to use algebraic shifting to prove significant special cases of the Holroyd-Talbot/Borg Conjectures. I will give several applications to independence complexes of graphs. (Received January 25, 2010)

1057-05-356 **Saúl A. Blanco*** (sabr@math.cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853. *Descent set distribution of labelings on Bruhat paths.*

Consider a Coxeter system (W, S) and $u, v \in W$ with $u \leq v$ in Bruhat order. Denote the set of u-v paths in the Bruhat graph of $[u, v]$ by $B(u, v)$. One can label the maximum elements of $B(u, v)$ using Björner and Wachs's CL-labeling. Furthermore, all elements in $B(u, v)$, not necessarily maximum, can be labeled using Dyer's reflection order. We compare the distribution of descent sets of the CL-labeling and the reflection order for cases where the CL-labeling can be used for non-maximum paths. We also provide ways to describe the distribution of descent sets in some special cases using Billera and Brenti's complete **cd**-index. (Received January 25, 2010)

1057-05-365 **Deborah Chun*** (dchun@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803-4918. *Elements in unavoidable minors of* 3*-connected binary matroids.*

Ding, Operowski, Oxley, and Vertigan proved that every sufficiently large 3-connected, binary matroid has as a minor a large binary spike, or, for a large n, the cycle or bond matroid of an n-spoked wheel or $K_{3,n}$. We discuss what can be said when one seeks to keep a specified element in one of the special minors. (Received January 26, 2010)

1057-05-397 **Jenny McNulty*** (mcnulty@mso.umt.edu), Department of Mathematical Sciences, The University of Montana, Missoula, MT 59812, and **Gary Gordon** and **Nancy Neudauer**. *Fixing Number and Matroids.* Preliminary report.

A fixing set S of a matroid M is a subset of the ground set E of M so that the only automorphism of M that fixes S pointwise is the identity. The fixing number of M is the minimum size of a fixing set. The notion of a fixing set (also called determining set) arose in graph theory, as both fixing sets as well as determining sets; we extend this study to matroid theory.

The fixing number of a binary matroid is bounded by the rank of the matroid. This bound is tight in the Fano matroid, for example. This bound does not hold in non-binary matroids; for example $U_{r,n}$ for $n - 1 > r$ has fixing number $n - 1$. In this talk, we present results of bounds on the fixing number of transversal matroids in terms of sizes of clones sets and the rank. (Received January 26, 2010)

1057-05-417 **Shirley Law** and **Nathan Reading*** (nathan_reading@ncsu.edu). *The Hopf algebra and lattice (and polytope?) of rectangulations.*

Twisted Baxter permutations arose (via lattice theory), as a natural basis for a sub Hopf algebra of the Malvenuto-Reutenauer Hopf algebra of permutations. The starting point of this research is the project of finding an intrinsic description of the Hopf algebra of twisted Baxter permutations in terms of a set of combinatorial objects in bijection with twisted Baxter permutations. This is accomplished using the (diagonal) rectangulations studied by Ackerman, Barequet, and Pinter, which are closely related to the twin binary trees of Dulucq and Guibert. In addition to the Hopf-theoretic results, we obtain a combinatorial characterization of the natural lattice structure on rectangulations, analogous to the Tamari lattice of triangulations. It appears that the Hasse diagram of this lattice is the 1-skeleton of a polytope. (We are checking the details of a nice fiber-polytopes proof.) We also find a new explicit bijection between twisted Baxter permutations and the better-known Baxter permutations.

The main tools include a surjective map from permutations to rectangulations, as well as combinatorial and lattice-theoretic results on a related family of maps from permutations to triangulations. (Received January 26, 2010)

1057-05-432 **Stefan A. Forcey*** (sforcey@tnstate.edu). *New Hopf algebra structures on compositions.*

Compositions, or bijectively boolean subsets, form the graded basis for the very important combinatorial Hopf algebra of quasisymmetric functions. Now, via a description of the simplices as cellular projections of associahedra, we introduce a new graded algebra with the n^{th} component of its basis the vertices of the standard $(n - 1)$-simplex. We extend this new algebra to a new graded Hopf algebra based upon the full face posets of simplices: the boolean posets. Next, from a description of the cubes as projections of the multiplihedra, comes another new Hopf algebra based upon the compositions illustrated as painted trees. Mysteriously, it appears that our two new algebras are in fact dual to each other. (Received January 26, 2010)

1057-05-456 **Neil Robertson*** (robertso@math.ohio-state.edu), 231 W 18th Avenue, Columbus, OH 43210. *Recent progress in graph and matroid theory.* Preliminary report.

In this talk, I will talk about some recent progress in graph and matroid theory. (Received January 27, 2010)

1057-05-458 **Daniel Slilaty*** (daniel.slilaty@wright.edu), Wright State University, Department of Mathematics and Statistics, Dayton, OH 45435. *The signed graph $-K_5$.* Preliminary report.

In the study of linear programming, matroids, and graph theory, signed graphs have become a prominent feature. (A signed graph is a graph along with a labeling of the edges with elements of the group of order 2, often denoted by $\{+1, -1\}$.) In many places where signed graphs are used, the signed graph $-K_5$ appears and plays an important role. (The signed graph $-K_5$ has K_5 as its underlying graph and all edges are labeled with -1.) We will discuss some of these places, their known results, and conjectures. (Received January 27, 2010)

06 ► Order, lattices, ordered algebraic structures

1057-06-13 **Dorina Hoxha*** (dhoxha@univlora.edu.al), Department of Mathematics, University of Vlora, Vlora, Albania, and **Tanush Shaska** (shaska@oakland.edu), Department of Mathematics, Oakland University, Rochester Hills, MI. *Codes over rings of size p^2 and lattices over imaginary quadratic fields.*

Let $\ell > 0$ be a square-free integer congruent to 3 mod 4 and $\mathcal{O}_K$ the ring of integers of the imaginary quadratic field $K = Q(\sqrt{-\ell})$. Codes C over rings $\mathcal{O}_K/p\mathcal{O}_K$ determine lattices $\Lambda_\ell(C)$ over K. If $p \nmid \ell$ then the ring $\mathbb{R} := \mathcal{O}_K/p\mathcal{O}_K$ is isomorphic to $\mathbb{F}_{p^2}$ or $\mathbb{F}_p \times \mathbb{F}_p$. Given a code C over $\mathbb{R}$, theta functions on the corresponding lattices are defined. These theta series $\theta_{\Lambda_\ell(C)}$ can be written in terms of the complete weight enumerator of C. In previous work of the third author it is shown that for any two $\ell < \ell'$ the first $\frac{\ell+1}{4}$ terms of their corresponding theta functions are the same. Moreover, it is conjectured that for $\ell > \frac{p(n+1)(n+2)}{2}$ there is a unique complete weight enumerator corresponding to a given theta function. We present some new results in this problem. (Received October 18, 2009)

08 ► General algebraic systems

1057-08-326 **Karel Casteels*** (kcasteel@sfu.ca), **Jason Bell** and **Stephane Launois**. *On the dimension of $\mathcal{H}$-strata in quantum matrices.*

We consider the prime spectrum of the algebra of quantum matrices. Goodearl and Letzter's $\mathcal{H}$-stratification theory has proven to be a useful tool, and in this talk we discuss the dimensions of the $\mathcal{H}$-strata. In particular, we give a surprisingly easy method to determine the dimension. This procedure is based on deriving a certain permutation from a combinatorial object known as a Cauchon diagram. (Received January 25, 2010)

11 ► Number theory

1057-11-2 **Bruce Reznick***, Department of Mathematics, University of Illinois, Urbana, IL. *The secret life of polynomial identities.*

Polynomial identities can reflect deeper mathematical phenomena. In this talk, I will discuss some of the stories behind the following three identities (and their relatives):

$$1024x^{10} + 1024y^{10} + (x + \sqrt{3}\ y)^{10} + (x - \sqrt{3}\ y)^{10} + (\sqrt{3}\ x + y)^{10} + (\sqrt{3}\ x - y)^{10} = 1512(x^2 + y^2)^5 \quad (1)$$

$$x^3 + y^3 = \left(\frac{x(x^3 + 2y^3)}{x^3 - y^3}\right)^3 + \left(\frac{y(y^3 + 2x^3)}{y^3 - x^3}\right)^3, \quad (2)$$

$$(x^2 + \sqrt{2}\ xy - y^2)^5 + (ix^2 - \sqrt{2}\ xy + iy^2)^5 + (-x^2 + \sqrt{2}\ xy + y^2)^5 + (-ix^2 - \sqrt{2}\ xy - iy^2)^5 = 0 \quad (3)$$

Equation (1) has roots in 19th century mathematics; (2) is due to Viéte (1592); (3) was independently found by Desboves (1880) and Elkies (1995). Their stories involve algebra, analysis, number theory, combinatorics, geometry and numerical analysis. Fourteenth powers of polynomials will show up. (Received April 09, 2009)

1057-11-81 **Eun Ju Cheon*** (enju1000@naver.com), 500W. Prospect, #2-I, Fort Collins, CO 80526. *On linear codes with parameters close to those of Belov type codes.*

We consider the problem to find the smallest length n, denoted by $n_q(k, d)$, for which there exists an $[n, k, d]_q$ linear code for given k and d. A linear code is said to be length optimal if its length is equal to $n_q(k, d)$. For an $[n, k, d]_q$ linear code C, it is well known that n is at least $g_q(k, d)$, the Griesmer bound, and that the Belov type codes meet the Griesmer bound. In this talk, we deal with codes whose parameters are near to those of Belov type ones. For $k \geq 5$ and $q \geq 3$, we prove that $n_q(k, d) = g_q(k, d) + 1$ for $q^{k-1} - q^{k-1-t} - q^t - q + 1 \leq d \leq q^{k-1} - q^{k-1-t} - q^t$ with $2 \leq t \leq \frac{k-2}{2}$. (Received January 08, 2010)

1057-11-299 **Bruce Reznick*** (reznick@math.uiuc.edu), 1409 W. Green St., Urbana, IL 61801. *Constructing Hilbert identities.* Preliminary report.

We will present methods, old and new, for constructing real identities of the form

$$(x_1^2 + \cdots + x_n^2)^r = \sum_{k=1}^{N} \lambda_k (c_{k1}x_1 + \cdots + c_{kn}x_n)^{2r}, \tag{1}$$

with a particular emphasis on minimizing N and the number of different c_{kj}'s. Among many other applications, these give isometric copies of ℓ_2^n in ℓ_{2r}^N. (Received January 25, 2010)

12 ► Field theory and polynomials

1057-12-296 **Aleams Barra*** (abarra@ms.uky.edu), abarra@ms.uky.edu, Lexington, KY 40503. .

We consider linear block codes over prime fields endowed with the Lee weight. We will show that the MacWilliams extension theorem holds true for codes over ($\mathbb{Z}_q$, Lee weight), where q is a prime number of the form $q = 2p + 1$ or $q = 4p + 1$ with p being an odd prime. The first case $q = 2p + 1$ has also been proven earlier, with different methods, by J.Wood.

(Received January 25, 2010)

13 ► Commutative rings and algebras

1057-13-4 **Bernd Ulrich***, Department of Mathematics, Purdue University, West Lafayette, IN. *Multiplicities, integral dependence, and equisingularity.*

Multiplicity theory is a classical topic in commutative algebra and algebraic geometry. The talk will survey aspects of this subject and highlight its connections to equisingularity theory. A goal in equisingularity theory is to decide whether singularities that appear in a family are 'equivalent' to one another, using numerical invariants such as multiplicities. Translated into algebra, a version of this problem amounts to proving multiplicity based criteria for the integral dependence of modules. Such criteria have a long history, spanning from work of Rees in the early sixties to more recent results that require generalizations of the classical notions of multiplicity.

(Received April 09, 2009)

1057-13-21 **Alexander Engström*** (alex@math.berkeley.edu), Department of Mathematics, University of California, Berkeley, 851 Evans Hall #3840, Berkeley, CA 94720. *Ideals of Graph Homomorphisms.*

Many toric ideals used in algebraic statistics can be described as ideals of graph homomorphisms. We will survey these connections and describe the basic theory. (Received November 28, 2009)

1057-13-33 **Zeinab Ashtab*** (z.ashtab@gmail.com), Tabriz, Iran. *A survey of zero-divisor graphs in commutative rings.* Preliminary report.

This work is a survey of recent results of different papers on the concept zero-divisor graphs of commutative rings. Also we investigate the subject that how ring-theoretic properties of R determine graph-theoretic properties of Γ(R), and conversely, how graph-theoretic properties of Γ(R) determine ring-theoretic properties of R.

(Received December 09, 2009)

1057-13-45 **Janet Striuli** and **Adela Vraciu*** (vraciu@math.sc.edu). *Homological properties of almost Gorenstein rings.*

We propose several notions of almost Gorenstein rings and study the relationships between them and the homological implications of these properties. (Received December 15, 2009)

1057-13-62 **Stefan O Tohaneanu***, Department of Mathematical Sciences, The University of Cincinnati, P O Box 210025, Cincinnati, OH 45221-0025. *Gorenstein Evaluation Codes.*

Let Γ be a set of n points in $\mathbb{P}^m$. The evaluation code $C(\Gamma)_a$ is the linear code of length n obtained by evaluating the homogeneous polynomials of degree a at all the points of Γ. In this talk we present a lower bound for the minimum distance of $C(\Gamma)_a$ for the case when Γ is an arithmetically Gorenstein nondegenerate reduced zero-dimensional scheme in $\mathbb{P}^m$. The bound is expressed in terms of the socle degree of the Artinian reduction of the ideal of Γ, and it generalizes the result of Gold-Little-Schenck when Γ is a reduced complete intersection zero-dimensional scheme. (Received January 01, 2010)

1057-13-84 **Mel Hochster*** (hochster@umich.edu), Mathematics Department, East Hall, 530 Church Street, University of Michigan, Ann Arbor, MI 48109-1043. *Quasilength, content of local cohomology, and closure operations on ideals.*

The talk will discuss the recently introduced notion of quasilength with respect to an ideal and how it is used to define a notion of content for local cohomology modules. Wenliang Zhang and the speaker have recently shown that these ideas can be used to define a closure operation on ideals that agrees with tight closure for local rings of positive characteristic under mild conditions. The talk will also survey many related open questions. (Received January 08, 2010)

1057-13-90 **Craig Huneke**, **Daniel Katz** and **Javid Validashti*** (jvalidas@math.ku.edu). *Comparing powers and symbolic powers of ideals.*

Let R be a Noetherian local ring. We show that the symbolic topology defined by a prime ideal $\mathfrak{p}$ is uniformly linearly equivalent to the $\mathfrak{p}$-adic topology for a large class of isolated singularities. In other words, there exists $h \geq 1$, independent of $\mathfrak{p}$, such that for all primes $\mathfrak{p} \subseteq R$, $\mathfrak{p}^{(hn)} \subseteq \mathfrak{p}^n$, for all n. (Received January 11, 2010)

1057-13-97 **Christopher Hillar** and **Seth Sullivant*** (smsulli2@ncsu.edu). *Finite Gröbner bases in infinite dimensional polynomial rings and applications.*

We introduce the theory of monoidal Gröbner bases, a concept which generalizes the familiar notion in a polynomial ring and allows for a description of Gröbner bases of ideals that are stable under the action of a monoid. The main motivation for developing this theory is to prove finiteness theorems in commutative algebra and its applications. A major result of this type is that ideals in infinitely many indeterminates stable under the action of the symmetric group are finitely generated up to symmetry. We use this machinery to give new proofs of some classical finiteness theorems in algebraic statistics as well as a proof of the independent set conjecture of Hosten and the second author. (Received January 13, 2010)

1057-13-102 **Manoj Kummini*** (nkummini@math.purdue.edu), 150 N University St, West Lafayette, IN 47907-2067, and **Satoshi Murai**, 1677-1 Yoshida, Yamaguchi, 753-8512, Japan. *Regularity of Canonical and Deficiency modules for Monomial ideals.*

We show that the Castelnuovo–Mumford regularity of the canonical or a deficiency module of the quotient of a polynomial ring by a monomial ideal is bounded by its dimension. (Received January 13, 2010)

1057-13-108 **Christopher A. Francisco*** (chris@math.okstate.edu), Department of Mathematics, Oklahoma State University, 401 Mathematical Sciences, Stillwater, OK 74078, and **Huy Tài Hà** and **Adam Van Tuyl**. *Hypergraph colorings, perfect graphs, and associated primes.*

I will discuss joint work with Hà and Van Tuyl connecting the associated primes of powers of cover ideals of hypergraphs to coloring properties of closely related hypergraphs. As a consequence of this work, we get new purely algebraic characterizations of perfect graphs, independent of the Strong Perfect Graph Theorem. (Received January 14, 2010)

1057-13-111 **Adam Van Tuyl***, Department of Mathematical Sciences, Lakehead University, Thunder Bay, Ontario P7B5E1, Canada, and **Chris Francisco** and **Tai Ha**. *A conjecture about coloring graphs and connections to associated primes of ideals.*

In this talk, I will introduce a conjecture about critically chromatic graphs. I will explain why a solution to this conjecture would show that the associated primes of square-free monomial ideals of height two have the persistence property. This is joint work with C.A. Francisco and H.T. Ha. (Received January 14, 2010)

1057-13-117 **Mats Boij**, **Juan C. Migliore**, **Rosa M. Miró-Roig**, **Uwe Nagel** and **Fabrizio Zanello*** (zanello@mtu.edu), Department of Mathematical Sciences, Michigan Tech, Houghton, MI 49931. *On the structure of pure O-sequences: unimodality, non-unimodality, and an interval conjecture.*

This is a report on an upcoming monograph joint with M. Boij, J. Migliore, R. Miró-Roig and U. Nagel.

An *order ideal* is a collection, X, of monomials in a finite number of variables such that, whenever $M \in X$ and N divides M, $N \in X$. If all maximal (by divisibility) monomials of X have the same degree, X is *pure*. A *pure O-sequence* is the vector counting the monomials of X in each degree.

The study of pure O-sequences began with one of the early works of Stanley in this area, and has since played a significant role in at least three theories: those of simplicial complexes, level algebras, and matroids.

Using both algebraic and combinatorial techniques, our monograph studies the structure of a pure O-sequence. In particular, it includes the following topics: a characterization of the first half of a pure O-sequence; a study of (the failing of) the unimodality property; the enumeration problem; a study of the Interval Conjecture for Pure

O-sequences, and a connection with Stanley's conjecture on matroid h-vectors; an analysis of the role played by the Weak Lefschetz Property.

This talk will consist of a brief general overview of the theory of pure O-sequences, with some focus on unimodality and the ICP. (Received January 15, 2010)

1057-13-160 **Angela L Kohlhaas*** (akohlhaa@nd.edu), 1176 Center Pl, Dubuque, IA 52001. *The core versus the adjoint of a monomial ideal.* Preliminary report.

Given an ideal I in a Noetherian ring R, the core of I is the intersection of all ideals contained in I with the same integral closure as I. The core naturally arises in the context of the Briançon-Skoda theorem as an ideal which contains the adjoint of a certain power of I. As the arbitrary-characteristic analog of the multiplier ideal, the adjoint is an important tool in the study of resolutions of singularities. The question of when the core and the adjoint of a power of I are equal has been tied to a celebrated conjecture of Kawamata about the non-vanishing of sections of line bundles. By illustrating symmetry properties of the core of a monomial ideal in a polynomial ring, I will show that for certain classes of monomial ideals, this equality holds if and only if the core is integrally closed. (Received January 20, 2010)

1057-13-169 **Yu Xie*** (yxie@nd.edu), 1329 Squire Dr. Apt E, South Bend, IN 46637. *Formulas for the multiplicity of graded algebras.*

Let $A = k[A_1] \subseteq B = k[B_1]$ be a homogeneous inclusion of standard graded Noetherian domains over an infinite field k. We want to express the multiplicity of A in terms of that of B and local multiplicities along $\mathrm{Proj}(B)$. One of the applications is to find the multiplicity of the special fibre ring of an ideal generated by forms of the same degree in a standard graded Noetherian k-algebra.

Observe that $\dim A \leq \dim B$ and they are equal if and only if their quotient fields extension is algebraic of degree r. If B is integral over A, i.e., $\dim B/A_1B = 0$, then $e(B) = re(A)$. In 2001, Simis, Ulrich and Vasconcelos gave a formula when $\dim A = \dim B$ and $\dim B/A_1B = 1$. We generalize their formula to arbitrary dimensions of B/A_1B. We also provide a formula for the case when $\dim A < \dim B$. Thus we give a complete answer to the original question.

The formulas we obtain can be used to find the degree of dual varieties for any hypersurfaces without any restrictions on its dual varieties and singularities. In particular, it gives a generalization of Teissier's Plücker formula to hypersurfaces with non-isolated singularities. (Received January 20, 2010)

1057-13-189 **J. Herzog**, **T. Hibi**, **F. Hreinsdottir** and **T. Kahle*** (kahle@mis.mpg.de), Inselstr. 22, D-04103 Leipzig, Germany, and **J. Rauh**. *Binomial Edge Ideals and Conditional Independence.*

We introduce binomial edge ideals attached to a simple graph G and discuss some of their algebraic properties. A reduced squarefree Gröbner basis shows that binomial edge ideals are radical ideals. Their minimal primes can be characterized combinatorially. Binomial Edge ideals arise naturally in the study of certain conditional independence models. Our results apply for the class of conditional independence ideals where a fixed binary variable is independent of a collection of other variables, given the remaining ones. In this case the prime decomposition has a natural statistical interpretation. (Received January 22, 2010)

1057-13-236 **Silvio Greco** (silvio.greco@mail.polito.it), Dipartimento di Matematica, Politecnico di Torino, I-10129 Torino, Italy, **Karlheinz Kiyek*** (karlh@math.upb.de), Institut fuer Mathematik, Universitaet Paderborn, D 33098 Paderborn, Germany, and **Jesus Soto**. *The blow-up of a simple complete ideal of a two-dimensional regular local ring.* Preliminary report.

Let R be a two-dimensional regular local ring with residue field k. Let $\wp$ be a simple complete ideal of R, set $r := \mathrm{ord}_R(\wp)$, let $R = R_0 \subsetneqq \cdots \subsetneqq R_h = S$ be the quadratic sequence determined by $\wp$, and assume that $S/\mathfrak{m} = k$. Let $\mathcal{T}$ be the rational points in the first neighbourhood of S. Let $X = \mathrm{Bl}_\wp(R)$ be the blow-up of $\wp$, let E be the exceptional locus, and set $E^* := \{Q \in E \mid Q \text{ closed and rational}\}$. The singular points of X lie on E^*; the number of singular points of X is equal to the number of satellite points of $\wp$.

From now on, assume that k is infinite. Let $\mathcal{S}$ be the set of complete ideals of R which are adjacent to $\wp$ from below. There exists exactly one ideal in $\mathcal{S}$ of order $r+1$; it is not simple. There exists exactly one ideal in $\mathcal{S}$ of order r which is not simple iff $\wp$ has two satellite points.

There exist natural bijections $\mathcal{S} \to \mathcal{T}$, $\mathcal{S} \to E^*$. (Received January 24, 2010)

1057-13-245 **Henrik Holm*** (hholm@life.ku.dk), Department of Basic Sciences and Environment, Thorvaldsensvej 40, DK-1871 Frederiksberg C, Copenhagen, Denmark. *Rings without a Gorenstein analogue of the Govorov-Lazard theorem.*

This talk is a report on joint work with Peter Jørgensen.

It was proved by Beligiannis and Krause that over certain Artin algebras, there are Gorenstein flat modules which are not direct limits of finitely generated Gorenstein projective modules. That is, these algebras have no Gorenstein analogue of the classical Govorov-Lazard Theorem.

We show that, in fact, there is a large class of rings without such an analogue. Namely, let R be a commutative local noetherian ring. Then the analogue fails for R if it has a dualizing complex, is henselian, not Gorenstein, and has a finitely generated Gorenstein projective module which is not free.

The proof is based on a theory of Gorenstein projective (pre)envelopes. We show, among other things, that the finitely generated Gorenstein projective modules form an enveloping class in the category of finitely generated R-modules if and only if R is Gorenstein or has the property that each finitely generated Gorenstein projective module is free.

This is analogous to a recent result on covers by Christensen, Piepmeyer, Striuli, and Takahashi, and their methods are an important input to our work. (Received January 24, 2010)

1057-13-249 **Sonja Mapes*** (smapes@math.duke.edu), Mathematics Department, 117 Physics Bldg, Box 90320, Durham, NC 27708. *Resolutions of monomial ideals and lcm lattices.*

It is known that monomial ideals which have equivalent LCM lattices also have equivalent minimal free resolutions. It has also been shown that given a finite atomic lattice L one can construct monomial ideals M whose LCM lattice is L. This talk takes a coordinate free approach to studying the structure of minimal resolutions of monomial ideals by studying the associated finite atomic lattice and the parameter space of all such lattices. (Received January 24, 2010)

1057-13-259 **Sean Sather-Wagstaff**, **Tirdad Sharif** and **Diana White*** (diana.white@ucdenver.edu), Campus Box 170, Box 173364, Denver, CO 80217-3364. *Iterating the construction of the Gorenstein projectives.*

The Gorenstein projectives arise naturally as cokernels of complete resolutions by free modules. In this talk, we investigate what happens if we iterate this construction. That is, we classify the cokernels of a complete resolution by Gorenstein projectives. (Received January 25, 2010)

1057-13-280 **Hirotachi Abo**, **Holger Kley** and **Chris Peterson*** (peterson@math.colostate.edu). *On Locally Cohen-Macaulay unions of Surfaces in $\mathbb{P}^4$.*

This talk will focus on some combinatorial and geometric issues surrounding the construction of unions of surfaces in $\mathbb{P}^4$ that are locally Cohen-Macaulay. When combined with techniques such as liaison, reducible unions can be used to give explicit constructions of smooth surfaces in $\mathbb{P}^4$ with a non-trivial automorphism group. In addition, reducible locally Cohen-Macaulay schemes are often associated with exceptional vector bundles. Several examples illustrating this connection will be presented. (Received January 25, 2010)

1057-13-288 **Rachelle R. Bouchat** and **Huy Tai Ha*** (tai@math.tulane.edu), Tulane University, Department of Mathematics, 6823 St. Charles Avenue, New Orleans, LA 70118, and **Augustine O'Keefe**. *Path ideals and their free resolutions.*

Let Γ be a rooted (directed) tree and let t be a positive integer. The path ideal $I_t(\Gamma)$ of Γ is the ideal generated by monomials corresponding to (directed) paths of length (t-1) in Γ. In this talk, we shall discuss the minimal free resolution and related invariants of $I_t(\Gamma)$. In particular, we give a bound for the regularity, compute the linear strand, and study property $N_{t,p}$ of $I_t(\Gamma)$. (Received January 25, 2010)

1057-13-328 **Hal Schenck*** (schenck@math.uiuc.edu), Math Department, UIUC, Urbana, IL 61801. *Blowups of $\mathbb{P}^2$ at singular points of line arrangements: resonance, syzygies, scrolls.*

Let A be a configuration of lines in $\mathbb{P}^2$, and X the rational surface obtained by blowing up $\mathbb{P}^2$ at the singular points of A. The Orlik-Terao algebra is a commutative version of the cohomology ring of $Y = \mathbb{C}^3 \setminus \widehat{A}$, where $\widehat{A}$ is the affine cone over A. In this note, we show that if D_A is a certain divisor on X related to A, then the Orlik-Terao algebra is the homogeneous coordinate ring of X in $\mathbb{P}(H^0(\mathcal{O}_X(D_A))^\vee)$. We use combinatorial properties of the Orlik-Terao algebra to understand the divisor D_A, and algebro-geometric results of Falk, Libgober and Yuzvinsky to study syzygies of the Orlik-Terao algebra. (Received January 25, 2010)

1057-13-336 **David Eisenbud** and **Daniel Erman*** (derman@math.berkeley.edu), University of California, 970 Evans Hall, Berkeley, CA 94720, and **Frank-Olaf Schreyer**. *Beyond Numerics: The existence of pure filtrations.*

A recent result of Boij-Soederberg and Eisenbud-Schreyer proves that the Betti diagram of any graded module decomposes as a positive rational linear combination of pure diagrams. We consider the follow-up question of whether this numerical decomposition ever corresponds to an actual filtration of the minimal free resolution itself. Our main result is an affirmative answer to this question in many surprising cases. (Received January 25, 2010)

1057-13-346 **Erik Stokes*** (estokes@mtu.edu), Department of Mathematical Sciences, Michigan Technological University, Houghton, MI 49931, and **Sonja Petrovic**. *Hierarchical Models, Markov Bases and Stanley-Reisner Ideals.*

Associated to each simplicial complex are two seemingly unrelated objects: a hierarchical model and a Stanley-Reisner ideal. In this talk, we discuss relationships between some invariants of the Stanley-Reisner ideal and the Markov basis of the model. In particular, for certain kinds of complexes (in particular vertex-decomposable complexes) there is a surprising connection between the degrees of the elements of the model's Markov basis and the Betti diagram of the complexes' Stanley-Reisner ideal, which we conjecture holds for all simplicial complexes. (Received January 25, 2010)

1057-13-355 **H. Ananthnarayan** (ahariharan2@math.unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588, **Luchezar L. Avramov*** (avramov@math.unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588, and **W. Frank Moore** (frankmoore@math.cornell.edu), Cornell University, Department of Mathematics, Ithaca, NY 14853. *Connected sums of Gorenstein local rings.*

We present a new construction of Gorenstein local rings and study its properties. (Received January 25, 2010)

1057-13-358 **Justin W. DeVries*** (s-jdevrie3@math.unl.edu), 203 Avery Hall, Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130. *A Bound on the Betti Number of Multi-graded Differential Modules.*

This talk concerns differential modules (i.e. modules with a square-zero endomorphism) over a polynomial ring $k[x_1, \dots, x_d]$, with k a field. We introduce a notion of a Betti number of a differential module, and establish lower bounds when the differential module is multi-graded with finite length homology. This also gives a lower bound for the total rank of a multi-graded complex of free modules with finite length homology. (Received January 25, 2010)

1057-13-360 **Lars Winther Christensen*** (lars.w.christensen@ttu.edu), Department of Mathematics and Statistics, M.S. 1042, Lubbock, TX 79409, and **David A Jorgensen**. *Vanishing of Tate homology and depth formulas over local rings.* Preliminary report.

Let R be a commutative noetherian local ring. Let M and N be finitely generated R-modules. One says that the *depth formula holds for M and N* if $s = \sup\{\, i \mid \operatorname{Tor}_i^R(M,N) \neq 0 \,\}$ is finite and one has

$$\operatorname{depth}_R \operatorname{Tor}_s^R(M,N) - s = \operatorname{depth}_R M + \operatorname{depth}_R N - \operatorname{depth} R.$$

Auslander noted that the depth formula holds if M has finite projective dimension and $s = 0$ or $\operatorname{depth}_R \operatorname{Tor}_s^R(M,N) \leq 1$. In works of Huneke and Wiegand and of Iyengar it has been shown that the formula remains valid if one replaces projective dimension with the weaker notion of complete intersection (CI) dimension. We prove that CI-dimension can be replaced by Gorenstein dimension under the extra assumption that the Tate homology modules $\widehat{\operatorname{Tor}}_*^R(M,N)$ vanish. For modules of finite CI-dimension this extra condition is automatically fulfilled when s is finite.

I will use the discussion of this result to introduce a new way to compute Tate homology; one that allows us to prove that Tate homology is balanced. (Received January 25, 2010)

1057-13-368 **Karl Schwede*** (kschwede@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, and **Kevin Tucker**. *On the behavior of the test ideal under finite separable morphisms.*

With the correspondence between the test ideal and the multiplier ideal as a guide, we study the behavior of the test ideal under a finite (generically) separable inclusion of normal domains. This generalizes work of other people (including Bravo-Smith and Hara-Takagi) to include cases where there is ramification. (Received January 26, 2010)

1057-13-374 **Will Traves*** (traves@usna.edu) and **Max Wakefield**. *Subspace arrangements yearning for freedom.* Preliminary report.

Free hyperplane arrangements are an active area of research. When one of the subspaces in the arrangement has higher codimension the arrangement cannot be free. We define derivation radical subspace arrangements to share many of the properties of free arrangements and investigate the combinatorial and algebraic properties of derivation radical subspace arrangements. (Received January 26, 2010)

1057-13-388 **Sonja Petrović*** (petrovic@math.uic.edu), UIC - dept of MSCS, 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60611, and **Tristram Bogart**. *Combinatorics of multihomogeneous toric ideals.* Preliminary report.

Multihomogeneous toric ideals arise frequently in applications (statistics), and questions about their geometric and combinatorial properties pose both computational and theoretical challenges. One of the positive constructive results in this direction is from joint work with Rinaldo and Fienberg: for a particular class of toric varieties, the part of the toric ideal that is "statistically relevant" can be obtained by homogenizing generators suitably. The motivation for this result came from the Graver basis construction for varieties of minimal degree, whose classification is purely combinatorial.

In this talk I will survey some of the previous work on Graver bases, as well as current work with Tristram Bogart which, with the help of some computations provided by Raymond Hemmecke, solves a universal Groebner basis conjecture for rational normal scrolls. (Received January 26, 2010)

1057-13-400 **Bonnie Smith*** (bsmith17@nd.edu), 255 Hurley Hall, Notre Dame, IN 46616. *The Core of a Strongly Stable Ideal.* Preliminary report.

The core of an ideal I in a Noetherian ring is the intersection of all ideals contained in I which have the same integral closure as I. The core of an ideal is an interesting object which appears naturally in the Briançon-Skoda theorem; is closely connected to adjoint/ multiplier ideals and coefficient ideals; and encodes information about the ideal itself and its possible reductions. However, the core is also difficult to describe explicitly, being by definition an infinite intersection of ideals. I will examine the properties of a class of ideals coming from graph theory, and show that there is a surprisingly simple formula for the cores of these ideals. (Received January 26, 2010)

1057-13-407 **Luchezar L Avramov**, **Inês B Henriques** and **Liana M Şega*** (segal@umkc.edu). *Homological algebra modulo an exact zero divisor.* Preliminary report.

An element a in a commutative local ring R is said to be an *exact zero divisor* if it satisfies $0 \neq R/aR \cong (0 :_R a) \neq R$. We will study the behavior of some basic homological and structural invariants with respect to the change of rings $R \to R/aR$. (Received January 26, 2010)

1057-13-422 **Jennifer Biermann*** (jbiermann@math.cornell.edu), 310 Malott Hall, Cornell University, Ithaca, NY 14853. *The edge ideal of the complement of a cycle.* Preliminary report.

We will describe a polytopal cell structure which supports the minimal free resolution of the edge ideal of the complement of an n-cycle for $n \geq 5$. (Received January 26, 2010)

1057-13-428 **Neil Epstein*** (nepstein@math.uos.de), Albrechtstrasse 28a, 49076 Osnabrueck, Germany, and **Yongwei Yao** (yyao@gsu.edu), 30 Pryor St., Atlanta, GA 30303. *Criteria for flatness and injectivity.*

Let R be a commutative Noetherian ring. We develop equivalent criteria for a module to be flat in terms of torsion-freeness of certain tensor products. We also develop equivalent criteria for a module to be injective in terms of divisibility of certain Hom modules. These criteria are at their cleanest when R is reduced, although they are not limited to such a circumstance. Connections with Grothendieck's *local flatness criterion* are also explored. As an application, we give equivalent criteria for a Noetherian (local) ring of prime characteristic to be regular. (Received January 26, 2010)

1057-13-442 **Giulio Caviglia*** (gcavigli@math.purdue.edu), 150 N. University st., Mathematics Department, Purdue University, West Lafayette, 47907. *A class of Gorenstein algebras that are Koszul.*

It is known, by a result of Vishik and Finkelberg, that the coordinate ring of a smooth curve in its canonical embedding is Koszul whenever it is defined by quadratic relations. Such rings are Gorestein with an h-vector of the form $1 + nz + nz^2 + z^3$. Conca, Rossi, and Valla proved that quadratic Gorenstein rings with the above h-vector are always Koszul whenever n=3, n=4 or when the ring is defined by a generic cubic in the sense of Macaulay's inverse system. We present some sufficient conditions for the koszulness of these rings which extend

the above result to the case n=5. Our methods are based on the construction of a koszul filtration by analizing the rank of the multiplication of certain linear forms. (Received January 26, 2010)

1057-13-450 **Hamid Kulosman*** (h0kulo01@louisville.edu), Department fo Mathematics, 328 Natural Science Building, University of Louisville, Louisville, KY 40292. *Some versions of Hilbert's Nullstellensatz.* Preliminary report.

We talk about some versions of Hilbert's Nullstellensatz in concrete situations where it is possible to get stronger statements. We discuss some applications. (Received January 26, 2010)

1057-13-452 **Louiza Fouli*** (lfouli@math.nmsu.edu), Department of Mathematical Sciences, New Mexico State University, P. O. Box 30001, Dept 3MB, Las Cruces, NM 88003, and **Janet C Vassilev** and **Adela Vraciu**. *Tight closure and reductions of an ideal.*

Let R be a Noetherian ring and let I be an ideal. Recall that J is a reduction of I if $J \subset I$ and $\overline{J} = \overline{I}$, where $\overline{I}$ and $\overline{J}$ denote the integral closure of I and J, respectively. Northcott and Rees proved that if R is a Noetherian local ring with infinite residue field then there are infinitely many reductions of I. The core of I, core(I), is defined to be the intersection of all reductions of I.

When R is a Noetherian ring of characteristic $p > 0$, Epstein defines tight closure reductions. In particular, an ideal J is a $*$-reduction of I if $J \subset I$ and $J^* = I^*$, where * denotes the tight closure of the corresponding ideal. Similarly we define the tight closure core of I, $*$-core(I), to be the intersection of all the $*$-reductions of I. We explore $*$-reductions, $*$-core(I) and its connection to core(I). We also provide formulas for computing $*$-core(I). This is joint work with Janet C. Vassilev and Adela Vraciu. (Received January 26, 2010)

1057-13-459 **Ben Richert*** (brichert@calpoly.edu), Mathematics Department, Cal Poly, San Luis Obispo, San Luis Obispo, CA 93407, and **Michael Mogull**, **Sam Saiki** and **David jansson**. *The poset tree of graded Betti numbers for a fixed Hilbert function and the degree to height function.* Preliminary report.

Given a homogeneous ideal I in a polynomial ring $R = k[x_1, \ldots, x_n]$, the degree to height function of I in degree d is defined to be the height of $I_{\leq d}$. This invariant is conjectured to identify unique maximal elements in subtrees of the poset tree of ideals in R whose quotients have a fixed Hilbert function. It has been asked whether the degree to height function can guarantee the existence of unique minimal elements in these same subtrees. By restricting to squarefree monomial ideals we discovered that this need not be the case. We also identified instances for which unique maximal elements need not exist among the resolutions of squarefree monomial ideals with given degree to height and Hilbert functions (showing that one possible extension of the lex-plus-powers conjecture to the squarefree monomial case does not hold), and instances in which the subtrees have holes. (Received January 27, 2010)

14 ► Algebraic geometry

1057-14-126 **Duiliu Emanuel Diaconescu*** (duiliu@physics.rutgers.edu), 126 Frelinghuysen Rd, Piscataway, NJ 08854. *ADHM Sheaves in Mathematics and Physics.*

This talk will be centered on a new connection between counting problems in algebraic geometry and certain moduli spaces of decorated bundles on curves. Wallcrossing formulas for virtual counting invariants will be derived using the formalism of Joyce and Song. Applications to local stable pair invariants and generalizations will be also presented. (Received January 17, 2010)

1057-14-139 **Enrico Carlini*** (enrico.carlini@polito.it), Dipartimento di Matematica, Politecnico di Torino, Turin, Italy. *Bipolinomial Hilbert functions.*

Given a closed subscheme X we let $HF(X, -)$ and $hp(X, -)$ denote, respectively, the Hilbert function and the Hilbert polynomial of X.

We say that X has bipolynomial Hilbert function if $HF(X, d) = \min\{hp(P^n, d), hp(X, d)\}$ for every non-negative integer d. Hence, schemes with a bipolynomial Hilbert function have, in some sense, the expected behaviour.

Finite set of points in generic position are known to have bipolynomial Hilbert functions. The same holds for a finite collection of generic lines. But, in general, it is not known whether a finite collection of generic linear spaces has a bipolynomial Hilbert function.

We will introduce non-trivial examples of schemes with bipolynomial Hilbert functions providing evidence for our conjecture about "small" configuration of linear spaces.

This is a joint work with Maria Virginia Catalisano (University of Genoa) and Anthony V. Geramita (Queen's University) (Received January 19, 2010)

1057-14-224 **Y. Jiang*** (jiangyf@math.utah.edu), 155S 1400E JWB233, Salt Lake City, UT 84112.
Gromov-Witten theory of etale gerbes.

Gromov-Witten theory of smooth Deligne-Mumford stacks was constructed in symplectic category by Chen-Ruan, and in algebraic geometry category by Abramovich-Graber-Vistoli. Let G be a finite group scheme, the G-gerbes over a smooth Deligne-Mumford stack X give very interesting Deligne-Mumford stacks. In this talk we will talk about the Gromov-Witten theory, especiously quantum cohomology of G-gerbes over the smooth Deligne-Mumford stacks. We prove the so called "decomposition conjecture" by physicists for quantum cohomology of root gerbes over smooth schemes. (Received January 23, 2010)

1057-14-232 **Tudor Dimofte*** (tdd@theory.caltech.edu), Caltech 452-48, 1200 E California Blvd, Pasadena, CA 91125, and **Sergei Gukov** and **Yan Soibelman**. *Quantum Wall Crossing in $\mathcal{N} = 2$ Gauge Theories.*

We consider refined and motivic wall crossing formulas in $\mathcal{N} = 2$ supersymmetric gauge theories with gauge group $SU(2)$ and $N_f < 4$ matter hypermultiplets in the fundamental representation. These theories provide an excellent testing ground for the recent proposal that, for BPS invariants, "refined = motivic." (Received January 23, 2010)

1057-14-237 **Luis David Garcia-Puente*** (lgarcia@shsu.edu), Department of Mathematics and Statistics, Sam Houston State University, Huntsville, TX 77341-2206, **Sarah Spielvogel** (SXS013@SHSU.EDU), Department of Mathematics and Statistics, Sam Houston State University, Huntsville, TX 77341-2206, and **Seth Sullivant** (smsulli2@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695. *Identifiability of Gaussian graphical models.* Preliminary report.

A graphical model is a representation method based on combinatorial graphs and probability theory used to formalize a variety of causal queries as certain types of probability distributions. A central problem in graphical models is the analysis of identification. A model is identified if it only admits a unique parametrization to be compatible with a given set of observed data. In this talk, I will present a computer algebra software to test model identifiability. I will also discuss data concerning all graphical models on at most five random variables. (Received January 24, 2010)

1057-14-256 **Burt A Ovrut*** (ovrut@elcapitan.hep.upenn.edu), Department of Physics, David Rittenhouse Laboratory, Philadelphia, PA 19104. *The Edge of Supersymmetry: Slope-Stability Walls in Heterotic String Theory.*

We discuss the the slope-stability of holomorphic vector bundles over Calabi-Yau threefolds. It is shown that if the Kahler cone has dimension greater than one, it is generically divided into regions where the bundle is stable, unstable and, on the "stability wall" between them, polystable. This wall corresponds physically to the boundary between unbroken and broken $N = 1$ supersymmetry. In the context of four-dimensional field theory, we provide a complete description of the spontaneous breaking of supersymmetry by the gauge connection near the stability wall, as well as a physical picture for the mathematical notion of bundle stability. (Received January 24, 2010)

1057-14-258 **Lawrence Man- Hou Ein*** (ein@uic.edu), Department of Mathematics, University of Illinois at Chicago, M/C 249, Chicago, IL 60607-7045, and **Robert K Lazarsfeld**, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109-1043. *Asymptotic Syzygies of Higher Dimensional Varieties.* Preliminary report.

We report on some joint work with Rob Lazarsfeld. Let X be a smooth complex variety and L be an ample line bundle on X. We study the projective coordinate ring of $(X, L^{\otimes r})$ for $r >> 0$. We obtain fairly precise results when X is a projective space and also when X is a smooth surface. We will discuss some open problems in this area. (Received January 24, 2010)

1057-14-283 **Lara B Anderson*** (andlara@physics.upenn.edu), Dept. of Physics, University of Pennsylvania, 209 South 33rd Street, Philadelphia, PA 19104. *Consequences of Heterotic Supersymmetry.*

In this talk, I will discuss some of the surprising consequences of global supersymmetric structure in heterotic theories. Heterotic theories generically do not admit supersymmetric vacua throughout their total moduli space. In particular, I will discuss the sub-structure of the heterotic Kahler moduli space that arises for vector bundles which are slope-stable in only part of the Kahler cone. Specifically, I will briefly explain the notion of vector bundle slope stability from an effective field theory point of view and discuss physical applications of this

description including branch structure which allows for transitions between vector bundles, constraints on yukawa couplings, and applications to moduli stabilization. (Received January 25, 2010)

1057-14-286 **David Jordan*** (djordan@math.mit.edu), 405 South Huntington Ave 1R, Jamaica Plain, MA 02130. *Quantum D-modules, torus braid groups, and the double affine Hecke algebra.*

We describe a technique for constructing representations of the double affine Hecke algebra of type A_n from a D-module on the quantum group $U_q(gl_N), (n, N \in \mathbb{N})$, which may be considered a higher genus analog of q-Schur-Weyl duality. Time permitting, we will discuss more recent constructions with Xiaoguang Ma, involving root systems of type B and C. (Received January 25, 2010)

1057-14-335 **Ian Cy Shipman***, Department of Mathematics, University of Chicago, 5734 S University Ave, Chicago, IL 60637. *Landau-Ginzburg B-Models and Higher Deformations of Projective Hypersurfaces.* Preliminary report.

A famous construction of Barannikov and Kontsevich defines a Frobenius manifold structure on the moduli space of deformation of a Calabi-Yau manifold. In the case of a projective hypersurface we will describe this structure using so called "matrix factorizations". (Received January 25, 2010)

1057-14-382 **Steven Dale Cutkosky*** (cutkoskys@missouri.edu), Dept. Math., Univ. Missouri, Columbia, MO 65211, and **Kazuhiko Kurano**. *Asymptotic regularity of symbolic powers of ideals of points in a weighted projective plane.*

We study the asymptotic behavior of symbolic powers of ideals of points in a weighted projective plane. Regularity of such powers behaves asymptotically like a linear function. We study the difference between regularity of such powers and this linear function. We prove that this difference is bounded, and under some conditions is eventually periodic. As a corollary, we show that if there exists a negative curve, then the regularity of symbolic powers of a monomial space curve is eventually a periodic linear function. (Received January 26, 2010)

1057-14-409 **David Eisenbud*** (de@msri.org), Dept of Math, UCB, Berkeley, CA 94720. *The hyperbolas in the plane and bundles on $P^1 \times P^1$.*

Frank Schreyer and I described the cone of cohomology tables of vector bundles on P^n as part of our proof of the Boij-Soederberg conjectures. I will explain our recent explorations of the corresponding question for vector bundles on $P^1 \times P^1$. Integral points on certain plane hyperbolas seem to play a key role. (Received January 26, 2010)

1057-14-414 **Anna Magdalena Kedzierska*** (anna.kedzierska@crg.es), c/Dr.Aiguader 88, Bioinformatics and Genomics, Barcelona Biomedical Research Park, 08003 Barcelona, Spain. *Model selection for mixture models.*

Phylogenetic data arising on different tree topologies might be mixed on a given alignment. Models taking it into account usually contain a large number of parameters and require tools beyond the standard model fitting framework. Here we discuss an approach for model selection of algebraic models on m-tree mixtures. This is joint work in progress with Marta Casanellas and Jesús Fernández-Sánchez (Received January 26, 2010)

15 ► Linear and multilinear algebra; matrix theory

1057-15-93 **V. Druskin*** (druskin1@slb.com), 1 Hampshire St., Cambridge, MA 02139, and **M. Zaslavsky** (mzaslavsky@slb.com), 1 Hampshire St., Cambridge, MA. *n convergence of Krylov subspace approximations of time-invariant dynamical systems.*

We extend the rational Krylov subspace algorithm from the computation of the action of the matrix exponential to the solution of stable dynamical systems

$$\tilde{A}\left(\frac{d}{dt}\right)u(t) = b(t),\ u|_{t<0} = 0, \qquad \tilde{A}\left(\frac{d}{dt}\right) = \sum_{i=0}^{m} A_i \left(\frac{d}{dt} + sI\right)^i,$$

where $m \in \mathbf{N} \cup \{\infty\}$, $A_i = A_i^* \in \mathbf{R}^{N\times N}$, $s \le 0$, and $u(t), b(t) \in \mathbf{R}^N$, $b|_{t<0} = 0$ (not assuming that evolution of $b(t)$ is described by a low-dimensional subspace of $\mathbf{R}^N$). This approach is equivalent or closely related to some known model reduction algorithms such as the interpolatory projection method, SPRIM and SOAR. We show that the reduced equation is stable and derive an a priori error bound via rational approximation of the exponential on the boundary of the nonlinear numerical range of $\tilde{A}$. We also describe a simple and easily computable external bound of this numerical range. The obtained results are applied to the infinite order problem arising in the solution of the dispersive Maxwell's system. (Received January 12, 2010)

1057-15-168 **Jianlin Xia*** (xiaj@math.purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907, and **Ming Gu**. *A new superfast and stable Toeplitz solver.*

In this talk, we will discuss a new stable and superfast solver for Toeplitz linear systems. With the displacement structure, our method solves the Cauchy-like system converted from the Toeplitz system in nearly O(N) flops with a small constant. Strong rank revealing LU factorizations are used in a hierarchical scheme to work on the Cauchy-like matrix. Two layers of structured representations are used: an outer layer HSS structure, and an inner Cauchy-like structure for each dense HSS generator. The method is significantly faster than some existing superfast Toeplitz solvers such as a previous structured solver by the authors in [SIMAX, 2007]. This is joint work with Ming Gu. (Received January 20, 2010)

1057-15-207 **Heide Gluesing-Luerssen** and **Elizabeth Weaver*** (eweaver@ms.uky.edu). *Minimal Tail-biting Trellises for Linear Block Codes.*

Linear block codes can be represented by a type of graph called a trellis which is used in decoding with the Viterbi algorithm. Since the computational complexity of this algorithm depends on the size of the trellis, it is useful to look at optimal trellises. I will consider constructions for minimal tail-biting trellises introduced by Koetter/Vardy and Nori/Shankar, and I will explore properties of both constructions and the relationships between them. (Received January 22, 2010)

1057-15-405 **Leonard Hoffnung*** (leonard.hoffnung@siemens.com), 10824 Hope Street, Cypress, CA 90630. *Householder-style M-orthogonal QR.* Preliminary report.

For the symmetric generalized eigenvalue problem $Kx = \lambda Mx$, the block Lanczos recurrence requires a QR factorization where Q is M-orthogonal. The industrial eigensolver in NX Nastran uses modified Gram-Schmidt to perform the factorization. As an alternative, the talk presents a Householder-style QR factorization that preserves M-orthogonality using unsymmetric reflectors. (Received January 26, 2010)

1057-15-431 **Katherine B Morrison*** (s-kmorri11@math.unl.edu), Department of Mathematics, 203 Avery Hall, University of Nebraska, Lincoln, NE 68588. *Towards a Duality Theory of Subspace Codes for Network Coding.*

Subspace codes were first proposed for use in error correction for random network coding by Koetter and Kschischang in 2008. One common construction for subspace codes is the lifting of linear codes whose codewords are either matrices over $\mathbb{F}_q$ or vectors over $\mathbb{F}_{q^m}$ with the rank metric; both space-time codes and rank-metric codes have been utilized to create efficient subspace codes. Grant and Varanasi proved a functional MacWilliams Identity for space-time codes, and Gadouleau and Yan proved a functional MacWilliams Identity for rank-metric codes. Yet, despite the fact that rank-metric codes can give rise to space-time codes, these MacWilliams Identities do not agree, as they are derived for different notions of dual. This talk aims to examine which notion of dual is more applicable to subspace codes and aims to use this to generate a duality theory for more general constructions of subspace codes as well. (Received January 26, 2010)

1057-15-434 **Vadim O Sokolov*** (vsokolov@anl.gov), 9700 S. Cass Avenue, Energy Systems Division, Argonne, IL 60439, and **Biswa Nath Datta**, NIU, Dept of Mathematical Sciences, DeKalb, IL 60115. *Numerical Methods for Quadratic Affine Inverse Eigenvalue Problem.*

The Quadratic Inverse Eigenvalue Problem (QIEP) is to find three matrices, M, C, and K, given a set of numbers and vectors, such that the given numbers become the eigenvalues of the matrix pencil $L(\lambda) = \lambda^2 M + \lambda C + K$ with the given vectors as the associated eigenvectors. The Quadratic Affine Inverse Eigenvalue Problem (QAIEP) has the additional requirement that the matrices M, C, and K must belong to an affine class of matrices, meaning that these are linear combinations of a given set of structured matrices.

In this talk, we consider the formulation and analysis of a locally quadratically convergent method and a globally convergent method for solving the QAIEP. We also describe how to modify the numerical methods to make them more efficient. The validity of the method is illustrated by means of a numerical example of spring-mass system. (Received January 26, 2010)

16 ► Associative rings and algebras

1057-16-42 **Emre Coskun*** (ecoskun@uwo.ca), 120 Middlesex College, Department of Mathematics, University of Western Ontario, London, Ontario N6A 5B7, Canada. *The Fine Moduli Space of Representations of Clifford Algebras.*

Given a fixed binary form $f(u, v)$ of degree d over a field k, the associated *Clifford algebra* is the k-algebra $C_f = k\{u, v\}/I$, where I is the two-sided ideal generated by elements of the form $(\alpha u + \beta v)^d - f(\alpha, \beta)$ with

α and β arbitrary elements in k. All representations of C_f have dimensions that are multiples of d, and occur in families. In this article we construct fine moduli spaces $U = U_{f,r}$ for the irreducible rd-dimensional representations of C_f for each $r \geq 2$. Our construction starts with the projective curve $C \subset \mathbb{P}^2_k$ defined by the equation $w^d = f(u, v)$, and produces $U_{f,r}$ as a quasiprojective variety in the moduli space $\mathcal{M}(r, d_r)$ of stable vector bundles over C with rank r and degree $d_r = r(d + g - 1)$, where g denotes the genus of C. (Received December 14, 2009)

1057-16-180 **Ellen E Kirkman*** (kirkman@wfu.edu), Box 7388, Wake Forest University, Winston-Salem, NC 27109, **James J Kuzmanovich**, Wake Forest University, and **James J Zhang**, University of Washington, Seattle, WA. *Invariants of AS-Regular Algebras: Complete Intersections.* Preliminary report.

Let G be a finite group acting on an Artin-Schelter regular $\mathbb{C}$-algebra A. Extending results of Watanabe we give conditions when the invariant subring A^G is an Artin-Schelter Gorenstein algebra. When $A = \mathbb{C}[x_1, \cdots, x_n]$ Gordeev (1986) and Nakajima (1984) independently determined when A^G is a complete intersection. We discuss extending these results to other Artin-Schelter regular algebras. (Received January 21, 2010)

1057-16-223 **Christopher Phan*** (c.phan@maths.gla.ac.uk), Department of Mathematics, University of Glasgow, 15 University Gardens, Glasgow, G12 8QW, Scotland. *Graded Ore extensions and the $\mathcal{K}_2$ property.*

Let A be a connected-graded algebra with trivial module $\Bbbk$, and let B be a graded Ore extension of A. We relate the structure of the Yoneda algebra $E(A) := Ext_A(\Bbbk, \Bbbk)$ to $E(B)$. Cassidy and Shelton have shown that when A satisfies their $\mathcal{K}_2$ property, B will also be $\mathcal{K}_2$. We prove the converse of this result. (Received January 24, 2010)

1057-16-228 **Andrew Conner*** (aconner@uoregon.edu), Department of Mathematics, University of Oregon, Eugene, OR 97403, and **Peter Goetz** (pdg11@humboldt.edu). *A_∞ structures and $\mathcal{K}_2$ algebras.*

Let K be a field and A be a connected graded K-algebra, finitely generated in degree 1. Let $(Q_\bullet, \partial)$ be a graded projective resolution of ${}_AK$ by left A-modules. Let $E(A) = H^*(\mathrm{End}(Q_\bullet))$ be the associated bigraded Yoneda algebra of A. A theorem of Kadeishvili states that $E(A)$ admits canonically defined higher multiplications which give $E(A)$ a minimal A_∞-algebra structure. If A is Koszul, all higher multiplications on $E(A)$ are zero. $\mathcal{K}_2$ algebras are a natural generalization of Koszul algebras. In this paper, we exhibit a family B_n of $\mathcal{K}_2$ algebras with quadratic and cubic relations such that an A_∞-structure on $E(B_n)$ provided by Kadeishvili's theorem has nonzero higher multiplications for all i, $2 \leq i \leq n$. (Received January 23, 2010)

1057-16-276 **Gwyn Bellamy*** (G.E.Bellamy@sms.ed.ac.uk), 7 Maes Wyre, Llanrhystud, Aberystwyth, Ceredigion SY23 5AH, Wales. *Rational Cherednik algebras at t=0.*

In this talk I shall describe some the basic properties of rational Cherednik algebras at $t = 0$. In particular, I shall explain how these algebras can be used to decide whether there exist symplectic resolutions for a large class of symplectic quotient varieties. (Received January 25, 2010)

1057-16-351 **Martin Lorenz*** (lorenz@temple.edu), Department of Mathematics, 1805 N. Broad Street, Philadelphia, PA 19122. *Some applications of Frobenius algebras to Hopf algebras.* Preliminary report.

We will discuss a unified ring theoretic approach, based on the theory of Frobenius algebras, to a variety of results on Hopf algebras. These include the so-called class equation, the determination of the semisimplicity locus of the Grothendieck ring, and a non-vanishing result for the adjoint character. (Received January 25, 2010)

1057-16-383 **Susan J. Sierra*** (ssierra@princeton.edu), Princeton University Mathematics Department, Fine Hall, Washington Road, Princeton, NJ 08544, and **Tom Nevins** (nevins@illinois.edu), University of Illinois Mathematics Department, Urbana, IL 61801. *Moduli spaces for point modules of naive blowups.*

Let $B(X, \mathcal{L}, \sigma)$ be the twisted homogeneous coordinate ring of an irreducible projective variety X of dimension ≥ 2, and let $z \in X$. Keeler, Rogalski, and Stafford construct a subalgebra $R(X, \mathcal{L}, \sigma, z) \subset B(X, \mathcal{L}, \sigma)$ by following the commutative method for blowing up X at z. The algebras $R = R(X, \mathcal{L}, \sigma, z)$ are known as *naive noncommutative blowup algebras*. Keeler, Rogalski, and Stafford show that if z and σ are in general enough position, then the images of point modules in $\mathrm{qgr} - R$ are naturally in bijective correspondence with closed points of X. However, in both $\mathrm{gr} - R$ and $\mathrm{qgr} - R$, point modules are not parameterized by any projective scheme.

We show that for a naive noncommutative blowup algebra $R(X, \mathcal{L}, \sigma, z)$ as above, the variety X is a coarse moduli space for isomorphism classes of point modules in $\mathrm{qgr} - R$. This gives a geometric structure to the bijection above, and has applications to the classification of noncommutative surfaces. (Received January 26, 2010)

1057-16-430 **Dag Madsen*** (dmadsen@syr.edu), Mathematics Department, 215 Carnegie, Syracuse University, Syracuse, NY. *T-Koszul algebras.*

Let $\Lambda = \bigoplus_{n\geq 0} \Lambda_n$ be a graded algebra over a field k. We assume $\dim_k \Lambda_i < \infty$ for all $i \geq 0$, but we do not assume that Λ_0 is semi-simple. Suppose $\mathrm{gldim}\, \Lambda_0 < \infty$. Let T be a graded Λ-module concentrated in degree zero.

In this talk I propose the following new definition of T-Koszul algebras: Λ is a T-Koszul algebra if both (1) and (2) hold.

(1) T is a tilting Λ_0-module.

(2) T is graded self-orthogonal as a Λ-module.

We prove that many quasi-hereditary Koszul algebras have a T-Koszul algebra structure coming form the standard (Verma) modules. (Received January 26, 2010)

17 ► Nonassociative rings and algebras

1057-17-391 **Anthony Giaquinto***, Department of Mathematics, Loyola University Chicago, Chicago, IL 60626, and **Murray Gerstenhaber** (mgersten@math.upenn.edu), Department of Mathematics, University of Pennsylvania, Philadelphia, PA 19104. *Graphs, Frobenius functionals, and the classical Yang-Baxter equation.*

A Lie algebra is Frobenius if it admits a linear functional F such that the Kirillov form F([x,y]) is non-degenerate. If g is the m-th maximal parabolic subalgebra P(n,m) of sl(n) this occurs precisely when (n,m) = 1. We define a "cyclic" functional F on P(n,m) and prove it is non-degenerate using properties of certain graphs associated to F. These graphs also provide in some cases readily computable associated solutions of the classical Yang-Baxter equation. Such solutions produce non-commutative versions of the associated parabolic group. (Received January 26, 2010)

18 ► Category theory; homological algebra

1057-18-134 **James Gillespie*** (jgillesp@ramapo.edu), 505 Ramapo Valley Road, School of Theoretical and Applied Science, Mahwah, NJ 07430. *Model structures on modules over Ding-Chen rings.*

M. Hovey used the theory of Gorenstein modules to show that the category of modules over an Iwanaga-Gorenstein ring has a formal homotopy theory. In analogy to the situation with chain complexes over a ring, there are three common model structures describing this homotopy theory: the projective, the injective and the flat model structures. The work of Nanqing Ding and coauthors shows that properties of Iwanaga-Gorenstein rings carry over to left and right coherent rings with finite self FP-injective dimension. We call such a ring a Ding-Chen ring. Similarly, the Gorenstein modules carry in the analogy and we make a case as to why we call these "Ding modules". We will describe these modules, and see how the homotopy theory on modules over Gorenstein rings extends to a homotopy theory of modules over Ding-Chen rings. In particular, when G is a finite group and R is a commutative Ding-Chen ring, then the group ring $R[G]$ is a Ding-Chen ring. The associated homotopy category is a generalization of the stable module category that exists when R is a field. (Received January 18, 2010)

1057-18-142 **Pedro A Guil-Asensio** (paguil@um.es), Departamento de Matematicas, Universidad de Murcia, Murcia, Spain, **Ivo Herzog** (herzog.23@osu.edu), Department of Mathematics, Lima, OH 45804, and **Blas Torrecillas*** (btorreci@ual.es), Departamento de Algebra y Analisis, Universidad de Almeria, 04071 Almeria, Spain. *Phantom maps and pure-injectivity.*

We study the ideal of all phantom maps in a category of modules and the existence of covers of modules by these morphisms. In this study, we introduce a new interesting class of modules which generalizes the class of pure-injective modules and that we call ϕ-pure-injective modules. This class coincide with cotorsion modules

in the case of Abelian groups and with pure-injective modules in the case of Quasi-Frobenius rings. (Received January 19, 2010)

1057-18-244 **Jinzhong Xu*** (jxu@theabfm.org), 1648 McGrathiana Parkway Suite 550, Lexington, KY 40511. *Bass Numbers and Dual Bass Numbers.*

Over a commutative Noetherian ring R, the Bass numbers, μ_i(p,M), were defined by H. Bass in 1963 through minimal injective resolution of R-module M for each prime ideal p in R. The properties of the invariants provide a powerful means in studying structures of certain important modules and rings. By existence of flat covers and flat resolutions, the dual Bass number, π_i(p, M), were defined in 1997. The Bass numbers and dual Bass numbers are homological invariants that share common characteristics in describing modules and rings and revealing their homological relationships, but in a manner of duality.

In this talk, we will first briefly review the Bass numbers and dual Bass numbers. We then will give a comparison of roles of these invariants in studying modules with focuses on vanishing properties. At the end, we will list some results and questions in studying dual Bass numbers. (Received January 25, 2010)

1057-18-265 **Sergio Estrada*** (sestrada@um.es), Departamento de Matematica Aplicada, Campus del Espinadro, Espinado, 30100 Murcia, Murcia, Spain. *Model category structures arising from Drinfeld vector bundles.* Preliminary report.

In the talk we present a general construction of monoidal model category structures on the category $\mathbb{C}(\mathfrak{Qco}(X))$ of unbounded chain complexes of quasi-coherent sheaves on a semi-separated scheme X. The construction is based on making compatible the filtrations of individual modules of sections at open affine subsets of X. It does not require closure under direct limits as previous methods. As particular instances, we recover recent results on the flat model structure for chain complexes of quasi-coherent sheaves. Our approach also includes the case of (infinite-dimensional) vector bundles, and of restricted flat Mittag-Leffler quasi-coherent sheaves, as introduced by Drinfeld. Finally, we indicate that the unrestricted case does not induce a model category structure as above in general.

The talk is based on a joint work with Pedro A. Guil-Asensio, Mike Prest and Jan Trlifaj. (Received January 25, 2010)

1057-18-357 **Luchezar L. Avramov*** (avramov@math.unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588, **Hans-Bjørn Foxby** (foxby@math.ku.dk), Department of Mathematics, University of Copenhagen, DK-2100 Copenhagen, Denmark, and **Stephen Halperin** (shalper@deans.umd.edu), University of Maryland, College of Computer, Mathematical and, Physical Sciences, College Park, MD 20742. *Minimal resolutions over differential graded algebras.*

A notion of minimality that applies to arbitrary DG modules over a DG algebra will be introduced. For resolutions of modules or complexes, it will be compared to existing notions. Various classes of DG modules will be shown to admit semiprojective or semiinjective minimal resolutions, which are unique up to isomorphism. (Received January 25, 2010)

1057-18-370 **Ana Jeremías López*** (ana.jeremias@usc.es), Dep. de Álxebra Fac. de Matemáticas, Universidade de Santiago, Santiago de Compostela, SPAIN, E-15782 Santiago de Comp., Galicia, Spain. *Classifying t-structures in Commutative Algebra.*

In this talk we will present our results on t-structures on the derived category of modules over a commutative noetherian ring R, developed jointly with Alonso and Saorín. A theorem of Hopkins and Neeman classifies triangulated t-structures a.k.a. Bousfield localizations, they are in bijection with subsets of Spec(R). As it was shown by Stanley, this classification is impossible for general t-structures because they form a proper class already for $\mathbb{Z}$. We will treat the case of *compactly generated* t-structures. They are classified by decreasing filtrations by supports of Spec(R). All t-structures on $\mathsf{D}^b_{fg}(R)$, the subcategory of bounded complexes with finite type homology, is the restriction of a compactly generated t-structure on $\mathsf{D}(R)$. A decreasing filtration by supports $\phi\colon \mathbb{Z} \to \mathrm{Spec}(R)$ satisfies the weak Cousin condition (wCc) if $\phi(i)$ contains all immediate generalizations of the points of $\phi(i+1)$. Every t-structure on $\mathsf{D}^b_{fg}(R)$ is induced by a compactly generated t-structure on $\mathsf{D}(R)$ whose associated filtration by supports satisfies wCc and these are all if R has a dualizing complex. (Received January 26, 2010)

1057-18-371 **Leovigildo Alonso Tarrío*** (leo.alonso@usc.es), Dep. de Álxebra Fac. de Matemáticas, Universidade de Santiago, Santiago de Compostela, SPAIN, E-15782 Santiago de Comp., Galicia, Spain. *The structure of the derived category of a scheme.*

We will discuss the structure of the category $\mathsf{A}_{\mathsf{qc}}(X)$ of quasi-coherent sheaves over a scheme X. It is a Grothendieck abelian category. This implies that its derived category, $\mathsf{D}(\mathsf{A}_{\mathsf{qc}}(X))$, satisfies three of the axioms of a stable homotopy category in the sense of Hovey, Palmieri and Strickland, namely it is triangulated, possesses products and satisfies Brown representability. If X is in addition quasi-compact and semi-separated (non necessarily noetherian) then $\mathsf{D}(\mathsf{A}_{\mathsf{qc}}(X))$ is a symmetric closed category with a set of strongly dualizable generators, thus satisfying all five axioms. This answers a question of Strickland. We will also show that in this case the category is also *unital*, the unit for the tensor is compact; and *algebraic*, the generators are compact objets. (Received January 26, 2010)

1057-18-377 **Jan Trlifaj*** (trlifaj@karlin.mff.cuni.cz), KA MFF UK, Sokolovska 83, Praha 8, Czech Rep. *Kaplansky classes.*

Enochs introduced Kaplansky classes as sources of module approximations. Gillespie then used them to construct model structures for complexes over a Grothendieck category. A connection to model theory was discovered by Baldwin et al. In all these cases the focus was on Kaplansky classes closed under direct limits. Eklof then introduced deconstructible classes, and Estrada et al. used them to extend Gillespie's work to classes not necessarily closed under direct limits.

We will prove that each deconstructible class of modules closed under transfinite extensions is Kaplansky, and the converse holds for classes closed under direct limits, but not in general: If D is the class of $\aleph_1$–projective modules then D is always Kaplansky, but D is deconstructible iff R is perfect. A deconstructible class closed under transfinite extensions, direct summands, and containing R, is special precovering, but this fails for Kaplansky classes: It is consistent that D is not precovering for any countable ring; moreover, D is not precovering for any 1-Gorenstein ring.

Joint work with D.Herbera and J.Saroch. (Received January 26, 2010)

1057-18-439 **Overtoun M Jenda*** (jendaov@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849. *A Survey of Gorenstein Homological Algebra.*

In this talk, we will give an overview of a variety of Relative Homological Algebra that we now call Gorenstein Homological Algebra. We will give a brief historical outline of the subject and discuss Gorenstein injective, Gorenstein projective, and Gorenstein flat modules that generalize the usual injective, projective, and flat modules. In particular, we will discuss homological properties of these modules over Iwanaga-Gorenstein rings. Finally, we will discuss special properties of Gorenstein injective modules over commutative noetherian rings. (Received January 26, 2010)

20 ► Group theory and generalizations

1057-20-247 **Joshua Roberts*** (jroberts@ms.uky.edu), 719 Patterson Office Tower, Department of Mathematics, University of Kentucky, Lexington, KY 40506. *Upper bounds and generators for low dimensional group homology.*

Group homology plays an important role in algebraic K-theory, and its computational aspects remain an issue of interest. Although significant progress has been made for finite groups, serious obstacles exist for infinite groups. However, given a finitely presented group G, Hopf's formula expresses the second integral homology of G in terms of generators and relators. We give an algorithm that exploits Hopf's formula to estimate $H_2(G;k)$, with coefficients in a finite field k. Moreover, we describe techniques to find explicit descriptions of generators for this vector space. Finally, we give example calculations which are related to a conjecture of Quillen. (Received January 24, 2010)

26 ► Real functions

1057-26-28 **Jafar Zafarani*** (jzaf@zafarani.ir), Department of Mathematics, Sheikhbahaee University and University, of Isfahan, Isfahan, Isfahan 81745-163. *Approximation for Baire functions.* Preliminary report.

Let X be a perfectly normal Hausdorff topological space and E be a Banach space. Suppose that $C^{\circ}(X,E)$ is the set of all of E-valued continuous functions with relatively compact ranges. Then for each ordinal α,

the class of ambiguous sets of class α is denoted by $\mathcal{H}_\alpha$ and the Baire functions of class α is defined by: $\beta_0^\circ(X,E) = C^\circ(X,E)$, and $\beta_\alpha^\circ(X,E)$ as the set of all $f : X \to E$ such that f is the point-wise limit of some sequence in $\beta_{\alpha-1}(X,E)$ and range of f is relatively compact. Here we show that the uniform closure of $\sigma_{\alpha,E}$ is $\beta_\alpha^\circ(X,E)$, where $\sigma_{\alpha,E} = \{\sum_{i=1}^n e_i\chi_{H_i} : n \in \mathbb{N}, e_i \in E \text{ and } H_i \in \mathcal{H}_\alpha \text{ for each } i\}$. As application of our results, we obtain a dual representation of the space $\beta_\alpha^\circ(X,E)$. (Received December 25, 2009)

1057-26-292 **Alexei Poltoratski**, **Barry Simon** and **Maxim Zinchenko*** (maxim.zinchenko@wmich.edu). *Absolute Continuity of Measures on Homogeneous Sets.*

We give a criterion for pure absolute continuity of a measure in terms of its Hilbert transform. Explicitly, we prove that $\lim_{t\to\infty} t|E \cap \{x : |H_\mu(x)| > t\}| = 0$ if and only if $\mu_s(E) = 0$, where μ is a finite positive measure on $\mathbb{R}$, μ_s its singular part, H_μ its Hilbert transform, and $E \subset \mathbb{R}$ is a homogeneous set in the sense of Carleson. The result has applications in the spectral theory of Schödinger, Jacobi, and CMV operators. (Received January 25, 2010)

28 ► Measure and integration

1057-28-68 **Marie A. Snipes*** (snipesm@kenyon.edu), Department of Mathematics, Kenyon College, Gambier, OH 43050. *Flat Forms in Banach Spaces.* Preliminary report.

We will discuss developments in the theory of flat forms in Banach spaces. (Received January 03, 2010)

1057-28-369 **Christopher S. Camfield*** (camfieldc@kenyon.edu), Department of Mathematics, Kenyon College, Gambier, OH 43022. *A Look at the BV space as an Extension of the (1,1)-Newtonian Space in Metric Measure Spaces.* Preliminary report.

We will look at the space of functions of bounded variation in a metric measure space as defined by Miranda Jr., and show its relationship to the (1,1)-Newtonian space defined by Shanmugalingam. In Euclidean spaces, the BV space is an extension of the (1,1)-Sobolev space with $W^{1,1}$ being the subspace of functions whose variation measure is absolutely continuous with respect to the Lebesgue measure. We will show that the analogous relationship holds in metric measure spaces with doubling measures supporting a (1,1)-Poincaré Inequality. (Received January 26, 2010)

30 ► Functions of a complex variable

1057-30-16 **Joseph A. Cima*** (cima@email.unc.edu), Department of Mathematics, University of North Carolina, CB# 3250, Phillips Hall, Chapel Hill, NC 27599-3250. *Truncated Toeplitz Operators.*

An exposition of some current results. Spatial isomorphisms of such operators. Compact truncated Toeplitz operators. The result of Baranov, Chalendar, Fricain, Mashreghi and Timotin on the Sarason conjecture. (Received November 03, 2009)

1057-30-27 **Alexander J. Izzo*** (aizzo@math.bgsu.edu), Department of Mathematics and Statistics, Bowling Green State University, Bowling Green, OH 43403. *A Tetrachotomy for Certain Algebras Containing the Disc Algebra.*

We will answer a question raised by Joseph Cima. Let D denote the open unit disc in the plane, and let $A(D)$ denote the disc algebra. A theorem of E. M. Čirka asserts that if f is a function in $C(\overline{D})$ and f is harmonic but nonholomorphic on D, then the uniformly closed subalgebra $A(D)[f]$ of $C(\overline{D})$ generated by $A(D)$ and f is equal to $C(\overline{D})$. An analogous result for $H^\infty(D)$ was proved by Sheldon Axler and Allen Shields: If f is a bounded function on D that is harmonic but nonholomorphic, then the uniformly closed subalgebra $H^\infty(D)[f]$ of $L^\infty(D)$ generated by $H^\infty(D)$ and f contains $C(\overline{D})$.

Taken together these two theorems suggest that perhaps the inclusion $A(D)[f] \supset C(\overline{D})$ holds whenever f is a bounded harmonic nonholomorphic function on D. However, this is false; it is not even true that $A(D)[f, \overline{f}\,] \supset C(\overline{D})$ whenever $f \in H^\infty(D)$. This led Cima to ask which continuous functions are in $A(D)[f]$ or $A(D)[f, \overline{f}\,]$ when the inclusion $A(D)[f] \supset C(\overline{D})$ or $A(D)[f, \overline{f}\,] \supset C(\overline{D})$ fails. We will answer this question for $A(D)[f, \overline{f}\,]$. (Received December 03, 2009)

1057-30-43 **William Wancang Ma*** (wma@pct.edu), School of Integrated Studies, Pennsylvania College of Technology, One College Avenue, Williamsport, PA 17701, and **Jinxi Ma**, Department of Mathematics, 37 Xueyuan Road, Haidian District, Beijing, Peoples Rep of China. *Estimates of the hyperbolic metric on the twice punctured plane.* Preliminary report.

We provide various estimates on the hyperbolic metric of the twice puntured plane and apply them to improve Landau's Theorem. We also give an improved upper bound on the hyperbolic metric of the twice puntured plane. (Received December 15, 2009)

1057-30-50 **Xiangdong Xie*** (xxie@georgiasouthern.edu), Department of Mathematical Sciences, Georgia Southern University, Statesboro, GA 30458. *Quasisymmetric maps on the ideal boundary of negatively curved $R^n \rtimes R$.*

We study quasisymmetric maps between the ideal boundaries of negatively curved $R^n \rtimes R$. We show that all self quasisymmetric maps are biLipschitz (except when the manifolds are biLipschitz to the real hyperbolic spaces). We also classify the ideal boundaries up to quasisymmetry. (Received January 24, 2010)

1057-30-54 **Leonid V. Kovalev*** (lvkovale@syr.edu), Department of Mathematics, 215 Carnegie Building, Syracuse University, Syracuse, NY 13244, and **Jani Onninen** and **Kai Rajala**. *Multiplicity of local homeomorphisms and invertibility of Sobolev mappings.*

We prove a version of the Inverse Function Theorem for continuous weakly differentiable mappings. Namely, a nonconstant $W^{1,n}$-mapping is a local homeomorphism if it has integrable inner distortion function and satisfies a certain differential inclusion. A crucial ingredient of our proof is that the integral of the inner distortion controls the multiplicity of a local homeomorphism, even though it does not control the radius of injectivity. This puts a new twist on the Global Homeomorphism Theorem of Zorich. (Received December 23, 2009)

1057-30-70 **T Sheil-Small*** (sheil_small@hotmail.com), Cyprus. *A Bergman space extremal problem for non-vanishing functions.*

Recent progress is given towards the solution of a classical unso lved problem on the Bergman space of non-vanishing functions in the unit discS (Received January 04, 2010)

1057-30-71 **Pietro Poggi-Corradini***, Department of Mathematics, Cardwell Hall, Kansas State University, Manhattan, KS 66506. *Evolution of analytic Jordan curves under conformal maps of an annulus.* Preliminary report.

Let f be an analytic map near 0 with $f(0) = 0$ and $f'(0) \neq 0$. For r fixed (small) $f(re^{i\theta})$ describes an analytic Jordan curve $J(r)$, and hence defines an inner domain G_1 and an outer domain G_2. Let $M_1(r)$ be the reduced modulus of $J(r)$ with respect to 0 in G_1, and let $M_2(r)$ the reduced modulus of $J(r)$ with respect to ∞ in G_2. Then $M_1(r) + M_2(r) \leq 0$ with equality if and only if $J(r)$ is a circle centered at 0. Teichmü ller's famous *Modulsatz* states that if $M_1 + M_2$ is close to 0, then J is closed to being a circle (geometrically). So the quantity $M_1 + M_2$ can be thought as a measure of how far J is from being a circle. In previous work we showed that $|M_1(r)+M_2(r)|$ is monotonically increasing with r. Inspired by the recent breakthrough of Iwaniec, Kovalev, and Onninen on the Nitsche conjecture, we have extended our result to conformal mappings defined on an annulus $\{1 < |z| < R\}$ such that $|f(z)| = 1$ for $|z| = 1$. We will finish the talk with some open problems related to the work of Pólya and Szegő. (Received January 04, 2010)

1057-30-199 **Erin R. Militzer*** (ermilitzer@gmail.com), 1234 Kastle Road, Lexington, KY 40502, and **J. E. Brennan** (brennan@ms.uky.edu). *L^p Rational Approximation.*

In 1968 Sinanjan proved the existence of a compact set X such that $R(X) \neq C(X)$ but $R^p(X, dA) = L^p(X, dA)$ for all p, $1 \leq p < \infty$. In 2009 the authors answered the corresponding question for $H^p(X, dA)$ which stands in contrast to Sinanjan's result. In this case, under the same assumption, a bounded point evaluation for the polynomials is present and therefore $H^p(X, dA) \neq L^p(X, dA)$. Here dA represents two dimensional Lebesgue measure and for each p, $1 \leq p < \infty$, $R^p(X, dA)$ is the closed subspace of $L^p(X, dA)$ that is spanned by rational functions whose pole's do not lie in X. We denote by $R(X)$ the class of functions that can be uniformly approximated on X by rational functions whose poles lie outside of X, and by $C(X)$ the space of all continuous functions on X. We provide an alternative proof to Sinanjan's result which depends on the fact that L^p capacities decrease modulo a constant under contraction whereas analytic capacity does not. (Received January 22, 2010)

1057-30-206 **Alexander Yu. Solynin*** (alex.solynin@ttu.edu), Department of Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409. *Choquet capacities, elliptic equations, and ordering of solutions.*

We will discuss *Choquet capacities* $C(E)$ generated by solutions of certain elliptic partial differential equations on a domain Ω. In particular, we will show that our set functions $C(E)$ satisfy the Choquet inequality $C(E_1 \cup E_2) + C(E_1 \cap E_2) \le C(E_1) + C(E_2)$ for any two compact subsets E_1 and E_2 of Ω. Then using the so-called *ordering transformation* of sets, we will explain how the Choquet inequality can be generalized for systems containing more than two sets. (Received January 22, 2010)

1057-30-229 **Alexandre Eremenko*** (eremenko@math.purdue.edu), Department of Mathematics, Purdue University, West Lafayete, IN 47907. *Brody curves omitting hyperplanes.*

For holomorphic curves $f : \mathbf{C} \to \mathbf{CP}^n$ we denote by $\|f'\|$ the "spherical derivative". It measures the length distortion from the Euclidean metric to the Fubini–Study metric in projective space $\mathbf{CP}^n$.

Theorem. *If $\|f'\|$ is bounded, and f omits n hyperplanes in general position, then $T(r, f) = O(r)$.*

The number n of omitted hyperplanes in this statement is the smallest possible. The case $n = 1$ follows from a theorem of Clunie and Hayman. For arbitrary n, the Theorem improves earlier results of Tsukamoto, Berteloot and Duval. (Received January 23, 2010)

1057-30-233 **David - Drasin*** (drasin@math.purdue.edu), Department of Mathematics, 150 N. University St., West Lafayette, IN 47907. *Nevanlinna theory of iterates.*

Let f be a rational function of degree n and $\mathcal{F}$ the family of its iterates. Some years ago, M. Sodin discussed how one may adapt R. Nevanlinna's theory of (a single) meromorphic function to a general family of rational mappings. When the family has the special form of $\mathcal{F}$ we are able to sharpen earlier work. Our results are essentially sharp. (Joint work with Y. Okuyama). (Received January 23, 2010)

1057-30-262 **Michael T. Lacey** (Lacey@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332, **Eric T. Sawyer** (sawyer@mcmaster.ca), Department of Mathematics and Statistics, McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4K1, Canada, **Xavier Tolsa** (xtolsa@mat.uab.cat), Departament de Matematiques, Universitat Autonoma de Barcelona, 08193 Bellaterra, Barcelona, Spain, and **Ignacio Uriarte-Tuero*** (uriarte@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Astala's conjecture on Hausdorff measure distortion under planar quasiconformal mappings and related removability problems.*

In his celebrated paper on area distortion under planar quasiconformal mappings (Acta 1994), Astala proved that if E is a compact set of Hausdorff dimension d and f is K-quasiconformal, then fE has Hausdorff dimension at most $d' = \frac{2Kd}{2+(K-1)d}$, and that this result is sharp. He conjectured (Question 4.4) that if the Hausdorff measure $\mathcal{H}^d(E) = 0$, then $\mathcal{H}^{d'}(fE) = 0$. This conjecture was known to be true if $d' = 0$ (obvious), $d' = 2$ (Ahlfors), and $d' = 1$ (Astala, Clop, Mateu, Orobitg and UT, Duke 2008.) The approach in the last mentioned paper does not generalize to other dimensions.

UT showed that Astala's conjecture is sharp in the class of all Hausdorff gauge functions (IMRN, 2008).

Lacey, Sawyer and UT jointly proved completely Astala's conjecture in all dimensions (Acta, 2009?) The proof uses Astala's 1994 approach, geometric measure theory, and new weighted norm inequalities for Calderón-Zygmund singular integral operators which cannot be deduced from the classical Muckenhoupt A_p theory.

These results are intimately related to removability problems for various classes of quasiregular maps. I will particularly mention sharp removability results for bounded K-quasiregular maps obtained jointly by Tolsa and UT. (Received January 25, 2010)

1057-30-271 **David A Herron*** (David.Herron@math.UC.edu), Department of Mathematical Sciences, P.O. Box 210025, University of Cincinnati, Cincinnati, OH 45221-0025, and **Daniel Meyer** (DMeyermail@gmail.com), Department of Mathematics and Statistics, University of Helsinki, P.O. Box 68, Gustaf Hällströmin katu 2b, FI-00014 Helsinki, Finland. *Catalogs for Bounded Turning Jordan Curves.* Preliminary report.

We present a dyadic model that provides a catalog for all (up to bilipschitz equivalence) bounded turning metric Jordan curves. (Received January 25, 2010)

1057-30-290 **Aimo Hinkkanen*** (aimo@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green St., Urbana, IL 61801, and **Ilgiz Kayumov**, Institute of Mathematics and Mechanics, Kazan State University, Kazan, 420 008, Russia. *Smale's problem for polynomials with critical points on two rays.*

Let f be a polynomial of degree $n \geq 2$ with $f(0) = 0$ and $f'(0) = 1$. Smale conjectured that there is a critical point ζ of f, that is, a zero of f', such that $|f(\zeta)/\zeta| \leq 1 - 1/n$. Addressing a special case of this problem, we prove that there is a critical point ζ of f with $|f(\zeta)/\zeta| \leq 1/2$ provided that the critical points of f lie in the sector $\{re^{i\theta} : r > 0, |\theta| \leq \pi/6\}$, and $|f(\zeta)/\zeta| \leq 2/3$ if they lie in the union of two rays from the origin to infinity (for example, the real axis), or in the union of the two rays $\{1 + re^{\pm i\theta} : r \geq 0\}$, where $0 < \theta \leq \pi/2$. We identify the cases of equality. The best previously known degree-independent upper bound for the case of real critical points was $e - 2$, due to Sheil-Small and to Rahman and Schmeisser. (Received January 25, 2010)

1057-30-399 **Maher M.H. Marzuq*** (mmarzuq@moc.edu), Maher M. H. Marzuq, Department of Science and Mathematics, Mount Olive College, Mount Olive, NC 28365. *Interpolation Sequence For The Spaces $H^q_+(\phi)(q \geq 1)$.*

Let ϕ be a subadditive increasing real valued function defined on $[0, \infty)$ and which satisfies $\phi(x) = 0$ if and only if $x = 0$. For $q \geq 1$ we define $H^q(\phi)$ to be the set of all functions f which are analytic in the open unit disc and satisfy

$$\sup_{0 \leq r < 1} \int_0^{2\pi} [\phi(|f(re^{i\theta})|]^q \, d\theta < \infty$$

and $H^q_+(\phi)$ to be the subspace of $H^q(\phi)$ of functions which satisfy

$$\lim_{r \to 1} \int_0^{2\pi} [\phi(|f(re^{i\theta})|)]^q \, d\theta = \int_0^{2\pi} [\phi(|f(e^{i\theta})|)]^q \, d\theta.$$

In this paper we prove some interpolation theorems for $H^q_+(\phi)$. (Received January 26, 2010)

31 ► Potential theory

1057-31-38 **Anders Björn*** (anbjo@mai.liu.se), Department of Mathematics, Linköpings universitet, SE-586 66 Linköping, Sweden. *The Baernstein problem for p-harmonic functions.*

In 1998 Al Baernstein asked the following problem: *Is the p-harmonic measure of E equal to the p-harmonic measure of $\overline{E}$?*, when E is the union of two open arcs on the unit circle in $\mathbf{R}^2$.

The p-harmonic measure of E is defined to be the Perron solution of χ_E, i.e. the solution to the Dirichlet problem for p-harmonic functions in the unit disc with boundary values χ_E. (In this case it is known that the upper and lower Perron solutions agree).

For $p = 2$ the affirmative answer to Baernstein's problem is trivial, but for $p \neq 2$ it is far from obvious. In 2006 Björn–Björn–Shanmugalingam made considerable progress showing that the answer is *yes* if $1 < p < 2$. Their method cannot be extended to the case $p > 2$ for several reasons.

In 2009 I used a completely different method to prove that the answer is *yes* for all $p > 1$. Kim–Sheffield has also independently shown that the answer is *yes* for all $p > 1$.

In this talk I will discuss the history and mathematics of this result. I also intend to discuss related problems and results for Perron solutions. (Received December 10, 2009)

1057-31-89 **Peter A Loeb*** (loeb@math.uiuc.edu), Department of Mathematics, University of Illinois, 1409 West Green Street, Urbana, IL 61801. *Nonstandard Analysis Applied to Ideal Boundaries.* Preliminary report.

The speaker has applied nonstandard analysis to three aspects of ideal boundary theory: Attaching appropriate boundaries to potential theoretic domains, constructing measures on boundaries that represent nonnegative harmonic functions, finding boundary approach neighborhoods that yield appropriate limits at boundary points. The original, motivating application of the speaker's work on measure theory was a nonstandard construction of standard representing measures for nonnegative harmonic functions. This work yielded new standard weak convergence methods for constructing such measures on spaces of extreme harmonic functions in very general settings. The search for a Martin-type ideal boundary for the placement of those measures missed, but a new almost everywhere regular boundary that supported the representing measures for a large subclass of nonnegative harmonic functions was produced and intensively investigated by Juergen Bliedtner and the speaker. In this talk, we review this background and then return to the problem of constructing an appropriate boundary associated with the nonstandard construction of general representing measures. (Received January 11, 2010)

1057-31-145 **Albert Baernstein II*** (al@math.wustl.edu) and **A. Yu. Solynin**. *Monotonicity and comparison results for conformal invariants.*

Suppose that Ω is an n-fold symmetric domain in the plane which satisfies a differential inequality $\Delta u \geq \gamma(u) + f$ in Ω. Assume also that u is constant outside Ω. We prove that if γ and f satisfy certain conditions, among them that f be n-fold symmetric, then u is n-fold symmetric. We prove also that if u is desymmetrized in a certain way, then the function thus obtained is majorized by a function v which satisfies $\Delta v \leq \gamma(v) + f_1$, where f_1 is a corresponding desymmetrization of f. This permits us to solve some extremal problems involving Poincare metrics, harmonic measures and capacities. (Received January 19, 2010)

1057-31-193 **John M Mackay*** (jmmackay@illinois.edu), 1409 W. Green Street, Urbana, IL 61801, and **Jeremy T Tyson** and **Kevin Wildrick**. *Poincare inequalities and non-self-similar Sierpinski carpets.* Preliminary report.

The classical construction of the Sierpinski carpet has a natural generalization to a class of non-self-similar carpets. We discuss properties of these spaces, considering in particular whether they admit a Poincare inequality. (Received January 22, 2010)

1057-31-217 **Alexander Yu. Solynin*** (alex.solynin@ttu.edu), Department of Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409. *Isoperimetric inequalities for curvilinear polygons.*

We will discuss several isoperimetric problems on the class of planar curvilinear polygons with at most $n \geq 3$ sides. In particular, we will show how the method of dissymmetrization and the method of partitioning of a domain can be used to solve some of these problems. (Received January 23, 2010)

1057-31-238 **Rodrigo Banuelos*** (banuelos@math.purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47906, **Iosif Polterovich** (iossif@dms.umontreal.ca), Département de mathématiques, Université de Montréal, Montreal, Canada, **Bartłomiej Siudeja** (siudeja@illinois.edu), Department of Mathematics, University of Illinois, Urbana-Champaign, IL 61801, and **Tadeusz Kulczycki** (tkulczycki@impan.pan.wroc.pl), Institute of Mathematics, Polish Academy of Sciences, Wrocław, Poland. *Eigenvalue inequalities for mixed Steklov problems.*

Let μ_n and λ_n be the eigenvalues of the mixed Steklov problem with Neumann and Dirichlet boundary conditions, respectively, in a domain of Euclidean space R^d, $d \geq 2$. Under certain assumptions on the domain it is proved that $\mu_{n+1} \leq \lambda_n$. For $n = 1$ this is a generalization of the classical Pólya inequality between the Neumann and Dirichlet eigenvalues for the Laplacian. (Received January 24, 2010)

1057-31-275 **Jana Bjorn*** (jabjo@mai.liu.se), Department of Mathematics, Linkoping University, SE-58183 Linkoping, Sweden. *Quasiminimizers - BMO, integrability and examples.*

Quasiminimizers are defined as a more robust generalization of p-harmonic functions. They share several good properties with p-harmonic functions, while other estimates fail, as shown by precise counterexamples. (Received January 25, 2010)

1057-31-389 **D Maldonado** and **Kabe Moen***, Department of Mathematics, Box 1146, St. Louis, MO 63130, and **Virginia Naibo**. *Multilinear Poincare inequalities for vector fields of Hormander type.*

In this joint work with D. Maldonado and V. Naibo we introduce a weighted Poincare inequality for products of functions. As the classical Poincare inequality fails for $0 < p < 1$, the multilinear Poincare inequality is a natural substitute in this situation. We prove such weighted multilinear Poincare inequalities in the subelliptic context associated to vector fields of Hormader type. We do so by establishing multilinear representation formulas and weighted estimates for multilinear potential operators in spaces of homogeneous type. (Received January 26, 2010)

32 ► Several complex variables and analytic spaces

1057-32-29 **Chia-chi Tung*** (chia.tung@mnsu.edu), Dept. of Math. and Stat., Minnesota State University, Mankato, Mankato, MN. *On Weak Metaharmonicity and Holomorphicity of Distributions.* Preliminary report.

The purpose of this note is to prove the differentiability, respectively, semireal-analyticity of a metaharmonic distribution on a complex analytic space with an (infinitely) differentiable, respectively, real-analytic, density. As applications, a generalized Gauss' mean-value property is etablished for meta- (as well as weakly) harmonic

functions, and characterizations of the weak holomorphicity of distributions (respectively, functions) on a complex space are given in terms of the local Cauchy-Riemann operators (respectively, $\bar{\partial}$-Euler currents). (Received December 24, 2009)

1057-32-56 **Jiri Lebl*** (jlebl@math.uiuc.edu), Department of Mathematics, 1409 W. Green Street, Urbana, IL 61801, and **Han Peters**. *Polynomials constant on a hyperplane and CR maps of hyperquadrics.*

We prove a sharp degree bound for polynomials constant on a hyperplane with a fixed number of distinct monomials for dimensions 2 and 3. We study the connection with monomial CR maps of hyperquadrics and prove similar bounds in this setup with emphasis on the case of spheres. The results support generalizing a conjecture on the degree bounds to the more general case of hyperquadrics. (Received December 26, 2009)

1057-32-65 **Jianguo Cao*** (cao.7@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556, and **Mei-Chi Shaw**, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Bounded holomorphic functions on open Kaehler manifolds with negative curvature.* Preliminary report.

In this lecture, we consider an open problem of S. T. Yau in complex analysis posted in 1979. Let M^{2n} be a simply-connected complete Kaehler manifold with negative sectional curvature $-b^2 \leq sec_M \leq -1$. Yau asked if M^{2n} admits a non-constant bounded holomorphic function. For instance, the Poincaré disk of constant negative curvature admits infinitely many and linearly independent bounded holomorphic functions. Using various results from comparison metric geometry and the so-called Kohn's d-bar-b theory on CR-hypersurfaces, we provide a new partial answer to Yau's problem for the case of complex dimension ≥ 3. (Received January 02, 2010)

1057-32-87 **Adam Coffman*** (CoffmanA@ipfw.edu), Department of Mathematical Sciences, IPFW, 2101 E. Coliseum Blvd., Fort Wayne, IN 46805-1499, and **Yifei Pan** (Pan@ipfw.edu). *Counterexamples to upper semicontinuity of the Kobayashi-Royden pseudonorm for rough almost complex structures.*

For each $\alpha \in (0, 1)$, we construct a manifold with an α-Hölder continuous almost complex structure, such that the Kobayashi-Royden pseudonorm is not upper semicontinuous. This generalizes an example due to Ivashkovich, Pinchuk, and Rosay, with $\alpha = \frac{1}{2}$. The main idea in the construction is an analysis of complex valued functions f on the unit disk satisfying $\partial f/\partial \bar{z} = |f|^\alpha$. (Received January 09, 2010)

1057-32-110 **Zeljko Cuckovic*** (zcuckovi@math.utoledo.edu), Department of Mathematics, 2801 W. Bancroft Street, Toledo, OH 43606, and **Sonmez Sahutoglu** (Sonmez.Sahutoglu@utoledo.edu), Department of Mathematics, 2801 W. Bancroft Street, Toledo, OH 43606. *Compactness of Hankel operators on pseudoconvex domains.*

Using the dbar-Neumann problem, we study compactness of Hankel operators whose symbols are smooth up to the boundary of a pseudoconvex domain. We show that the compactness depends on the behavior of the symbol on the analytic structure in the boundary of the domain. We also study compactness of a product of the adjoint of a Hankel operator with another Hankel operator. This is joint work with Sonmez Sahutoglu. (Received January 14, 2010)

1057-32-129 **Manuel Maestre*** (manuel.maestre@uv.es), Departamento de Análisis Matemático, Universidad de Valencia, Doctor Moliner, 50, 46010 Burjassot, Valencia, Spain. *Vectorial Bohr radii and Dirichet series.*

In 2009, Defant et alters gave asymptotic optimal estimates for K_n, the Bohr radius of scalar valued holomorphic functions on the polydisk. But Blasco in 2009 has shown that the vector valued Bohr radius can be 0. We present a study showing that for $\lambda > 1$, the vector valued Bohr radii $K_n(\lambda, X)$ is always strictly positive. If X is finite dimensional then we obtain optimal asypmtotic bounds for $K_n(\lambda, X)$. We also give "almost" asympotic bounds for the case X infinitely dimensional related to the cotype of X. For that we make the connection with the strip of uniform but not absolute convergence of vector valued Dirichlet series.

This is joint work with Andreas Defant (University of Oldenburg)

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(Received January 18, 2010)

33 ► Special functions

1057-33-341 **Alexander R Its*** (itsa@math.iupui.edu), Indiana University Purdue University, Indianapolis, Mathematical Sciences, Indianapolis, IN 46202-3216. *Asymptotics of Toeplitz, Hankel and Toeplitz + Hankel determinants with Fisher-Hartwig singularities. The Riemann-Hilbert approach.*

We will discuss some new results obtained via the Riemann-Hilbert method in the area of asymptotic analysis of Hankel and Toeplitz determinants whose symbols possess Fisher-Hartwig singularities on a smooth background. Specifically, we will discuss the proof of the Basor-Tracy conjecture concerning the Toeplitz determinants, the asymptotics of Hankel and Toeplitz + Hankel determinants on a finite interval, and the Painlevé-type crossover formulae describing a transition between the Szegö and the Fisher-Hartwig type of asymptotic behavior for Toeplitz determinants. The talk is based on the joint works with P. Deift, T. Claeys, and I. Krasovsky. (Received January 25, 2010)

34 ► Ordinary differential equations

1057-34-26 **Kwang C. Shin*** (kshin@westga.edu), Department of Mathematics, University of West Georgia, Carrollton, GA 30118. *All cubic and quartic polynomials P for which $f'' + P(z)f = 0$ has a solution with infinitely many real zeros and at most finitely many non-real zeros.* Preliminary report.

In 1883 Steven Bank posed the question of classifying polynomials P for which $f'' + P(z)f = 0$ has a solution that has only real zeros and infinitely many of them (Problem 2.71 of Hayman's Collection). In this talk, we completely characterize all cubic and quartic polynomials P for which the equation has a solution that has infinitely many real zeros and at most finitely many non-real zeros.

Titchmarsh, Gundersen, Shin, and Eremenko *et. al.* have found some classes of such polynomials P. (Received December 02, 2009)

1057-34-350 **Ovidiu Costin*** (costin@math.ohio-state.edu), 231 W 18th Ave, Columbus, OH 43210, and **Rodica D Costin** (rcostin@math.ohio-state.edu), 231 W 18th Ave, Columbus, OH 43210. *Integrability of differential systems: connections with Borel summability.*

The talk will focus on the behavior of solutions of ODEs in the complex domain. New approaches based on Borel summability provide detailed behavior about the singularity structure, and about the form of the constants of motion in integrable cases. (Received January 25, 2010)

35 ► Partial differential equations

1057-35-24 **Benjamin J. Jaye*** (bjjm93@mizzou.edu), Mathematical Sciences Building 18, University of Missouri, Columbia, MO 65211. *Positive solutions of nonlinear equations with natural growth terms.*

We will present conditions for solvability along with global bounds for positive solutions of quasilinear and fully nonlinear operators perturbed by a 'natural growth' term. The model equations for our study are:

$$-\Delta_p u = \sigma |u|^{p-2} u + \omega$$

and

$$\mathrm{F}_k(-u) = \sigma u^k + \omega$$

where σ and ω are nonnegative Borel measures. Here Δ_p is the quasilinear p-Laplacian operator, defined by:

$$\Delta_p u = \mathrm{div}(|\nabla u|^{p-2} \nabla u)$$

and $\mathrm{F}_k(u)$ is the fully nonlinear k-Hessian operator, defined by

$$\mathrm{F}_k(u) = \sum_{1 \le i_1 < \cdots < i_k \le n} \lambda_{i_1} \dots \lambda_{i_k}$$

where $\lambda_1, \dots, \lambda_n$ are the eigenvalues of the Hessian matrix of u. The results presented are joint work with Igor E. Verbitsky. (Received November 30, 2009)

1057-35-30 **Jerry L. Bona*** (bona@math.uic.edu), Dept. Mathematics, Statistics & Computer Sci., University of Illinois at Chicago, 851 S. Morgan Street MC 249, Chicago, IL 60607, and **Didier Pilod** (pilod@impa.br), Universidade Fereral do Rio de Janeiro, Instituto de Matemática, P.O. Box 68530, Rio de Janeiro, RJ CEP: 21945, Brazil. *Stability of Hirota-Satsuma Solitary Waves.*

Hirota and Satsuma have derived a non-local integro-differential equation as a model for surface water waves. This evolution equation has solitary-wave solutions akin to those of the better known Korteweg-de Vries and BBM equations. By analogy with these equations, one expects the Hirota-Satsuma solitary waves to be stable. Theory leading to exactly this conclusion will be outlined. (Received December 08, 2009)

1057-35-35 **Gerard Misiolek***, Dept. of Mathematics, University of Notre Dame, IN. *Regularity of the data-to-solution map for the Euler equations.*

I will describe the data-to-solution map for incompressible Euler equations in largangian and eulerian coordinates and show that with respect to Sobolev topologies it is smooth in the former but in general not even uniformaly continuous in the latter case. (Received December 09, 2009)

1057-35-39 **David R Adams*** (dave@ms.uky.edu), Mathematics Department, 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506. *A Frostman type characterization of Hausdorff-Netrusov Measures.*

Using the medium of Besov capacity, the capacities associated with the Besov spaces $B_\alpha^{p,1}$ and $B_\alpha^{1,q},\ 1 \le p < \infty,\ 1 \le q < \infty$, we give a Frostman type characterization of Hausdorff-Netrusov measure:

$$\epsilon \overrightarrow{\lim} 0 \quad \inf \left[\sum_{i=1}^{\infty} \left(\sum_{j \in I_i} r_j^d \right)^\theta \right]^{1/\theta} \equiv H^{d,\theta}(E),$$

E compact subset of $\boldsymbol{R}^N,\ I_i = \{j : 2^{-i-1} \le r_j < 2^{-i}\},\ r_j \le \epsilon,\ 0 < \theta < \infty,\ 0 < d \le N$; the infimum is over all countable covers of E by balls of radius $r_j,\ j = 1, 2, \ldots$ Frostman's result is: Classical Hausdorff d-measure $H^{d,1}(E) > 0$ iff there exists a measure μ supported on E such that $\mu(B(x,t)) \le At^d,\ 0 < t \le 1$, and all $x \in E$. $B(x,t)$ is a Euclidean ball centered at x of radius $t > 0$; A is some constant independent of x and t. (Received December 10, 2009)

1057-35-41 **Emma Previato*** (ep@bu.edu), Department of Mathematics and Statistics, Boston, MA. *Isomonodromy and Integrability.*

The property of having no moveable critical points for an Ordinary Differential Equation (Painlevé property) was linked with integrable systems via theta functions in the 19th century, and more recently, since the 1970s, with hierarchies of integrable Partial Differential Equations (of KdV and KP type) via similarity reduction. A differential-algebraic interpretation of the Painlevé property by H. Flaschka (1980), motivated by inverse scattering, will be revisited in order to explore an explicit dictionary between the isospectral curve of the hierarchy of PDEs and the isomonodromy curve, branched at the regular-singular points of the ODE. R. Fuchs (1906) connected the isomonodromy property and the absence of moveable critical points for second-order equations with four singularities, using the Legendre operator which acts on the periods of the elliptic curve. Picard-Fuchs equations for the periods of a hyperelliptic curve have been expressed recently in terms of special functions, specifically the Kleinian sigma function. They can be used to derive a higher-genus analog of Painlevé VI, by viewing the isomonodromy equations as systems of ODEs, following R. Garnier (1912). This is a joint project with F.W. Nijhoff. (Received December 13, 2009)

1057-35-47 **Robert S. Callihan*** (robert.callihan@afit.edu), 2950 Hobson Way, Wright-Patterson AFB, OH 45433, and **Aihua Wood**. *Maxwell's Equations for Electromagnetic Scattering of an Overfilled Cavity with Mixed Boundary Conditions.* Preliminary report.

We consider the time-domain scattering problem of a two-dimensional overfilled cavity embedded in the infinite ground plane with Robin or mixed boundary conditions. An artificial boundary condition is introduced on a semicircle enclosing the cavity that couples the fields from the infinite exterior domain to those fields inside to include the cavity portion. This establishes a Dirichlet-to-Neumann (DtN) operator on the artificial boundary. The problem is first discretized in time using the Newmark time-marching scheme. At each time step, we derive the variational formulation of the semidiscrete problem, and establish existence and uniqueness using properties of the DtN operator. In addition, the problem is fully discretized in both time and space to perform finite element error and stability analysis. This sets the foundation for finite element numerical techniques, which further establish the efficiency and validity of the method. The problem hinges on solving the exterior problem

above the infinite half-plane. This involves the time domain form of the wave equation, $-\Delta E_z^s + \dfrac{\partial^2 E_z^s}{\partial t^2} = 0$, where E_z^s represents the z-component of the scattered electric field that satisfies a mixed boundary condition at the surface. (Received December 17, 2009)

1057-35-48 **Robert Smits*** (rsmits@nmsu.edu), 1395 Panlener Ave, Las Cruces, NM 88001. *Brownian Motion and the Bass Note of a Drum, What's New.*

We show that the reciprocal of the principal eigenvalue of some general operators is comparable to the supremum of the solution to associated torsion problems for the same operator. The work includes the case of the p-Laplacian as well as stable processes. (Received December 17, 2009)

1057-35-58 **Alexander P Sviridov*** (aps14@pitt.edu), 301 Thackeray Hall, Pittsburgh, PA 15260. *p-harmonic functions with drift on graphs.*

Consider a connected finite graph E with set of vertices $\mathfrak{X}$. Choose a nonempty subset $Y \subset \mathfrak{X}$, not equal to the whole $\mathfrak{X}$, and call it the boundary $Y = \partial\mathfrak{X}$. We are given a real valued function $F : Y \to \mathbb{R}$. Our objective is to find function u on $\mathfrak{X}$, such that $u = F$ on Y and u satisfies the following equation for all $x \in \mathfrak{X} \setminus Y$

$$u(x) = \alpha \max_{y \in S(x)} u(y) + \beta \min_{y \in S(x)} u(y) + \gamma \left(\frac{\sum_{y \in S(x)} u(y)}{\#(S(x))} \right),$$

where $\alpha, \beta,$ and γ are some predetermined non-negative constants such that $\alpha + \beta + \gamma = 1$, for $x \in \mathfrak{X}$, $S(x)$ is the set of vertices connected to x by an edge, and $\#(S(x))$ denotes the cardinality of $S(x)$. We prove uniqueness and existence of the solution of the above Dirichlet problem and study qualitative studies of the properties of the solutions. (Received December 28, 2009)

1057-35-67 **Robert Jensen*** (rjensen@luc.edu), Dept. Mathematics and Statistics, Loyola University Chicago, 6525 N. Sheridan Rd., Chicago, IL 60626. *On solutions of $-\Delta_\infty u = g$.* Preliminary report.

In this talk I will explain the significance of Yifeng Yu's result and present a greatly simplified proof, showing the unique dependence of g on u for solutions of

$$-\Delta_\infty u = g$$

This is highly non-trivial because solutions of this PDE must be interpreted in the context of viscosity solutions as formulated by M. G. Crandall and P.-L. Lions, which only assumes continuity of the function u. Yu's result also verified the conjecture that the running cost is unique with respect to the "value function" for the time continuous random tug-of-war game as described in

"Tug-of-war and the infinity Laplacian"

by Yuval Peres, Oded Schramm, Scott Sheffield, and David B. Wilson., *J. Amer. Math. Soc.*, 22(1):167–210, 2009. (Received January 03, 2010)

1057-35-73 **David M Ambrose***, 3141 Chestnut Street, Philadelphia, PA 19104, and **J. Douglas Wright**. *Weak Solutions and Traveling Waves for Some Equations with Nonlinear Dispersion.* Preliminary report.

Equations with nonlinear dispersion, such as the Rosenau-Hyman compacton equations, exhibit very different behavior from equations with linear dispersion, such as the KdV equation. For instance, equations with nonlinear dispersion can possess compactly supported traveling waves, or can be positivity preserving. Unfortunately, there is very little existence theory for such equations. We present new examples of such equations which do possess compactly supported traveling waves and for which the existence of weak solutions can be proved. (Received January 06, 2010)

1057-35-76 **Burgess Davis*** (bdavis@stat.purdue.edu), Mathematics Department, Purdue University, West Lafayette, IN 47906, and **Majid Hosseini** (majid.hosseini@gmail.com), Division of Natural Sciences, Lakeland College, PO Box 359, Sheboygan, WI 53082. *On the spectral gap of convex doubly symmetric planar domains.*

It is known that the spectral gap (the difference between the second and first eigenvalues) of an oriented convex domain D symmetric about both axes can not be smaller than the gap of a rectangle symmetric about both axes which contains D. We use the ergodic theorem to give a lower bound for the difference of these gaps. (Received January 07, 2010)

1057-35-94 **Dhanapati Adhikari** (dadhika@math.okstate.edu), Department of Mathematics, Oklahoma State University, Stillwater, OK 74078, **Chongsheng Cao** (caoc@fiu.edu), Department of Mathematics, Florida International University, Miami, FL 33199, and **Jiahong Wu*** (jiahong@math.okstate.edu), Department of Mathematics, Oklahoma State University, Stillwater, OK 74078. *The 2D Boussinesq Equations with vertical viscosity and vertical diffusivity.*

This talk presents recent results on the global regularity of classical solutions to the 2D Boussinesq equations with vertical dissipation and vertical thermal diffusion. We prove that the L^r-norm of the vertical velocity v for any $1 < r < \infty$ is globally bounded and that the L^∞-norm of v controls any possible breakdown of classical solutions. In addition, we show that an extra thermal diffusion given by the fractional Laplace $(-\Delta)^\delta$ for $\delta > 0$ would guarantee the global regularity of classical solutions. (Received January 12, 2010)

1057-35-101 **M. Burak Erdogan** and **William R. Green*** (wgreen4@uiuc.edu), Dept. of Mathematics University of Illinois, 1409 W. Green St., Urbana, IL 61801. *Dispersive Estimates for the Schrödinger Equation for $C^{(n-3)/2}$ Potentials in Odd Dimensions.*

In this talk we discuss $L^1 \to L^\infty$ dispersive estimates for the linear Schrodinger equation on $\mathbb{R}^n$ with a real-valued potential V. In light of the results of Goldberg and Visan, for $n > 3$ dispersive estimates may fail if the potential is not in $C^{(n-3)/2}$. We obtain dispersive estimates under the optimal smoothness condition on the potential, $V \in C^{(n-3)/2}$, in dimensions five and seven. (Received January 13, 2010)

1057-35-109 **Andrzej Swiech*** (swiech@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, 686 Cherry Street, Atlanta, GA 30332, and **Shigeaki Koike**. *Some new results on ABP maximum principle and weak Harnack inequality.*

Aleksandrov-Bakelman-Pucci (ABP) maximum principle and Harnack inequality are classical tools in the theory of elliptic PDE . In the last two decades these topics have been revisited for fully nonlinear uniformly elliptic equations from the point of view of viscosity solutions. We will discuss when the ABP maximum principle is true for viscosity solutions of equations with superlinear growth in the gradient in which case it has been known to fail in general. Moreover we will present an improvement in the weak Harnack inequality for fully nonlinear equations. We will show how these techniques allow to obtain new results about solvability of fully nonlinear PDE, in particular of certain Pucci extremal equations. (Received January 14, 2010)

1057-35-113 **Monica Torres*** (torres@math.purdue.edu), 150 N. University Street, West Lafayette, IN 47907, and **Thierry DePauw** (thierry.depauw@uclouvain.be), Chemin du Cyclotron 2, Louvain-la-Neuve, Belgium. *On the solvability of the equation* div $v = F$.

We show that the equation div $v = F$ has a solution v in the space of continuous vector fields vanishing at infinity if and only if F acts linearly on $BV_{\frac{m}{m-1}}(\mathbb{R}^m)$ (the space of functions in $L^{\frac{m}{m-1}}(\mathbb{R}^m)$ whose distributional gradient is a vector valued measure) and satisfies the following continuity condition: $F(u_j)$ converges to zero for each sequence $\{u_j\}$ such that the measure norms of ∇u_j are uniformly bounded and $u_j \rightharpoonup 0$ weakly in $L^{\frac{m}{m-1}}(\mathbb{R}^m)$. In this talk we will also discuss the solvability of the equation in other spaces of vector fields. (Received January 14, 2010)

1057-35-116 **Björn Bennewitz**, **Kaj Nyström**, **John Lewis** and **Andrew L Vogel*** (alvogel@syr.edu), 215 Carnegie, Syracuse University, Syracuse, NY 13244. *Dimension of p-harmonic measure in space.* Preliminary report.

Let $\Omega \subset \mathbb{R}^n$, $n \geq 3$, and let p, $1 < p < \infty$, $p \neq 2$, be given. In this paper we study the dimension of p-harmonic measures that arise from non-negative solutions to the p-Laplace equation, vanishing on a portion of $\partial\Omega$, in the setting of δ-Reifenberg flat domains. In particular, we prove, for $p \geq n$, that there exists $\tilde{\delta} = \tilde{\delta}(p, n) > 0$ small such that if Ω is a δ-Reifenberg flat domain with $\delta < \tilde{\delta}$, then p-harmonic measure is concentrated on a set of σ-finite H^{n-1}-measure. The situation is more interesting when $1 < p < n$ as we show by examples involving certain Wolff snowflakes. Our results complement work of the first three authors in $\mathbb{R}^2$ (along with Pietro Poggi-Corradini) where similar results for the dimension p-harmonic measure were obtained in a Jordan domain bounded by a quasicircle and in simply connected domains. (Received January 15, 2010)

1057-35-118 **Cristian E Gutierrez***, Department of Mathematics, Temple University, Philadelphia, PA 19122, and **Qingbo Huang**, Department of Mathematics and Statistics, Wright State University, Dayton, OH 45435. *The near field refractor problem.*

Let Ω be a domain in the sphere S^{n-1} and let $D \subset \mathbf{R}^n$ be a domain contained in an $n-1$ dimensional surface called the target domain or screen to be illuminated. Let n_1 and n_2 be the indexes of refraction of two homogeneous and isotropic media I and II, respectively, for example, glass and air. Suppose that from a point

O surrounded by medium I, light emanates with intensity $f(x)$ for $x \in \Omega$, and D is surrounded by media II. We prove the existence of an optical surface $\mathcal{R}$ parameterized by $\mathcal{R} = \{\rho(x)x : x \in \overline{\Omega}\}$, interface between media I and II, such that all rays refracted by $\mathcal{R}$ into medium II illuminate the object D, and the prescribed illumination intensity received at each point $P \in D$ is $g(P)$. This yields the existence of a lens refracting light in a prescribed way. It is also proved that the solution satisfies a pde of Monge-Ampère type. (Received January 15, 2010)

1057-35-119 **Jun Geng*** (jgeng@ms.uky.edu), 700 Woodland Ave. Apt E127, Lexington, KY 40506, and **Zhongwei Shen**. *The Neumann Problem and Helmholtz Decomposition in Convex Domains.*

We show that the Neumann problem for Laplace's equation in a convex domain Ω with boundary data in $L^p(\partial\Omega)$ is uniquely solvable for $1 < p < \infty$. As a consequence, we obtain the Helmholtz decomposition of vector fields in $L^p(\Omega, R^d)$. (Received January 15, 2010)

1057-35-121 **Phuc Cong Nguyen*** (pcnguyen@math.lsu.edu), Department of Mathematics, Louisiana State University, 303 Lockett Hall, Baton Rouge, LA 70803. *Quasilinear Riccati type equations with super-critical growth in the gradient.*

We establish explicit criteria of solvability for the quasilinear Riccati type equation $-\Delta_p u = |\nabla u|^q + \omega$ in a bounded $\mathcal{C}^1$ domain $\Omega \subset \mathbb{R}^n$, $n \geq 2$. Here Δ_p, $p > 1$, is the p-Laplacian, q is in the supper critical range $q > p$, and the datum ω is a measure. Our existence criteria are given in the form of potential theoretic or geometric (capacitary) estimates that are sharp when ω is compactly supported in the ground domain Ω. A key in our approach to this problem is capacitary inequalities for certain nonlinear singular operators arising from the p-Laplacian. (Received January 16, 2010)

1057-35-122 **Oleg L Safronov*** (osafrono@uncc.edu), 9201 University City Blvd, charlotte, NC 28223. *Absolutely continuous spectrum of multi-dimensional Schrödinger operators.*

We are going to discuss the relation between the negative and positive spectra of Schrödinger operators. The unusual side of the situation we are going to talk about is that instead of one operator we need two of them:

$$H_+ = -\Delta + V, \qquad H_- = -\Delta - V.$$

It turns out that we can obtain a certain information about the positive part of the spectrum from the information about the accumulation of negative eigenvalues of H_+ and H_- to zero.

Among our applications are results about random Schrödinger operators. In particular, applying the suggested method, one can prove the following result.

Let $d \geq 5$ and let ω_n be bounded independent identically distributed random variables with the zero expectation, $n \in \mathbb{Z}^d$. Define

$$V_\omega = \sum_{n \in \mathbb{Z}^d} \omega_n \chi(x - n),$$

where *chi* is the characteristic function of the unit cube $[0, 1)^d$. Consider the operator

$$H_\omega = -\Delta + (-\Delta_\theta)|x|^{-s} + V_\omega,$$

where Δ_θ is the Laplace-Beltrami operator on the unit sphere. The statement is that, if $s > 0$ is sufficiently small, then the absolutely continuous spectrum of H_ω covers the positive half-line almost surely. (Received January 16, 2010)

1057-35-123 **W. Y. Chan*** (wchan@semo.edu), Department of Mathematics, Southeast Missouri State University, Cape Girardeau, MO 63701. *Blow-up and Quenching for Coupled Semilinear Parabolic Systems.*

Let γ, μ, and q be positive real numbers, p be a positive real number greater than or equal to 1, $T \leq \infty$, D be a bounded n-dimensional domain, ∂D and $\bar{D}$ be the boundary and closure of D respectively, Ω be $D \times (0, T)$, and Δ be the Laplace operator. In this talk, we study the blow-up and quenching of the following coupled semilinear parabolic systems:

$$u_t - \Delta u = \gamma v^p \text{ in } \Omega,$$

$$v_t - \Delta v = \mu \frac{1}{(1-u)^q} \text{ in } \Omega,$$

$$u(x,0) = u_0(x) \text{ on } \bar{D} \text{ and } v(x,0) = v_0(x) \text{ on } \bar{D},\ u(x,t) = 0 = v(x,t) \text{ on } \partial D \times (0,T),$$

where $u_0(x)$ and $v_0(x)$ belong to $C^{2+\alpha}(\bar{D})$ for some $\alpha \in (0, 1)$, and they are nonnegative functions on $\bar{D}$ such that $u_0(x) < 1$ on $\bar{D}$ and $u_0(x) = 0 = v_0(x)$ on ∂D. (Received January 16, 2010)

1057-35-131 **Michael W. Frazier*** (frazier@math.utk.edu), Mathematics Department - 104 Aconda Court, 1534 Cumberland Ave, University of Tennessee, Knoxville, TN 37996-0614, and **Fedor Nazarov** and **Igor E. Verbitsky**. *Global Estimates for Kernels of Neumann Series, Green's Functions, and the Conditional Gauge.* Preliminary report.

We consider estimates for kernels of resolvent series $(I-T)^{-1}=\sum_{j=0}^{\infty}T^j$, for integral operators of the form $Tf(x)=\int_\Omega K(x,y)f(y)\,d\omega(y)$, where (Ω,ω) is a σ-finite measure space, $K:\Omega\times\Omega\to(0,\infty]$ is symmetric and measurable, $1/K$ satisfies a quasi-metric condition, and $\|T\|_{L^2(\omega)\to L^2(\omega)}<1$. Let K_j denote the kernel of T^j. Then there exists $c>0$ depending only on the quasi-metric constant κ and $C>0$ depending only on κ and $\|T\|$ such that

$$K(x,y)e^{cK_2(x,y)/K(x,y)}\le\sum_{j=1}^{\infty}K_j(x,y)\le K(x,y)e^{CK_2(x,y)/K(x,y)}.$$

We apply this result to obtain estimates for Green's functions associated with fractional Schrödinger operators $(-\triangle)^{\alpha/2}-q$, for $q\ge0$ and $0<\alpha\le2$, on a domain Ω which could be all of $\mathbb{R}^n$ or a bounded domain in $\mathbb{R}^n$ which satisfies the boundary Harnack principle. These estimates are equivalent to estimates for the conditional gauge for α-stable processes. (Received January 18, 2010)

1057-35-137 **Selma Yildirim-Yolcu*** (selma.yildirim-yolcu@gcsu.edu), Department of Mathematics, CBX 017, Georgia College & State University, Milledgeville, GA 31061. *On Eigenvalue Inequalities for the Klein-Gordon Operators.*

In this talk, I will present some universal eigenvalue inequalities for Klein-Gordon operators $H_{m,\Omega}$ restricted to a bounded domain Ω in $\mathbb{R}^d$. Many of these results concern finding bounds for some spectral functions of these operators. The subject is examined from the spectral theory perspective through some of the tools used to prove analogues results for the Laplacian. For instance, the Weyl asymptotics and semiclassical bounds for the operator $H_{m,\Omega}$ are developed. In addition, I will present a Berezin-Li-Yau type inequality and an improvement of the bound. (joint work with Evans Harrell) (Received January 19, 2010)

1057-35-143 **Ivana Alexandrova*** (alexandrovai@ecu.edu), 124 Austin Building, Department of Mathematics, East Carolina University, Greenville, NC 27858, and **Hideo Tamura**, Okayama University. *Resonances for Magnetic Scattering by Two Solenoidal Fields at Large Separation.*

We consider the problem of quantum resonances in magnetic scattering by two solenoidal fields at large separation in two dimensions. We study the distribution of resonancest near the real axis when the distance between the centers of the two fields goes to infinity. We give a sharp lower bound on resonance widths in terms of backward amplitudes calculated explicitly for scattering by each solenoidal field. The study is based on a new type of complex scaling method. As an application, we also discuss the relation to semiclassical resonances in scattering by two solenoidal fields. This is joint work with Hideo Tamura. (Received January 19, 2010)

1057-35-148 **Roman G. Shterenberg*** (shterenb@math.uab.edu), Department of Mathematics, University of Alabama at Birmingham, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170, and **Leonid Parnovski** (Leonid@math.ucl.ac.uk), Department of Mathematics, University College London, Gower Street, London, WC1E 6BT. *Asymptotic expansion of the integrated density of states of a periodic or quasi-periodic Schrodinger operator.* Preliminary report.

We discuss the complete asymptotic expansion of the integrated density of states of a Schrodinger operator with a smooth periodic or special quasi-periodic potential. (Received January 19, 2010)

1057-35-153 **Carlos E Kenig*** (cek@math.uchicago.edu), Dept. of Mathematics, University of Chicago, 5734 University Avenue, Chicago, IL 60637. *Homogenization of periodic boundary value problems.*

I will discuss recent joint work with Z.Shen on the homogenization of second order elliptic boundary value problems on Lipschitz domains. (Received January 20, 2010)

1057-35-164 **M Chen*** (chen4544@gmail.com), 3413 covington street, west lafayette, IN 47906, **S Dumont**, , France, **L Dupaigne**, , France, and **O Goubet**. *Decay of solutions to a water wave model with a nonlocal viscous dispersive term.* Preliminary report.

In this talk, we investigate a water wave model with a nonlocal viscous term

$$u_t+u_x+\beta u_{xxx}+\frac{\sqrt{\nu}}{\sqrt{\pi}}\int_0^t\frac{u_t(s)}{\sqrt{t-s}}ds+uu_x=\nu u_{xx}.$$

The theoretically and numerically results on wellposedness of the equation and the decay rate of solutions are presented. This is a joint work with S. Dumont, L. Dupaigne and O. Goubet. (Received January 20, 2010)

1057-35-170 **Yifeng Yu*** (yyu1@math.uci.edu) and **Jack Xin** (jxin@math.uci.edu). *Periodic Homogenization of Inviscid G-equation for Incompressible Flows.*

G-equations are popular front propagation models in combustion literature and describe the front motion law of normal velocity equal to a constant plus the normal projection of fluid velocity. G-equations are Hamilton-Jacobi equations with convex but non-coercive Hamiltonians. We prove homogenization of inviscid G-equation for space periodic incompressible flows. The effective Hamiltonian is convex and homogeneous of degree one. It is also coercive if we further assume that the flow is mean zero. This is a joint work with Jack Xin (University of California at Irvine). (Received January 21, 2010)

1057-35-178 **John B. Gonzalez*** (johngonz@alum.mit.edu), Northeasten University, Department of Mathematics, Room 567 Lake Hall, 360 Huntington Avenue, Boston, MA 02115. *Solutions of Nonlinear Dispersive Equations in Spaces of Functions Having Prescribed Asymptotics.* Preliminary report.

In this talk we shall discuss some well-posedness results for the Korteweg-De Vries, modified Korteweg-De Vries, and nonlinear Schrödinger equations in spaces of functions which admit asymptotic expansions at infinity in decreasing powers of x. We show that an asymptotic solution differs from a genuine solution by a smooth function that is of Schwartz class with respect to x and that solves a generalized version of the respective equation. The latter equations are solved by discretization methods. (Received January 21, 2010)

1057-35-179 **Hans Christianson*** (hans@math.mit.edu), 77 Massachusetts Ave., Cambridge, MA 02139. *Imperfect geometric control and overdamping for the damped wave equation.*

In joint work with N. Burq, we study the damped wave equation on a simple manifold with a periodic hyperbolic geodesic and show the energy decays sub-exponentially (with loss in derivative) if the damping controls the manifold geometrically away from the periodic geodesic. This decay rate is sharp, however, if the damping is stronger (overdamped), the decay rate can be improved to exponential. (Received January 21, 2010)

1057-35-183 **Justin Holmer**, **Rodrigo Platte** and **Svetlana Roudenko*** (svetlana@math.asu.edu), School of Math & Stat, Arizona State University, Tempe, AZ 85287-1804. *Behavior of solutions to the focusing 3D cubic nonlinear Schroedinger equation.*

We consider the 3d NLS equation $iu_t + \Delta u + |u|^2 u = 0$. We are interested in finding criteria on the initial data u_0 that predict the asymptotic behavior of $u(t)$: whether $u(t)$ blows-up in finite time, exists globally in time but behaves like a linear solution for large times (scatters), or exists globally in time but does not scatter. This question has been resolved (for H^1 data) in series of papers by Duyckaerts-Holmer-Roudenko when $M[u]E[u] \leq M[Q]E[Q]$, where $M[u]$ and $E[u]$ denote the mass and energy of u, and Q denotes the ground state solution to $-Q + \Delta Q + |Q|^2 Q = 0$. We now study the complementary case $M[u]E[u] > M[Q]E[Q]$. First, we review Lushnikov's result giving a sufficient condition for blow-up. Then, using a sharp interpolation-type inequality in his argument we obtain a new blow-up condition that in some cases improves upon Lushnikov's condition. This approach also allows for an adaptation to radial infinite-variance initial data. We also prove that there exist Gaussian data u_0 with negative quadratic phase such that $\|u_0\|_{\dot{H}^{1/2}} < \|Q\|_{\dot{H}^{1/2}}$ but $u(t)$ blows-up. Lastly, we examine Gaussian type data and give the theoretical predictions for scattering or blow-up provided as well as the results of numerical simulation. (Received January 21, 2010)

1057-35-186 **Christopher D Sogge**, **Hart F Smith** and **Chengbo Wang*** (wangcbo@jhu.edu), Department of Mathematics, Johns Hopkins University, 3400 N. Charles Street, Baltimore, MD 21218. *2-dimensional Strauss conjecture for nontrapping obstacles.* Preliminary report.

In this talk, we discuss our recent work on the 2-dimensional Strauss conjecture for nontrapping obstacles.

Recently, Hidano, Metcalfe, Smith, Sogge and Zhou proved the Strauss conjecture for nontrapping obstacles when the spatial dimension n equals 3 and 4. Their method is to prove abstract Strichartz estimates, including the $|x|$-weighted Strichartz estimates.

In the Minkowski spacetime, the $|x|$-weighted Strichartz estimates (also from the work of Fang and Wang) can be utilized to prove the Strauss conjecture with $n = 2, 3, 4$. The reason that they can only prove the general results for $n = 3, 4$ is that the abstract Strichartz estimates are proved only for the case with regularity $s \in [-\frac{n-3}{2}, \frac{n-1}{2}]$ (that is, $s = 1/2$ if $n = 2$). It seems that this restriction is essential for the general abstract Strichartz estimates.

In this work, we remedy this difficulty for $n = 2$ by proving the generalized Strichartz estimates of the type $L^q_t L^r_{|x|} L^2_\theta$. The corresponding problem for $n \geq 5$ are still open. (Received January 21, 2010)

1057-35-204 **Shu-Ming Sun*** (sun@math.vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061. *Initial Boundary Value Problems of the Schrodinger Equation.* Preliminary report.

The talk will focus on the initial- and boundary-value problems (IBVP) of the Schrodinger equation posed in a quarter plane and on a bounded interval with nonhomogeneous boundary conditions. The problems arise naturally in certain circumstances when the Schrodinger equation is used as a model for waves and a numerical scheme is needed. It will be shown that the IBVP is locally and globally well-posed in certain Banach spaces. The local well-poseness results are sharp, while the partial global well-posedness is obtained. The ideas used for the local well-posedness is similar to our early results on the KdV equation. (This is a joint work with J. Bona and B. Zhang) (Received January 22, 2010)

1057-35-209 **Qingbo Huang*** (qingbo.huang@wright.edu), Department of Mathematics & Statistics, Wright State University, Dayton, OH 45435. *Geometric properties and regularity of solutions to the Monge-Ampère equation.*

In this talk, we will discuss geometric properties and regularity theory of solutions to the Monge-Ampère equation $\det D^2u = f(x)$, where f is in VMO type spaces. (Received January 22, 2010)

1057-35-210 **S. Molchanov** and **B. Vainberg*** (brvainbe@uncc.edu). *On negative spectrum for perturbations of the Anderson Hamiltonian.*

Consider the Anderson Hamiltonian on $L^2(R^d)$

$$H_0 = -\Delta + hV(x,\omega),\ x \in R^d,\ \omega \in (\Omega, F, P).$$

The potential has the simplest Bernoulli structure. Let $R^d = \bigcup Q_n$ be a partition of R^d onto unit cubes $Q_n,\ n \in Z^d$. Then

$$V(x,\omega) = \sum_{n\in Z^d} \varepsilon_n I_{Q_n}(x),$$

where ε_n are i.i.d.r.v., $P\{\varepsilon_n = 1\} = p > 0,\ P\{\varepsilon_n = 0\} = 1 - p > 0$.

Consider a perturbation of H_0 by a non-random continuous potential:

$$H = -\Delta + hV(x,\omega) - w(x),\ w(x) \geq 0,\ w \to 0,\ |x| \to \infty.$$

We will discuss the proof of the following statement. Put $N_0(w,\omega) = \#\{\lambda_i \leq 0\}$.

There are two constants $c_1 < c_2$ (which depend on d only) such that the condition

$$w(x) \leq \frac{c_1}{\ln^{\frac{2}{d}}(2+|x|)\ln 1/(1-p)},\ |x| \to \infty,$$

implies $N_0(w,\omega) < \infty$ P-a.s., and the inverse inequality (with c_2 instead of c_1) implies $N_0(w,\omega) = \infty$ P-a.s.. (Received January 22, 2010)

1057-35-212 **Marta Lewicka** and **Reza Pakzad*** (pakzad@pitt.edu), Department of Mathematics, University of Pitt, 301 Thackeray Hall, Pittsburgh, PA 15260. *Growing tissues, non-Euclidean elasticity and thin film models.*

Certain elastic bodies, e.g. some growing tissues, exhibit non-zero stress at their free equilibria. In particular, they do not seem to attain their ideal configuration due to some internal constraints. We will first discuss this phenomenon from a differential geometric point of view: the growth changes the intrinsic metric of the tissue to a new target non-flat metric. The non-vanishing curvature is the cause of the residual stress at equilibria. We further discuss the scaling laws and the thin film limits of the introduced 3d functional on thin plates in the limit of vanishing thickness. Relationships with Sobolev isometric immersions and some related geometric inequalities will be discussed in this context. (Received January 22, 2010)

1057-35-216 **Mishio Kawashita*** (kawasita@math.sci.hiroshima-u.ac.jp), Department of Mathematics, Graduate School of Science, Hiroshima University, Higashi-Hiroshima, Hiroshima 739-8526, Japan. *Scattering for the Rayleigh waves in perturbed half-spaces.*

In this talk, some problems arising scattering theory for the Rayleigh wave on perturbed half-spaces are considered. Here perturbed half-spaces mean the regions with the flat boundary $x_3 = 0$ in the outside of some ball $B_{R_0} = \{x \in \mathbb{R}^3 | |x| < R_0\}$. About the scattering of the Rayleigh waves, the following problems are considered:

1) to formulate scattering theory for perturbed half-spaces and to introduce the scattering operators and its distribution kernel called the scattering kernels,

2) to give a formula of the scattering kernel using the outgoing time dependent solutions,

3) to study where and how singularities of the scattering kernel corresponding to scattering of these waves on the boundary appears.

(Received January 23, 2010)

1057-35-227 **Sergey Denisov*** (denissov@math.wisc.edu), UW-Madison, Mathematics Department, 480 Lincoln Drive, Madison, WI 53706. *The probability measure on the paths and multidimensional scattering.*

We focus on the scattering problem for multidimensional Schrodinger operator and study the minimal conditions on "decay" of potential that lead to wave propagation. Certain sufficient conditions can be given through probability measure on the paths going to infinity. That measure is defined via simple Ito's differential equation. From the analytical perspective, this necessitates the study of special Potential Theory and introduction of modified Harmonic Measure. This is an ongoing project with S. Kupin (Received January 23, 2010)

1057-35-243 **Tomasz Adamowicz*** (adamowtz@math.uc.edu), 839 Old Chemistry, Cincinnati, OH 45221-0025, and **Peter Hästö**. *Recent developments in nonstandard growth PDEs.*

We generalize p-harmonic equation to the setting of variable exponent PDEs, obtaining equation with many interesting properties not shared by the other existing nonstandard growth extensions of the p-Laplacian. Our discussion includes Harnack inequality, the relation between planar mappings of finite distortion and the gradient of solution and the global integrability of $p(x)$-supersolutions.

The talk is based on the joint work with Peter Hästö, Oulu University. (Received January 24, 2010)

1057-35-250 **Jerry L Bona**, IL, **Hongqiu Chen*** (hchen1@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152, and **Ohannes A Karakashian**. *Solitary-wave Solutions of a System of Nonlinear Dispersive Wave Equations.* Preliminary report.

Considered here is a system of nonlinear, dispersive wave equations of the form

$$\begin{cases} u_t + u_{xxx} + (Au^2 + Buv + Cv^2)_x = 0, \\ v_t + v_{xxx} + (Du^2 + Euv + Fv^2)_x = 0 \end{cases}$$

recently derived by Bona, Cohen and Wang, where $A, B, \cdots, F$ are real constants. This talk is concerned with explicit solitary-wave solutions and their stability. (Received January 24, 2010)

1057-35-254 **Yulia Karpeshina*** (karpeshi@math.uab.edu), Department of Mathematics, UAB, 1300 University blvd, Birmingham, AL 35294, and **Young-Ran Lee** (youngranl@gmail.com). *Quasi-intersections of isoenetgetic surface and complex angle variable.*

Isoenergetic surface of a periodic Schrödinger operator $H = -\Delta + V_1$ changes its form when an additional periodic potential V_2 is added, $V_1 + V_2$ being periodic. This change is particularly essential near self-intersections of the isoenetgetic surface (they correspond to degenerated Bloch eigenvalues of H). Generally speaking, intersections become quasi-intersections. In particular, quasi-intersections appear when the periods of V_2 are multiples of the periods of V_1. We show how quasi-intesections can be studyied by the means of complex analysis applied to an angle variable. The method is used to investigate Schröedinger operator with limit-periodic potential in two dimensions. (Received January 24, 2010)

1057-35-255 **Catherine Sulem*** (sulem@math.toronto.edu), Department of Mathematics, University of Toronto, 40 St George Street, Toronto, Ontario M5S2E4, Canada. *Water waves over a random topography.*

We discuss the problem of nonlinear wave motion of the free surface of a body of fluid over a variable bottom. The object is to describe the character of wave propagation in a long wave asymptotic regime, under the assumption that the bottom of the fluid region is described by a stationary random process whose variations take place on short length scales. Our principal result is the derivation of effective equations and a consistency analysis. We compute the effects of random modulation of solutions, and give an explicit expression for the scattered component of the solution due to waves interacting with the random bottom. (Received January 24, 2010)

1057-35-260 **Peter D. Miller*** (millerpd@umich.edu), Department of Mathematics, East Hall, 530, Ann Arbor, MI 48109, and **Zhengjie Xu** (zhengjxu@umich.edu), Department of Mathematics, East Hall, 530 Church St., Ann Arbor, MI 48109. *The Benjamin-Ono Equation in the Small Dispersion Limit.*

The Benjamin-Ono equation is a model for several physical phenomena, including gravity-driven internal waves in certain density-stratified fluids. It has the features of being a nonlocal equation (the dispersion term involves the Hilbert transform of the disturbance profile) and also of having a Lax pair and an associated inverse-scattering

algorithm for the solution of the Cauchy initial-value problem. We will review known phenomena associated with this equation in the limit when the dispersive effects are nominally small, and compare with the better-known Korteweg-de Vries equation. Then we will present a new result establishing the zero-dispersion limit of the solution of the Benjamin-Ono Cauchy problem for certain initial data, in the topology of weak convergence. The proof relies on aspects of the method of moments from probability theory. (Received January 25, 2010)

1057-35-263 **Zhen Lei**, School of Math, Fudan University, Shanghai, Peoples Rep of China, and **Qi S. Zhang*** (qizhang@math.ucr.edu), Math Dept. UC Riverside, Riverside, CA 92521. *The structure of solutions of axis symmetric Navier-Stokes equations near maximal points.*

Let $v = v(x,t)$ be a solution to the 3 d axis symmetric NS. Let (x_0, t_0) be a point such that the flow speed $|v(x_0,t_0)|$ is comparable to the maximum speed for time $t < t_0$. Suppose also $r_0|v(x_0,t_0)|$ is sufficiently large, where r_0 is the distance from x_0 to the z axis. Then v, after scaling around (x_0,t_0), is close to a constant vector of norm 1 in $C^{2,1}$ norm in a space time neighborhood of fixed size.

The same conclusion also holds if the scaling invariant quantity $r_0|v(x_0,t_0)|$ is large and that it is comparable to its maximum of $r|v(x,t)|$ for $t < t_0$. (Received January 25, 2010)

1057-35-274 **Erin Haller Martin*** (erin.martin@westminster-mo.edu), 501 Westminster Ave., Fulton, MO 65251. *Evolution of Graphs in Carnot Groups by Horizontal Gauss Curvature.*

In the Euclidean setting, there has been extensive study of the flow of surfaces by their Gauss curvature. In this talk, we will investigate the extension of the Gauss curvature flow to the sub-Riemannian setting of Carnot groups. By considering the surfaces as level sets of a function, the problem is reduced to showing the existence, uniqueness, and regularity of viscosity solutions to a degenerate parabolic differential equation. By extending the work of C.-Y Wang to the case of sub- and supersolutions defined on unbounded domains, we are able to establish a comparison principle and thus show the existence and uniqueness of the flow. (Received January 25, 2010)

1057-35-282 **Bo Guan** (guan@math.ohio-state.edu), Dept. Math. The Ohio State University, Columbus, OH 43210, and **Qun Li*** (qun.li@wright.edu), Dept. Math. & Stats., Wright State University, Dayton, OH 45435. *Complex Monge-Ampere Equations on Hermitian Manifolds.*

We will study the complex Monge-Ampere equations on Hermitian manifolds. We shall also introduce some geometric problems which can be reduced to the Dirichlet problem of a complex Monge-Ampere equation. (Received January 25, 2010)

1057-35-284 **Ariel Elizabeth Barton*** (abarton@math.uchicago.edu), Department of Mathematics, University of Chicago, 5734 S. University Ave., Chicago, IL 60637. *The Dirichlet and Neumann problems for elliptic partial differential equations with almost-real coefficients.*

Given a Lipschitz domain $\Omega \subset \mathbf{R}^2$ and a real, elliptic 2×2 coefficient matrix $A(x)$ which depends only on one of the two coordinates, it is possible to solve $\operatorname{div} A\nabla u = 0$ in Ω with Dirichlet boundary data $f \in L^p(\partial\Omega)$ for $p < \infty$ large enough (Kenig, Koch, Pipher and Toro, Adv. Math. **153**, 2000) or for Neumann boundary data $g \in L^p(\partial\Omega)$ for $p > 1$ small enough (Kenig and Rule, Trans. Amer. Math. Soc. **361**, 2009).

I generalize these results to complex coefficient matrices A which satisfy the same conditions and are near in L^∞ to some real coefficient matrix A_0. (Received January 25, 2010)

1057-35-285 **Yanzhao Cao** (yzc0009@auburn.edu), Department of Mathematics and Statistics, 221 Parker Hall, Auburn University, Auburn, AL 36849, and **A. J. Meir*** (ajm@auburn.edu), Department of Mathematics and Statistics, 221 Parker Hall, Auburn University, Auburn, AL 36849. *Steady Flow in a Deformable Porous Medium.*

In this work we study a model for steady fluid flow in a deformable (elastic) porous medium. The model which was developed in the context of modeling one of the processes in paper production is distinguished in its use of a Kozeny-Carman type relation for the fluid's permeability, resulting in a quasilinear elliptic system. (Received January 25, 2010)

1057-35-298 **Justin Lee Taylor*** (jtaylor2@ms.uky.edu). *The Dirichlet Eigenvalue Problem for Elliptic Systems on Perturbed Domains.*

We consider the Dirichlet eigenvalues of an elliptic operator

$$(A_\varepsilon u)^\beta = \sum_{i,j,\alpha} -\frac{\partial}{\partial x_j}\left(a_{ij}^{\alpha\beta}\frac{\partial u^\alpha}{\partial x_i}\right) \qquad \beta = 1, ..., m$$

where $u = (u^1, ..., u^m)^t$ is a vector valued function and $a^{\alpha\beta}(x)$ are $(n \times n)$ matrices whose elements $a_{ij}^{\alpha\beta}(x)$ are at least uniformly bounded measurable real-valued functions such that

$$a_{ij}^{\alpha\beta}(x) = a_{ji}^{\beta\alpha}(x)$$

for any combination of α, β, i, and j. If we have two non-empty, open, disjoint, and bounded sets, Ω and $\widetilde{\Omega}$, in $\mathbb{R}^n$, and add a set T_ε of small measure to form the domain $\Omega_\varepsilon = \Omega \cup \widetilde{\Omega} \cup T_\varepsilon$, then we show that as $\varepsilon \to 0^+$, the Dirichlet eigenvalues corresponding to the family of domains $\{\Omega_\varepsilon\}_{\varepsilon>0}$ converge to the Dirichlet eigenvalues corresponding to $\Omega_0 = \Omega \cup \widetilde{\Omega}$. In this paper, we consider the Lamé system or systems which satisfy a strong ellipticity condition or a Legendre-Hadamard ellipticity condition. (Received January 25, 2010)

1057-35-300 **Svitlana Mayboroda*** (svitlana@math.purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907. *The connections between Dirichlet, Regularity and Neumann problems for second order elliptic operators with complex bounded measurable coefficients.*

I will discuss the relations between regularity, Dirichlet, and Neumann problems. In particular, I will prove that the solvability of the regularity problem does not imply the solvability of the dual Dirichlet problem for general elliptic operators with complex bounded measurable coe cients. This is strikingly different from the case of real operators, for which such an implication was established in 1993 by C.Kenig, J. Pipher [Invent. Math. 113] and since then has served as an integral part of many results. (Received January 25, 2010)

1057-35-305 **Robert Jenkins*** (rmjenkin@umich.edu). *Small dispersion limit of the focusing nonlinear Schrödinger equation for square barrier initial data.*

The small dispersion limit of the focusing nonlinear Schrödinger equation (fNLS) exhibits a rich structure with rapid oscillations at microscopic scales. Due to the non self-adjoint scattering problem associated to fNLS, very few rigorous results exist in the semiclassical limit. The asymptotics for reflectionless real WKB-like initial data was worked out by Kamvisis, McLaughlin, and Miller in 2003. In 2005, Tovbis, Venakides, and Zhou described the small dispersion limit for the family $q(x, 0) = \text{sech}^{1+\frac{i}{\epsilon}\mu}$.

We consider here another exactly solvable family of initial data, specifically the family of square barriers, $q(x, 0) = q\chi_{[-L,L]}$ for real amplitudes q. Using Riemann-Hilbert techniques we obtain rigorous point-wise asymptotics for the semiclassical limit of fNLS globally in space and up to an $\mathcal{O}(1)$ maximal time. In particular we show that the discontinuities in the initial data regularize by the immediate generation of slowly modulated genus one oscillations emitted into the support of the initial data whose Riemann invariants evolve according to a self-similar solution of the corresponding Whitham equations. (Received January 25, 2010)

1057-35-306 **Jeremy Marzuola** and **Sarah Raynor*** (raynorsg@wfu.edu), P.O. Box 7388, Department of Mathematics, Wake Forest University, Winston Salem, NC 27109, and **Gideon Simpson**. *A system of ODEs for a Perturbation of a Minimal Mass Soliton.*

We study soliton solutions to the nonlinear Schrödinger equation (NLS) with a saturated nonlinearity. NLS with such a nonlinearity is known to possess a minimal mass soliton. We consider a small perturbation of a minimal mass soliton and identify a system of ODEs extending the work of Comech and Pelinovsky, which models the behavior of the perturbation for short times. We then provide numerical evidence that under this system of ODEs there are two possible dynamical outcomes, in accord with the conclusions of Pelinovsky, Afanasjev, and Kivshar. Generically, initial data which supports a soliton structure appears to oscillate, with oscillations centered on a stable soliton. For initial data which is expected to disperse, the finite dimensional dynamics initially follow the unstable portion of the soliton curve. (Received January 25, 2010)

1057-35-308 **Nikolaos Tzirakis*** (tzirakis@math.uiuc.edu), **Burak Erdogan** and **Vadim Zharnitsky**. *Near-linear dynamics of the KdV equation.*

We show that the evolution of periodic (in space) high frequency solutions of the Korteweg de Vries equation is almost linear for large times. (Received January 25, 2010)

1057-35-309 **Robert P Lipton*** (lipton@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton rouge, LA 70803. *Dispersion relations for sub-wavelength plasmonic crystals.*

We introduce a new convergent infinite order homogenization theory. This is used to calculate accurate dispersion relations characterizing light propagation inside crystals with inclusions having frequency dependent dielectric properties. We use the theory to identify a new branch of dispersion relations inside plasmonic crystals. This is joint work with Santiago Fortes and Stephen Shipman. (Received January 25, 2010)

1057-35-315 **Marianne K Korten** and **Charles N Moore*** (cnmoore@math.ksu.edu), Department of Mathematics, Kansas State University, Manhattan, KS 66506. *The two-phase Stefan problem.*

We consider the two-phase Stefan problem $u_t = \Delta\alpha(u)$ where $\alpha(u) = u+1$ for $u < -1$, $\alpha(u) = 0$ for $-1 \leq u \leq 1$, and $\alpha(u) = u - 1$ for $u > 1$. This models the flow of heat within a substance which can be in a liquid phase or a solid phase, and for which there is a latent heat to initiate phase change. This allows for the presence of a mushy zone, that is, a region which is between the liquid and solid phases. We will discuss existence and regularity of solutions, as well as uniqueness. (Received January 25, 2010)

1057-35-317 **Philip C. Argyres*** (philip.argyres@gmail.com), Physics Department, POBox 210011, University of Cincinnati, Cincinnati, OH 45221-0011. *Onset of Instabilities in Hydrodynamic Flows via the AdS/CFT Correspondence.* Preliminary report.

We study the linear stability of the dragged string solution in the 5-dimensional AdS black brane space-time. This solution is dual to a laminar flow in the conformal relativistic fluid of strongly-coupled N=4 superYang-Mills theory in 4 dimensions at finite temperature. The linear stability problem is equivalent to a shooting problem for the quasi-normal modes of an associated ordinary differential equation on an interval with a regular singular point in the interior. We describe a limiting case where this shooting problem can be solved exactly. (Received January 25, 2010)

1057-35-322 **Ivonne Rivas*** (rivasie@mail.uc.edu), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221, and **Bingyu Zhang** (zhangb@ucmail.uc.edu), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221. *On a class of initial-boundary-value problems of the Kortweg-de Vries equation posed on finite domain.*

In this talk, we are going to consider the Kortweg-de Vries equation posed on the finite domain $(0, L)$,

$$u_t + u_x + uu_x + u_{xxx} = 0, \quad t > 0,\ x \in (0, L)$$

with the initial condition

$$u(x, 0) = \phi(x), \quad x \in (0, L)$$

and the boundary conditions

$$u(0, t) = h_1(t), \quad u_x(L, t) = h_2(t), \quad u_{xx}(L, t) = h_3(t).$$

This initial-boundary-value problem (IBVP) has been studied by Colin and Ghidaglia (An initial-boundary-value problem for the Korteweg-de Vries Equation posed on a finite interval, Adv. Differential Equations 6 (2001), 1463-1492). They showed that the IBVP is locally well-posed in the space $H^1(0, L)$ with the initial data drawn from $H^1(0, L)$ and the boundary data $h_1,\ h_2,\ h_3$ taken from the product space $C^1(0, T) \times C^1(0, T) \times C^1(0, T)$. In this talk, we will show that the IBVP is locally well-posed in the space $H^s(0, L)$ for any $s > -1$ with ϕ drawn from the space $H^s(0, L)$ and the boundary data taken from the space $H^{\frac{s+1}{3}}(0, T) \times H^{\frac{s}{3}}(0, T) \times H^{\frac{s-1}{3}}(0, T)$. (Received January 25, 2010)

1057-35-327 **Richard S Laugesen*** (Laugesen@illinois.edu), Department of Mathematics, University of Illinois, Urbana, IL 61801, and **Bartlomiej A Siudeja**. *Sums of Dirichlet eigenvalues: maximizing with rotationally symmetric domains.* Preliminary report.

Many sharp inequalities are known for the low Dirichlet eigenvalues of the Laplacian. We present new sharp inequalities for higher eigenvalues, namely for sums of the first n eigenvalues, for each n.

Consider a plane domain D having rotational symmetry of order 3 or greater. We prove that among all domains obtained from D by affine transformation, the scale-invariant eigenvalue sum

$$S_n = (\lambda_1 + \cdots + \lambda_n)\frac{A^3}{I}$$

is maximal for D, for each n. Here A denotes the area and I is the moment of inertia of the domain.

Corollaries: S_n is maximal for the equilateral triangle among all triangles. S_n is maximal for the square among all parallelograms. These corollaries extend work of Pólya on the fundamental tone, the case $n = 1$.

These results suggest a conjecture for convex plane domains: is the normalized eigenvalue sum S_n maximal for the disk? (Received January 25, 2010)

1057-35-331 **Jean Dolbeault**, **Ari Laptev** and **Michael Loss*** (loss@math.gatech.edu), School of Mathematics, Georgia Tech, 686 Cherry Street, Atlanta, GA 303320160. *Lieb-Thirring inequalities with improved constants.*

Following Eden and Foias we obtain a matrix version of a generalized Sobolev inequality in one-dimension. This allows us to improve on the known estimates of best constants in Lieb-Thirring inequalities for the sum of the negative eigenvalues for multi-dimensional Schroedinger operators. (Received January 25, 2010)

1057-35-333 **Jeff Baker** and **Michael Loss*** (loss@math.gatech.edu), School of Mathematics, Georgia Tech, 686 Cherry Street, Atlanta, GA 303320160, and **Guenter Stolz**. *Low energy properties of the random displacement model.*

We study low-energy properties of the random displacement model, a random Schrödinger operator describing an electron in a randomly deformed lattice. All periodic displacement configurations which minimize the bottom of the spectrum are characterized. While this configuration is essentially unique for dimension greater than one, there are infinitely many different minimizing configurations in the one- dimensional case. The latter leads to unusual low energy asymptotics for the integrated density of states of the one-dimensional random displacement model. (Received January 25, 2010)

1057-35-334 **Richard S Laugesen** and **Bartlomiej A Siudeja*** (siudeja@illinois.edu), Department of Mathematics, University of Illinois, Urbana, IL 61801. *Sums of Dirichlet eigenvalues: minimizing with equilateral triangles.* Preliminary report.

We prove that among all triangles with fixed diameter the sum of Dirichlet eigenvalues $\lambda_1 + \cdots + \lambda_n$ is minimal for equilateral triangles, for each n.

For the first eigenvalue, stronger results are known: area or perimeter can be fixed instead of diameter. Neither result is true for the sum of the first two eigenvalues, let alone for just the second eigenvalue. We prove that the second eigenvalue is minimal for equilateral triangles, when diameter is fixed.

This result supports the spectral gap conjecture that $\lambda_2 - \lambda_1$ is minimal among triangles for the equilateral one, under diameter normalization, as conjectured by Freitas and Antunes. Our result also provides evidence for the conjecture of Bucur, Buttazzo and Henrot, that λ_2 is minimal for disks among all convex domains having fixed diameter. (Received January 25, 2010)

1057-35-343 **Justin Taylor**, Department of Mathematics, University of Kentucky, Lexington, KY 40506, **Katharine Ott**, Department of Mathematics, University of Kentucky, Lexington, KY 40506, and **Russell Brown***, Department of Mathematics, University of Kentucky, Lexington, KY 40506. *The mixed problem in Lipschitz domains.* Preliminary report.

I will discuss recent work on the mixed problem for Laplace's equation in Lipschitz domains when the Dirichlet data has a derivative in L^p and the Neumann data is in L^p. (Received January 25, 2010)

1057-35-364 **Dong Li**, 14 Maclean Hall, Iowa City, IA 52242, and **Xiaoyi Zhang***, 14 Maclean Hall, Iowa city, IA 52242. *The threshold solutions for nonlinear Schrodinger equations.*

We will review recent results on the study of the threshold solutions for focusing nonlinear Schrodinger equations. (Received January 26, 2010)

1057-35-367 **Turkay Yolcu*** (turkay.yolcu@gcsu.edu), Department of Mathematics, CBX017, Georgia College & State University, Milledgeville, GA 31061. *An application of Monge-Kantorovich theory to a class of parabolic PDEs.*

In this talk, I'll talk about a type of parabolic partial differential equations (PDEs) derived from a system governed by a Lagrangian and explain briefly how these kind of PDEs can be solved by using Monge-Kantorovich Theory and construct its dual problem and its solution. (Received January 26, 2010)

1057-35-372 **Hiroya Ito*** (ito@ice.uec.ac.jp), Department of Mathematics, The University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585, Japan. *On the dispersion curves for guided waves in an anisotropic plate.*

We consider time-harmonic waves with wavenumber k and angular frequency ω propagating in an infinite plate — a homogenous, anisotropic elastic layer bounded by two parallel plane surfaces satisfying fixed-fixed, free-free or fixed-free boundary condition — to an assigned direction parallel to the boundary. Such waves with parameter k, in an infinite set of wave modes, exhibit velocity dispersion, that is, their velocities $v = \omega/k$ depend on k as well as on the elastic stiffness and density of the material. We are interested in the dispersion curves $v = v(k)$, especially asymptotic behavior of each branch of them as $k \to \infty$. The problem is reduced to a certain eigenvalue problem of ODE with parameter k, where the eigenvalue is ω^2. In the isotropic case and a certain anisotropic case, explicit calculation enables us to obtain, for all the branches of dispersion curve,

not only detailed asymptotic behavior as $k \to \infty$ but also asymptotic profile of the corresponding wave. In the general anisotropic case, we use, as a key tool, the theory of matrix polynomials — by means of factorization of matrix polynomials and the concept of elementary divisors, the asymptotic behavior of branches of dispersion curve in lower modes are examined. (Received January 26, 2010)

1057-35-375 **Gregory C. Verchota*** (gverchot@syr.edu), Department of Mathematics, 215 Carnegie, Syracuse University, Syracuse, NY 13244. *The coerciveness problem redux.* Preliminary report.

The problem of obtaining the classical coercive estimate over the full Sobolev space $W^{m,2}(\Omega)$ for higher order constant coefficient elliptic operators in Lipschitz domains is discussed. (Received January 26, 2010)

1057-35-376 **Alex Freire*** (freire@math.utk.edu), Mathematics Department, University of Tennessee, Knoxville, TN 37996. *Mean Curvature Motion of Triple Junctions of Graphs.*

We consider a system of three surfaces, graphs over a bounded domain in $\mathbb{R}^2$, intersecting along a time-dependent curve and moving by mean curvature while preserving the pairwise angles at the curve of intersection (equal to $2\pi/3$.) This defines a two-dimensional parabolic free boundary problem, for which we prove short-time existence of classical solutions (for sufficiently regular initial data satisfying a compatibility condition). For the corresponding symmetric problem (a graph over a time-dependent domain intersecting $\mathbb{R}^n$ at a constant angle and moving by mean curvature) there are also results on long-time behavior. (Received January 26, 2010)

1057-35-378 **Bingyu Zhang*** (zhangb@ucmail.uc.edu), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221. *Control and Stabilization of the Nonlinear Schrödinger Equation on Rectangles.*

In this this talk, we will discuss the local exact controllability and the local stabilization of the semilinear Schrödinger equation posed on a product of n intervals ($n \geq 1$). Both internal and boundary controls are considered, and the results are given with periodic (resp. Dirichlet or Neumann) boundary conditions. In the case of internal control, we will present some local controllability results which are sharp as far as the localization of the control region and the smoothness of the state space are concerned. It will also be proved that for the linear Schrödinger equation with Dirichlet control, the exact controllability holds in $H^{-1}(\Omega)$) whenever the control region contains a neighborhood of a vertex.

The results reported in this talk are joint work with Lionel Rosier. (Received January 26, 2010)

1057-35-387 **Fang Wan** (yip@math.purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907, and **Nung Kwan Aaron Yip*** (yip@math.purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907. *A model of crystal growth with corner regularization.*

We investigate a model of two dimensional crystal growth described by a forward-backward parabolic equation. The ill-posed region of the equation describes the motion of corners on the surface. We analyze a fourth order regularization of the equation and show that the dynamical behavior of the regularized corner can be described by a traveling wave solution. The speed of the wave is found by rigorous asymptotic analysis. The interaction between multiple corners will also be presented together with numerical simulations. This is joint work in progress with Fang Wan. (Received January 26, 2010)

1057-35-390 **Daniel Phillips*** (phillips@math.purdue.edu), Department of Mathematics, Purdue University, 150 North University Street, West Lafayete, IN 47907. *Smectic Energies and Existence Results for Liquid Crystals.*

We examine the problem of minimizing the Chen-Lubensky liquid crystal energy. This is a Ginzburg-Landau type energy where the smectic layering is described by a complex valued order parameter. In the case that the energy has a smectic C ground state we show that anchoring conditions on the smectic layering at the boundary are needed in order for minimizers to exist. We further give examples of strong and weak anchoring conditions that suffice. (Received January 26, 2010)

1057-35-393 **Patricia Bauman*** (bauman@math.purdue.edu), Department of Mathematics, Purdue University, 150 North University Street, West Lafayete, IN 47907. *Stable Solutions to the Lawrence-Doniach Equations in Tilted Magnetic Fields.*

We consider minimizers to the Lawrence-Doniach energy for layered superconductors with nonlinear Josephson coupling which is used to model a large class of superconductors. When the exterior magnetic field is nearly parallel to the layers and the Josephson constant is sufficiently small, we show that the global minimizer has no vortices in the layers. We estimate the upper critical magnetic fields in different directions, and show that it is

inversely proportional to the sine of the angle between the applied field and the layers. We identify the pattern of the order parameters in this case. (Received January 26, 2010)

1057-35-395 **Cristian Rios*** (crios@math.ucalgary.ca), Department of Mathematics, University of Calgary, 2500 University Dr. NW, Calgary, AB T2N1N4, Canada, and **Eric T Sawyer** and **Richard Wheeden**. *Regularity of Quasilinear Equations with Infinite Vanishing Ellipticity.*

We consider a class of degenerate elliptic equations with non-isotropic ellipticity which might vanish to infinite order. We prove a-priori estimates for continuous weak solutions. As a consequence we obtain existence and regularity for solutions of the Dirichlet problem.

In two dimensions these results may be applied to show regularity for Monge-Ampere equations with infinite vanishing right hand side. (Received January 26, 2010)

1057-35-396 **Arshak Petrosyan*** (arshak@math.purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907, and **Tung To** (tto@math.purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907. *Optimal Regularity in Rooftop-Like Obstacle Problem.*

We study the regularity of solutions of the obstacle problem when the obstacle is smooth on each half of the unit ball but only Lipschitz across the shared boundary. We prove that the optimal regularity of these solutions is $C^{1,\frac{1}{2}}$ up to the shared boundary on each half of the unit ball. The proof uses a modification of Almgren's frequency formula. (Received January 26, 2010)

1057-35-398 **Zhuomin Liu*** (zhl26@pitt.edu), Department of Mathematics, 301 Thackeray Hall, University of Pittsburgh, Pittsburgh, PA 15217, and **Pawel Konieczny**. *A new proof of Liouville's theorem.* Preliminary report.

We provide a new proof of the Liouville's theorem about conformal mappings in the dimension at least three under the assumption that the mapping is 1-quasiconformal. Our method is based on the study of regularity of a conformal killing field generated by the mapping. (Received January 26, 2010)

1057-35-402 **Barbara Lee Keyfitz*** (bkeyfitz@math.ohio-state.edu), Department of Mathematics, The Ohio State University, Columbus, OH 43210. *Approaching a transonic flow problem with Fourier transforms.*

Recent work by the speaker and co-authors points to open questions involving continuous solutions at a sonic line in steady or quasi-steady transonic flow. This has motivated the formulation of a very simple perturbation problem for the steady transonic small disturbance equation. One class of solutions will be presented here. These solutions can be found using the hodograph transform followed by a partial Fourier transform. We obtain both existence and non-existence results which appear somewhat surprising. (Received January 26, 2010)

1057-35-411 **Matthew Wright*** (mwright@missouristate.edu), Mathematics Department, Missouri State University, 901 S. National Ave., Springfield, MO 65897. *Transmission problems for higher order equations in Lipschitz domains.* Preliminary report.

A transmission boundary value problem seeks to find solutions of a partial differential equation in both the interior and exterior of a fixed boundary that interact in a precise fashion along the boundary. This talk will explain the connections between transmission problems and more standard Dirichlet and Neumann problems and will also demonstrate how the method of layer potentials can be applied to solve higher order transmission problems in Lipschitz domains, including the biharmonic transmission problem. (Received January 26, 2010)

1057-35-418 **Alexandre Girouard*** (alex.girouard@gmail.com). *Shape optimization for lower eigenvalues of the Neumann and Steklov problems on planar domains.*

The Pólya conjecture (1954) states that the k-th Neumann eigenvalue of a planar domain is bounded above by $4k\pi$. In this talk I will present a sharp isoperimetric inequality for the second non-zero eigenvalue. This implies the Pólya conjecture for $k = 2$. I will also discuss similar results for the spectrum of the Dirichlet-to-Neumann map and for the spectrum of the Laplace-Beltrami operator on spheres. Surprisingly, this extension to spheres is possible only for odd dimensions. (Received January 26, 2010)

1057-35-427 **Mark S. Ashbaugh*** (ashbaughm@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211-4100. *The Buckling Problem and the Krein Laplacian.*

Recent developments on the buckling problem and the Krein Laplacian in which the author has been involved will be discussed, including connections between these two problems, analysis of their spectral asymptotics, and inequalities for their eigenvalues. In particular, we note that the buckling problem is intimately related to the

Krein Laplacian, and that, in fact, there is a unitary equivalence between the two problems if one considers the Krein Laplacian on the space orthogonal to its kernel. Old conjectures concerning the eigenvalues of the buckling problem will also be discussed, including the Polya-Szego conjecture for the first eigenvalue (which would be the Faber-Krahn result for this problem) and Payne's conjecture comparing the buckling eigenvalues to those of the Dirichlet Laplacian on the same domain.

Much of the recent work presented in the talk represents joint work with Fritz Gesztesy, Marius Mitrea, Roman Shterenberg, and/or Gerald Teschl. (Received January 26, 2010)

1057-35-429 **L. Mercredi Chasman*** (lchasman@knox.edu), Box K-67, Knox College, 2 East South Street, Galesburg, IL 61401. *An isoperimetric inequality for the free plate in all dimensions.*

We establish an isoperimetric inequality for the fundamental tone (first nonzero eigenvalue) of the free plate of a given area, proving the ball is maximal in all dimensions and for all positive values of the tension parameter τ. Given $\tau > 0$, the free plate eigenvalues ω and eigenfunctions u are determined by the equation $\Delta\Delta u - \tau\Delta u = \omega u$ together with certain natural boundary conditions. The boundary conditions are complicated but arise naturally from the plate Rayleigh quotient, which contains a Hessian squared term $|D^2u|^2$.

We adapt Weinberger's method from the corresponding free membrane problem, taking the fundamental modes of the unit ball as trial functions. These solutions are a linear combination of Bessel and modified Bessel functions. (Received January 26, 2010)

1057-35-446 **Lotfi Hermi*** (hermi@math.arizona.edu), Department of Math, University of Arizona, 617 N. Santa Rita Ave., Tucson, AZ 85721. *Quadratic Interpolation and Rayleigh-Ritz Methods for Bifurcation Coefficients.*

We study the estimation of bifurcation coefficients in nonlinear branching problems by means of Rayleigh-Ritz approximation to the eigenvectors of the corresponding linearized problem. It is essential that the approximations converge in a norm of sufficient strength to render the nonlinearities continuous. Quadratic interpolation between Hilbert spaces is used to seek sharp rate of convergence results for bifurcation coefficients. Examples from ordinary and partial differential problems are presented. This is joint work with W. M. Greenlee. (Received January 26, 2010)

1057-35-454 **Dong Li*** (dli@math.uiowa.edu), 14 MacLean Hall, Iowa City, IA 52240. *Sharp decay of solutions for nonlinear dispersive equations.*

Sharp decay of solutions for nonlinear dispersive equations (Received January 27, 2010)

1057-35-457 **Joel M Kilty*** (joel.kilty@centre.edu), Centre College, 600 W. Walnut Street, Danville, KY 40422. *The L^p Regularity problem for the Stokes system in Lipschitz domains.* Preliminary report.

In this talk we'll discuss progress on establishing a necessary and sufficient condition for the solvability of the the L^p regularity problem for the stationary Stokes system when $p > 2$, as well as duality between the L^p Dirichlet and $L^{p'}$ regularity problem for the Stokes system. (Received January 27, 2010)

1057-35-461 **Katharine Ott*** (katharine.ott@uky.edu), 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40508, and **Irina Mitrea**. *Spectral theory for the Maxwell system of equations in nonsmooth domains.*

In this talk I will discuss spectral properties of boundary integral operators which arise in the study of the Maxwell system of equations in a Lipschitz domain $\Omega \subseteq \mathbb{R}^3$. (Received January 27, 2010)

37 ► Dynamical systems and ergodic theory

1057-37-1 **Percy A. Deift***, Courant Institute-New York University, 251 Mercer St., New York, NY. *Open problems in integrable systems and random matrix theory.*

In addition to specific open problems, the speaker will also discuss some problems concerned with the development of the area. (Received April 09, 2009)

1057-37-449 **Alica Miller*** (a0mill01@louisville.edu), Department of Mathematics, 328 Natural Science Building, University of Louisville, Louisville, KY 40292. *Some properties of transitive semiflows.* Preliminary report.

We will talk about some properties of transitive semiflows (with an arbitrary acting topological semigroup). (Received January 26, 2010)

41 ► Approximations and expansions

1057-41-86 **Pavel Bleher*** (bleher@math.iupui.edu), Department of Mathematical Sciences, IUPUI, 402 N. Blackford Street, Indianapolis, IN 46202. *Random matrix model with external source and a constrained vector equilibrium problem.*

This is a joint work with Steven Delvaux and Arno Kuijlaars. We consider the random matrix model with external source, in case where the potential $V(x)$ is an even polynomial and the external source has two eigenvalues $\pm a$ of equal multiplicity. We show that the limiting mean eigenvalue distribution of this model can be characterized as the first component of a pair of measures (μ_1, μ_2) that solve a constrained vector equilibrium problem. The proof is based on the steepest descent analysis of the associated Riemann-Hilbert problem for multiple orthogonal polynomials.

We illustrate our results in detail for the case of a quartic double well potential $V(x) = \frac{1}{4}x^4 - \frac{t}{2}x^2$. We are able to determine the precise location of the phase transitions in the ta-plane, where either the constraint becomes active, or the two intervals in the support come together (or both). (Received January 09, 2010)

1057-41-172 **L Bos*** (lpbos@math.ucalgary.ca). *Multivariate Polynomial Inequalities and Near Optimal Points for Polynomial Interpolation.*

We discuss Markov type inequalities on the derivatives of multivariate polynomials and their relation to the spacing of near optimal points for polynomial interpolation, such as the so-called Fekete and Leja points. We also discuss some efficient procedures for the computation of what we call Approximate Fekete points, as well as for discrete versions of Leja points. (Received January 21, 2010)

42 ► Fourier analysis

1057-42-152 **Sarah N Ziesler*** (sziesler@uchicago.edu), Dept. of Mathematics, University of Chicago, 5734 University Avenue, Chicago, IL 60637. *Restriction theorems for surfaces.* Preliminary report.

We will discuss recent progress, in joint work with A. Carbery and C. Kenig, on restriction theorems for surfaces, when the affine curvature is introduced as a mitigating factor. (Received January 19, 2010)

1057-42-213 **Leonid Slavin*** (leonid.slavin@uc.edu) and **Vasily Vasyunin**. *The embedding $BMO \subset L^p_{loc}$ and sharp equivalence of BMO norms.*

The space $\mathrm{BMO}_p(\mathbb{R})$ is defined, for all $p \geq 1$, by

$$\mathrm{BMO}_p = \left\{ \varphi \in L^1_{loc} : \sup_{\text{interval } Q} \langle |\varphi - \langle \varphi \rangle_Q|^p \rangle_Q \leq C^p < \infty \right\},$$

with $\langle \varphi \rangle_Q \stackrel{\text{def}}{=} \frac{1}{|Q|} \int_Q \varphi$ and the best such C being the corresponding norm. It is known that the norms are equivalent for all p, with one direction following from Hölder's inequality and the other usually regarded as a consequence of the John–Nirenberg inequality. However, the constants of this equivalence are not known.

We find the explicit upper and lower Bellman functions for the embedding $\mathrm{BMO}_2 \subset L^p_{loc}$ thus establishing the sharp embedding constant. As a consequence, we can relate, sharply, all BMO_p norms to the BMO_2 norm. The proof depends on solving a Monge–Ampeère equation on a non-convex domain, coupled with a delicate induction argument. As an integral part of the solution, we construct the Bellman foliation of the domain, yielding the extremizers in the inequalities being proved. This is joint work with V. Vasyunin. (Received January 22, 2010)

1057-42-215 **Marius Beceanu** and **Michael Goldberg*** (Michael.Goldberg@uc.edu), Department of Mathematical Sciences, 839 Old Chem, Cincinnati, OH 45221-0025. *A Schrödinger Dispersive Estimate in $\mathbf{R^3}$ with Singular Potentials.* Preliminary report.

We prove a dispersive estimate on the linear propagator e^{-itH} for a family of Schrödinger operators $H = -\Delta + V(x)$. The admissible class of potentials is invariant with respect to the Laplacian's natural inverse-square scaling law, and includes singular examples where $V(x)$ is a measure rather than a function. (Received January 22, 2010)

1057-42-261 **Michael T. Lacey** (Lacey@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332, **Eric T. Sawyer** (sawyer@mcmaster.ca), Department of Mathematics and Statistics, McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4K1, Canada, and **Ignacio Uriarte-Tuero*** (uriarte@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *A characterization of the two weight norm inequality for the Hilbert transform.*

The two weight inequality for the Hilbert transform for locally finite Borel measures with no point masses in common is characterized in terms of (1) a Poisson A_2 condition on the weights (2) A forward testing condition, in which the two weight inequality is tested on intervals (3) and a backwards testing condition, dual to (2). A critical new concept in the proof is an Energy Condition, which incorporates information about the distribution of the weights in question inside intervals. This condition is a consequence of the three conditions above. The notion of Energy also provides a decisive improvement of a standard 'off-diagonal' estimate on singular integrals, used in the sufficient direction. This new concept is combined with a known proof strategy devised by Nazarov-Treil-Volberg. A counterexample shows that the energy condition must be used in the characterization. (Received January 25, 2010)

1057-42-304 **Alexander Fish**, **Fedor Nazarov** and **Dmitry Ryabogin*** (ryabogin@math.kent.edu), 122 Chesterton Lane, Aurora, OH 44202, and **Artem Zvavitch**. *On the $L^p(S^{n-1})$, $1 \leq p \leq \infty$, boundedness of the smooth multiplier operator on the unit sphere S^{n-1} in R^n.*

This is a part of a joint work with Alexander Fish, Fedor Nazarov and Artem Zvavitch. Let ϕ be an infinitely smooth function with a compact support (a Mexican hat function) on the real line. For every $n \in N$ consider the multiplier operator on the unit sphere,

$$f \sum_{k=0}^{\infty} H_k^f \to \sum_{k=0}^{\infty} \phi(k/n) H_k^f,$$

where H_k^f stands for a "zonal block" of spherical harmonics of degree k. We give a short proof of the (should be well-known) fact that a convolution operator $f \to M_n f$ generated by the above multiplier is bounded on $L^p(S^{n-1})$ for all $1 \leq p \leq \infty$, i.e. $\|M_n f\|_{L^p(S^{n-1})} \leq c \|f\|_{L^p(S^{n-1})}$, and c is independent of n. (Received January 25, 2010)

1057-42-359 **Matthew R Bond*** (bondmatt@msu.edu), 500 W Lake Lansing Rd D26, East Lansing, MI 48823, and **Alexander Volberg** (volberg@math.msu.edu). *Buffon's needle lands in an ϵ-neighborhood of a 1-Dimensional Sierpinski Gasket with probability at most $|\log \epsilon|^{-c}$.*

In recent years, relatively sharp quantitative results in the spirit of the Besicovitch projection theorem have been obtained for self-similar sets by studying the L^p norms of the "projection multiplicity" functions, f_θ, where $f_\theta(x)$ is the number of connected components of the partial fractal set that orthogonally project in the θ direction to cover x. In arXiv:0801.2942 [Nazarov, Peres, and the 2nd author], it was shown that n-th partial 4-corner Cantor set with self-similar scaling factor 1/4 decays in Favard length at least as fast as $\frac{C}{n^p}$, for $p < 1/6$. In arXiv:math.0911.0233, we proved the same estimate for the 1-dimensional Sierpinski gasket for some $p > 0$. A few observations were needed to adapt the approach of arXiv:0801.2942 to the gasket: we sketch them here. We also formulate a result about all self-similar sets of dimension 1. (Received January 25, 2010)

43 ► Abstract harmonic analysis

1057-43-385 **Marlos A.G. Viana*** (viana@uic.edu). *Spectral Analysis of Dihedral Data.*

The notion of data indexed by planar rotations and reversals defined by the dihedral groups is introduced and formulated within the context of the canonical decomposition theorem for finite groups and its (dihedral) Fourier analysis equivalence. It is shown that the methodology can be used to determine exploratory summaries of the data that often reflect a number of analytic properties of interest, and systematically obtain the analysis of those summaries within the context of quadratic forms, when appropriate. (Received January 26, 2010)

44 ► Integral transforms, operational calculus

1057-44-17 **Ibrahim A. Salehbhai*** (ibrahimmaths@gmail.com). *Laguerre Transform in two Variables and its properties.*

Laguerre polynomials play an important role in the field of science, engineering, numerical mathematics, quantum mechanics, communication theory and numerical inverse Laplace transform. Some explicit evaluation of integrals

involving Laguerre polynomials are required in applied areas of mathematical and physical sciences. Debnath [2] first introduced the Laguerre transform of one variable and its properties; he also discussed its applications in study of heat conduction, diffusion equation and to the oscillations of a very long and heavy chain with variable tension. Debnath et al. [3] reported this work in their book. Recently Shukla et al. [1] introduced Laguerre transform in two variables. Present talk is extension of this paper [1] and some new properties are to be discussed. Some applications of this transforms in partial differential equation have also been discussed. [1] A.K. Shukla, I.A. Salehbhai and J.C. Prajapati, On the Laguerre transform in two variables, Integral Transforms and Special Functions, Vol. 20, No. 6, 2009, 459-470. [2] Debnath, L.: On Laguerre transform, Bull. Cal. Math. Soc., 55 (1960) 69-77. [3] L. Debnath and D. Bhatta, Integral Transforms and their Applications, Chapman & Hall/CRC Press, Boca Raton/London/New York, 2007. (Received November 07, 2009)

45 ► Integral equations

1057-45-3 **Irina Mitrea*** (imitrea@wpi.edu), 100 Institute Road, Worcester Polytechnic Institute, Department of Mathematical Sciences, Worcester, MA 01609. *Recent Progress in the Area of Elliptic Boundary Value Problems on Rough Domains.* Preliminary report.

I will survey some recent developments in the area at the crossroads between Partial Differential Equations, Harmonic Analysis, and Geometric Measure Theory. This is part of an effort to understand the extent to which the classical theory can be adapted to a setting in which the underlying domain is not locally the graph of a function, but instead has properties which can be described in the geometric measure theoretic language. This includes both second order and higher order operators. (Received January 22, 2010)

46 ► Functional analysis

1057-46-20 **Luiza A. Moraes*** (luiza@im.ufrj.br), Instituto de Matemática, Universidade Federal do Rio de Janeiro, CP 68530, Rio de Janeiro, 20511-270, Brazil. *Algebras of Lorch Analytic Mappings.*

If E is a Banach algebra, a mapping $f : U \subset E \to E$ is Lorch-analytic if given any $a \in U$ there exists $\rho > 0$ and there exist unique elements $a_n \in E$, such that $f(z) = \sum_{n=0}^{\infty} a_n (z-a)^n$, for all z in $\|z - a\| < \rho$. The theory of Lorch-analytic mappings goes back to the 1940's and is a very natural extension of the classical concept of analytic function to infinite dimensional algebras that allows concepts as Laurent series, singularities or a Mittag-Leffler's theorem.

The main purpose of this talk is to show results from [1] where we describe the spectra of different algebras of Lorch-analytic mappings in connection with the spectrum of the underlying algebra.

References

[1] L.A. Moraes and A. F. Pereira, The spectra of algebras of Lorch analytic mappings, Topology, IDAT Special Issue, to appear. (Received November 22, 2009)

1057-46-32 **Semail ULGEN YILDIRIM*** (sulgen@math.northwestern.edu), 2033 Sheridan Rd, Lunt Hall 223, Evanston, IL 60208. *Gap Labeling Theorems.*

We will review the use of noncommutative topology in the generalisation of Bloch theory from crystals to quasicrystals. After introducing Bloch theory, we will construct the noncommutative space of tilings and we will argue that this is the noncommutative analogue of the Brillouin zone which is used in Bloch theory. The K-theory of the noncommutative Brillouin zone will be used to provide a labeling of the gaps in the spectrum of quasiperiodic Hamiltonians, which can be seen as first step towards a generalisation of Bloch theory to quasicrystals. We will talk about the Gap Labeling Theorems and their proofs. (Received December 09, 2009)

1057-46-99 **Pilar Rueda*** (pilar.rueda@uv.es), Dpto. Analisis Matematico, Universidad de Valencia, C/ Dr. Moliner 50, 46100 Burjassot, Valencia, Spain. *Pietsch domination theorem and beyond.*

Pietsch domination theorem is a central and basic result in the theory of absolutely summing linear operators. Generalizations to multilinear mappings, polynomials or sub-homogeneous mappings use strongly the algebraic properties of the mappings involved and need to adapt Pietsch's linear argument to the new non-linear context at each time. In this work we give an abstract version of Pietsch's domination theorem which unify a number of

known domination theorems for classes of linear and non-linear mappings. Actually, we show that the Pietsch-type domination does not depend really on any algebraic condition. This is a joint work with Geraldo Botelho and Daniel Pellegrino. (Received January 13, 2010)

1057-46-106 **Yun Sung Choi*** (mathchoi@postech.ac.kr), Department of Mathematics, Pohang University of Science and Technology, Pohang, Kyungpook , South Korea, and **Han Ju Lee** and **Hyun Gwi Song**. *Denseness of norm-attaining mappings on Banach spaces.*

Let X and Y be Banach spaces. Let $P(^nX : Y)$ be the space of all Y-valued continuous n-homogeneous polynomials on X. We show that the set of all the norm-attaining elements is dense in $P(^nX : Y)$ when a set of u.s.e. points of the unit ball B_X is dense in the unit sphere S_X. Applying strong peak points instead of u.s.e. points, we generalize this result to a closed subspace of $C_b(M, Y)$, where M is a complete metric space. For complex Banach spaces X and Y, Let $A_b(B_X : Y)$ be the Banach space of all bounded continuous Y-valued mappings f on B_X whose restrictions $f|_{B_X^\circ}$ to the open unit ball are holomorphic. It follows that the set of all the norm-attaining elements is dense in $A_b(B_X : Y)$ if the set of all strong peak points in $A_b(B_X)$ is a norming subset for $A_b(B_X)$. (Received January 14, 2010)

1057-46-127 **Antonio M. Peralta*** (aperalta@ugr.es), Departamento de Análisis Matemático, Facultad de Ciencias, Avda. Fuente Nueva s/n, 18071 Granada, Spain. *Right-norm and strong*-norm continuous polynomials and holomorphic mappings.*

It is well known that a linear operator, T, between two Banach spaces X and Y is weakly compact if and only if T^{**} is Y-valued. The same statement doesn't hold in the setting of multilinear operators. Concretely, there exist multilinear operators $T : X_1 \times \ldots \times X_n \to Y$ which are not weakly compact whose Aron-Berner extension is unique and Y-valued. Recent contributions by Peralta, Villanueva, Wright and Ylinen introduce the right and strong* topologies in the study of those multilinear operators T whose Aron-Berner extension is Y-valued. It was proved that, in a wide class of Banach spaces (including C*-algebras and JB*-triples), a multilinear operator admits an Y-valued Aron-Berner extension if and only if it is quasi completely continuous, that is, jointly sequentially strong*-to-norm continuous.

We shall present some new advances in the study of those linear operators between Banach spaces which are strong*-to-norm continuous obtained in collaboration with J. Diestel and D. Puglisi. We shall also survey new results establishing necessary and sufficient conditions to guarantee that a holomorphic mapping of bounded type f between two Banach spaces X and Y admits an Y-valued Aron-Berner extension. (Received January 17, 2010)

1057-46-128 **Richard M Aron*** (aron@math.kent.edu), Department of Mathematics, Kent State University, Kent, OH 44240, and **Galindo Pablo** (pablo.galindo@uv.es), Departamento de Análisis Matemático, Universidad de Valencia, 46100 Burjassot (Valencia), Spain. *Symmetric polynomials on spaces of continuous functions (preliminary report).* Preliminary report.

Let $X = \mathcal{C}(K)$ denote the continuous scalar-valued functions on a compact Hausdorff space K. We study the space $\mathcal{P}_s(^nX)$ of continuous $n-$homogeneous polynomials $P : X \to \mathbb{K}$ with the following symmetric property:

$$\forall \varphi : K \to K, \text{ homeomorphisms, and } \forall f \in X, \ P(f) = P(f \circ \varphi).$$

In addition, we examine the algebra $A_{us}(B_X)$ of symmetric, uniformly continuous holomorphic functions $f : B \to \mathbb{C}$. These concepts are generalizations of earlier work of R. Alencar, A. Zagorodnyuk, and the authors [*Algebras of symmetric holomorphic functions on l_p*, Bull. London Math. Soc. 35 (2003), no. 1, 55-64, *Uniform algebras of symmetric holomorphic functions,* to appear.].
(Received January 17, 2010)

1057-46-132 **Lawrence A. Harris*** (larry@ms.uky.edu), Mathematics Department, University of Kentucky, Lexington, KY 40506. *A Proof of Markov's Theorem for Polynomials on Banach Spaces.*

Our object is to present an independent proof of the extension of V. A. Markov's theorem to the Gâteaux derivatives of continuous polynomials on any real normed linear space. Specifically, we prove that if X and Y are such spaces and if $P : X \to Y$ is a polynomial of degree at most m satisfying $\|P(x)\| \leq 1$ for all $x \in X$ with

$\|x\| \leq 1$, then

$$\begin{aligned} \|\hat{D}^k P(x)\| &\leq T_m^{(k)}(1) \text{ for all } x \in X \text{ with } \|x\| \leq 1 \text{ and} \\ \|\hat{D}^k P(x)\| &\leq T_m^{(k)}(\|x\|) \text{ for all } x \in X \text{ with } \|x\| \geq 1, \end{aligned}$$

where T_m is the Chebyshev polynomial of degree m. An erroneous proof of the first inequality has been given by A. D. Michal in 1954 while a rather daunting proof of a bit more general theorem has been given by V. I. Skalyga in 2005.

We have shown in a previous paper that to prove both inequalities it suffices to prove the second inequality for the case where X is $\mathbb{R}^2$ with the max norm and $Y = \mathbb{R}$. We do this by extending a simple Lagrange interpolation argument of Rogosinski to two variables and applying a bivariate Christoffel-Darboux formula for the Lagrange interpolation polynomials at the Chebyshev nodes. (Received January 25, 2010)

1057-46-171 **Bernardo Cascales*** (beca@um.es), Universidad de Murcia-Kent State University, Kent, OH 44240, and **Vladimir Kadets** and **Jose Rodriguez**. *The Gelfand integral for multi-valued functions.*

We study the existence of measurable selectors and measurable almost selectors for w^*-measurable multi-functions with values in dual Banach spaces. We define and study Gelfand and Dunford integral for multi-functions. This new theory of integrable multi-functions is developed with the help of some non-trivial functional analysis tools. Pettis integral for multi-functions, studied by different authors over the years, naturally appears as a particular case of Dunford integral now. Explanations about the ultimate reason for the compactness of Pettis integral are given. (Received January 21, 2010)

1057-46-185 **Carlo Morpurgo*** (morpurgoc@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, and **Luigi Fontana** (luigi.fontana@unimib.it), Dipartimento di Matematica e Applicazioni, Universita' di Milano-Bicocca, Via Cozzi, 53, 20125 Milano, Italy. *Adams inequalities on measure spaces.*

In 1988 David Adams obtained sharp Moser-Trudinger inequalities on bounded domains of $\mathbb{R}^n$. The main step was a sharp exponential integral inequality for convolutions with the Riesz potential. In a joint paper with Luigi Fontana we extend and improve Adams' results to functions defined on arbitrary measure spaces with finite measure. The Riesz fractional integral is replaced by general integral operators, whose kernels satisfy suitable and explicit growth conditions, given in terms of their distribution functions; natural conditions for sharpness are also given. Most of the known results about Moser-Trudinger inequalities can be easily adapted to our unified scheme. New applications of our theorems include: sharp higher order Moser-Trudinger trace inequalities, sharp Adams/Moser-Trudinger inequalities for general elliptic differential operators (scalar and vector-valued), for sums of weighted potentials, and for operators in the CR setting. (Received January 21, 2010)

1057-46-270 **Yang Kang*** (ykang@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824, and **Jeffrey Schenker** and **Eman Hamza**. *Diffusive propagation of wave packets in a fluctuating periodic potential.*

We consider the evolution of a tight binding wave packet propagating in a fluctuating periodic potential. If the fluctuations stem from a stationary Markov process satisfying certain technical criteria, we show that the square amplitude of the wave packet, after diffusive rescaling, converges to a superposition of solutions of a heat equation. (Received January 25, 2010)

1057-46-293 **Svitlana Mayboroda*** (svitlana@math.purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907, and **Alexander Volberg**. *Boundedness of the square function and rectifiability.*

A celebrated 1991 theorem of David and Semmes ascertains that the L^2-boundedness of all Caderón-Zygmund operators with respect to a Hausdorff measure H^s on a set E implies that s is an integer and E is rectifiable ("contains big pieces of Lipschitz graphs"). In the present work we establish that it is, in fact, sufficient to assume boundedness of a single operator, namely, the square function associated to the Riesz transform, in order to arrive to the same conclusion. (Received January 25, 2010)

1057-46-344 **Piotr Hajlasz*** (hajlasz@pitt.edu), University of Pittsburgh, Department of Mathematics, 301 Thackeray Hall, Pittsburgh, PA 15260. *Density of Lipschitz mappings in the Sobolev space of mappings into a metric space.* Preliminary report.

I will discuss new results on density of Lipschitz mappings in the Sobolev space of mappings from a manifold to a metric space. (Received January 25, 2010)

1057-46-345 **Piotr Hajlasz*** (hajlasz@pitt.edu), University of Pittsburgh, Department of Mathematics, 301 Thackeray Hall, Pittsburgh, PA 15260, and **Pawel Goldstein**. *Sobolev mappings, degree, homotopy classes and rational homology spheres.* Preliminary report.

In the talk I will discuss degree theory in the Orlicz-Sobolev space of mappings between manifolds. The manifolds are n-dimensional, smooth, compact, orientable and without boundary. The Orlicz-Sobolev space is close to $W^{1,n}$, but larger and, in particular, the Jacobian of an Orlicz-Sobolev mapping is not necessarily integrable, so we cannot define degree by the usual integral formula and there is no obvious way to control degree by the Orlicz-Sobolev norm. It turns out, however, that in this setting degree is integer valued and continuous in the Orlicz-Sobolev norm if and only if the universal cover of the target manifold is not a rational homology sphere. I will also discuss related results about the existence of homotopy classes in the Sobolev space of mappings. (Received January 25, 2010)

1057-46-379 **Almut Burchard*** (almut@math.toronto.edu), Department of Mathematics, 40 St. George Street, 6th Floor, Toronto, ON. *"On Stability of the rearrangement inequality for the Coulomb energy".*

It is well known that the Coulomb energy of a (positive) charge distribution will increase, if the distribution is rearranged to be symmetric decreasing. One may ask if a charge distribution whose Coulomb energy is close that of its rearrangement must already be close to symmetric about some point? I will present a simple stability result on the Coulomb energy and sketch its proof. (Received January 26, 2010)

1057-46-408 **David Hasler*** (dghasler@gmail.com), Department of Mathematics, College of William & Mary, P.O. Box 8795, Williamsburg, VA 23187, and **Richard Froese** and **Wolfgang Spitzer**. *On the AC spectrum of one-dimensional random Schroedinger operators with matrix-valued potentials.*

We consider discrete one-dimensional random Schroedinger operators with decaying matrix-valued, independent potentials. We show that if the l^2-norm of this potential has finite expectation value with respect to the product measure then almost surely the Schroedinger operator has an interval of purely absolutely continuous (ac) spectrum. We apply this result to Schroedinger operators on a strip. This work provides a new proof and generalizes a result obtained by Delyon, Simon, and Souillard. (Received January 26, 2010)

1057-46-419 **Luke G Rogers***, Mathematics Department, 196 Auditorium Road, Unit 3009, Storrs, CT 06269-3009. *Smooth bump functions, smooth cut-offs, and heat kernel estimates.*

On a metric measure space with a Dirichlet form we construct a (weak) Laplacian operator and define a function f to be smooth if all powers of the Laplacian applied to f yield continuous functions. Given a smooth function f, a compact set K and a neighborhood U of K, it is natural to ask whether one can smoothly cut off f to obtain a smooth F that is equal f on K and equal zero outside U. In the special case that f is the constant function 1 on K we call F a smooth bump function.

I will discuss how one can construct smooth bump functions under the assumption of suitable estimates on the heat operator associated to the Laplacian, and discuss a partial result and some challenges for the general smooth cut-off question. Some applications of these results may be described if time permits.

(This talk is based on work with R. S. Strichartz and A. Teplyaev) (Received January 26, 2010)

1057-46-462 **Gheorghe Nenciu** and **Irina Nenciu*** (nenciu@math.uic.edu), Department of Mathematics, M/C 249, 851 S. Morgan Street, Chicago, IL 60657. *Essential self-adjointness for Schrödinger operators on bounded domains.*

We consider the Schrödinger operator $H = -\Delta + V(x)$ on a bounded domain Ω in $\mathbb{R}^n$. We seek the weakest conditions we can find on the rate of growth of the potential V close to the boundary $\partial\Omega$ which guarantee essential self-adjointness of H on $C_\infty^0(\Omega)$. As a special case of an abstract condition, we add optimal logarithmic type corrections to the known condition $V(x) \geq 3/(4d(x)^2)$ where $d(x) = dist(x, \partial\Omega)$. The proof is based on a refined exponential Agmon estimate combined with a well known multidimensional Hardy inequality. Time permitting, we will also present some applications of our results to magnetic Schrödinger operators. This is joint work with Gh. Nenciu. (Received January 27, 2010)

47 ► Operator theory

1057-47-49 **Evans M. Harrell*** (harrell@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332-0160. *Semiclassical estimates of eigenvalues of quantum Hamiltonians arising in nanophysics.*

I will discuss "sum rule" identities that can be derived using traces of commutators of operators. One use of these identities is is to derive sharp semiclassical estimates of Lieb-Thirring type. I will explain this connection and derive sharp Lieb-Thirring inequalities for Schroedinger operators on curves, surfaces, and graphs, which are models for quantum wires, waveguides and networks in nanophysics. Parts of this work are joint with Semra Demirel, Lotfi Hermi, Joachim Stubbe, and Selma Yildirim Yolcu. (Received December 19, 2009)

1057-47-57 **Raluca Felea*** (rxfsma@rit.edu), School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623. *FIOs with fold and cusp singularities.*

We consider the composition of Fourier integral operators (FIOs) with certain singularities: two-sided folds and cusps for which the composition operator is not again a FIO. We show that its kernel belongs to a class of distributions associated to two Lagrangians. Such operators appear in linearized inverse problems from seismology for the acoustic wave equation where the normal operator F^*F is used to recover the soundspeed within the earth. (Received December 27, 2009)

1057-47-187 **Helge Krueger*** (hk7@rice.edu), Dept. of Math., Rice Univ., 6100 S. Main St., Houston, TX 77005. *Recent progress on Schroedinger operators with potential $V(n) = 2\lambda\cos(2\pi\alpha n^\rho)$.*

I will discuss recent progress concerning understanding the Schroedinger operator with potential $V(n) = 2\lambda\cos(2\pi\alpha n^\rho)$. The case $\rho = 1$ corresponds to the Almost–Mathieu operator, and is reasonably well understood, I will discuss results for other values of ρ. (Received January 21, 2010)

1057-47-301 **Roger A. Nichols*** (rnich_35180@yahoo.com), 1300 University Boulevard, Campbell Hall, Suite 452, Birmingham, AL 35294. *Spectral Properties of Discrete Displacement Models.*

We consider a discrete displacement model h_ω on $\ell^2(\mathbb{Z}^d)$ indexed by a displacement configuration $\omega = \{\omega_k\}_{k\in\mathbb{Z}^d}$ and determine a configuration ω^* with the property that h_{ω^*} has the lowest possible ground and highest possible ceiling state energies. For the random displacement model, i.e. for ω_k i.i.d. random vectors, the configuration ω^* allows to calculate the minimum and maximum of the almost-sure spectrum. Using this result and positivity properties of generalized eigenfunctions, we show the almost-sure spectrum Σ_λ of the one-dimensional Bernoulli displacement model $h_\omega(\lambda)$, where $\lambda \in \mathbb{R}\setminus\{0\}$ is a fixed coupling constant, contains a gap for every $\lambda \neq 0$. We explicitly calculate Σ_λ for $0 < |\lambda| \leq 2$. Consequences for the integrated density of states are also discussed. (Received January 25, 2010)

1057-47-319 **Luka Grubišić**, **Vadim Kostrykin** and **Konstantin A. Makarov*** (makarovk@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, and **Krešimir Veselić**. *The Tan 2Θ-Theorem for Indefinite Quadratic Forms.* Preliminary report.

A version of the Davis-Kahan Tan 2θ-Theorem for not necessarily semi-bounded operators defined via quadratic forms is proven. This theorem generalizes a recent result by Motovilov and Selin [Itegr. Equat. Oper. Theory **56** (2006), 511-542]. (Received January 25, 2010)

1057-47-366 **Vita Borovyk*** (borovykv@math.arizona.edu), Department of Mathematics, The University of Arizona, P.O. Box 210089, Tucson, AZ 85721, and **Konstantin A. Makarov**. *On the weak and ergodic limits of the spectral shift function.*

We discuss convergence properties of the spectral shift functions associated with a pair of Schrödinger operators with Dirichlet boundary conditions at the end points of a finite interval $(0, r)$ as the length of the interval approaches infinity. (Received January 26, 2010)

1057-47-415 **Janine Dahl*** (janine.dahl@rice.edu), Rice University, Department of Mathematics - MS 136, Houston, TX 77005. *The Dimension of the Spectrum of the Off-Diagonal Fibonacci Hamiltonian.* Preliminary report.

We will consider the off-diagonal Fibonacci operator, which has zero Lebesgue measure spectrum and purely singular continuous spectral measures, and show upper and lower bounds on the fractal dimension of the spectrum for large coupling by considering periodic approximations of the operator. (Received January 26, 2010)

1057-47-464 **Zheng Gan*** (zheng.gan@rice.edu), Math Department - MS 136, Rice University, 6100 S. Main Street, Houston, Texas 77005. *Cantor groups and Limit-periodic Schoedinger Operators*

We study the spectral properties of one-dimensional discrete limit-periodic Schoedinger operators. The perspective we take was first proposed by Avila and is based on regarding such potentials as generated by continuous sampling function along the orbits of a minimal translation of a Cantor group. This point of view allows one to separate the base dynamics and the sampling function. For any such base dynamics, we will show that the spectrum of each type (a.c., s.c. & p.p) can occur for limit-periodic potentials and how often it does so. We will also discuss the uniform localization of the p.p. spectrum. (Received February 01, 2010)

49 ► Calculus of variations and optimal control; optimization

1057-49-44 **A Lorent*** (lorentaw@uc.edu), Mathematics Department, University of Cincinnati, 2600 Clifton Ave., Cincinnati, OH 45221. *A quantitative characterisation of functions with low Aviles Giga energy on convex domains.*

Given a connected Lipschitz domain Ω we let $\Lambda(\Omega)$ be the subset of functions in $W^{2,2}(\Omega)$ with $u = 0$ on $\partial\Omega$ and whose gradient (in the sense of trace) satisfies $\nabla u(x) \cdot \eta_x = 1$ where η_x is the inward pointing unit normal to $\partial\Omega$ at x. The functional

$$I_\epsilon(u) = \frac{1}{2}\int_\Omega \epsilon^{-1}\left|1 - |\nabla u|^2\right|^2 + \epsilon\left|\nabla^2 u\right|^2$$

minimised over $\Lambda(\Omega)$ serves as a model in connection with problems in liquid crystals and thin film blisters, it is also the most natural higher order generalisation of the Modica Mortola functional. After surveying the area we will outline our recent result on the charactisation of low energy functions and domains:

There exists positive constant γ_1 such that if Ω is a convex set of diameter 2 and $u \in \Lambda(\Omega)$ with $I_\epsilon(u) = \beta$ then $|B_1(x) \triangle \Omega| \leq c\beta^{\gamma_1}$ for some x and

$$\int_\Omega \left|\nabla u(z) + \frac{z-x}{|z-x|}\right|^2 dz \leq c\beta^{\gamma_1}.$$

(Received December 15, 2009)

1057-49-205 **Arunachalam Chockalingam*** (arunachalam@purdue.edu), 315 N. Grant Street, School of Industrial Engineering, Purdue University, West Lafayette, IN 47907, and **Haolin Feng** and **Kumar Muthuraman**. *American Options and Sub-optimal Exercise Policies.* Preliminary report.

The American option pricing problem gives rise to a free-boundary problem, the solution of which yields the price function and associated optimal exercise policy. Chockalingam and Muthuraman (2009) develop an exercise policy improvement scheme to price these options in a variety of settings. In this work, we derive error bounds for option prices obtained using exercise policies that lie below the optimal exercise policy, and relate these to the exercise policy improvement scheme of Chockalingam and Muthuraman (2009). These error bounds are applicable for a variety of market models. We provide numerical illustrations to verify these error bounds. Furthermore, we list a result for option prices obtained using exercise policies that lie above the true policy. (Received January 22, 2010)

1057-49-248 **Jasun Gong*** (jasun@pitt.edu), Department of Mathematics, University of Pittsburgh, 301 Thackeray Hall, Pittsburgh, PA 15260. *Regularity of Quasi-minimizers for Non-homogeneous Energy Functionals on Metric Spaces.* Preliminary report.

It is well-known that on domains Ω on Euclidean spaces, minimizers of the p-Dirichlet energy integral

$$u \mapsto \int_\Omega |\nabla u|^p dx$$

enjoy a rich regularity theory. For instance, they are Hölder continuous and satisfy the Harnack inequality. Though such functions are solutions to an associated Euler-Lagrange equation (of elliptic type), there are techniques of proof that rely solely on their energy-minimizing property. In fact, quasi-minimizers — roughly speaking, functions which almost minimize energy — also have similar regularity properties, as shown by Giaquinta and Giusti in the 1980s.

Many notions of analysis, such as Sobolev spaces, extend to the setting of metric measure spaces (that is, metric spaces equipped with Borel measures). In this setting, we will show that quasiminimizers of energy integrals — both homogeneous and non-homogeneous — have similar regularity properties as their Euclidean

counterparts. These results extend the work of J. Kinnunen and N. Shanmugalingam, as well as of J. Björn and N. Marola.

This is based on joint work with J.J. Manfredi and M. Parviainen, and separately with P. Hajłasz. (Received January 24, 2010)

1057-49-297 **Andres A. Contreras*** (ancontre@indiana.edu), 2200 Lingelbach ln, Apt. 1202, Bloomington, IN 47408. *Ginzburg-Landau on thin shells and manifolds subject to an arbitrary external field.*

The Ginzburg-Landau energy in the presence of an external field when the superconducting sample occupies a thin neighborhood of a bounded compact manifold without boundary is considered. The results presented include Gamma-convergence of the functionals for small thickness to one posed on the manifold, construction of symmetric vortex solutions and determination of the first critical field H_{c1} for large values of the Ginzburg-Landau parameter. In the case of a simply connected surface of revolution and a constant and vertical applied field, the exact number of vortices present in minimizers is obtained for fields slightly above H_{c1}. This is joint work with Peter Sternberg. (Received January 25, 2010)

1057-49-339 **Scott N Armstrong*** (armstrong@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Convexity criteria and uniqueness of absolute minimizers of L^∞ variational problems.*

I will present results obtained in joint work with Crandall, Julin, and Smart on the uniqueness of absolute minimizers of L^∞ variational problems for a convex Hamiltonian. Previous proofs of uniqueness have relied on the equivalence of the variational problem and Aronsson's equation, which has been confirmed only for C^2 Hamiltonians. In contrast, our new approach does not make use of viscosity solution machinery, and therefore permits us to completely remove the regularity hypothesis on the Hamiltonian. Our argument is generalization of the recent new proof of uniqueness of infinity harmonic functions obtained in joint work with Smart. (Received January 25, 2010)

1057-49-361 **Chiu-Yen Kao*** (kao@math.ohio-state.edu), 410 Math Tower, 231 West 18th Ave., Columbus, OH 43202. *An Efficient Rearrangement Algorithm for Shape Optimization on Elliptic Eigenvalue Problems.*

In this talk, we will discuss an efficient rearrangement algorithm to find the optimal shape and topology for elliptic eigenvalue problems in an inhomogeneous media. The method is based on Rayleigh quotient formulation of eigenvalue and a monotone iteration process to achieve the optimality. The common numerical approach for these problems is to start with an initial guess for the shape and then gradually evolve it, until it morphs into the optimal shape. One of the difficulties is that the topology of the optimal shape is unknown. Developing numerical techniques which can automatically handle topology changes becomes essential for shape and topology optimization problems. The level set approach based on both shape derivatives and topological derivatives has been well known for its ability to handle topology changes. However, CFL constrain significantly slows down the algorithm when the mesh is further refined. Due to the efficient binary update and optimal rearrangement, our method not only has the ability of topological changes but also is exempt from CFL condition. We provide numerous numerical examples to demonstrate the robustness and efficiency of our approach. (Received January 26, 2010)

51 ► Geometry

1057-51-112 **Fabrice Baudoin** and **Nicola Garofalo*** (garofalo@math.purdue.edu), Department of Mathematics, 150 N. University Street, West Lafayette, IN 47907-2067. *Perelman's entropy and doubling property on Riemannian manifolds.*

The purpose of this work is to study some monotone functionals of the heat kernel on a complete Riemannian manifold with nonnegative Ricci curvature. In particular, we show that on these manifolds the gradient estimate of Li and Yau, the gradient estimate of Lei Ni, the monotonicity of the Perelman's entropy and the volume doubling property are all consequences of an entropy inequality recently discovered by the authors in their work on the sub-Riemannian Ricci tensor. Such inequality is a linearized version of a logarithmic Sobolev inequality that is due to D. Bakry and M. Ledoux. (Received January 14, 2010)

1057-51-278 **Patrick Clarke*** (pclarke@math.upenn.edu). *Categorical T-duality.*
When studying homological mirror symmetry for toric Landau-Ginzburg models it is tempting to apply T-duality to the moment map fibers. However, this approach runs into considerable difficulties as the interesting data lies on the degenerate fibers, and it is not geometrically obvious how to proceed.

We present a way to circumvent this problem using a categorical formulation of T-duality in terms of cones in the Fukaya category and Kontsevich's approach to the deformation theory of categories. (Received January 25, 2010)

52 ► Convex and discrete geometry

1057-52-174 **Benjamin J Braun*** (benjamin.braun@uky.edu), 714 Patterson Office Tower, Dept of Math, University of Kentucky, Lexington, KY 40506. *An Ehrhart Series Formula for Reflexive Polytopes.*
For lattice polytopes P and Q, the Ehrhart polynomial of the product of P and Q is the product of their Ehrhart polynomials. We show that when P is reflexive and Q contains 0 in its interior, there is a similar multiplicative relationship between the Ehrhart series for P, the Ehrhart series for Q, and the Ehrhart series for the free sum of P and Q. (Received January 21, 2010)

1057-52-303 **Ivan Soprunov** (i.soprunov@csuohio.edu), 2121 Euclid Ave. RT 1536, Cleveland State University, Cleveland, OH 44115, and **Jenya Soprunova*** (soprunova@math.kent.edu), Summit Street, Kent State University, Kent, OH 44242. *Minimum distance for toric codes and geometry of lattice polytopes.*
Fix a convex lattice polytope P in $\mathbb{R}^n$, and define $\mathcal{L}_P$ to be the $\mathbb{F}_q$-vector space spanned by the monomials whose exponent vectors lie in P. The codewords of a *toric code* are obtained by evaluating polynomials in $\mathcal{L}_P$ at the points of the torus $(\mathbb{F}_q \setminus \{0\})^n$, taken in some fixed order. The question of computing or giving bounds on the minimum distance of toric codes has been studied by Hansen, Joyner, Little and Schenk, and others.

In this talk, I will explain our results that demonstrate a strong connection between the minimum distance of a toric code and the geometry of its lattice polytope P. In the surface case, $n = 2$, we came up with new lower bounds for the minimum distance which involve a geometric invariant $L(P)$, the full Minkowski length of a polygon P. For higher-dimensional toric codes, we have shown that the minimum distance is multiplicative with respect to taking the product of polytopes, and behaves in a simple way when one builds a k-dilate of a pyramid over a polytope. This allowed us to construct a large class of examples of higher-dimensional toric codes where we can compute the minimum distance explicitly. (Received January 25, 2010)

1057-52-362 **Jay Schweig***, KU Mathematics Dept., 405 Snow Hall, 1460 Jayhawk Blvd., Lawrence, KS 66045. *Lattice path matroids and polymatroids.*
Lattice path matroids are a special type of transversal matroids whose bases are in correspondence with planar lattice paths. We discuss some interesting enumerative properties of the h-vectors of these matroids. We then show how such matroids are naturally related to discrete polymatroids, monomial order ideals which generalize classical matroid theory to multisets. Finally, we suggest several generalizations to larger classes of matroids. (Received January 26, 2010)

1057-52-435 **Ezra Miller** and **Megan Owen*** (maowen@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695, and **J. Scott Provan**. *Averaging Metric Trees.*
The space of metric phylogenetic trees is a polyhedral complex, as constructed by Billera, Holmes, and Vogtmann (2001). Because this space is also non-positively curved, there is a well-defined notion of an average or mean tree for a given set of trees. We describe this mean tree and how to compute it. We will also discuss what it represents in some applications, such as reconstructing species trees from gene trees and comparing the topology of blood vessels in the brain. (Received January 26, 2010)

53 ► Differential geometry

1057-53-53 **Tadeusz Iwaniec** and **Leonid V. Kovalev*** (lvkovale@syr.edu), Department of Mathematics, 215 Carnegie Building, Syracuse University, Syracuse, NY 13244, and **Jani Onninen**. *If Grötzsch had met Nitsche: Doubly connected minimal surfaces and extremal harmonic mappings.*

The concept of a conformal deformation has two natural extensions: quasiconformal and harmonic mappings. Both classes do not preserve the conformal type of the domain, however they cannot change it in an arbitrary way. Doubly connected domains are where one first observes nontrivial conformal invariants. Herbert Grötzsch and Johannes C. C. Nitsche addressed this issue for quasiconformal and harmonic mappings, respectively. Combining these concepts we obtain sharp estimates for quasiconformal harmonic mappings between doubly connected domains. We then apply our results to the Cauchy problem for minimal surfaces. Specifically, we obtain a sharp estimate of the modulus of a doubly connected minimal surface that evolves from its inner boundary with a given initial slope. (Received December 23, 2009)

1057-53-201 **Thomas Bieske*** (tbieske@math.usf.edu), 4202 E. Fowler Ave., PHY 114, Tampa, FL 33620. *The Carnot-Caratheodory distance and the infinite Laplacian.*

In an arbitrary Carnot-Caratheodory space, we find geometric conditions under which the Carnot-Caratheodory distance is a viscosity solution to the infinite Laplace equation. Exploring these conditions in the Heisenberg group and the Grushin plane, we see these conditions are sharp. (Received January 22, 2010)

1057-53-225 **Julie Marie Miker*** (Julie.Miker@arbor.edu), 3310 Trillium Lane Apt 22, Jackson, MI 49201. *Eigenvalue Inequalities for a Family of Spherically Symmetric Riemannian Manifolds.* Preliminary report.

We will consider two isoperimetric inequalities for the eigenvalues of the Laplacian on a family of spherically symmetric Riemannian manifolds. The Payne-Pólya-Weinberger Conjecture (PPW) states that for a bounded domain Ω in Euclidean space $\mathbb{R}^n$, the ratio $\lambda_1(\Omega)/\lambda_0(\Omega)$ of the first two eigenvalues of the Dirichlet Laplacian is bounded by the corresponding eigenvalue ratio for the Dirichlet Laplacian on the ball B_Ω of equal volume. The Szegö-Weinberger inequality states that for a bounded domain Ω in Euclidean space $\mathbb{R}^n$, the first nonzero eigenvalue of the Neumann Laplacian $\mu_1(\Omega)$ is maximized on the ball B_Ω of the same volume. In this talk, we will look at a family a spherically symmetric manifolds given by $\mathbb{R}^n$ with a spherically symmetric metric determined by a radially symmetric function f. We will then give a PPW-type upper bound for the eigenvalue gap, $\lambda_1(\Omega) - \lambda_0(\Omega)$, and also the Szegö-Weinberger inequality for this family of manifolds on a restricted class of domains in this space. This is joint work with Peter Hislop. (Received January 23, 2010)

1057-53-311 **Scott Pauls*** (scott.pauls@dartmouth.edu), 6188 Kemeny Hall, Hanover, NH 03755. *Minimal surfaces in sub-Riemannian spaces: nonsmooth solutions and their consequences.*

Numerous researchers have made substantial progress in the last decade in understanding and describing the properties of area minimizing surfaces in the sub-Riemannian setting. In contrast to the classical case, a growing body of this work is devoted such surfaces with low regularity. In this talk, we will discuss some of the known examples and their properties as well as some new examples in the setting of the rototranslation group.

Via the Citti-Sarti model of the primary visual cortex, these examples have a direct link to neural processes of contour completion and disocclusion. We will discuss some potential applications in this direction. (Received January 25, 2010)

1057-53-445 **Bo Guan*** (guan@math.osu.edu), Department of Mathematics, Ohio State University, Columbus, OH 43210, and **Joel Spruck**, Department of Mathematics, Johns Hopkins University, Baltimore, MD 21218. *Complete hypersurfaces of constant curvature in hyperbolic Space.*

We shall report some results, part of which obtained jointly with Marek Szapiel, on the problem of finding, in hyperbolic space, complete hypersurfaces of constant Weingarten curvature with prescribed asymptotic boundary at infinity. We will discuss several special cases. But our methods apply to a very general class of curvature functions. (Received January 26, 2010)

54 ► General topology

1057-54-363 **Paul Bankston*** (paulb@mscs.mu.edu), 1313 West Wisconsin Ave., Milwaukee, WI 53201. *Using model theory to characterize when two classes of mappings coincide.*

A mapping between continua is monotone if inverse images of subcontinua are subcontinua. We introduce the class of semimonotone mappings as those for which the inverse image of a subcontinuum has a component that both maps onto the subcontinuum and contains the inverse image of the subcontinuum's interior. Our main theorem is that a continuum is locally connected iff every semimonotone mapping onto it is also monotone. The construction of semimonotone nonmonotone mappings onto continua that are not locally connected involves model-theoretic methods, particularly the ultrapower construction and the Loewenheim-Skolem theorem. (Received January 26, 2010)

1057-54-436 **Malgorzata A Marciniak*** (malgorzata.marciniak@utoledo.edu), 2801 W. Bancroft, UH 4410K, Toledo, OH 43606-3390, and **Matt Insall** (insall@mst.edu), Department of Mathematics and Statistics, 315 Rolla Building, Rolla, MO 65401. *Ends of Topological Spaces.*

During my talk I will explain how holomorphic extension problems motivate the research on ends of topological spaces. (Received January 26, 2010)

55 ► Algebraic topology

1057-55-11 **Mindy Beth Capaldi*** (mindy_capaldi@ncsu.edu), North Carolina State University, Department of Mathematics, Campus Box 8205, Raleigh, NC 27695. *L_∞ Algebras and Symmetric Braces.* Preliminary report.

This presentation introduces L_∞, symmetric braces, and L_∞ morphisms, provides examples of each, and then shows how we can use L_∞ morphisms to derive new L_∞ algebras from existing ones. The proof that we do indeed have a new L_∞ algebra is in the context of symmetric brace algebras. We can demonstrate this process with a concrete example where we start with a small, but nontrivial, L_∞ algebra as well as a simple set of morphisms. (Received September 14, 2009)

1057-55-63 **Sunil Kumar Chebolu*** (schebol@ilstu.edu), Department of Mathematics, Illinois State University, Campus box 4520, Normal, IL 61790. *Progress report on the generating hypothesis.*

Freyd's generating hypothesis is a very fundamental and deep statement about the category of finite spectra. It is a conjecture due to Peter Freyd (1965) which states that the stable homotopy functor on the category of finite spectra is faithful. An unbelievable consequence of this conjecture is that it reduces the study of finite CW spectra to that of graded modules over the homotopy ring of the sphere spectrum. Therefore this conjecture stands as a central problem in the homotopy theory which is still open. To the best of my knowledge there hasn't been any progress on this conjecture in the recent years. However, there has been lots of developments on analogues and variations of this conjecture on other axiomatic stable homotopy categories including equivariant stable homotopy categories, derived categories, and the stable module categories of finite groups. This talk will be a survey of these results with particular emphasis on the stable module categories which is joint work with Jon Carlson and Jan Minac. (Received January 02, 2010)

1057-55-136 **A. Bahri*** (bahri@rider.edu), Department of Mathematics, Rider University, Lawrenceville, NJ 08648, and **M. Bendersky**, **F. R. Cohen** and **S. Gitler**. *The cohomology rings of generalized moment-angle complexes.*

Associated to a simplicial complex K on m vertices and a family of m based CW pairs, is a CW complex called a generalized moment-angle complex. The moment-angle construction allows the representation of many familiar spaces as combinatorially defined subspaces of a product. After one suspension, this space decomposes into a wedge of spaces determined by the full sub-complexes of K. Paradoxically, the stable splitting can be exploited to give a description of the cohomology ring structure. The results complement cases studied by Hochster, Franz, Panov, Buskakov-Buchstaber-Panov and Davis-Januszkiewicz. (Received January 18, 2010)

1057-55-184 **Nicholas J. Kuhn*** (njk4x@virginia.edu), Mathematics Department, University of Virginia, Charlottesville, VA 22904-4137. *A polynomial functor approach to some equivariant K–theory algebras.* Preliminary report.

Given a finite complex X, we consider the graded abelian group

$$\mathcal{K}(X) = \bigoplus_{r=0} K_{\Sigma_r}(X^r).$$

This connects to various disparate things. On one hand, there is a natural map $\alpha : \mathcal{K}(X) \to K(\Omega^\infty\Sigma^\infty X)$ that can be viewed as a completion. On the other hand, Graeme Segal has observed that $\mathcal{K}(X) \otimes \mathbb{C}$ is the free Λ–ring generated by $K(X) \otimes \mathbb{C}$. Recently Joe Johnson has constructed a λ–ring structure on $\mathcal{K}(X)$ such that in the diagram

$$\mathcal{K}(X) \otimes \mathbb{C} \xleftarrow{i} \mathcal{K}(X) \xrightarrow{\alpha} K(\Omega^\infty\Sigma^\infty X)$$

both i and α are maps of Hopf algebras and Λ–rings.

I will briefly survey this, and then offer a global approach to $\mathcal{K}(X)$, inspired by observations in the 1970's by I. G. MacDonald.

Let $\mathrm{Vect}(X)$ be the category of complex vector bundles over X. We let $\mathcal{P}(X)$ be the category of polynomial functors $F : \mathrm{Vect}(X) \to \mathbb{C}$–vector spaces. This abelian category splits into its homogeneous components, and thus so does its K–theory.

Theorem $K(\mathcal{P}(X)) \simeq \mathcal{K}(X)$. (Received January 21, 2010)

1057-55-198 **Laurentiu Maxim*** (maxim@math.wisc.edu), Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706, and **Joerg Schuermann**. *Geometry and Topology of Symmetric Products.*

I will discuss how a very simple relationship between symmetric group actions on exterior products and the theory of lambda rings can be used to obtain generating series formulae for very general topological/analytical invariants of symmetric products of complex spaces. (Received January 22, 2010)

1057-55-380 **Kate Ponto*** (kponto1@nd.edu), 255 Hurley Hall, Notre Dame, IN 46556-4618. *Equivariant fixed point invariants.*

There is an integer, called the Lefschetz number, associated to each endomorphism of a closed smooth manifold. The Lefschetz fixed point theorem states that the Lefschetz number of an endomorphism with no fixed points is zero. Unfortunately, this number can also be zero when the endomorphism has fixed points and all endomorphisms homotopic to it have fixed points.

The Lefschetz number admits a refinement, called the Reidemeister trace, that (with some hypotheses) is zero if and only if the endomorphism is homotopic to a fixed point free endomorphism. This gives a converse to the Lefschetz fixed point theorem.

The Reidemeister trace has three equivalent, but very different descriptions. Generalizations of two of these descriptions have been studied in the case of spaces with an action by a finite group. I will discuss a generalization of the third description to the equivariant case and describe how it compares with the other two descriptions. (Received January 26, 2010)

1057-55-406 **Michael A Hill***, PO Box 400137, Charlottesville, VA 22904, and **Michael J Hopkins** and **Douglas C Ravenel**. *A solution to the Kervaire Invariant One Problem.*

I will sketch an outline of our solution to the Kervaire problem, highlighting some of the techniques from equivariant homotopy theory. (Received January 26, 2010)

1057-55-455 **Vassily Gorbounov*** (vgorb@maths.abdn.ac.uk), university of aberdeen, aberdeen, ab25 2ts, Scotland. *Hilbert schemes of points of a surface and the black hole entropy of hyper Kahler manifolds.* Preliminary report.

Mathematically the black hole entropy of a hyper Kahler manifold M as defined by Vafa is related to a special property of the elliptic genus of M. Namely the elliptic genus of M is not just a Jacobi form it but admits a decomposition into the characters of the N=4 super conformal algebra. These are of two types, the massive and massless. The former are essentially theta functions and the later are the Mock theta functions. The collection of the multiplicities of the massless characters defines the entropy. In a series of papers T. Eguchi calculated the multiplicities of the massless characters in the Hilbert scheme of points on K3 surface. He has stated a problem of calculating these multiplicities for an arbitrary hyper Kahler manifold. In this talk we propose a way of solving this problem. We claim that the set of manifolds of the Hilbert schemes of n points on K3 surface is a set of multiplicative denerators of the cobordism ring of the symplectic manifolds, hence the Eguchi calculation

defines the entropy of any hyper Kahler manifold. To prove the claim we need to show that the Milnor number of the hilbert scheme of points on K3 is not zero. (Received January 27, 2010)

57 ► Manifolds and cell complexes

1057-57-289 **Qayum Khan*** (qkhan@nd.edu), Department of Mathematics, 255 Hurley Hall, University of Notre Dame, Notre Dame, IN 46556. *Rigidity of connected sums of certain 4-manifolds.*

We establish the topological s-cobordism surgery sequence for any closed oriented 4-manifold X that is homotopy equivalent to a connected sum X1 # ... # Xn of certain factors Xi. Here, it suffices that the fundamental group Gi of each Xi is "good" in the sense of Freedman–Quinn. More generally, each Xi must have an exact s-cobordism surgery sequence.

As a corollary, if each Xi is aspherical and each Gi satisfies the Farrell–Jones Conjecture, then X is topologically s-rigid. The methods use topological cobordisms and homology rather than direct surgeries. (Received January 25, 2010)

60 ► Probability theory and stochastic processes

1057-60-182 **Ha-Young Kim*** (kim156@purdue.edu), 150 N. University Street, West Lafayette, IN 47907-2067, and **Frederi G Viens** (viens@stat.purdue.edu), 150 N. University Street, West Lafayette, IN 47907-2067. *Portfolio Optimization with Discrete Proportional Transaction Costs under Stochastic Volatility.*

This study is devoted to evaluating the optimal self-financing portfolio and the optimal trading frequency on a risky and risk-free asset to maximize the expected future utility of the terminal wealth in a stochastic volatility setting, when proportional transaction costs are incurred at each discrete trading time. The HARA utility function is used, allowing a simple approximation of the optimization problem, which is implementable forward in time. For each of various transaction cost rates, we find the optimal trading frequency, i.e. the one that attains the maximum of the expected utility at time zero. We study the relation between transaction cost rate and optimal trading frequency. The numerical method used is based on a stochastic volatility particle filtering algorithm, combined with a Monte-Carlo method. (Received January 21, 2010)

1057-60-192 **Jinho Baik*** (baik@umich.edu), 530 Church Street, Ann Arbor, MI 48103. *Random complete matching and Ablowitz-Ladik.* Preliminary report.

We will discuss the so-called maximal number of crossings and nestings of a random complete matching. A few years ago, Chen, Deng, Du, Stanley and Yan found a determinant formula for the joint distribution of them. We will discuss that this determinant is related to the Ablowitz-Ladik equations in integrable systems and compute the limiting joint distribution using the Riemann-Hilbert problem. This is a joint work with Bob Jenkins from U.Michigan. (Received January 22, 2010)

1057-60-202 **Tomasz R Bielecki** and **Igor Cialenco*** (igor@math.iit.edu), Department of Applied Math, IIT, 10 West 32nd Str, Bld E1, Room 208, Chicago, IL 60616, and **Zhao Zhang**. *Dynamic Acceptability Indices.*

Acceptability index is defined as a unitless measure of performances of a random cash-flow that satisfies a set of natural axioms. We will present a general theoretical framework of studying acceptability indices from dynamic point of view. We will discuss on some representation type theorems for dynamic coherent acceptability indices and provide several practical examples. (Received January 22, 2010)

1057-60-234 **Jim Gatheral**, **Elton P Hsu**, **Peter Laurence** and **Cheng Ouyang*** (couyang@math.purdue.edu), 150 N. University Street, Department of Mathematics, Purdue University, West Lafayette, IN 47907, and **Tai-Ho Wang**. *Asymptotics of implied volatility in local volatility models and stochastic volatility models.*

Using the heat kernel expansion technique, we obtain an asymptotic formula for European call option prices with respect to the time to maturity. We use this formula to calculate both the leading value of the implied volatility $\hat{\sigma}$ and the first order deviation of $\hat{\sigma}$ from its leading value. Some geometric interpretations will be discussed for these two terms. This is a joint work with Jim Gatheral, Elton Hsu, Peter Laurence and Tai-Ho Wang. (Received January 23, 2010)

1057-60-242 **michael m.g. goldstein*** (gold@math.toronto.edu), Dept. of Mathematics, University of Toronto, Toronto, Ontario M5S 1A1, Canada. *Estimate for the exterior power of the resolvent of Andeson model in a quasi-one-dimensional domain.*

We consider the Schrödinger operator of the Anderson model

$$\big[H_\Lambda\psi\big](n) := \Delta_\Lambda\psi(n) + v_n\psi_n \ , v = (v_n)$$

in a quasi-one-dimensional domain $\Lambda = [1, N] \times [1, K] \subset \mathbb{Z}^2$, $K \leq N^\delta$, $\delta \ll 1$, with Dirichlet boundary condition on $\partial\Lambda$. We assume that x_n are i.i.d and the common distribution $dP_0(v_0)$ has a bounded density. We consider the exterior K-th power $\bigwedge^K (H_\Lambda(v) - E)^{-1}$ of the resolvent $(H_\Lambda(v) - E)^{-1}$. Let $\alpha_l = (x_{1,l}, \dots, x_{K,l})$, $\alpha_r = (x_{1,r}, \dots, x_{K,r})$, where $x_{1,l} = (1, 1), \dots, x_{K,l} = (1, K)$, $x_{1,r} = (N, 1), \dots, x_{K,r} = (N, K)$. Then there exists $\gamma_0 > 0$ such that with probability $\geq 1 - \exp(-N^{1/2})$ holds

$$\Big|\bigwedge^K (H_\Lambda(v) - E)^{-1}(\alpha_l, \alpha_r)\Big| < \exp(-\gamma_0 N) \tag{1}$$

(Received January 24, 2010)

1057-60-267 **Kiseop Lee*** (kiseop.lee@louisville.edu), Department of Mathematics, Louisville, KY 40292, and **Mingxin Xu**. *Parameter Estimation from Multinomial Trees to Jump Diffusions with K Means Clustering.*

Ever since the pioneering work of Cox, Ross and Rubinstein, tree models have been popular among asset pricing methods. On the other hand, statistical estimation of parameters of tree models has not been studied as much. In this paper, we use K Means Clustering method to estimate the parameters of multinomial trees. By the weak convergence property of multinomial trees to continuous-time models, we show that this method can be in turn used to estimate parameters in continuous time models, illustrated by an example of jump-diffusion model. (Received January 25, 2010)

1057-60-272 **Jose E. Figueroa-Lopez*** (figueroa@stat.purdue.edu), Department of Statistics, Purdue University, 250 N. University Street, West Lafayette, IN 47907. *Nonparametric estimation for a time-changed Lévy model.*

Time-changed Lévy process are known to capture several stylized features of asset prices. In this talk we study the problem of estimating the infinite-dimensional parameter controlling the jump behavior of the process as well as the underlying random clock. We obtain consistent estimation of the relevant parameters when both the sampling frequency and time-horizon get larger, and illustrate the performance of the estimators with simulated and real data. (Received January 25, 2010)

1057-60-307 **Robert E Molzon*** (molzon@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *Random Matching and the Central Limit Theorem.* Preliminary report.

Much of economic theory and policy is based on expected value. Although models are often formulated in a way that takes stochastic shocks into consideration, the analysis of the models is often so intractable that a way out of the mathematical difficulties is sought. One way out is to employ a heuristic "law of large numbers" to argue that the stochastic shocks will cancel out if the population size is allowed "to go to infinity". Thus the stochastic model is replaced with a deterministic model with parameters computed as the expected values of the variables in the stochastic model. Katrina type disasters remind us that fluctuations from the mean really do matter.

In this paper we develop a powerful mathematical tool, a central limit theorem for matching processes, that allows us to study the distribution of equilibria in a number of economic models. Our examples show that a very different picture presents itself once we go beyond expected value and consider variation in the outcome of matching models. Our first example examines a simple two strategy game played by a (large) finite number of players who switch strategies based on the outcome of the previous round played. (Received January 25, 2010)

62 ► Statistics

1057-62-19 **Maria Angelica Cueto** and **Jason R Morton***, Department of Mathematics, McAllister Building, University Park, PA 16802, and **Bernd Sturmfels**. *Geometry of the Restricted Boltzmann Machine.*

The restricted Boltzmann machine is a graphical model for binary random variables. Based on a complete bipartite graph separating hidden and observed variables, it is the binary analog to the factor analysis model. We study this graphical model from the perspectives of algebraic statistics and tropical geometry, starting with the observation that its Zariski closure is a Hadamard power of the first secant variety of the Segre variety of

projective lines. We derive a dimension formula for the tropicalized model, and we use it to show that the restricted Boltzmann machine is identifiable in many cases. Our methods include coding theory and geometry of linear threshold functions. (Received November 20, 2009)

1057-62-115 **Helene M Massam*** (massamh@yorku.ca), Math and Stats Department, York University, 4700 Keele Street, Toronto, Ontario M3J1P3, Canada, and **Gerard G Letac** (gerard.letac@alsatis.net), Laboratoire de Statistiques et Probabilites, 118 Route de Narbonne, Toulouse, 31062. *The geometry of hierarchical discrete loglinear models.* Preliminary report.

Given a contingency table of counts, a standard problem is that of model selection in the class of hierarchical loglinear models. In Bayesian analysis, this is done through the Bayes factor which is the ratio of the posterior probabilities of two models given the data. When the prior distribution on the class of models is chosen to be uniform, this problem is reduced to computing the ratio of normalizing constants for the prior and posterior distributions. As a prior on the loglinear parameters, we use the prior defined by Massam, Liu and Dobra (2009) which comprises two hyperparameters. One of these hyperparameters is the equivalent sample size α which represents the total number of counts of a fictive contingency table. Taking this equivalent sample size as small as possible has the effect of "regularizing" the selected models. Letting α go to 0, we are lead to study the geometry of the convex hull of the support of the multinomial model. The faces of this convex hull are of particular importance. We show that as α tends to 0, the Bayes factor is equivalent to a power of α which depends on the position of the data point with respect to the faces of the convex hulls of the support of each one of the two multinomials hierarchical models. (Received January 15, 2010)

1057-62-120 **Stephen E. Fienberg*** (fienberg@stat.cmu.edu), Department of Statistics, Carnegie Mellon University, Pittsburgh, PA 15213-3890. *Large Sparse Data and Algebraic Statistics: Is There a Connection?*

Many of the most active areas of statistical research involve large sparse data problems where the number of variables and/or parameters is large, especially relative to the number of independent observations. Often standard statistical theory for estimation and results related to asymptotic behavior fail in such settings. The computational tools associated with algebraic statistics are often only useful for low-dimensional problems, e.g., involving a small number of parameters. In this presentation I describe how algebraic statistical and the related computational tools can nonetheless provide important insights of value in large sparse settings. My example come from contingency table settings and an array of problems involving network structures. (Received January 15, 2010)

1057-62-147 **Alexander Schoenhuth*** (alexsch@math.berkeley.edu), Department of Mathematics, University of California at Berkeley, 748 Evans Hall #3840, Berkeley, CA 94720-3840. *How to identify hidden Markov processes—an algebraic statistical answer.*

Identifiability of hidden Markov processes has been a driving question since their introduction to the related communities. Two major questions have evolved from the related discussions. The first one is to decide whether two hidden Markov parameterizations give rise to equivalent processes which has recently been solved to practical satisfaction. The second one is to decide whether a probability distribution stems from a hidden Markov process. The solution so far available defies any computational testing and is of very limited practical use. Here, we combine related results into an algebraic statistical setting, thereby obtaining new theorems. As a result, we can give a comprehensive, algorithmic explanation of how to solve the related decision problem. (Received January 19, 2010)

1057-62-149 **Caroline Uhler*** (cuhler@stat.berkeley.edu), 367 Evans Hall, Berkeley, CA 94720-3860. *Semidefinite matrix completion and Gaussian graphical models.*

The question of existence of ML-estimators in Gaussian graphical models can be rephrased as a positive definite matrix completion problem with additional rank constraints on the specified entries. If the underlying graph is chordal, both problems are well understood. However, for non-chordal graphs the only known results treat the simple cycle. I will extend those results to the bipartite graph $K_{2,m}$ and small grids. If time permits, I will discuss some asymptotic results and the connection to convex algebraic geometry. (Received January 19, 2010)

1057-62-190 **Fabio Rapallo*** (fabio.rapallo@mfn.unipmn.it), Department DISTA, University of Eastern Piedmont, viale Teresa Michel 11, 15121 Alessandria, Italy. *Study of diagonal-effect models as toric and mixture models.*

In this talk we present several types of diagonal-effect models for two-way square contingency tables in the framework of Algebraic Statistics. We use both toric models and mixture models to encode the different behaviour

of the diagonal cells with respect to the independence model. We compute the invariants of these models and we explore their geometrical structure. This class of models has major applications, from social mobility analysis to rater agreement analysis and some results in Algebraic Statistics for this kind of models have already been discussed in previous works.

The main aim of this talk is to discuss the geometric structure of the diagonal-effect models, showing the differences between toric models and mixture models. In particular, we compute the invariants of these models, and we show that the toric and mixture models differ not only on the boundary of the probability simplex but also in its interior, also when the models have the same invariants.

This work is joint with Cristiano Bocci and Enrico Carlini. (Received January 22, 2010)

1057-62-197 **Yanhui Mi*** (ymi@purdue.edu), 3113 Chapelgate way, Apt N, West lafayette, IN 47906. *A stochastic volatility model for Levy process and Bayesian analysis with MCMC method.*

A stochastic volatility model for Black-Scholes and Levy process based on Ornstein-Uhlenbeck process was proposed before. In order to make faster and easier Monte Carlo simulation, we use some process (such as Levy subordinator and infinite divisible process) to modify this model and make more accurate estimation and prediction based on daily and higher frequency stock data. Then we develop Markov chain Monte Carlo (MCMC) and partical filtering algorithms for Bayesian estimation of these models. (Received January 22, 2010)

1057-62-239 **Shaowei Lin*** (shaowei@math.berkeley.edu), University of California, Berkeley, 970 Evans Hall #3840, Berkeley, CA 94720. *Asymptotic Approximation of Marginal Likelihood Integrals.*

The accurate asymptotic evaluation of marginal likelihood integrals is a fundamental problem in Bayesian statistics. Following the approach introduced by Watanabe, we translate this into a problem of computational algebraic geometry, namely, to determine the real log canonical threshold of a polynomial ideal, and we present effective methods for solving this problem. Our results are based on resolution of singularities, and they apply to all statistical models for discrete data that admit a parametrization by real analytic functions. (Received January 24, 2010)

1057-62-241 **Enrico Carlini***, Corso degli Abruzzi 24, 10129, Turin. *Parameterization of mixture of independence models.* Preliminary report.

In this talk we will deal with the problem of parameterizing contingency tables, i.e. probability matrices, for mixture models. In particular we will focus on matrices of rank at most two showing how to produce a parameterization involving the least possible number of parameters, i.e. a non-redundant parameterization. This is a joint work with Fabio Rapallo. (Received January 24, 2010)

1057-62-257 **Hisayuki Hara** (hara@tmi.t.u-tokyo.ac.jp), **Tomonari Sei** (sei@stat.t.u-tokyo.ac.jp) and **Akimichi Takemura*** (takemura@stat.t.u-tokyo.ac.jp), 7-3-1 Hongo Bunkyo-ku, Tokyo, 113-8656, Japan. *Hierarchical subspace models for contingency tables.*

Modeling of the interaction term of log-affine models is an important topic for contingency tables and many models have been considered especially for low dimensional contingency tables.

We introduce the notion of hierarchical subspaces model (HSM) and give a unified treatment of these models as submodels of hierarchical models. This approach provides parsimonious models with smaller degrees of freedom than the usual hierarchical model, while preserving conditional independence structures in the hierarchical model. Then the inference is localized in the same way as the hierarchical model. HSM also provides an extension of the models defined for low dimensional contingency tables to the models for multiway contingency tables.

We also discuss maximum likelihood estimation and exact tests by using Markov bases of the proposed models and illustrate the advantage of the proposed modeling with some data sets. (Received January 24, 2010)

1057-62-264 **Roberto Fontana*** (roberto.fontana@polito.it), Corso Duca degli Abruzzi, 24, I-10129 Torino, Italy, and **Giovanni Pistone** (giovanni.pistone@polito.it), Corso Duca degli Abruzzi, 24, I-10129 Torino, Italy. *Algebraic generation of Orthogonal Fractional Factorial Designs.*

The joint use of counting functions, Hilbert basis and Markov basis allows to define a procedure to generate all the fractional factorial designs that satisfy a given set of constraints in terms of orthogonality (Fontana, Pistone and Rogantin (JSPI,2000), Pistone and Rogantin (JSPI, 2008)). The general case of mixed level designs, without restrictions on the number of levels of each factor (such as power of prime number) is studied. The generation problem is reduced to finding positive integer solutions of a linear system of equations (e.g. Carlini and Pistone (JSTP, 2007)). This new methodology has been experimented on some significant classes of fractional factorial

designs, including mixed level orthogonal arrays and sudoku designs (Fontana and Rogantin in Algebraic and Geometric Methods in Statistics, CUP (2009)). For smaller cases the complete generating set of all the solutions can be computed. For larger cases we resort to the random generation of a sample solution. (Received January 25, 2010)

1057-62-269 **Ali Al-Sharadqah*** (chernov@math.uab.edu), Math Department UAB, Birmingham, AL 35294, and **Nikolai Chernov** (chernov@math.uab.edu), Math Department UAB, Birmingham, AL 35294. *Statistical analysis of EIV regression models.*

We study the maximum likelihood estimate (MLE) for the linear and circular regression in Errors-In-Variables (EIV) model where both coordinates of observed points are uncertain. It is widely known that MLE is the most accurate estimate even though its theoretical moments are infinite!. To demonstrate the optimality and superiority of MLE, higher order error analysis was employed to derive some approximations, which have finite moments. Then numerical experiments were conducted to show that these approximations and the exact MLE are virtually equal when the noise in the data does not exceed its typical values. (Received January 25, 2010)

1057-62-412 **Slavkovic B Aleksandra*** (sesa@stat.psu.edu) and **Karwa Vishesh** (vishesh@psu.edu). *Algebraic statistics framework for causal inference and data privacy with discrete data.* Preliminary report.

We present an algebraic computational framework that handles special cases of latent class analyses. Specifically, we consider discrete data problems with unobserved variables such that arbitrary linear constraints are imposed on the possible realizations of the complete data, and thus on the possible states of the joint distribution of all the variables (observed and unobserved) in the analysis. The constraints are imposed either by the modeling assumptions, the structure of the latent variables or for consistency reasons. We illustrate our methods by applying them to two important related problems. The first problem pertains to the assessment of disclosure risk of releasing potentially sensitive information from a latent class analysis in the form of class membership probabilities and probability distribution of covariates conditional on the classes. The second problem pertains to estimation of average causal effect in presence of unobserved confounders , under the Neyman-Rubin framework of potential outcomes. The code is implemented in R, but interfaces with 4ti2. (Received January 26, 2010)

1057-62-433 **Mathias Drton** (drton@uchicago.edu), 5734 S University Ave, Chicago, IL 60637, and **Han Xiao*** (xiao@galton.uchicago.edu), 5734 S University Ave, Chicago, IL 60637. *Smoothness of Gaussian conditional independence models.*

Conditional independence in a multivariate normal (or Gaussian) distribution is characterized by the vanishing of subdeterminants of the distribution's covariance matrix. Gaussian conditional independence models thus correspond to algebraic subsets of the cone of positive definite matrices. For statistical inference in such models it is important to know whether or not the model contains singularities. We study this issue in models involving up to four random variables. In particular, we give examples of conditional independence relations which, despite being probabilistically representable, yield models that non-trivially decompose into a finite union of several smooth submodels. (Received January 26, 2010)

1057-62-460 **Alessandro Rinaldo*** (arinaldo@stat.cmu.edu), **Stephen E. Feinberg** and **Yi Zhou**. *On the Geometry of Discrete Exponential Families with Application to Exponential Random Graph Models.*

There has been an explosion of interest in statistical models for analyzing network data, and considerable interest in the class of exponential random graph (ERG) models. In this talk I will relate the properties of ERG models to the properties of the broader class of discrete exponential families. I will describe a general geometric result about discrete exponential families with polyhedral support. Specifically, I will show how the statistical properties of these families can be well captured by the normal fan of the convex support. I will discuss the relevance of such results to maximum likelihood estimation and apply them to the analysis of ERG models. By means of a detailed example, I will provide some characterization and a partial explanation of certain pathological features of ERG models known as degeneracy. (Received January 27, 2010)

65 ► Numerical analysis

1057-65-60 **Edwin M Behrens** and **Johnny Guzman***, Brown University, Division of Applied Mathematics, 182 George St, Providence, RI 02912. *A new family of methods for the Reissner-Mindlin plate problem based on a system of first order equations.*

The Reissner-Mindlin plate problem is written as a system of first order equations and all the resulting variables are approximated. A hybrid form of the method is presented which allows one to eliminate all the variables locally and have a final system only involving the Lagrange multipliers which approximate the transverse displacement and rotation at the edges of the triangulation. Optimal estimates independent of the plate thickness are proved for the transverse displacement, rotation and bending moment. A post-processing technique is provided for the displacement variable and we show numerically that it converges faster than the original approximation. (Received December 31, 2009)

1057-65-64 **Noel J Walkington*** (noelw@andrew.cmu.edu), Department of Mathematical Sciences, Forbes Ave, Pittsburgh, PA 15213. *Compactness Properties of Discrete Solutions of Parabolic Equations.*

A classical result of P. Lax states that "a (linear) numerical scheme converges if and only if it is stable and consist". For nonlinear problems this statement needs to augmented to include a compactness hypotheses sufficient to guarantee convergence of the nonlinear terms. This talk will focus on the development of numerical schemes for parabolic equations that are stable and inherit compactness properties of the underlying partial differential equations. For the discontinuous Galerkin time stepping scheme I will present a discrete analog of the classical Lions-Aubin compactness theorem. Examples will be presented to illustrate how this theorem may be used establish convergence of numerical schemes for nonlinear parabolic problems. (Received January 02, 2010)

1057-65-80 **Christopher R Schrock*** (christopher.schrock@wpafb.af.mil), Wright-Patterson AFB, OH 45433, and **Aihua W Wood** (aihua.wood@afit.edu), Wright-Patterson AFB, OH 45433. *Initial Development of Distributional Direct Simulation Monte Carlo (DSMC) Methods.*

The Direct Simulation Monte Carlo (DSMC) method has gained popularity in recent years for treatment of flows in which the assumptions behind the continuum equations of fluid mechanics break down. Such flows are of key importance in rarefied aerodynamics and micro-scale flows. Although the value and necessity of computational kinetic theory has been realized, there are still a number of issues that make DSMC unattractive for practical use. In traditional DSMC methods, simulated particles may possess only a single velocity. As each simulated particle may represent millions of actual particles, this representation leads to a nonphysical representation of the velocity distribution function and limits the method to converge only weakly in L^1. The authors will present our recent developments and preliminary results of new DSMC algorithms that allow each simulated particle's velocity to be distributed and for which numerical evidence suggests strong convergence, as well as a proof of weak convergence. Initial estimates of computational complexity will also be presented. (Received January 08, 2010)

1057-65-91 **Vladimir Druskin** (druskin1@slb.com), 1 Hampshire str, Cambridge, MA 02139, **Leonid Knizhnerman** (lknizhnerman@gmail.com), 38 Narodnogo opolcheniya str, build. 3, Moscow, 123298, Russia, and **Chad Lieberman** (celieber@mit.edu) and **Valeria Simoncini** (valeria@dm.unibo.it), Piazza di Porta S. Donato 5, I-40127 Bologna, Italy, and **Mikhail Zaslavsky*** (mzaslavsky@slb.com), 1 Hampshire str, Cambridge, MA 02139. *Solution of large scale evolutionary problems using rational Krylov subspaces with optimized shifts.*

We consider the computation of $u(t) = \exp(-tA)\varphi$ using Rational Krylov Subspace Reduction for $0 \leq t < \infty$, where $u(t), \varphi \in \mathbf{R}^N$ and $0 < A = A^* \in \mathbf{R}^{N\times N}$. The objective of this work is the optimization of the shifts for the Rational Krylov Subspace. We developed two approaches: with a priori choice of shifts and with adaptive choice. The a priori approach is derived from a classical Zolotaryov problem and proved to yield an asymtotically optimal solution with real shifts for the cases with uniform spectral distributions. The adaptive approach is based on a recursive greedy algorithm for choice of shifts taking into account non-uniformity of the spectrum. This algorithm uses an explicit formula for the residual in the frequency domain allowing adaptive shift optimization at negligible cost. The effectiveness of the developed approaches is demonstrated on examples of the 3D diffusion problem for Maxwell's equation arising in geophysical exploration. For examples with near-uniform spectral distributions both algorithms show the same (optimal) linear convergence rates, but adaptive algorithm becomes superior for

cases with non-uniform spectra. We also consider generalizations of the adaptive approach for the nonsymmetric A. (Received January 12, 2010)

1057-65-92 **Lili Ju*** (ju@math.sc.edu), Department of Mathematics, Unievrsity of South Carolina, Columbia, SC 29208, **Huai Zhang**, Department of Mathematics, Unievrsity of South Carolina, Columbia, SC 29208, **Max Gunzburger**, Department of Scientific Computing, Florida State University, Tallahassee, FL 32306, **Todd Ringler**, Fluid Dynamics Group, Los Alamos National Laboratory, Los Alamos, NM 87545, and **Stephen Price**, Fluid Dynamics and Solid Mechanics Group, Los Alamos National Laboratory, Los Alamos, NM 87545. *A Parallel Solver for Three Dimensional Full-Stokes Ice Sheet Modeling.*

The governing equations for modeling ice sheet evolution include a nonlinear Stokes system for momentum, an energy equation for temperature evolution, and a mass-conservation equation for ice thickness evolution. Desired solvers for the coupled system should be able to handle large-scale realistic data from land and space-based observatories and laboratory experiments and, more important, to take full advantages of the up-to-date high-performance computing power. Our work focuses on the development of an efficient parallel finite element package for 3D full-Stokes ice sheet modeling. Our implementation utilizes the high-quality nonuniform centroidal Voronoi Delaunay triangulation (CVDT) meshing technology and existing popular parallel linear system solvers. Some numerical results will be presented to demonstrate its efficiency and scalability. (Received January 27, 2010)

1057-65-133 **Michele Benzi*** (benzi@mathcs.emory.edu), Department of Mathematics and Comp. Science, Mathematics and Science Center, 400 Dowman Drive, Atlanta, GA 30322, and **Paola Boito**. *Computation of matrix functions arising in the analysis of complex networks.*

Quantitative methods of network analysis naturally lead to large-scale computations for functions of matrices associated with graphs. This talk will describe some of the main quantities of interest in network analysis as introduced by Estrada, Hatano, D. Higham and others. A priori bounds and efficient numerical methods for estimating the quantities of interest will be discussed and illustrated by numerical experiments using small-world, range-free, and Erdös-Rényi graphs. (Received January 18, 2010)

1057-65-146 **Yulong Xing*** (xingy@math.utk.edu), Department of Mathematics, Univeristy of Tennessee, 1534 Cumberland Avenue, knoxville, TN 37996. *Positive preserving high order well balanced discontinuous Galerkin methods for the shallow water equations.*

Shallow water equations with a non-flat bottom topography have been widely used to model flows in rivers and coastal areas. They have steady state solutions in which the flux gradients are nonzero but exactly balanced by the source term. In this presentation we propose a recently developed high order discontinuous Galerkin (DG) method which can preserve the steady state exactly, and at the same time is positivity preserving. A rigorous proof will show that this DG method keeps the water height non-negative, without destroying the mass-conservation. Some numerical tests are performed to verify the positivity, well balanced property, high order accuracy, and good resolution for smooth and discontinuous solutions. (Received January 19, 2010)

1057-65-156 **Jie Shen*** (shen@math.purdue.edu), Mathematics Department, Purdue University, West Lafayette, IN 47907. *Numerical Approximations of Allen-Cahn and Cahn-Hilliard Equations.*

Stability analyses and error estimates are carried out for a number of commonly used numerical schemes for the Allen-Cahn and Cahn-Hilliard equations. It is shown that all the schemes we considered are either unconditionally energy stable, or conditionally energy stable with reasonable stability conditions in the semi-discretized versions. Error estimates for selected schemes with a spectral-Galerkin approximation are also derived. The stability analyses and error estimates are based on a weak formulation thus the results can be easily extended to other spatial discretizations, such as Galerkin finite element methods, which are based on a weak formulation. (Received January 20, 2010)

1057-65-158 **Juping Wang**, **Yanqiu Wang** and **Xiu Ye*** (xxye@ualr.edu), 2801 S. university Ave., University of Arkansas, Little Rock, AR 72204. *A Posterior error estimate for the Stokes equations.* Preliminary report.

We establish a posterior error analysis for solving the Stokes equations by finite element methods. This residual estimator can be applied to almost all the existing finite element methods including conforming, nonconforming and discontinuous finite elements. (Received January 20, 2010)

1057-65-159 **D. C. Sorensen*** (sorensen@rice.edu), Dept. Computational and Applied Math., Rice University, 6100 S. Main, Houston, TX 77030, and **M. Rojas**. *Efficient Numerical Methods for Least-Norm Regularization.* Preliminary report.

The problem

$$\min_{\mathbf{x}} \|\mathbf{x}\|, \quad s.t. \quad \|\mathbf{b} - \mathbf{A}\mathbf{x}\| \leq \epsilon$$

arises in the regularization of discrete forms of ill-posed problems when an estimate of the noise level in the data is available. After deriving necessary and sufficient optimality conditions for this problem, we propose two different classes of algorithms: a factorization-based algorithm for small to medium problems, and matrix-free iterations for the large-scale case. Numerical results illustrating the performance of the methods demonstrate that both classes of algorithms are efficient, robust, and accurate. An interesting feature of our formulation is that there is no situation corresponding to the so-called hard case that occurs in the standard trust-region subproblem. Neither small singular values nor vanishing coefficients present any difficulty to solving the relevant secular equations. (Received January 20, 2010)

1057-65-161 **Qiang Ye*** (qye@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *Computing Eigenvalues of Symmetric Diagonally Dominant Matrices to High Relative Accuracy with Application to Differential Operators.*

For a (row) diagonally dominant matrix, if all of its off-diagonal entries and its diagonally dominant parts (which are defined for each row as the absolute value of the diagonal entry subtracted by the sum of the absolute values of off-diagonal entries in that row) are known accurately, we present an algorithm that computes all the singular values with relative errors in the order of the machine precision. When the matrix is also symmetric with positive diagonals (i.e a symmetric positive semi-definite diagonally dominant matrix), the algorithm computes all eigenvalues to high relative accuracy. Implications to computing eigenvalues of differential operators will be discussed. (Received January 20, 2010)

1057-65-162 **Douglas N Arnold** and **Richard S Falk*** (falk@math.rutgers.edu), Department of Mathematics, Rutgers University, Piscataway, NJ 08854, and **Ragnar Winther**. *Bounded Cochain Projections and Approximation of the Hodge Laplacian.*

We study the numerical discretization by mixed finite element methods of boundary value problems associated to the de Rham complex, and more specifically to the Hodge Laplacian. In concrete terms, this allows us to simultaneously study the approximation of a number of important partial differential equations that can be stated in terms of the operators grad, curl, and div. These include Poisson's equation, the vector Laplacian, Maxwell's equations, and div-curl systems. We show that a stable discretization is achieved if (i) the finite element spaces can be arranged as a subcomplex of the de Rham complex and (ii) there exists a bounded cochain projection from the de Rham complex to the subcomplex. The theory can be extended to other applications in which the de Rham complex is replaced by a more general complex of Hilbert spaces. (Received January 20, 2010)

1057-65-163 **Biswa Nath Datta*** (dattab@math.niu.edu), Department of Mathematics, Northern Illinois University, De Kalb, IL 60115. *Finite Element Model Updating : A Structured Inverse Eigenvalue Problem for Quadratic Matrix Pencil.*

The finite element model updating problem is a special inverse eigenvalue problem for a quadratic matrix pencil and arises in vibration industries in the context of designing automobiles, air and space crafts, and others. The problem is to update a very large theoretical finite element model with more than a million degree of freedom using only a few measured data from a real-life structure. The model has to be updated in such a way that the measured eigenvalues and eigenvectors are incorporated into the model, the symmetry of the original model is preserved and the eigenvalues and eigenvectors that do not participate in updating remain unchanged. When the model has been updated this way, the updated model can be used for future design with confidence. Finite Element Model Updating has also useful applications in health monitoring and damage detection in structures, including bridges, buildings, highways, and others.

In this talk, I shall present a brief overview of the existing techniques and their practical difficulties along with the new developments within the last few years. The talk will conclude with a few words on future research direction on this topic. (Received January 20, 2010)

1057-65-175 **Michael J. Neilan*** (neilan@math.lsu.edu), Center for Computation and Technology, Louisiana State University, Baton Rouge, LA 70803, and **Susanne C. Brenner** (brenner@math.lsu.edu), Center for Computation and Technology, Louisiana State University, Baton Rouge, LA 70803. *A $\mathcal{C}^0$ interior penalty method for a fourth order elliptic singular perturbation problem.*

In this talk, we develop a $\mathcal{C}^0$ interior penalty method for a fourth order singular perturbation elliptic problem in two dimensions on polygonal domains. Using some a posteriori error analysis techniques, we are able to show that the method converges in the energy norm uniformly with respect to the perturbation parameter under minimal regularity assumptions. In addition, we analyze the convergence of the numerical solution to the unperturbed second order problem. Finally, we perform some numerical experiments which back up the theoretical results. (Received January 21, 2010)

1057-65-218 **Vincent J Ervin*** (vjervin@clemson.edu), Dept. Math. Sci., Clemson University, Clemson, SC 29634-0975, and **Lea Jenkins**, **William J Layton** and **Monika Neda**. *Filter based stabilization for evolution equations.*

We consider a filter based stabilization for evolution equations (in general) and for the Navier-Stokes equations (in particular). Typically filter based stabilization, although algorithmically appealing, introduce too much numerical dissipation to achieve a quality approximate solution. We consider a modification: *Evolve one time step, Filter, Deconvolve then Relax* to get the approximation at the new time step. We give a precise analysis of the numerical diffusion and error in this process. Several numerical experiments are given to illustrate the method. (Received January 23, 2010)

1057-65-226 **Peter Monk*** (monk@math.udel.edu), Department of Mathematical Sciences, University of Delaware, Newark, DE 19350, and **Richard Falk**. *Hexahedral H(div) and H(curl) Finite Elements.*

We study the approximation properties of some finite element subspaces of $H(div)$ and $H(curl)$ defined on hexahedral meshes in three dimensions. These finite elements are relevant to numerical methods for porous media flow and Maxwell's equations respectively. The finite element spaces we consider are constructed starting from a given finite dimensional space of vector fields on the reference cube, which is then transformed to a space of vector fields on a hexahedron using the appropriate transform (e.g., the Piola transform) associated to a trilinear isomorphism of the cube onto the hexahedron. After determining what vector fields are needed on the reference element to insure $O(h)$ approximation in $L^2(\Omega)$ and in $H(div)$ and $H(curl)$ on the physical element, we study the properties of the resulting finite element spaces. In particular we show that standard spaces may not give a convergent scheme. We then give an extension of the standard spaces that does guarantee convergence on a regular mapped hexahedral grid. (Received January 23, 2010)

1057-65-251 **Haijun Yu*** (hyu@math.purdue.edu), 3711 Desoto Dr, West Lafayette, IN 47906, and **Jie Shen**. *Fast Spectral Methods for Fokker-Planck Equation of the FENE Model.*

The Fokker-Planck equation of the FENE model is an evolution equation of a probability distribution function(PDF) in a sphere (for 3D case) or a disk (for 2D case) with unbounded drift. We propose several very fast and accurate spectral methods for this equation. All the methods properly handle the drift singularity near the boundary and the mapping singularity at the pole, and conserve the momenta of the PDF. The complexity of those methods is linear for 2D case and is very close to linear for 3D case, and all methods have spectral accuracy. (Received January 24, 2010)

1057-65-252 **Jungong Xue*** (xuej@fudan.edu.cn), School of Mathematical Science, Fudan University, Shanghai, 200433, Peoples Rep of China, and **Qiang Ye**. *Computing Exponentials of Essentially Non-negative Matrices Entrywise to High Relative Accuracy.* Preliminary report.

A real square matrix is said to be essentially non-negative if all of its off-diagonal entries are non-negative. The exponential of an essentially non-negative matrix is determined entrywise to high relative accuracy by its entries. For general essentially nonnegative matrices, a stable method based on Taylor series is presented to compute their exponentials with high entrywise relative accuracy. For symmetric matrices, upper triangular matrices and tridiagonal matrices that are essentially non-negative, it is shown that the polynomial method for exponentials can be implemented to achieve high entrywise relative accuracy. (Received January 24, 2010)

1057-65-266 **Hiroshi Fujiwara*** (fujiwara@acs.i.kyoto-u.ac.jp), Sakyo-ku, Yoshida-Honmachi, Kyoto, 606-8501, Japan. *Numerical Real Inversion of the Laplace Transform by Multiple-Precision Arithmetic.*

We consider real inversion of the Laplace transform. It appears in engineering or physics, and it is ill-posed in the sense of Hadamard. We introduce a new real inversion formula employing Tikhonov regularization on a certain reproducing kernel Hilbert space. We also introduce multiple-precision arithmetic, that enables us to reduce rounding errors and is effective for numerical computation of ill-conditioned problems. We apply multiple-precision arithmetic to the regularized equation and establish reliable real inversion algorithm. (Received January 25, 2010)

1057-65-268 **Steven M Wise*** (swise@math.utk.edu). *Energy Stable FInite Difference Schemes for the Phase Field Crystal (PFC) and Modified Phase Field Crystal (MPFC) Equations.*

The PFC and MPFC equations decribe crystals at the atomic scale in space but on diffusive scales in time. The models account for the periodic structure of a crystal lattice through a free energy functional of Swift-Hohenberg type that is minimized by periodic functions. The models naturally incorporate elastic and plastic deformations, multiple crystal orientations and defects and have been used to simulate a wide variety of microstructures. In this talk I describe energy stable and convergent finite difference schemes and their effcient solution using nonlinear multigrid methods. A key point in the numerical analysis is the convex splitting of the functional energy corresponding to the gradient systems. In more detail, the physical energy in both cases can be decomposed into purely convex and concave parts. The convex part is treated implicitly, and the concave part is updated explicitly in the numerical schemes. I will discuss both first- and second-order accurate convex splitting schemes. The proposed schemes are unconditionally stable in terms of the physical energy and unconditionally solvable, which allows for arbitrarily large time step sizes. This property is vital for coarsening studies that require very long time scales. (Received January 25, 2010)

1057-65-273 **Charbel Farhat**, **Jing Li*** (li@math.kent.edu), **Philip Avery** and **Tezaur Radek**. *A dual-primal FETI method for solving a class of fluid-structure interaction problems in frequency domain.* Preliminary report.

The dual-primal finite element tearing and interconnecting method (FETI-DP) is extended to solving systems of linear equations arising from finite element discretization simulating a class of fluid-structure interaction problems in frequency domain. Time harmonic solutions are sought after for a given frequency. A preconditioned GMRES iteration is used to solve the resulting linear equations of Lagrange multipliers introduced on the subdomain boundaries. The coupling between the fluid and the structure on the fluid-structure wet interface requires appropriate choice of coarse level degrees of freedom in the FETI-DP algorithm to achieve fast convergence. Numerical experiments of solving several three-dimensional fluid-structure interaction problems in the mid-frequency regime demonstrate the satisfactory performance of the proposed algorithm. (Received January 25, 2010)

1057-65-310 **Carl Jagels***, Hanover College, PO Box 890, Hanover, IN 47243, and **Lothar Reichel**. *Rational approximations of matrix functions.*

Matrix function approximation schemes based on the Lanczos method applied to a large, possibly sparse, symmetric matrix, A, are polynomial based methods. An orthonormal basis for the Krylov subspace of smaller dimension is determined, and then a projection onto this subspace is evaluated by a method designed for small problems. Analogous methods based on the extended Krylov subspace $\mathbb{K}^{m,mi+1}(A) = \text{span}\{A^{-m+1}\boldsymbol{v}, \ldots, A^{-1}\boldsymbol{v}, \boldsymbol{v}, A\boldsymbol{v}, \ldots, A^{mi}\boldsymbol{v}\}$, have recently been explored. $m = 1$ yields the standard Lanczos polynomial based method whereas $m \geq 2$ yield rational approximation methods. These methods are discussed and some experimental results for $m = 1, 2, 3, 4$ are presented. (Received January 25, 2010)

1057-65-316 **Chao Yang*** (cyang@lbl.gov), Lawrence Berkeley National Laboratory, MS-50F, 1 Cyclotron Rd, Berkeley, CA 94720. *Solving Nonlinear Eigenvalue Problems in Electronic Structure Calculations.*

One of the fundamental problems in electronic structure calculations is to determine the electron density associated with the minimum total energy of molecules, solids or other types of nanoscale materials. This can, in theory, be done by computing the smallest eigenvalue and the corresponding eigenfunction of a many-body Schrodinger's operator. However, such an approach is computationally infeasible except for systems with only a few electrons. Through the density functional theory formalism, the many-body eigenvalue problem can be reduced to a single particle eigenvalue problem with far fewer degrees of freedom. However, the eigenvalue problem is nonlinear in the sense that the matrix Hamiltonian to be diagonalized is a function of the eigenfunctions

to be computed. In this talk, I will discuss a number of approaches for solving this type of problem and examine their convergence properties. (Received January 25, 2010)

1057-65-321 **Ohannes Karakashian*** (ohannes@math.utk.edu), Mathematics department, University of Tennessee, Knoxville, TN 37996. *A Domain Decomposition Method for a Discontinuous Galerkin formulation for second-order elliptic equations.*

We consider the interior penalty discontinuous Galerkin (IPDG) formulation for second-order elliptic equations. In solving the resulting linear equations we use an additive Schwarz domain decomposition technique. As is well-known, the success of the method depends on the coarse mesh correction of the error. As is common in this context, we define the bilinear form on the coarse mesh to be the restriction of the bilinear form defined on the fine (working) mesh to the coarse subspace. It turns out that this introduces an incompatibility between the penalty terms in the two bilinear forms which is especially problematic when working with locally refined meshes. This incompatibility causes the condition number of the preconditioned matrix to be larger by an amount proportional to the ratio of the fine and coarse meshes.

We show that these difficulties are resolved by using a coarse subspace of H^1 thereby resulting in a hybrid CG-DG method. We present the theory and results of numerical experiments. (Received January 25, 2010)

1057-65-324 **Julianne M Chung*** (jmchung@cs.umd.edu), Computer Science Department, University of Maryland, College Park, MD 20742, and **Dianne O'Leary** and **Glenn Easley**. *An Efficient Multi-channel Approach for Image Deblurring.*

Image deblurring is an important application that arises in a variety of scientific applications ranging from satellite imaging to medical image processing. Given a blurred image that is contaminated with noise, the goal is to reconstruct an approximation of the true image. This is an ill-posed inverse problem, meaning small perturbations in the data may result in large errors in the solution. Filtering techniques such as Tikhonov regularization can be used to filter out hazardous components of the inverse solution and compute stable solutions. However, one of the main computational difficulties in image deblurring is that the blurring matrix is prohibitively large. By incorporating assumptions on the blur structure as well as on the boundary conditions, highly specific matrix structures can be exploited for efficient matrix computations. In this talk, we present a new multi-channel approach for Tikhonov regularization in the context of image deblurring and describe methods for choosing regularization parameters in a multi-channel framework. (Received January 25, 2010)

1057-65-329 **Ren-Cang Li*** (rcli@uta.edu), Department of Mathematics, University of Texas at Arlington, Arlington, TX 76019. *Perturbation of Partitioned Hermitian Generalized Eigenvalue Problem.*

We are concerned with Hermitian positive definite generalized eigenvalue problem $A - \lambda B$ for partitioned

$$A = \begin{pmatrix} A_{11} & \\ & A_{22} \end{pmatrix}, \quad B = \begin{pmatrix} B_{11} & \\ & B_{22} \end{pmatrix},$$

where both A and B are Hermitian and B is positive definite. Bounds on how its eigenvalues varies when A and B are perturbed by Hermitian matrices. These bounds are generally of linear order with respect to the perturbations in the diagonal blocks and of quadratic order with respect to the perturbations in the off-diagonal blocks. The results for the special case of no perturbations in the diagonal blocks can be used to bound the changes of eigenvalues of a Hermitian positive definite generalized eigenvalue problem after its off-diagonal blocks are dropped, a situation occurs frequently in eigenvalue computations.

Stewart and Sun (1990) observed that different copies of a multiple eigenvalue for the generalized eigenvalue problem may behave very differently. Recently, Nakatsukasa (2009) successfully obtained quantitative estimates to explain the behavior. In this talk, we will present different estimates. (Received January 25, 2010)

1057-65-332 **Zhiqiang Cai*** (zcai@math.purdue.edu), Department of Mathematics, 150 N. University Street, West Lafayette, IN 47907, and **Shun Zhang** (zhang@math.purdue.edu), Department of Mathematics, 150 N. University Street, West Lafayette, IN 47907. *Flux Recovery and A Posteriori Error Estimation: Conforming Elements for 2^{nd} Order Elliptic PDEs.*

In this talk, we will introduce two flux recovery procedures for the conforming finite element approximation to general second-order elliptic partial differential equations. One is accurate in a weighted L^2 norm for linear elements, and the other is accurate in a weighted $H(\mathrm{div})$ norm, up to the accuracy of the current finite element approximation.

For the L^2 recovered flux, we introduce an a posteriori error estimator that is more accurate than the explicit residual-based estimator. Based on the $H(\mathrm{div})$ recovered flux, we introduce two *a posteriori* error estimators. One estimator may be regarded as an extension of a recently developed recovery-based estimator to higher-order

conforming elements. The global reliability and the local efficiency bounds for this estimator are established provided that the underlying problem is neither convection nor reaction dominant. The other is proved to be exact locally and globally on any given mesh with no regularity assumptions with respect to a norm depending on the underlying problem. Finally, numerical results on test problems for these estimators will be presented as well. (Received January 25, 2010)

1057-65-342 **Bryan W Lewis*** (bwaynelewis@gmail.com), 3876 Humphrey Rd., Richfield, OH 44286. *How good are Krylov methods for nonsymmetric discrete ill-posed problems?* Preliminary report.

We observe that the Krylov subspaces used by the GMRES and range-restricted GMRES (RRGMRES) methods may contain much better regularized solutions than subspaces generated by the truncated SVD and vice-versa for common discrete ill-posed problems, demonstrating that neither approach is indispensable. The existence of a good solution in the Krylov subspaces, however, is not sufficient for the GMRES or RRGMRES methods to produce a good solution. We propose new computationally-simple solution methods based on least-angle regression that can produce better results than the ordinary least-squares solution method used by GMRES and RRGMRES. (Received January 25, 2010)

1057-65-352 **Younbae Jun*** (yjun@uwa.edu), Department of Mathematics, Station 7, University of West Alabama, Livingston, AL 35470. *An efficient domain decomposition method for three-dimensional parabolic partial differential equations.*

A non-overlapping domain decomposition algorithm to solve three-dimensional parabolic partial differential equations is presented. It has been shown in this paper that the algorithm is unconditionally stable and efficient. Spectral radii for the interface and interior region are provided. Unlike two-dimensional problem, it has been found out that estimating the values of the points of the interface in three-dimensional problem is no longer negligible. (Received January 25, 2010)

1057-65-373 **Kening Wang*** (kening.wang@unf.edu), Department of Mathematics and Statistics, University of North Florida, Jacksonville, FL 32224, and **Shuang Li** (ben.shuangli@gmail.com), Derivative Valuation Center, Ernst & Young LLp, New York, NY 10036. *Strong Superconvergence of Finite Element Methods for Linear Parabolic Problems.*

We study the strong superconvergence of a semi-discrete finite element scheme for linear parabolic problems on $Q = \Omega \times (0, T]$, where Ω is a bounded domain in $\mathcal{R}^d (d \leq 4)$ with piecewise smooth boundary. We establish the global two order superconvergence results for the error between the approximate solution and the Ritz projection of the exact solution of our model problem in $W^{1,p}(\Omega)$ and $L_p(Q)$ with $2 \leq p < \infty$ and the almost two order superconvergence in $W^{1,\infty}(\Omega)$ and $L_\infty(Q)$. Results of the $p = \infty$ case are also included in two space dimensions ($d = 1$ or 2). By applying the interpolated postprocessing technique, similar results are also obtained on the error between the interpolation of the approximate solution and the exact solution. (Received January 26, 2010)

1057-65-392 **Jay Gopalakrishnan*** (jayg@ufl.edu), 358 Little Hall, PO Box 118105, Gainesville, FL 32611-8105, and **Johnny Guzman**, Gainesville. *Two new families of mixed finite elements for elasticity.*

By using a characterization of divergence free tensors with vanishing normal components, using a new matrix bubble, we develop two families of finite elements for elasticity. We consider the mixed Hellinger-Reissner formulation, where symmetry is imposed weakly. Optimal error estimates can be obtained for stress, displacement, and rotation variables in each case. We compare with a few other known elements. Finally we discuss a few surprising cases of special meshes where weak symmetry imply exact symmetry. (Received January 26, 2010)

1057-65-401 **Arthur Neuman*** (aneuman@kent.edu), **Lothar Reichel** and **Hassane Sadok**. *Range Restricted Iterative Methods for Linear Discrete Ill-posed Problems.*

This paper is concerned with iterative solution methods for large linear systems of equations with a matrix of ill-determined rank and an error-contaminated right-hand side. The numerical solution is delicate, because the matrix is very ill-conditioned and may be singular. It is natural to require that the computed iterates live in the range of the matrix when the latter is symmetric, because then the iterates are orthogonal to the null space. Computational experience indicates that it can be beneficial to require that the iterates live in the range of the matrix also when the latter is nonsymmetric. We discuss the design and implementation of iterative methods that determine iterates with this property, and focus on the situation when the error in the right-hand side is small. (Received January 26, 2010)

1057-65-410 **Jeffrey S Ovall***, Patterson Office Tower 761, Department of Mathematics, University of Kentucky, Lexington, KY 40503. *A robust and flexible a posteriori error estimator in 3D.* Preliminary report.

Joint work with Michael Holst and Ryan Szypowski

We propose and offer effectivity analysis of an a posteriori error for tetrahedral linear Lagrange finite elements. The error estimate is based on the (provably inexpensive) computation of an approximate error function in an auxiliary space. We will provide an equivalence (up to oscillation terms) theorem of the true and approximate H^1-error, which applies for piecewise smooth coefficients. A brief cost analysis will also be provided, as such estimators are sometimes believed to be too expensive. Finally, we will discuss a variety of applications of the approximate error function and of the general methodology, such as: functional error estimation, error estimation in other norms, error estimation for eigenvalue problems, and selection of auxiliary spaces in which to compute approximate error functions for different finite elements. Some aspects have been proven, and others are work in progress. (Received January 26, 2010)

1057-65-413 **Nathaniel Mays*** (nate.mays@gmail.com), 1712 Dagmar Ave, Pittsburgh, PA 15216, and **C. Rosano**, **H. Aizenstein**, **L. Marai**, **K. Wong**, **S. L. Yilmaz** and **W. Layton**. *Correlation of brain aging to mobility degradation.* Preliminary report.

With advances in magnetic resonance imaging techniques, it is now possible to provide new insights into the relationship between neurological aging and mobility impairment. This presentation will focus on the preliminary results obtained in correlating brain scan data to mobility data. (Received January 26, 2010)

1057-65-438 **M E Hochstenbach** and **L Reichel*** (reichel@math.kent.edu), Department of Mathematics, Kent State University, Kent, OH 44242, and **F Sgallari** and **Q Ye**. *Iterative methods for Tikhonov regularization.* Preliminary report.

We consider the solution of large-scale linear discrete ill-posed problems with the aid of Tikhonov regularization with a general regularization operator. The choice of iterative method for the solution of the Tikhonov minimization problem and the determination of the regularization parameter by the discrepancy principle is examined. (Received January 26, 2010)

1057-65-440 **Eric de Sturler*** (sturler@vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061-0123, and **Michael L Parks**. *The Convergence of Krylov Methods with Invariant Subspace Recycling.*

In many computational science and engineering problems we have to solve a sequence of large, sparse, linear systems, in which the matrix changes slowly from one system to the next or changes in an algebraically structured way. The right hand side can change more drastically, although in many applications this is not the case. We have developed several methods that significantly improve the convergence of iterative solvers by recycling from one system to the next an approximate invariant subspace. For efficiency and because the system matrix changes continually, we do not expect the approximate invariant subspace to be accurate. Nevertheless, this technique has proved very successful in reducing total iteration counts for a range of applications. In this presentation, we provide a convergence analysis for iterative linear solvers recycling an approximate invariant subspace. An important result of the analysis is that significant improvement of convergence results for very modest accuracy of the invariant subspace approximation. (Received January 26, 2010)

1057-65-451 **Ricardo H. Nochetto*** (rhn@math.umd,edu), Department of Mathematics, University of Maryland, College Park, MD 20742, **Andrea Bonito**, Department of Mathematics, Texas A&M University, College Station, TX , and **M. Sebastian Pauletti**, Department of Mathematics, Texas A&M University, College Station, TX. *Geometrically Consistent Mesh Modification.*

We discuss a new paradigm in adaptivity: how to execute refinement, coarsening, and smoothing of meshes on manifolds with incomplete information about their geometry and yet preserve position and curvature accuracy. (Received January 26, 2010)

68 ► Computer science

1057-68-246 **Ahmed H. Sameh*** (sameh@cs.purdue.edu), Department of Computer Science, Purdue University, 305 N. University Street, WEst Lafayette, IN 47907, and **Murat Manguoglu** and **Faisal Saied**. *A Scalable Parallel Sparse Linear System Solver.*

The SPIKE family of parallel banded linear system solvers have proved to be more scalable than other publicly available banded solvers for a variety of parallel architectures. In this paper, we present a generalization of the SPIKE schemes for handling general sparse linear systems. We show that our resulting parallel hybrid sparse solver is more scalable than current parallel direct solvers, and more robust than approximate LU-factorization-based preconditioned Krylov subspace methods. (Received January 24, 2010)

74 ► Mechanics of deformable solids

1057-74-10 **Kazumi Tanuma*** (tanuma@math.sci.gunma-u.ac.jp), Kiryu, Gunma 376-8515, Japan, and **Chi-Sing Man**, **Gen Nakamura** and **Shengzhang Wang**. *Perturbation and dispersion of Rayleigh waves in prestressed anisotropic elastic media.*

Rayleigh waves are elastic surface waves which propagate along the traction-free surface with the phase velocity v_R in the subsonic range and whose amplitude decays exponentially with depth below that surface. Such waves serve as a useful tool in nondestructive characterization of materials. The problem there is what material information we obtain if we could measure accurately Rayleigh waves propagating in any direction on the traction-free surface.

We first consider Rayleigh waves propagating along the traction-free surface of a homogeneous anisotropic elastic half-space. We present a first order perturbation formula for v_R, which expresses the shift of phase velocity of Rayleigh waves from the value pertaining to a comparative unstressed and isotropic state, caused by the perturbative anisotropic part of the elasticity tensor and by the initial stress.

Secondly we consider Rayleigh waves propagating along the traction-free surface of a vertically inhomogeneous anisotropic elastic half-space. We investigate the dispersion of v_R, i.e., derive a high-frequency asymptotic formula for v_R, which expresses the frequency-dependence of phase velocity of Rayleigh waves caused by the vertical inhomogeneity of the elasticity tensor and the initial stress. (Received September 08, 2009)

1057-74-59 **J. Sivaloganathan** (masjs@bath.ac.uk), Department of Mathematical Sciences, University of Bath, and **S. J. Spector*** (sspector@math.siu.edu), Department of Mathematics, Southern Illinois University. *On the Symmetry of Energy-Minimizing Deformations in Nonlinear Elasticity.*

Consider a homogeneous, isotropic, hyperelastic body that occupies an n-dimensional annulus in its reference state and is subject to radially symmetric displacement boundary conditions on its inner or outer boundary. We show that for a large class of polyconvex stored-energy functions the radial minimizer of this problem is an absolute minimizer of the energy. The key ingredient is a new radial-symmetrization procedure that yields a one-to-one map.

For the pure displacement boundary-value problem, the radial symmetrization of an orientation preserving $\mathbf{u} : A \to A^*$ between annuli A and A^* is the deformation

$$\mathbf{u}_{\mathrm{r}}(\mathbf{x}) = \frac{r(R)}{R}\mathbf{x}, \qquad R = |\mathbf{x}|,$$

that maps each sphere $S_R \subset A$, of radius $R > 0$, centered at the origin into another such sphere $S_r = \mathbf{u}_{\mathrm{r}}(S_R) \subset A^*$ that encloses the same volume as $\mathbf{u}(S_R)$. Since the volumes enclosed by the two surfaces are equal, the isoperimetric inequality yields

$$\mathrm{area}(\mathbf{u}_{\mathrm{r}}(S_R)) \leq \mathrm{area}(\mathbf{u}(S_R)).$$

The equality of the volumes together with this reduction in surface area gives rise to a reduction in total energy for many of the constitutive relations used in elasticity. (Received December 28, 2009)

1057-74-79 **Michel Jabbour*** (jabbour@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506, and **Paolo Cermelli** (paolo.cermelli@unito.it), Department of Mathematics, University of Turin, Via Carlo Alberto, 10, 10123 Torino, Italy. *On the stability of epitaxial growth in the step-flow regime.*

Recent experiments have established that one- and two-dimensional instabilities, bunching and meandering, coexist during step-flow growth, in contrast to the predictions of the standard Burton-Cabrera-Frank model. In this talk, an alternative theory is presented that captures these observations. A main ingredient is the step

chemical potential for which a generalized Gibbs-Thomson relation is variationally derived, resulting in boundary conditions along step edges that couple adjacent terraces. Specialization to the case of a periodic train of steps reveals a competition between the stabilizing Ehrlich-Schwoebel kinetics and a destabilizing energetic correction that, for sufficiently high adatom equilibrium coverage, leads to step collisions. The underlying physics can be understood in terms of the tendency of the crystalline surface to minimize its total grand canonical potential. (Received January 08, 2010)

1057-74-104 **Leigh L. Noble*** (noble@leighnoble.org). *A non-destructive measurement scheme for depth dependent crystallographic texture coefficient functions in cubic metal sheets.*

Through-thickness crystallographic texture differences in rolled sheet metals affects various mechanical behaviors of the sheets. An effective process control mechanism would reduce waste and increase product quality. One technique for quantitative nondestructive evaluation during processing is ultrasound resonance spectroscopy (URS) which measures the resonance spectrum of a sample. In a homogeneous elastic sheet, the resonance spectrum of each wave mode is expected to be a multiple of the fundamental frequency. In practice, however, resonance frequencies are shifted away from the expected multiple. This paper develops a thorough understanding of the mathematical theory explaining how the through-thickness texture gradient gives rise to such shifts and how measuring resonance shifts can be used to recover two texture coefficients as functions of depth. This recovery scheme for two through-thickness texture functions is tested on rolled copper samples. (Received January 25, 2010)

1057-74-125 **Brian Seguin*** (bseguin@andrew.cmu.edu), Dept. of Math Sciences, Wean Hall 6113, Carnegie Mellon University, Pittsburgh, PA 15213. *An Introduction to Frame-Free Continuum Mechanics.*

The Principle of Material Frame-Indifference is a fundamental concept in continuum mechanics. In 1972 Walter Noll showed that one can formulate constitutive laws without using any external frames of reference. Constitutive laws formulated in this way vacuously satisfy the Principle of Material Frame-Indifference. I will motivate and describe the basic concepts involved in this frame-free formulation. I will also describe how other basic concepts in continuum mechanics, such as a continuous body and a deformation, can be formulated without the use of a frame of reference. (Received January 16, 2010)

1057-74-140 **Robert J Ronkese*** (bob.ronkese@usma.edu), Dept of Mathematical Sciences, United States Military Academy, West Point, NY 10996. *An Asymptotic Model of a Nonlinear Adaptive Orthotropic Elastic Rod.* Preliminary report.

Cancellous bone can be viewed as a lattice of asymptotically thin rods and plates. It is assumed that cancellous bone has at least orthotropic symmetries and the planes of orthotropic symmetry coincide with the fabric tensor. van Rietbergen et al. found that errors in the stress-strain calculation when using the orthotropic stiffness matrix instead of the full matrix amounts to a few percent or less. Cowan and Yang used a spectral decomposition method to find the average eigenbasis of stiffness matrices. They found that a set of human cancellous bone specimens had orthotropic symmetry at a 95% confidence level.

Considering the above, a model of the orthotropic elastic rod will be presented. Scalings will transform the stress and strain tensors in the original domain into their scaled counterparts in an enlarged domain. Simplifications will be made in the asymptotic expansions of the tensors and the displacement vector. The results will be used in an ODE governing the rate of bone growth and reabsorption. (Received January 19, 2010)

1057-74-144 **Yi-chao Chen*** (chen@uh.edu), N207 Engineering Building 1, Houston, TX 77204-4006. *Growth Mechanics and Growth of Mechanics.*

Growth mechanics studies mechanical aspects of growth (and resorption) of biological tissues. While the classical theory of mechanics has provided useful tools in such studies, some fundamental concepts of continuum mechanics need to be modified, redefined, or abandoned altogether when growth is studied. We develop a growth theory using consistent kinematical and constitutive equations. The kinematics of a growing body is described by the velocity field and a growth rate field defined on the region occupied by the body at the current time. An equation for the balance of mass is derived. For constitutive equations, we use the current configuration as the reference. The response function of a growing elastic body in the present theory gives the Cauchy stress when the body in the current grown/deformed configuration is subjected to an imaginary further elastic deformation. The form of such a response function changes constantly with growth and deformation even when the intrinsic mechanical properties of the material remain unchanged. The evolution equation for the response function is derived by considering a sequence of growth/deformation processes. An example of using the present theory to analyze the surface growth of a tree trunk is presented. (Received January 19, 2010)

1057-74-194 **Roberto Paroni*** (paroni@uniss.it), Dipartimento di Architettura, Universita' di Sassari, 07041 Alghero, (SS), Italy. *A Variational Justification of Linear Elasticity with Residual Stress.*

The aim of this talk is to give a rigorous justification of the linear theory of elasticity with residual stress. Starting from the finite deformation theory of uniform hyperelastic bodies we show that the finite variational problem Gamma-converges, in the limit of vanishing loads, to the classical variational problem of linear elasticity with residual stress. Our result, in particular, implies that the (quasi) minimizing deformations of the finite variational problem converge, in the appropriate topology, to the unique solution of the linear problem obtained.

The talk is based on joint work with G. Tomassetti. (Received January 22, 2010)

1057-74-231 **Paolo Cermelli**, **Michel E. Jabbour** and **Nicholas O. Kirby*** (nkirby@ms.uky.edu). *Step collisions during nanowire growth: the BCF model and beyond.* Preliminary report.

In this talk I will compare a model of epitaxial growth due to Burton, Cabrera, and Frank and a thermodynamically consistent extension. Both are formulated as free-boundary problems, in which the motion of a step is governed by the adatom density or chemical potential defined on the adjacent terraces. I will consider the quasistatic version of each model applied to two concentric circular steps bounded by a wall to derive qualitative conditions under which step collision occurs. This choice of geometry models crystal growth on a nanowire. Surprisingly, we find that the normal Schwoebel–Ehrlich (nSE) effect is destabilizing for the given geometry and boundary conditions, in contrast to the standard understanding of how the nSE barrier affects the stability of step flow. (Received January 23, 2010)

1057-74-314 **Tim P. Schulze*** (schulze@math.utk.edu), Department of Mathematics, University of Tennessee, 104 Aconda Court · 1534 Cumberland Avenue, Knoxville, TN 37996-0614, and **Peter Smereka**. *Efficient Computational Methods for the Simulation of Heteroepitaxial Growth using Kinetic Monte Carlo.*

Heteroepitaxial growth is a process where one atomic species is deposited upon a substrate of another. If the natural atomic spacing of the two species is different, then elastic effects can become important. In particular the film can lower its elastic energy by forming three dimensional islands. Therefore, layer-by-layer growth can be destabilized by elastic effects. It has been suggested that new materials with interesting electronic properties could be developed by exploiting this instability.

One modeling approach is based on a discrete solid-on-solid model. The elastic effects are incorporated using a ball and spring type model and the system is evolved using kinetic Monte Carlo. This talk introduces several new ideas which allow a very efficient implementation of the method. Results for simulations in both two and three dimensions will be presented. (Received January 25, 2010)

1057-74-320 **Chi-Sing Man*** (mclxyh@ms.uky.edu), Department of Mathematics, University of Kentucky, 715 Patterson Office Tower, Lexington, KY 40506-0027, and **Mojia Huang**, Institute for Advanced Study, Nanchang University, Nanchang, Jiangxi 330031, Peoples Rep of China. *Irreducible Tensor Bases of the Rotation Group and Material Tensors of Weakly-Textured Polycrystalline Materials.*

Polycrystalline materials usually carry crystallographic texture whose effect on mechanical properties often cannot be ignored. When the mechanical property in question is determined by one or by a set of material tensors (e.g., the elasticity tensor, the acoustoelastic tensor, tensors that appear as terms in plastic potentials and yield functions, etc.), the problem reduces to that of determining effects of crystallographic texture on material tensors. In this paper a group-theoretic method is developed by which explicit expressions that delineate the effects of crystallographic texture on material tensors of weakly-textured polycrystalline materials can be derived systematically. A representation theorem is proved which reduces the problem to that of finding irreducible tensor bases of the rotation group. A method by which irreducible tensor bases can be generated for a given tensor space is outlined. Specific instances important for applications in acoustoelasticity and plasticity are presented as examples. (Received January 25, 2010)

1057-74-338 **Anna Vainchtein*** (aav4@pitt.edu), Department of Mathematics, University of Pittsburgh, 301 Thackeray Hall, Pittsburgh, PA 15260. *Effect of nonlinearity on the steady motion of a twinning dislocation.* Preliminary report.

We consider a steady motion of a twinning dislocation in a Frenkel-Kontorova lattice with a double-well substrate potential that has a non-degenerate spinodal region. Semi-analytical traveling wave solutions are constructed for the piecewise quadratic potential, and their stability and further effects of nonlinearity are investigated numerically. We show that the width of the spinodal region and nonlinearity of the potential have a significant effect on the dislocation kinetics, resulting in stable steady motion in some low-velocity intervals and lower

propagation stress. We also conjecture that a stable steady propagation must correspond to an increasing portion of the kinetic relation between the applied stress and dislocation velocity. (Received January 25, 2010)

1057-74-340 **Scott Godefroy*** (scott.godefroy@gmail.com), 5809 Dale Dr., Sykesville, MD 21784. *A Mean for Orientation Imaging Microscopy of Cubic Polycrystals.*

In analyzing an orientation map obtained from a polycrystal, the notion of a mean orientation is complicated by the presence of crystal symmetry. We consider a Riemannian manifold suited to polycrystals of cubic symmetry and obtain a notion of mean orientation in terms of the natural metric for orientations, the so-called disorientation. We will also consider the use of this mean in estimating crystallographic texture from an orientation map. (Received January 25, 2010)

1057-74-394 **Thomas J Pence*** (pence@egr.msu.edu), Department of Mechanical Engineering, 2452 Engineering Building, Michigan State University, East Lansing, MI 48824. *Swelling in highly elastic materials.*

Swelling, sometimes by a large amount, can occur in a variety of soft materials including rubbery polymers, elastomeric gels and biological tissue. The amount of swelling can depend on a variety of factors such as temperature and chemical environment. This talk will focus on the use of large deformation theories for modeling the mechanical effect of material swelling. One type of modeling applies to situations in which the amount of swelling is relatively insensitive to mechanical stress. In this case there is a simple generalization of both the compressible theory of hyperelasticity and the incompressible theory of hyperelasticity. Interesting deformations can then be created by exploiting either spatially inhomogeneous swelling or directionally anisotropic swelling. Boundary value problems for both of these possibilities can be analyzed in some detail. A second type of modeling applies when the amount of swelling is directly coupled to the state of mechanical stress. In this case there is the possibility of stress induced absorption of all of the swelling agent (typically water). The resulting transition saturated response and unsaturated response also gives rise to some interesting mathematical issues. (Received January 26, 2010)

76 ► Fluid mechanics

1057-76-191 **Jeongwhan Choi*** (jchoi@korea.ac.kr), Dept. of Math., Korea University, Seoul, South Korea, and **SungIm Whang**, **Shu-Ming Sun**, **Dal-Soo Lee** and **Sangho Oh**. *Supercritical surface waves generated by a positive forcing - Theory and Experiments.*

Two dimensinal surface waves of an inviscid and incompressible fluid of constant density are studied. A forced KdV equation is derived when the horizontal speed at far upstream is near a critical number. We study the equation theoritically and numerically. Experiments corresponding to some numerical solutions are also carried out. (Received January 22, 2010)

80 ► Classical thermodynamics, heat transfer

1057-80-46 **Amitkumar Dilipbhai Patel*** (p.amitkumar@ashd.svnit.ac.in), Department of Applied Mathematics and Hum., S. V. National Institute of Technology, Ichchhanath, Surat, Gujarat 395007, India, **Jyotirmay Banerjee** (jbaner@med.svnit.ac.in), Department of Mechanical Engineering, S. V. National Institute of Technology, Ichchhanath, Surat, Gujarat 395007, India, and **Ajay K Shukla** (aks@ashd.svnit.ac.in), Department of Applied Mathematics and Hum., S. V. National Institute of Technology, Ichchhanath, Surat, Gujarat 395007, India. *A semi-analytic method for the solution of Radiative transfer equation in absorbing-emitting non-gray medium.*

A semi-analytic methodology is developed for the solution of radiative transfer equation in an absorbing and emitting medium. The absorption cross-section and absorption line black body distribution function is obtained from Spectral line based weighted sum of gray gas model. The radiative transfer equation is soled for each gray gases following and exact approach involving exponential function. The contribution of each gray gases is integrated to obtain the radiative heat flux and divergence of radiative heat flux. The model is validated with the work of Denison, M. K., and B. W. Webb. The medium chosen for solution consist of CO2 and H2O for both Air-Broadening and Self-Broadening. (Received December 17, 2009)

81 ► Quantum theory

1057-81-124 **George A. Hagedorn*** (hagedorn@math.vt.edu), Department of Mathematics, 460 McBryde Hall, Virginia Tech, Blacksburg, VA 24061-0123. *The Born–Oppenheimer Approximation for Diatomic Molecules with Large Angular Momentum.*

Almost everything that is known about molecular quantum mechanics is obtained from the Born–Oppenheimer approximation. The approximation is based on the smallness of the fourth root, ϵ, of the ratio of the electron mass divided by the mean nuclear mass, which is typically 10^{-1}. The standard approximation yields error bounds proportional to ϵ^5 if the vibrational and rotational quantum numbers belong to bounded sets. We describe an extension for diatomic molecules (obtained in work with Sharon Hughes) that has uniform error bounds proportional to ϵ^5 if the angular momentum quantum number is bounded by a constant times $\epsilon^{-3/2}$. In contrast to the standard approximation, one must include non-trivial couplings between the vibrational and rotational motions in this situation.

We compare the results of this approximation with published data for the H_2^+ and HD^+ ions. (Received January 16, 2010)

1057-81-165 **Paul S Aspinwall*** (psa@cgtp.duke.edu), Department of Mathematics, Duke University, Durham, NC 27708-0320. *Decompactifications and Massless D-Branes in Hybrid Models.*

A simple but interesting class of hybrid models with Landau–Ginzburg fibres over CPn are analyzed using special Kahler geometry and a D-brane probes. In some cases the hybrid limit is an infinite distance in moduli space and corresponds to a decompactification. In other cases the hybrid limit is at a finite distance and acquires massless D-branes. An example studied appears to correspond to a novel theory of supergravity with an SU(2) gauge symmetry where the gauge and gravitational couplings are necessarily tied to each other. (Received January 20, 2010)

1057-81-166 **Christian Remling***, Math Department, University of Oklahoma, Norman, OK 73019. *Reflectionless Jacobi matrices.*

Reflectionless Jacobi matrices may be viewed as the fundamental building blocks of general Jacobi operators with some absolutely continuous spectrum. In this talk, I'd like to discuss specific classes of reflectionless operators in more detail. (Received January 20, 2010)

1057-81-235 **Davide Gaiotto*** (dgaiotto@gmail.com), Einstein Drive, Princeton, NJ 08540, and **Gregory W Moore** and **Andrew Neitzke**. *Wall-crossing and Hitchin Systems. Part 1: Motivic Wallcrossing and Line Operators in $N = 2$ Gauge Theory.*

Part 1: We will describe a new physical proof of the wall-crossing formula for BPS states in N=2 supersymmetric field theories, using properties of supersymmetric line operators. This new proof also yields an extension of the wall-crossing formula which keeps track of the spin content of the BPS spectrum. We also introduce and prove a new variant of the wall-crossing formula, for BPS states which live on surface operators. (Received January 24, 2010)

1057-81-287 **Mark S Herman*** (herman@math.rochester.edu), UR Mathematics, University of Rochester, RC Box 270138, Rochester, NY 14627. *A Born-Oppenheimer Expansion Near a Renner-Teller Type Intersection.*

It is known that the usual Born-Oppenheimer approximation can break down near nuclear configurations at which electronic energy levels intersect. This occurs at most of the electronic states at the linear configuration of molecules due to symmetry required degeneracies in the electronic states. Also from symmetry, these intersections are non-generic in the sense that the first derivatives of the energy levels with respect to the bending coordinate vanish at the intersection. This is called the Renner-Teller effect. We discuss the bending modes of a linear triatomic molecule that exhibits the Renner-Teller effect, in a case that admits bound states. Assuming the potentials are smooth, we show that the wave functions and energy levels have asympotic expansions in powers of ϵ, where ϵ^4 is the ratio of the electron mass to the mass of a nucleus. Various properties of the leading order equations and their solutions will be discussed. (Received January 25, 2010)

1057-81-294 **Allan Adams*** (awa@mit.edu), MIT Center For Theoretical Physics, 77 Mass Ave. 6-405, Cambridge, MA 02139. *Orbifolds and Intrinsic Torsion.*

Like Calabi-Yau manifolds, non-Kahler SU(3) manifolds with intrinsic torsion play an important role in the geometry of string theory. Unlike Calabi-Yaus, these manifolds cannot be ricci-flat, with their curvature canceling against their torsion in a quantum-modified Bianchi identity. By following this cancellation into small-radius loci in moduli space with a linear model, it is possible to construct orbifold cft descriptions of these manifolds in

which the role of the intrinsic torsion is played by phases in the orbifold partition function (reminiscent of discrete torsion) which make the orbifold action asymmetric and non-geometric. This talk will review this construction and explain how it can be used to compute the exact massless spectrum of various flux vacua of the heterotic string. (Received January 25, 2010)

1057-81-295 **Eman Hamza** (eman.hamza07@gmail.com), Physics Department, Cairo, Egypt, **Robert Sims*** (rsims@math.arizona.edu), Department of Mathematics, 617 N. Santa Rita Avenue, Tucson, AZ 85721, and **Gunter Stolz** (stolz@math.uab.edu), Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170. *Fractional moments for the one-dimensional continuum Anderson model.*

We give a proof of dynamical localization in the form of exponential decay of spatial correlations in the time evolution for the one-dimensional continuum Anderson model via the fractional moments method. This follows via exponential decay of fractional moments of the Green function, which is shown to hold at arbitrary energy and for any single-site distribution with bounded, compactly supported density. (Received January 25, 2010)

1057-81-353 **Rupert Frank**, **Elliott Lieb**, **Robert Seiringer** and **Lawrence E. Thomas*** (let@virginia.edu), Mathematics Department, Kerchof Hall, University of Virginia, Charlottesville, VA 22904. *Remarks on the ground state energy for the N-particle polaron system.* Preliminary report.

The N-polaron Hamiltonian describes N electrons interacting with a quantized phonon field and with each other via Coulomb repulsion. In their paper *Bounds on the minimal energy of translation invariant N-polaron systems* (to appear in Commun.Math.Phys.), M. Griesemer and J. S. Møller provided upper and lower bounds on the ground state energy for this Hamiltonian. These bounds show a phase transition in the the ground state energy $N \to \infty$ as a function of the relative strengths of the electron-phonon coupling constant and the electron charge: for small repulsion, the ground state energy behaves as $\propto -CN^{7/3}$, whereas for sufficiently strong repulsion the energy is bounded below by $-CN^2$. We review key inequalities employed in their analysis, including a commutator estimate controlling the ultraviolet modes of the phonon field, and present new inequalities for the ground state energy in the restricted situation in which the phonon field is supported on proper subsets of R^3. (Received January 25, 2010)

1057-81-384 **Davide Gaiotto**, **Gregory W Moore** and **Andrew Neitzke*** (neitzke@math.utexas.edu), Department of Mathematics, 1 University Station C1200, Austin, TX 78712-0257. *Wall-crossing and Hitchin systems. Part 2: Dimensional reduction, hyperkahler metrics and Hitchin's equations.* Preliminary report.

(This talk is a continuation of Part 1.) We consider reducing the field theory from 4 to 3 dimensions on S^1. The moduli space of the 3-dimensional theory is a hyperkähler manifold, which in many examples is a moduli space of solutions of Hitchin's equations. The vacuum expectation values of supersymmetric line operators then give holomorphic functions on this moduli space. We explain how these vacuum expectation values can be computed using a variant of the thermodynamic Bethe ansatz, and how this leads to a new description of the hyperkähler metric on the moduli space. Moreover, adding surface operators to the story, we similarly obtain a new description of the solutions of Hitchin's equations themselves. (Received January 26, 2010)

1057-81-416 **Richard G Froese*** (rfroese@math.ubc.ca), Department of Mathematics, University of British Columbia, Vancouver, BC V6T 1Z2, Canada, and **Florina Halasan** and **David Hasler**. *Absolutely continuous spectrum at low disorder for the Anderson model on products of trees with finite graphs.* Preliminary report.

We consider the Anderson model on graphs of the form $T \times G$, where T is a tree and G a suitable finite graph. Such graphs can have loops of unbounded size. We show existence of absolutely continuous spectrum at low disorder. (Received January 26, 2010)

1057-81-463 **Alexander Elgart*** (aelgart@vt.edu), Virginia Tech, Blacksburg, VA 24061. *An Adiabatic Theorem for Resonances*

We prove a robust extension of the quantum adiabatic theorem. The theorem applies to systems that have resonances instead of bound states, and to systems for which just an approximation to a bound state is known. To demonstrate the theorem's usefulness in a concrete situation, we apply it to shape resonances. This is a joint result with G. Hagedorn. (Received February 01, 2010)

82 ► Statistical mechanics, structure of matter

1057-82-157 **David Damanik** (damanik@rice.edu), Department of Mathematics, Rice University, Houston, TX 77005, and **Günter Stolz*** (stolz@uab.edu), Department of Mathematics, CH 452, University of Alabama at Birmingham, Birmingham, AL 35294-1170. *A Continuum Version of the Kunz-Souillard Approach to Localization in One Dimension.*

We consider continuum one-dimensional Schrödinger operators with potentials that are given by a sum of a suitable background potential and an Anderson-type potential whose single-site distribution has a continuous and compactly supported density. We prove exponential decay of the expectation of the finite volume correlators, uniform in any compact energy region, and deduce from this dynamical and spectral localization. The proofs implement a continuum analog of the method Kunz and Souillard developed in 1980 to study discrete one-dimensional Schrödinger operators with potentials of the form background plus random. (Received January 20, 2010)

1057-82-230 **Abel Klein*** (aklein@uci.edu), University of California, Irvine, Department of Mathematics, Irvine, CA 92697-3875. *Poisson Statistics for Eigenvalues of Continuum Random Schrödinger Operators.*

We show absence of energy levels repulsion for the eigenvalues of random Schrödinger operators in the continuum. We prove that, in the localization region at the bottom of the spectrum, the properly rescaled eigenvalues of a continuum Anderson Hamiltonian are distributed as a Poisson point process with intensity measure given by the density of states. We also obtain simplicity of the eigenvalues.

The key ingredient is a proof of Minami's estimate for random Schrödinger operators in the continuum. We will discuss the new local Wegner estimates used in this proof.

This is joint work with J.-M. Combes and F. Germinet. (Received January 23, 2010)

1057-82-313 **Lawrence E. Thomas***, Mathematics Department, Kerchof Hall, University of Virginia, Charlottesville, VA 22904, and **Yao Wang**. *On a nonlinear stochastic wave equation modeling heat flow.* Preliminary report.

We consider a one-dimensional non-linear stochastic wave equation modeling heat flow between thermal reservoirs at different temperatures. We show that the equation with ultraviolet cutoffs has, for each cutoff, a unique invariant measure exhibiting steady-state non-equilibrium heat flow, and we provide estimates on the field covariances with respect to the invariant measures which are uniform in the cutoffs. The analysis requires detailed estimates on the spectrum and eigenfunctions for a Schrödinger operator associated with the wave equation. (Received January 25, 2010)

1057-82-318 **Mihai Stoiciu*** (mstoiciu@williams.edu), Williams College, Department of Mathematics and Statistics, Bronfman Science Center, Williamstown, MA 01267, and **Norbert Peyerimhoff**. *Eigenvalue Distribution of Unitary Operators Associated to Hyperbolic Reflection Groups.* Preliminary report.

The CMV matrices are the unitary analogues of the discrete one-dimensional Schrödinger operators. We study singular continuous measures generated by hyperbolic reflection groups and the spectral properties of the CMV matrices associated to these measures. As the Hausdorff dimension of the support of the singular measures increases from 0 to 1, the distribution of the eigenvalues of the CMV matrices approaches the "clock" (picket fence) distribution. (Received January 25, 2010)

83 ► Relativity and gravitational theory

1057-83-82 **Shamit Kachru*** (skachru@kitp.ucsb.edu), Kavli Institute for Theoretical Physics, University of California, Santa Barbara, CA 93106. *New Horizons in Holography.*

AdS/CFT duality provides a new window into the behavior of strongly coupled quantum field theories. Recent progress has uncovered new avatars of this duality which apply to non-relativistic systems at finite charge density and temperature, and may be reasonable toy models of condensed matter systems. The generic infrared phases of these theories are captured by the attractor mechanism, which governs the near-horizon geometry of charged black branes. One central lesson which is emerging is that behaviors of strongly coupled field theories at finite charge density can be classified by a zoo of new kinds of black brane horizons which carry intricate hair. (Received January 08, 2010)

90 ► Operations research, mathematical programming

1057-90-211 **Nathan Axvig*** (s-naxvig1@math.unl.edu), 203 Avery Hall, 880130, Lincoln, NE 68588-0130. *The Generalized Omura Decoder.*

It is well known that maximum-likelihood decoding on the binary symmetric channel can be reduced to finding a minimum-weight error vector whose syndrome is equal to that of the received vector. As observed by Omura, this task can be viewed as a minimization problem in which the objective function (the weight of the error vector) is computed in the real numbers while the constraints (the parity-check equations) are computed in the binary field. Using the simplex algorithm as a guide, Omura develops an iterative decoding algorithm that attempts to solve this minimization problem. While encouraging simulation results are presented, Omura does not give theoretical results on the performance of this decoder.

We present a generalization of Omura's iterative decoding algorithm that is capable of operating on any binary-input memoryless channel. Further, we show that the probability that the generalized Omura decoder outputs the maximum-likelihood codeword approaches 1 as the number of iterations goes to infinity. (Received January 22, 2010)

91 ► Game theory, economics, social and behavioral sciences

1057-91-31 **Jeremy Sandford*** (jeremy.sandford@uky.edu), Gatton College of Business and Economics, University of Kentucky, Lexington, KY 40507. *Experts and quacks.*

What happens when "type" is endogenous in a reputational setting? Here, customers cannot tell "experts" from imitative "quacks", but gain information through repeated interaction. Firm incentives to invest in expertise vary non-monotonically in how tolerant customers are of bad outcomes; more tolerant customers are both more forgiving, making expertise less necessary, and longer-tenured, increasing the value of retaining them. In equilibrium, the proportion of expert firms is bounded away from one; some quacks are necessary to keep incentives of experts in line. The fraction of experts is decreasing in customers' switching costs and the relative cost of expertise over quackery. (Received December 08, 2009)

1057-91-173 **David E Wildasin*** (dew@davidwildasin.us), Martin School of Public Policy, University of Kentucky, Lexington, KY 40506-0027. *Fiscal Competition for Imperfectly-Mobile Labor and Capital: A Comparative Dynamic Analysis.*

Interjurisdictional flows of imperfectly-mobile migrants, investment, and other productive resources result in the costly dynamic adjustment of resource stocks. This paper investigates the comparative dynamics of adjustment to changes in local fiscal policy with two imperfectly mobile productive resources. The intertemporal adjustments for both resources depend on complementarity/substitutability in production and the adjustment cost technologies for each, implying that the evaluation of the fiscal treatment of one resource must account for the simultaneous adjustment of both. (Received January 21, 2010)

1057-91-176 **Adib Bagh*** (abagh@ucdavis.edu), Gatton school of business, Lexington, KY 40502. *Existence of Nash Equilibrium in Open-Loop Dynamic Games.*

We establish the existence of Nash equilibrium in a large class of open-loop dynamic games. We illustrate why Standard fixed point arguments usually fail for such game. We then show that such games are better reply secure, and therefore by a theorem by P. Reny, have a Nash equilibrium. (Received January 21, 2010)

1057-91-195 **Adib Bagh** and **Francesco Ruscitti*** (ruscitti@yu.edu), Yeshiva University, Wilf Campus, 2495 Amsterdam Avenue, BH suite 501, New York, NY 10033, and **Galeazzo Impicciatore**. *An Open Graph Theorem for Correspondences with Applications.* Preliminary report.

We prove an open graph theorem for correspondences mapping an arbitrary metric space into an euclidean space. That is, let S be a set-valued map from an arbitrary metric space into R^n. Assume that S has convex and open upper sections. Then S is lower hemicontinuous if and only if the graph of S is open. We construct a counterexample that shows that our theorem does not hold when the range space is a separable Hilbert space equipped with the weak topology. We work out a few applications of our open graph theorem in order to illustrate its usefulness. The main example deals with Economics: we prove the existence of a continuous uitlity-like function for non-transitive preferences. It is a generalization of a theorem due to Shafer (1974). The second and third examples concern lower hemicontinuous set-valued maps. In the second example we show the

existence of fixed points assuming neither compactness nor convexity of the domain. The third one shows that continuity of a set-valued map with open and convex upper sections is very restrictive. (Received January 22, 2010)

1057-91-291 **Jungmin Choi*** (choi@math.fsu.edu), 208 Love Building, Academic Way, Tallahassee, FL 32306, and **Max Gunzburger**. *Approximation and Application of the Musiela Stochastic PDE in Forward Rate Models.*

We consider Musiela equation of the forward rates, which is a hyperbolic stochastic differential equation. A weak formulation of the problem using the SUPG (Streamline Upwind Petrov Galerkin) method is analyzed. Error analysis of the method yields estimates for the convergence rates. Computational examples are provided that illustrate not only the discretization methods used, but the type of results relevant to bond pricing that can be obtained from the equation. (Received January 25, 2010)

92 ► Biology and other natural sciences

1057-92-96 **Elizabeth Allman**, **Sonja Petrovic**, **John Rhodes** and **Seth Sullivant***, Department of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695. *Identifiability of Phylogenetic Mixture Models.*

Phylogenetic data arising on two possibly different tree topologies might be mixed through several biological mechanisms, including incomplete lineage sorting or horizontal gene transfer in the case of different topologies, or simply different substitution processes on characters in the case of the same topology. Recent work on a 2-state symmetric model of character change showed such a mixture model has non-identifiable parameters, and thus it is theoretically impossible to determine the two tree topologies from any amount of data under such circumstances. Here the question of identifiability is investigated for 2-tree mixtures of the 4-state group-based models, which are more relevant to DNA sequence data. Using algebraic techniques, we show that the tree parameters are identifiable for the JC and K2P models. We also prove that generic substitution parameters for the JC mixture models are identifiable, and for the K2P and K3P models obtain generic identifiability results for mixtures on the same tree. This indicates that the full phylogenetic signal remains in such mixtures, and that the 2-state symmetric result is thus a misleading guide to the behavior of other models. (Received January 13, 2010)

1057-92-130 **Steven N. Evans**, **Valerie Hower*** (vhower@math.berkeley.edu) and **Lior Pachter**. *Using sequence coverage statistics to determine protein binding sites in a genome.*

Inspired by the notion of persistence in topological data analysis, we introduce a tree depicting sequence coverage via fragment placement on a genome. We then describe statistically the trees that correspond to random fragment placement and use this theory to determine the binding sites for a given protein in a genome. Our method for calling statistically significant protein binding sites reduces to the study of certain tree-based statistics derived from the data. (Received January 18, 2010)

1057-92-323 **David Haws*** (dchaws@gmail.com), UNIVERSITY OF KENTUCKY, Department of Statistics, 817 PATTERSON OFFICE TOWER, Lexington, KY 40506-0027, and **Eric M O'Neill**, **Peter Huggins**, **David Weisrock** and **Ruriko Yoshida**. *Identifying Outlier Gene Trees: Gene Tree Distributions and Support Vector Machinery.*

The increased use of multi-locus data sets for species tree reconstruction has strengthened the need to identify particular loci with gene tree patterns that deviate from those generated under neutral processes. Gene trees reconstructed from neutral unlinked loci are expected to be correlated with one another through evolution within a single shared species tree history. Identifying outlier gene trees that significantly deviate from the general genome-wide distribution is, therefore, important in meeting assumptions of species tree reconstruction, and in the identification of genes with unique evolutionary properties. One approach for identifying outlier genes is to statistically test for deviations from an overall distribution of neutrally-evolving gene trees. Here, we propose a methodology for using support vector machine (SVM) as a statistical tool for testing for differences between distributions of gene trees sampled from different underlying histories, applying either the dissimilarity or path-difference map to vectorize trees. We first apply our GeneOut algorithm to two known distributions of coalescent trees each simulated within two different specie tree histories. We then apply our algorithm to the analysis of gene trees reconstructed from simulated DNA sequence data. (Received January 25, 2010)

93 ► Systems theory; control

1057-93-443 **Christopher Beattie*** (beattie@vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061. *Optimal Interpolatory Model Reduction of Parameterized and Stochastic Systems.*

We develop interpolatory model reduction methods for parameterized linear dynamical systems allowing the parametric dependence of the original system to be reproduced in the reduced order model. Interpolation is guaranteed both respect to selected complex frequencies and selected parameter value choices. We describe optimal parameter selection strategies that will produce $\mathcal{H}_2$-optimal reduced order systems that also minimize a least squares error measure over the parameter range and discuss consequences for stochastic models. (Received January 26, 2010)

94 ► Information and communication, circuits

1057-94-8 **Jay A. Wood*** (jay.wood@wmich.edu), Department of Mathematics, Western Michigan University, 1903 W. Michigan Ave., Kalamazoo, MI 49008-5248. *Ring Involutions and Self-Dual Codes.*

Expanding on work of Nebe, Rains, and Sloane, I will discuss the role of ring involutions in the study of self-dual codes over non-commutative rings. (Received August 20, 2009)

1057-94-52 **Yoonjin Lee*** (yoonjinl@ewha.ac.kr), Department of Mathematics, Ewha Womans University, 11-1 Daehyun-Dong, Seodaemun-Gu, Seoul, 120-750, South Korea. *Construction of MDS self-dual codes and quasi-cyclic self-dual codes.*

We present our development on an efficient construction method (so called *building-up construction*) of MDS self-dual codes and quasi-cyclic self-dual codes. Using this method we produce many new MDS or near MDS self-dual codes over various finite fields or finite chain rings. We also find many quasi-cyclic self-dual codes over finite fields via this construction. In fact, every self-dual code over a finite field can be obtained by this method. (Received December 23, 2009)

1057-94-100 **Finley Freibert***, 328 Natural Science Building, University of Louisville, Louisville, KY 40292, and **Jon-Lark Kim**, 328 Natural Science Building, University of Louisville, Louisville, KY 40292. *Codes in Random Network Coding.* Preliminary report.

Yeung & Zhang introduced the concept of network coding theory in 1999. Since then, network coding theory has become very popular because of its wide applications. Koetter & Kschischang in 2008 considered a random network coding and introduced the Hamming bound, the G-V bound, and the Singleton bound for codes in the finite-field Grassmannian. In this talk, we overview recent developments of these codes. (Received January 13, 2010)

1057-94-141 **Xiong Tingyao*** (xiongtin@msu.edu), A519 WH, Michigan State University, East lansing, MI 48824, and **Hall I. Jonathan** (jhall@math.msu.edu), D219 WH, Michigan State University, East Lansing, MI 48824. *Construction of Binary Sequences of Large Even Length with High Merit Factor* 6.0. Preliminary report.

The known families of binary sequences having asymptotic merit factor ≥ 6 are modifications to the families of Legendre sequences, Jacobi, or modified Jacobi sequences. In this paper, we show that at length $N = p_1 p_2 \dots p_r$, where p_i's are distinct odd primes, we can construct a binary sequence of length $2N$ so that such families of sequences have asymptotic merit factor 6.0 without cyclic shifting on the base sequences. *Keywords*: aperiodic correlation, merit factor, real primitive characters (Received January 19, 2010)

1057-94-181 **W. Cary Huffman*** (whuffma@luc.edu), Department of Mathematics and Statistics, Loyola University Chicago, 1032 W. Sheridan Rd., Chicago, IL 60660. *Cyclic $\mathbb{F}_q$-Linear $\mathbb{F}_{q^t}$-Codes.*

Additive codes over $\mathbb{F}_4$ are intimately related to quantum codes. We consider a natural generalization of additive codes to $\mathbb{F}_q$-linear $\mathbb{F}_{q^t}$-codes. We develop the theory of these codes when they are cyclic and count them. Then we place two different trace inner products on these codes and decide precisely when the cyclic ones are self-orthogonal under these two inner products. We also present counts for the number of self-orthogonal and self-dual cyclic codes under each of these inner products. (Received January 21, 2010)

1057-94-219 **Wittawat Kositwattanarerk*** (wkositw@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634-0975, and **Gretchen L. Matthews** (gmatthe@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634-0975. *Pseudocodewords and Tanner graph representation.*

The performance of message-passing iterative decoding and linear programming (LP) decoding depends on the Tanner graph representation of the code. If the underlying graph contains cycles, then the algorithm could produce a non-codeword output called a pseudocodeword. We study the structure of pseudocodewords and present a sufficient condition for a code from a certain class to be pseudocodeword-free even if its Tanner graph contains a cycle. (Received January 26, 2010)

1057-94-277 **Sergio R López-Permouth*** (lopez@math.ohiou.edu), 321 Morton Hall, Department of Mathematics, Athens, OH 45701, and **Steve Szabo** (szabo@math.ohiou.edu), 321 Morton Hall, Ohio University, Athens, OH 45701. *Convolutional Codes with Additional Structure.* Preliminary report.

The notion of cyclic convolutional codes as studied in various papers by Gluessing-Luersen et al is extended to describe a larger family of codes which is large enough to include, among others, the group convolutional codes studied by Estrada et al. The ingredients to create such codes are a semisimple artinian algebra A (the word ambient), an automorphism σ on A, and a σ-derivation δ on A. One of the contributions of this study is precisely the introduction of δ as an element to consider in this construction.

In general, the convolutional codes we study here are certain left ideals of the general skew polynomial ring $R = A[z; \sigma, \delta]$. Conditions on σ and δ for the existence of non-block convolutional codes are given. It is shown that when the word ambient A is commutative the induced convolutional codes are principal left ideals of R. Various techniques from the theory of cyclic convolutional codes are expanded to this new setting and used to provide a matrix based view of group convolutional codes.

Our presentation will focus on showing how this approach allows us to extend previous results on cyclic convolutional codes to explicitly produce duals for some group convolutional codes. (Received January 25, 2010)

1057-94-279 **Xiaoyu Liu*** (xiaoyu.liu@wright.edu), 3640 Colonel Glenn HWY, Dayton, OH 45435. *A Ward type bound on divisible codes over finite abelian groups.*

Divisible codes were first introduced by Ward as linear codes over finite fields whose codewords all have weights divisible by a non-trivial common divisor. The concept of divisibility can be naturally generalized to codes over any algebraic alphabets. In his earlier work, Ward proved an upper bound on dimension of linear divisible codes over finite fields in terms of the weight spectrum of the code. The bound was a starting point to prove the Gleason-Pierce-Ward theorem for linear codes over finite fields. In this paper, we prove an analogous upper bound on dimension of additive divisible codes over finite abelian groups, using the fact that Ward's bound is equivalent to a set of congruences having integer solutions. This bound, as expected, helps to generalize the Gleason-Pierce-Ward theorem for linear or additive codes over various algebraic alphabets other than finite fields. (Received January 25, 2010)

1057-94-312 **Vladimir D Tonchev*** (tonchev@mtu.edu), 1400 Townsend Drive, Michigan Technological University, Mathematical Sciences, Houghton, MI 49931. *Geometric designs and Hamada's conjecture.*

The coding-theoretical interest in combinatorial designs defined by subspaces of a finite geometry was motivated in the 1960's by their use for the construction of majority-logic decodable codes. In 1973, Noboru Hamada computed the ranks of the incidence matrices of finite geometry designs over the underlying finite field and made the conjecture that any geometric design is characterized by its minimum rank. In all proven cases of the conjecture, the geometric designs not only have minimum rank, but are also the unique designs of minimum rank. Until recently, only a handful of non-geometric designs were known that share the same rank with geometric designs. This talk discusses the recent discovery of some infinite families of non-geometric designs that have the same parameters and the same rank as certain geometric designs. (Received January 25, 2010)

1057-94-381 **Ricardo Alfaro*** (ralfaro@umflint.edu), Mathematics Department, University of Michigan-Flint, Flint, MI 48502. *On Distances and Self-Dual Codes over $\mathbb{F}_q[u]/(u^t)$.*

General metrics for linear codes over the ring $\mathbb{F}_q[u]/(u^t)$ are defined, generalize some Gray maps, Lee weight, and Bachoc weight; and new bounds on distances are given. Two characterizations of self-dual codes over $\mathbb{F}_q[u]/(u^t)$ are determined in terms of linear codes over $\mathbb{F}_q$. An algorithm to produce such self-dual codes is also established. (Received January 26, 2010)

1057-94-403 **Christine A. Kelley*** (ckelley2@math.unl.edu), Department of Mathematics, 203 Avery Hall, Lincoln, NE 68506. *Distance bounds for generalized LDPC codes using graph connectivity.*

Generalized LDPC codes form the basis of several important code constructions including expander codes and asymptotically good codes. In this talk, we present lower bounds on distance parameters for two classes of generalized LDPC codes. These bounds rely on the connectivity of the underlying Tanner graph and are extensions of Tanner's bit and parity-oriented bounds to the generalized LDPC code case. These bounds complement existing distance bounds that require additional knowledge of the expansion properties of the graph. (Received January 26, 2010)

1057-94-437 **Hai Q Dinh*** (hdinh@kent.edu), Department of Mathematical Sciences, Kent State University, 4314 Mahoning Avenue, Warren, OH 44483. *Repeated-Root Constacyclic Codes Of Prime Power Length Over $\mathbb{F}_{p^m} + u\mathbb{F}_{p^m}$.*

All constacyclic codes of length p^s over the ring $\mathcal{R} = \mathbb{F}_{p^m} + u\mathbb{F}_{p^m}$ are investigated. The units of the ring $\mathcal{R}$ are of the forms γ, and $\alpha + u\beta$, where α, β, γ are nonzero elements of $\mathbb{F}_{p^m}$, which provide $p^m(p^m - 1)$ such constacyclic codes. First, the structure and Hamming distances of all constacyclic codes of length p^s over the finite field $\mathbb{F}_{p^m}$ are obtained, and used as a tool to establish the structure and Hamming distances of all $(\alpha + u\beta)$-constacyclic codes of length p^s over $\mathcal{R}$. We then classify all cyclic codes of length p^s over $\mathcal{R}$, and obtain the number of codewords in each of those cyclic codes. Finally, an one-to-one correspondence between cyclic and γ-constacyclic codes of length p^s over $\mathcal{R}$ is constructed via a ring isomorphism, that carries over the results about cyclic codes correspondingly to γ-constacyclic codes of length p^s over $\mathcal{R}$. (Received January 26, 2010)

97 ► Mathematics education

1057-97-14 **David M Bressoud*** (bressoud@macalester.edu), 1600 Grand Ave., Saint Paul, MN 55105. *The MAA and Outreach to Teachers.* Preliminary report.

This will be an overview of the issues of the transition from high school to college mathematics that are of high importance to the MAA and of the programs that the MAA is sponsoring or associated with that work with K-12 teachers. (Received November 02, 2009)

1057-97-15 **James R. Valles Jr.*** (james.valles@ttu.edu), TTU Mathematics, Math Bldg., Room 201, Box 41042, Lubbock, TX 79409-1042. *Effects and Outcomes of Participation in an NSF GK-12 Project.* Preliminary report.

The Building Bridges program is an NSF-funded project at Texas Tech University that seeks to develop the experience and communication skills of doctoral-level Science, Technology, Engineering, and Mathematics (STEM) graduate students with fellow STEM researchers in other disciplines and with in-service secondary mathematics and science teachers. This talk will focus on my participation, as a mathematics graduate student, within the program. The expectations and experiences gained by participation in the Building Bridges program will be explored though the discussion of classroom lessons I created and implemented in math and chemistry classes. Reactions to the lessons from the students, teachers, and myself will explore the benefits gained through participation in Building Bridges. (Received November 02, 2009)

1057-97-23 **Richard Millman*** (richard.millman@ceismc.gatech.edu), 760 Spring St, CEISMC, Georgia Institute of Technology, Atlanta, GA 30332. *Discussing Mathematics Outreach as Working with a Variety of Stakeholders on Math Content.*

What can be considered "math outreach"? As a first definition, it consists of mathematicians working on the application of math content knowledge to projects with a variety of constituencies. These include collaboration with K-12 students, practicing and future teachers, parents, school and state administrators, colleagues at colleges and universities, and are motivated by Hyman Bass's view that the collaboration ".... can be productively pursued in the spirit of "applied mathematics" by first deeply understanding the domain of application." A major point is the need for the statewide core content to play a central role in the collaboration. An example will be in estimation (or modeling) for fourth graders and the use of that material for future teachers. A second outreach point is to involve parents in their children's mathematical education as a reality check about mathematics. A third is for mathematicians to integrate mathematics into STEM projects. In that context, SLIDER, an NSF supported project at Georgia Tech (GT) which is dedicated to physics of 8th grade, will be described. In addition, GT's Calculus II and III project for high school students and its role in new quality, content mathematics courses for all high school seniors will be presented. (Received November 29, 2009)

1057-97-61 **Loren D Pitt*** (ldp@virginia.edu), Department of Mathematics, University of Virginia, Kerchof Hall, Charlottesville, VA 22903. *The Virginia Statewide Collaborative Mathematics Specialist Outreach Project.* Preliminary report.

Since 2003 a partnership of colleges and universities in Virginia has collaborated with school divisions across the state to develop and offer a statewide masters program for elementary and middle school leading to the Virginia K-8 Mathematics Specialist endorsement. The program was designed to prepare specialists who could support mathematics instruction in the schools by offering mathematical and curricular support to the teachers in the schools. The program was developed collaboratively by university mathematics and mathematics education faculty, classroom teachers, and school division mathematics administrators. To date nearly 200 teachers have completed the program. The impact of these specialists has been researched in a large scale NSF teacher Professional Continuum study Mathematics Specialists in K-5 Schools: Research and Policy Pilot Study and a highly significant beneficial impact has been observed on student achievement scores. In this report attention will be given both to the mathematics specialist's job and to the mathematical requirements of that job. (Received January 01, 2010)

1057-97-66 **Michael Mays*** (mays@math.wvu.edu), Institute for Math Learning, WVU Department of Mathematics, Morgantown, WV 26506-6310. *The ACCLAIM Capstone Mathematics Course.*

One of the primary goals of the NSF-CLT project ACCLAIM (The Appalachian Collaborative Center for Learning, Assessment, and Instruction in Mathematics) has been to build mathematics capacity and expertise in rural areas through advanced degree programs in mathematics. The cooperative doctoral degree program in mathematics education has been made available to three cohorts of students, with a mix of coursework in mathematics and mathematics education offered in summer residential programs and via distance education, leading to a doctoral dissertation at one of five cooperating universities. The course "Elementary Mathematics from an Advanced Standpoint" was designed as a capstone course to build on previous courses in Advanced Calculus, Geometry, Linear Algebra, Discrete Mathematics, Advanced Algebra, and History of Math. For the third cohort it was offered in the first summer of residency, as a "springboard."

We discuss the course in the context of ACCLAIM's outreach mission, and demonstrate some of the course activities developed to coordinate with the text, Mathematics for High School Teachers, An Advanced Perspective, by Usiskin et.al. (Received January 03, 2010)

1057-97-196 **Bill Haver*** (whaver@vcu.edu), Department of Mathematics, Box 2014, Virginia Commonwealth University, Richmond, VA 23284. *Collaboration in K-12 Mathematics.* Preliminary report.

The report includes some observations of a mathematician working with K-12 teachers: advantages of starting with calculus and moving down the K-12 curriculum; addition of K-12 teachers to the mix helps mathematicians and mathematics educators work together; collaboration is essential, fun and trying. Report concludes with description of a collaboratively developed masters level program to prepare elementary school teachers to serve as mathematics specialists and coaches of other teachers. Treatment/control research has shown that the use of coaches results in significant improvement in student learning. (Received January 22, 2010)

1057-97-214 **Walter J. Whiteley*** (whiteley@mathstat.yorku.ca), Mathematics and Statistics, York University, 4700 Keele Street, Toronto, Ontario M3J 1P3, Canada. *At what cost: Career recognition for Contributions to Outreach.*

In math departments, students who plan to be teachers of mathematics make a large group among our majors. This is an incentive to offer courses and support for these groups in coordination with the Faculty of Education. There is a growing consensus of what types of courses should be offered within mathematics departments, for future teachers of mathematics.

Who will take the leadership, including modifying our pedagogy to offer these courses? Will such contributions receive sufficient credit in the career path of faculty members? Would making these contributions their priority, including spending a sabbatical on scholarship of teaching, block their chance of promotion to full professor, if they are already tenured? Would it block their chance of tenure, if they are not yet tenured? Will the department place hiring such a person as a top priority for the limited positions which are available and if, by chance they do, will they offer support and a tenure process which supports the career development of such a person.

I will address these question, drawing on conversations with people at a number of universities, including my own experience developing such collaborations. Relevant resources can be found at: *http : //wiki.math.yorku.ca/index.php/Math_to_Math_Ed* (Received January 22, 2010)

1057-97-404 **Matthew S. Benander**, **Casey Gregory Monday**, **Josh Roberts** and **Daniel J. Wells*** (dwells@ms.uky.edu), Department of Mathematics, University of Mathmatics, Lexington, KY 40506. *Algebra Cubed - An NSF Graduate K-12 Project.* Preliminary report.

Algebra Cubed was a three year educational outreach Graduate K-12 project of the University of Kentucky, sponsored by the National Science Foundation. The project was designed for many purposes including increasing the mathematical conceptual understanding and procedural fluency of Middle and High school students in Bath and Powell counties, developing and utilizing lessons for algebra that stress the use and applications of algebra in the context of the Kentucky Core Content. The "cubes" (fellows) from the STEM disciplines will discuss lessons created and interactions that aided in achieving these expected outcomes as well as some unexpected outcomes. (Received January 26, 2010)

03 ► Mathematical logic and foundations

1058-03-22 **Dmitry Bredikhin*** (bredikhin@mail.ru), Lermontova 7-22, Saratov, AS 410002, Russia.
On algebras of relations with operations of cylindrification. Preliminary report.

Let $Q\{\Omega, \subset\}$ be the quasivariety generated by partial ordered algebras of binary relations whose operations are members of Ω. We shall consider the operations of relation product $\circ$ and two unary operations of cylindrification ∇_1, ∇_2 [1].

Theorem. An partial ordered algebra $(A, \cdot, {}^*, {}^\bullet, \leq)$ of the type $(2, 1, 1)$ belongs to the quasivariety $Q\{\circ, \nabla_1, \nabla_2, \subset\}$ if and only if it satisfies the identities:

$(xy)z = x(yz)$, $(x^\star)^\bullet = (x^\bullet)^\star$, $x^\star y = xy^\bullet$, $(x^\star)^\star = x^\star$, $(x^\star)^2 = x^\star$, $(xy)^\star = xy^\star$, $xy^\star x^\star = xy^\star$, $x^\star y^\star z^\star = x^\star z^\star y^\star$, $x^\star y^\star zy = x^\star zy$, $(x^\bullet)^\bullet = x^\bullet$, $(x^\bullet)^2 = x^\bullet$, $(xy)^\bullet = x^\bullet y$, $x^\bullet y^\bullet x = y^\bullet x$, $x^\bullet y^\bullet z^\bullet = y^\bullet x^\bullet z^\bullet$, $xyx^\bullet z^\bullet = xyz^\bullet$, $x \leq x^\star$, $x \leq x^\star x$, $x^\star y \leq x$, $x \leq x^\bullet$, $x \leq xx^\bullet$, $xy^\bullet \leq y$.

[1] L. Henkin, J. D. Monk, A. Tarski. Cylindric algeras I, II. North-Holland, Amsterdam, 1971, 1985. (Received December 01, 2009)

05 ► Combinatorics

1058-05-33 **Brian Hopkins*** (bhopkins@spc.edu). *Sand Piles and Related Partition Dynamics.*

The Sand Pile Model is perhaps the smallest operation on partitions: in terms of the Ferrers diagram, a single dot moves from one part to the next if the result is still non-increasing. E.g., (4,1) maps to (3,2). It was introduced in the computer science literature in 1993, inspired by "self-organized criticality" in physics. In this talk, I will review what is known about fixed points under the operation, number of components in the state diagram, and present new results on "Garden of Eden" states with no predecessor. These classes of partitions will also be considered under a family of related operations, known as the Ice Pile Model and θ maps. (Received December 22, 2009)

1058-05-36 **Iain Gordon** and **Stephen Griffeth*** (S.Griffeth@ed.ac.uk), Edinburgh, Scotland.
Catalan numbers and diagonal coinvariant rings for complex reflection groups.

For real reflection groups, work of Berest-Etingof-Ginzburg and Gordon connects the representation theory of rational Cherednik algebras to diagonal coinvariant rings and q,t-Catalan numbers. We will explain how to extend this to complex reflection groups by using results of Opdam and Rouquier on the relationship between finite Hecke algebras and rational Cherednik algebras of complex reflection groups. This is joint work with Iain Gordon. (Received January 11, 2010)

1058-05-59 **Georgia Benkart*** (benkart@math.wisc.edu), Department of Mathematics, University of Wisconsin-Madison, 480 Lincoln Dr., Madison, WI 53706, and **Tom Halverson** (halverson@macalester.edu), Department of Mathematics & Computer Science, Macalester College, 1600 Grand Ave., St. Paul, MN 55105. *Motzkin Paths and Representation Theory.*

Motzkin paths are certain lattice paths that arise in combinatorics and also in physics in the study of Q-systems. This talk will relate them to the representation theory of sl(2)and its quantum analogue. Motzkin paths can be used as a basis for the irreducible modules of a certain cellular algebra that we introduce and call the Motzkin algebra. This is joint work with Tom Halverson. (Received January 28, 2010)

1058-05-60 **William T Trotter*** (trotter@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332, and **David M Howard**. *On the Size of Maximal Antichains and the Number of Pairwise Disjoint Maximal Chains.* Preliminary report.

Fix integers n and k with $n \geq k \geq 3$. Duffus and Sands proved that if P is a finite poset and $n \leq |C| \leq n + (n-k)/(k-2)$ for every maximal chain in P, then P must contain k pairwise disjoint maximal antichains. They also constructed a family of examples to show that these inequalities are tight. These examples are 2-dimensional which suggests that the dual statement may also hold. In this paper, we show that this is correct. Specifically, we show that if P is a finite poset and $n \leq |A| \leq n + (n-k)/(k-2)$ for every maximal antichain

in P, then P has k pairwise disjoint maximal chains. Our argument actually proves a somewhat stronger result, and we are able to show that an analogous result holds for antichains. (Received January 28, 2010)

1058-05-61 **Alexander Yong*** (ayong@math.uiuc.edu), Math Dept., 1409 W. Green Street, Urbana, IL 61801. *Jeu de taquin for increasing tableaux.*

I'll discuss a theory of jeu de taquin for increasing tableaux, a generalization of Schützenberger's classical ideas. I'll also explain applications to the study of the Grothendieck ring of Grassmannians and other homogeneous spaces, and separately, to the study of longest strictly increasing subsequences of random words. This is joint work with Hugh Thomas. (Received January 29, 2010)

1058-05-62 **Steve Butler*** (butler@math.ucla.edu), UCLA Mathematics Department, Box 951555, Los Angeles, CA 90095-1555, and **Kevin Costello** (kcostell@math.gatech.edu) and **Ron Graham** (graham@ucsd.edu). *How to find a two coloring of $\{1, 2, \ldots, n\}$ that has few monochromatic constellations.*

A constellation pattern is a collection of rationals q_i with $0 \leq q_i \leq 1$. A constellation in $\{1, 2, \ldots, n\}$ is a scaled translated copy of the constellation pattern. For example, when the constellation pattern consists of the rationals $0, \frac{1}{2}, 1$; then a constellation in $\{1, 2, \ldots, n\}$ corresponds to a three term arithmetic progression.

For a given constellation pattern, we show a method to hunt for a two coloring of $\{1, 2, \ldots, n\}$ that has few (ideally fewest) monochromatic constellations. We also show that for constellation patterns with three points that there is *always* a coloring which beats random. (Received January 29, 2010)

1058-05-64 **Reshmi Nair*** (rnair@uwyo.edu) and **Bryan Shader** (BShader@uwyo.edu). *Acyclic matrices with a small number of distinct eigenvalues.*

We continue the study of the spectral properties of $\mathcal{S}(\mathcal{T})$, the set of all n by n symmetric matrices for a tree $\mathcal{T}$ on n vertices where $a_{ij} \neq 0$ for $i \neq j$ if and only if i–j is an edge in $\mathcal{T}$. For a given list of integers $m_1, m_2, \ldots, m_k$, we study the problem of characterizing the trees $\mathcal{T}$ for which there is an $A \in \mathcal{S}(\mathcal{T})$ whose eigenvalues have multiplicities $m_1, m_2, \ldots, m_k$. An approach based on Smith Normal Form, Hamming distance, and Parter and Fiedler vertices is used to characterize the acyclic matrices that have atmost 5 distinct eigenvalues. (Received January 29, 2010)

1058-05-66 **Julianna Tymoczko*** (tymoczko@math.uiowa.edu), Department of Mathematics, 14 MacLean Hall, University of Iowa, Iowa City, IA 52242. *A simple construction of the irreducible webs in the spider for $\mathfrak{sl}_3$.*

A combinatorial spider is a model for representations of a Lie algebra: webs are combinatorial graphs corresponding to representations, and graph-theoretic operations on webs correspond to algebraic operations on representations. Kuperberg described combinatorial spiders explicitly for rank 2 Lie algebras and for $\mathfrak{sl}_3$, and in later work with Khovanov gave a bijection between standard Young tableaux of shape (n, n, n) and irreducible webs. We give a simple and direct construction of this bijection, which also simplifies more recent work of Petersen-Pylyavskyy-Rhoades. (Received January 30, 2010)

1058-05-67 **Timothy D. LeSaulnier**, **Christopher Stocker**, **Paul S. Wenger** and **Douglas B. West*** (west@math.uiuc.edu), Mathematics Department, University of Illinois, 1409 West Green Street, Urbana, IL 61801-2975. *Rainbow Matching in Edge-Colored Graphs.*

A *rainbow subgraph* of an edge-colored graph is a subgraph whose edges have distinct colors. The *color degree* of a vertex v is the number of different colors on edges incident to v. Wang and Li conjectured that for $k \geq 4$, every edge-colored graph with minimum color degree at least k contains a rainbow matching of size at least $\lceil k/2 \rceil$. We prove the slightly weaker statement that a rainbow matching of size at least $\lfloor k/2 \rfloor$ is guaranteed. We also give sufficient conditions for a rainbow matching of size at least $\lceil k/2 \rceil$ that fail to hold only for finitely many exceptions (for each odd k). (Received February 01, 2010)

1058-05-72 **Ronald J. Gould*** (rg@mathcs.emory.edu), Department of Math and Computer Science, Atlanta, GA 30322. *On Saturated Graphs.*

A graph G on n vertices is said to be H-saturated if G does not contain H as a subgraph, but the addition of any edge to G produces H as a subgraph.

One of the classic questions in graph theory is what is the maximum number of edges in a graph that fails to contain H as a subgraph, that is, what is the maximum size of an H-saturated graph? This number is denoted $ex(n, H)$. This question has seen considerable work and produced a deep and rich theory.

The other extreme has been far less studied. That is, what is the minimum number of edges in an H-saturated graph? We denote this number by $sat(n, H)$.

In this talk we explore some of the basic facts about saturated graphs and consider some recent results on $sat(n, H)$ and clique saturated graphs in particular. (Received February 02, 2010)

1058-05-85 **Philippe Di Francesco** and **Rinat Kedem*** (rinat@illinois.edu), Department of Mathematics, MC-382, Urbana, IL 61821. *Non commutative rank 2 cluster algebras and the Kontsevich conjecture.*

Rank 2 cluster algebras fall into categories according to the classification of Cartan matrices as finite, affine and of determinant less than zero. Kontsevich introduced a non-commutative version of rank two discrete evolutions, which tend to the cluster algebra mutations in the commutative limit. Their behavior is very similar to the commutative case. In particular in the affine case, the evolution is integrable and we show how to use a path model on graph weighted with non commutative weights to solve them. We thus prove Kontsevich's conjecture in those cases, which states that the evolution produces only positive non-commutative Laurent polynomials, generalizing the "Laurent property" [Fomin-Zelevinsky] and positivity conjecture for cluster algebras. (Received February 04, 2010)

1058-05-94 **Hasan Coskun*** (hasan_coskun@tamu-commerce.edu), Department of Mathematics, 2600 S Neal St, Binnion Hall 314, Commerce, TX 75429. *Multiple special numbers.*

Multiple qt-binomial coefficients and multiple analogues of several celebrated families of related special numbers will be constructed. These higher dimensional generalizations include the first and the second kind of qt-Stirling numbers, qt-Bell numbers, qt-Bernoulli numbers, qt-Catalan numbers and the qt-Fibonacci numbers. Certain significant applications will also be presented including two discrete probability measures on the set of integer partitions. (Received February 07, 2010)

1058-05-97 **H. A. Kierstead*** (kierstead@asu.edu), AZ , and **William Cushing** (wcushing@asu.edu), AZ. *Planar graphs are 1-relaxed, 4-choosable.*

Let $G = (V, E)$ be a graph. A k-list assignment for G is a function L that assigns each vertex v a set $L(v)$ of k colors. An L-coloring is a vertex coloring f (not necessarily proper) such that $f(v) \in L(v)$ for every vertex $v \in V$. A vertex coloring f of G is d-relaxed if every color class $X = f^{-1}(\alpha)$ induces a subgraph $G[X]$ with maximum degree at most d. The graph G is d-relaxed, k-choosable if for every k-list assignment L there exists a d-relaxed L-coloring of G. When $d = 0$ then this is the usual notion of k-choosability.

Thomassen proved that every planar graph is 5-choosable and Voigt constructed a planar graph that is not 4-choosable. We prove that every planar graph is 1-relaxed, 4-choosable. (Received February 07, 2010)

1058-05-100 **M Cioaba Sebastian*** (cioaba@math.udel.edu), Department of Mathematical Sciences, University of Delaware, Newark, DE 19713. *A spectral version of the degree-diameter problem.*

The spectral radius of a graph G is the largest eigenvalue of the adjacency matrix of G. In this talk, I will discuss the problem of minimizing the spectral radius of a connected graph of given number of vertices n and diameter D. When D is constant, this problem is related to the degree-diameter problem in extremal graph theory. When D is close to n or $\frac{n}{2}$, this problem is related to the problem of classifying connected graphs with small spectral radius. This is joint work with Edwin van Dam (Tilburg University, The Netherlands), Jack Koolen (POSTECH, South Korea) and Jae-Hoo Lee (University of Wisconsin, Madison). (Received February 08, 2010)

1058-05-103 **Tao Jiang*** (jiangt@muohio.edu), Department of Mathematics, Miami University, Oxford, OH 45056, and **Oleg Pikhurko** and **Zelealem Yilma**. *Set systems without a strong simplex.*

A *d-simplex* is a collection of $d+1$ sets such that every d of them have non-empty intersection and the intersection of all of them is empty. A *strong d-simplex* is a collection of $d+2$ sets $A, A_1, \ldots, A_{d+1}$ such that $\{A_1, \ldots, A_{d+1}\}$ is a d-simplex, while A contains an element of $\cap_{j \neq i} A_j$ for each i, $1 \leq i \leq d+1$.

Generalizing Chvátal's conjecture on d-simplices (which was proved by Frankl and Füredi for large n and later completely settled by Mubayi and Verstraëte) Mubayi and Ramadurai conjectured that if $k \geq d+1 \geq 3$, $n > k(d+1)/d$, and $\mathcal{F}$ a family of k-element subsets of an n-element set that contains no strong d-simplex, then $|\mathcal{F}| \leq \binom{n-1}{k-1}$ with equality only when $\mathcal{F}$ is a star. We prove their conjecture when $k \geq d+2$ and n is large.

Around the same time as we obtained our result, Füredi and Özkahya proved a stronger result concerning so-called a-clusters. While their approach employs an intensive use of a complex version of the Delta-system method developed in earlier papers, our approach uses stability but is otherwise elementary and self-contained. At the core of the proof is a simple but effective induction. (Received February 11, 2010)

1058-05-119 **A. Jamie Radcliffe*** (aradcliffe1@math.unl.edu), Department of Mathematics, 205 Avery Hall, University of Nebraska-Lincoln, Lincoln, NE 68588-0130, and **Andrew Ray**. *Extremal trees for homomorphism enumeration.*

We present results on which trees have the largest number of homomorphisms into a fixed image graph H, for various classes of graph H. We also present a new perspective on the extremal trees, called *festoons*. (Received February 10, 2010)

1058-05-123 **Drew Armstrong** and **Patricia Hersh*** (plhersh@ncsu.edu), Box 8205, North Carolina State University, Raleigh, NC 27695. *Sorting orders, subword complexes and a map to Bruhat order.*

We will discuss a new poset map from Boolean algebras to Bruhat order having subword complexes as fibers and the sorting order as the suborder on distinguished elements of the fibers. This gives a new proof by the Quillen fiber lemma that the proper part of Bruhat order is homotopy equivalent to a sphere and also gives a geometric interpretation for sorting orders. We also show that the union of all sorting orders is Bruhat order while the intersection of all sorting orders is weak order. (Received February 10, 2010)

1058-05-133 **Todd G Will*** (will.todd@uwlax.edu) and **Futaba Okamoto**. *Computing the Modular Chromatic Number of Trees.*

A modular k-coloring of a graph G without isolated vertices is a coloring of the vertices of G with the elements in $\mathbb{Z}_k$ having the property that for every two adjacent vertices in G the sums of the colors of their neighbors are different in $\mathbb{Z}_k$. The minimum k for which G has a modular k-coloring is the modular chromatic number $\mathrm{mc}(G)$ of G. It is known that $2 \leq \mathrm{mc}(T) \leq 3$ for every nontrivial tree T. We present an efficient algorithm that computes the modular chromatic number of a given tree. (Received February 11, 2010)

1058-05-138 **Adriano M. Garsia***, Department of Mathematics, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093, **Guoce Xin**, Center for Combinatorics, Nankai University, Tianjin, 300071, Peoples Rep of China, and **Mike Zabrocki**, York University, Mathematics and Statistics, 4700 Keele Street, Toronto, Ontario M3J 1P3, Canada. *Hall Littlewood operators in the Theory of Parking Functions.*

We prove here the symmetric function side of a recursion which combined with a recent Parking Function recursion of Angela Hicks settles some special cases of the Haglund-Morse-Zabrocki refinement of the Shuffle conjecture. As a by-product we obtain surprisingly simple proofs of refinements of the q,t-Catalan and the Schröder results. (Received February 11, 2010)

1058-05-148 **Joan P. Hutchinson*** (hutchinson@macalester.edu), PO Box 23584, Silverthorne, CO 80498. *An extension of Thomassen's results on 2- and 3-extendable planar graphs.* Preliminary report.

Carsten Thomassen has proven that if G is a plane graph with a path of two vertices precolored on the exterior face F, with otherwise $|L(u)| = 3$ for u on F, and $|L(x)| = 5$ for all other vertices x, then G is L-list-colorable; he calls such a plane graph *2-extendable with respect to a 2-path.* He has also characterized the plane graphs that are *3-extendable with respect to a 3-path*, which have three vertices of a boundary path pre-colored and similarly 3- and 5-lists elsewhere; not all such plane graphs are 3-extendable. We begin the study of *(1,1)-extendable* plane graphs; these are the plane graphs with two nonadjacent precolored vertices on the exterior face and similarly 3- and 5-lists elsewhere. They are not always list-colorable. Let G be an *outerplane graph* with nonadjacent vertices v, w in $V(G)$ having $|L(v)|, |L(w)| \leq 2$ and otherwise $L(x) = 3$ for x in $V(G)$. We characterize when G is L-list-colorable and formulate a conjecture on the obstructions for (1,1)-extendability for all planar graphs G. (Received February 12, 2010)

1058-05-150 **Eric S. Egge** and **Nicholas A. Loehr*** (nloehr@vt.edu), Va. Tech. Dept. of Mathematics, 460 McBryde Hall, Blacksburg, VA 24061-0123, and **Gregory S. Warrington**. *A Modified Inverse Kostka Matrix.*

The inverse Kostka matrix is the transition matrix that converts monomial expansions of symmetric functions to Schur expansions. Egecioglu and Remmel gave a combinatorial description of the entries in this matrix using signed special rim-hook tableaux. We will describe a modified version of this matrix that converts fundamental quasisymmetric expansions of symmetric functions into Schur expansions. Such conversions are useful, for instance, in the theory of Macdonald polynomials and LLT polynomials. This work provides a linear-algebraic complement to a recent combinatorial construction of Sami Assaf. (Received February 12, 2010)

1058-05-151 **Ortrud R Oellermann*** (o.oellermann@uwinnipeg.ca), Department of Maths and Stats, University of Winnipeg, 515 Portage Avenue, Winnipeg, Manitoba R3B 2E9, Canada.
Graph Classes Determined by Convexity Notions in Graphs.

Let V be a finite set and $\mathcal{M}$ a collection of subsets of V. Then $\mathcal{M}$ is an alignment of V if $\mathcal{M}$ is closed under taking intersections and contains both V and the empty set. In this case the elements of $\mathcal{M}$ are called convex sets. If $S \subseteq V$, then the convex hull of S is the smallest convex set that contains S. Suppose $X \in \mathcal{M}$. Then $x \in X$ is an extreme point for X if $X \setminus \{x\} \in \mathcal{M}$. A convex geometry on a finite set is an alignment with the additional property that every convex set is the convex hull of its extreme points. We survey characterizations of graph classes that are defined in terms of convexities on the vertex set of a graph. (Received February 12, 2010)

1058-05-157 **Penny Haxell***, C and O Dept, University of Waterloo, Waterloo, ON , Canada. *On characterising Vizing's edge colouring bound.*

We address the problem of characterising those multigraphs G for which equality holds in Vizing's classical edge colouring bound $\chi'(G) \leq \Delta + \mu$, where Δ denotes the maximum degree and μ denotes the maximum edge multiplicity of G. By the well-known theorem of Holyer, this should not be possible when $\mu = 1$ (unless P=NP). However, if the famous Seymour-Goldberg conjecture holds, then whenever $\mu \geq 2$ it should be true that G attains Vizing's bound if and only if there exists an odd subset $S \subseteq V(G)$ with $|S| \geq 3$, such that $|E[S]| > (|S| - 1)(\Delta + \mu - 1)/2$. We show that this characterisation does hold if μ is bounded below by a logarithmic function of Δ.

This represents joint work with Jessica McDonald. (Received February 12, 2010)

1058-05-158 **Tao Jiang**, **Zevi Miller** and **Dan Pritikin*** (pritikd@muohio.edu), Department of Mathematics, Miami University, Oxford, OH 45056. *The Steiner problem in the hypercube.*

Let S be a set of vertices in the hypercube Q_n. We study the *Steiner cost* of S, denoted $cost(S)$, the minimum number of edges among connected subgraphs of Q_n containing S. We obtain the the following results by probabilistic methods.

(1) If $|S| = k$, then $cost(S) \leq \frac{1}{3}(k + 1 + ln(k-1))n$.

(2) The above bound is nearly best possible for a certain range in k as follows. Let $\epsilon > 0$ be a fixed small real number, and let n be sufficiently large as a function of ϵ. Further let k lie in the range $K_1 \leq k \leq K_2 c^n$, where K_1, K_2, and c constants which depend only on ϵ, with $1 < c < 2$. Then there exist sets S in Q_n of size k such that $cost(S) \geq (\frac{1}{3} - \epsilon)kn$. (3) In some random sense, these Steiner costs are tightly concentrated about their mean.

The work naturally generalizes to a "squashed cube" setting concerning optimal interconnection of a set of subcubes of Q_n instead of handling only the case in which each subcube has dimension 0 (i.e., is a single vertex). (Received February 12, 2010)

1058-05-164 **Alexander Woo*** (woo@stolaf.edu), 1520 Saint Olaf Avenue, Northfield, MN 55057, and **Brant C Jones**. *Deodhar sets for cograssmannian permutations.*

Deodhar gave a framework for understanding Kazhdan–Lusztig polynomials by showing that they count some set of masks on a reduced word for the permutation. We construct two distinct such sets of masks for cograssmannian permutations. One is based directly on the combinatorial formula of Lascoux and Schutzenberger. The other is based on the geometric explanation of this formula by Zelevinsky. (Received February 13, 2010)

1058-05-165 **jianmin Ma*** (jianmin.ma@emory.edu), Oxford College, Oxford, GA 30054. *On decomposition of a complete graph into Latin square graphs.*

A connected regular graph on n^2 vertices with eigenvalues $(n-1)g, n-g, -g$ is called a Latin square graph. If the edges of a complete graph can be decomposed a set of Latin square graphs, these graphs have an wonderful property: the union of each subset gives rise to a Latin square graph. In fact, this decomposition gives an amorphous symmetric association scheme. In this talk, we allow some of basis graphs in an amorphous scheme to be digraphs. We will use matrix techniques to show the nonexistence of certain amorphous schemes and give some constructions. (Received February 14, 2010)

1058-05-171 **Mike Zabrocki*** (zabrocki@mathstat.yorku.ca), Mathematics and Statistics, York University, Toronto, ON M5B 1B4, Canada. *q,t Counting Dyck Paths with Forced and Forbidden Touch Points.*

I will give a combinatorial formula for certain coefficients of the operator ∇ when it acts on a Hall-Littlewood symmetric functions. This result (almost completely) answers a conjecture posed by Alain Lascoux in the paper

by (F)Bergeron-Garsia-Haiman-Tesler that introduced the operator ∇. The combinatorial formula is proven by showing that q,t-counting Dyck paths satisfy the same recursion as a symmetric function expression.

This is joint work with N. Bergeron, F. Descouens, A. Garsia, J. Haglund, A. Hicks, J. Morse and G. Xin. (Received February 14, 2010)

1058-05-175 **Aba Mbirika*** (ambirika@math.uiowa.edu), 505 Iowa Avenue, apt. 3, Iowa City, IA 52240. *Exploring the cohomology ring of generalized Springer varieties.*

The Springer variety is the set of flags stabilized by a nilpotent operator. Its cohomology ring is a long-studied object. In 1976, Springer introduced a famed symmetric group action on this ring, and he offered a deep geometric construction. Fourteen years later, Garsia, Procesi, Tanisaki, and others succeeded in giving a more tangible combinatorial description of this ring. We begin to generalize their results and extend it to a family of varieties called Hessenbergs, a two-parameter generalization of Springer varieties. Little is known about their cohomology. For the class of regular nilpotent Hessenbergs, we conjecture a quotient presentation for this ring and exhibit an explicit basis. Tantalizing new evidence supports our conjecture for a subclass of regular nilpotent varieties called Peterson varieties. (Received February 14, 2010)

1058-05-178 **Lee Kyungyong** and **Li Li*** (llpku@math.uiuc.edu), Math Department, University of Illinois at Urbana-Champaign, Urbana, IL 61801. *On the algebra and combinatorics of q,t-Catalan numbers.*

Haiman proved that the q,t-Catalan number is the Hilbert series of the graded vector space $M = \oplus M_{d_1,d_2}$ spanned by a minimal set of generators for the ideal of the diagonal locus of $(\mathbb{C}^2)^n$. It is natural to ask for a combinatorial construction of such generators. In this talk we give upper bounds for the dimension of M_{d_1,d_2} in terms of partition numbers, and find all bi-degrees (d_1, d_2) that attain equality. For these bi-degrees, we answer the aforementioned question. (Received February 14, 2010)

1058-05-180 **Marcelo Aguiar*** (maguiar@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843-3368, and **Swapneel Mahajan** (swapneel@math.iitb.ac.in), Indian Institute of Technology, Mumbai, Mumbai, India. *Hyperspecies and hyperoperads.*

The notion of operad can be formulated in purely combinatorial terms. The key ingredients are provided by the Coxeter complex of type A. We make use of this observation to extend the notion of operad to the setting of arbitrary finite Coxeter complexes and even central hyperplane arrangements. No previous knowledge of operads will be assumed.

Joint work with Swapneel Mahajan. (Received February 15, 2010)

1058-05-189 **Sami H Assaf*** (sassaf@math.mit.edu), Department of Mathematics, 77 Massachussets Ave, Cambridge, MA 02139, and **Peter R.W. McNamara**. *A skew Pieri rule.*

The Pieri rule expresses the product of a Schur function and a single row Schur function in terms of Schur functions. We extend the classical Pieri rule by expressing the product of a skew Schur function and a single row Schur function in terms of skew Schur functions. Like the classical rule, our rule involves simple additions of boxes to the original skew shape. (Received February 15, 2010)

1058-05-191 **Sami Assaf*** (sassaf@math.mit.edu), Department of Mathematics, 77 Massachusetts Ave, Cambridge, MA 02139. *Crystal graphs and dual equivalence graphs.*

In this talk, we present connections between crystal graphs for classical groups and dual equivalence graphs for the corresponding Weyl groups using tableaux combinatorics and local characterizations of the graphs. (Received February 15, 2010)

1058-05-192 **Seth A. Meyer*** (smeyer@math.wisc.edu), 480 Lincoln Dr., Madison, WI 53706. *Zero Forcing Numbers for Graphs.* Preliminary report.

Consider a graph whose vertices are each colored either black or white. We will study the following phenomenon: we allow a black vertex v to change a white neighbor w to black whenever all the neighbors of v other than w are black. Any set of black vertices is called a zero forcing set as long as when the graph is entirely white except for these vertices, repeated applications of the previous rule eventually make every vertex black. In this talk we will discuss both the minimum size of a zero forcing set for cubic, bipartite matrices and applications to problems concerning the minimum rank of such graphs. (Received February 15, 2010)

1058-05-194 **Stephen Lewis** and **Nathaniel Thiem*** (thiemn@colorado.edu), University of Colorado at Boulder, Department of Mathematics, Campus Box 395, Boulder, CO 80309. *Branching coefficients in the finite unipotent upper-triangular groups.*

It is becoming increasingly clear that the supercharacter theory of the finite group of unipotent upper-triangular matrices $U_n(F_q)$ has a rich combinatorial structure built on set-partitions that is analogous to the partition combinatorics of the classical representation theory of the symmetric group. This talk reviews the notion of a supercharacter theory and then explores the branching coefficients in the restrictions and tensor products of supercharacters of $U_n(F_q)$. We reveal a surprising combinatorial interpretation in terms of complete matchings in bipartite graphs. (Received February 15, 2010)

1058-05-196 **P. Haxell** (pehaxell@math.uwaterloo.ca), Dept of Combinatorics and Optimization, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada, **A. Kostochka*** (kostochk@math.uiuc.edu), 1409 W. Green St., Dept. of Mathematics, Urbana, IL 61801, and **S. Thomasse** (Stephan.Thomasse@lirmm.fr), Universite Montpellier II, 34392 Montpellier, France. *Stability results on covering of triangles by edges.* Preliminary report.

Let $\nu(G)$ denote the maximum number of edge-disjoint triangles in a graph G and $\tau(G)$ denote the minimum number of edges covering all triangles of G. Motivated by Tuza's conjecture that $\tau(G) \leq 2\nu(G)$ for every graph G, we sharpen two known results in this direction. Tuza proved that his conjecture holds for planar graphs. This result is sharp, since for the graph K_4 we have $\nu(K_4) = 1$ and $\tau(K_4) = \tau^*(K_4) = 2$. We prove that for every planar graph G with no K_4, $\tau(G) \leq 1.5\nu(G)$. This bound is attained at the 5-wheel. It implies that every planar graph G with $\tau(G)$ "close" to $2\nu(G)$ contains "many" K_4-subgraphs.

Let $\tau^*(G)$ denote the minimum total weight of a fractional covering of its triangles by edges. Krivelevich proved that $\tau^*(G) \leq 2\nu(G)$ for every graph G. We refine this result by showing that if a graph G has $\tau^*(G) \geq 2\nu(G) - x$, then G contains $\nu(G) - \lfloor 10x \rfloor$ edge-disjoint K_4-subgraphs plus $\lfloor 10x \rfloor$ additional edge-disjoint triangles. Our proof also yields that $\tau^*(G) \leq 1.8\nu(G)$ for each K_4-free graph G. (Received February 16, 2010)

1058-05-199 **Martha Yip*** (yip@math.wisc.edu), 480 Lincoln Dr, Madison, WI 53706. *A Littlewood-Richardson rule for Macdonald polynomials.*

Macdonald polynomials are orthogonal polynomials associated to root systems and depend on parameters q and t. The double affine Hecke algebra H is a fundamental tool for studying Macdonald polynomials, which can be constructed by applying intertwining operators on the polynomial representation of H.

Using objects known as alcove walks, we give a combinatorial description for the coefficients in the expansion of a product of two Macdonald polynomials. At q=0, the formula specializes to Schwer's formula for Macdonald spherical functions in terms of positively folded walks, and at q=t, this specializes to Littelmann's formula for Weyl characters in terms of the path model. (Received February 15, 2010)

1058-05-208 **Stephen G Hartke*** (hartke@math.unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130, and **Tyler Seacrest**, Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130. *Finding a large balanced bipartite subgraph with high minimum degree.* Preliminary report.

It is well known that every graph G contains a bipartite subgraph H with at least half the edges of G. The standard "pushing" argument shows that in fact the degree of each vertex in H is at least half its degree in G. A linearity of expectation argument also shows that a spanning balanced bipartite subgraph exists with at least half the edges. Can both properties be simultaneously obtained? That is, does there exist a spanning balanced bipartite subgraph H of G such that the degree of each vertex in H is at least half its degree in G? We will discuss partial results on this question, including a potential version: for any degree sequence π, we show that there exists a realization G of π that has a bipartite subgraph H with (almost) the desired properties. (Received February 16, 2010)

1058-05-209 **Jessica Striker*** (jessica@math.umn.edu). *A simple bijection between alternating sign matrices with no -1's and descending plane partitions with no special parts.*

We present a straightforward bijection between descending plane partitions with no special parts and alternating sign matrices with no -1's (i.e. permutation matrices). This bijection has the desirable property that the number of parts of the descending plane partition corresponds to the inversion number of the permutation. Additionally, the number of maximum parts in the descending plane partition corresponds to the position of the 1 in the last column of the permutation matrix. We also discuss the possible extension of this approach to finding a bijection between all alternating sign matrices and descending plane partitions. (Received February 15, 2010)

1058-05-220 **Jeffrey B. Remmel*** (jremmel@ucsd.edu), Department of Mathematics, University of California, San Diego, La Jolla, CA 92093-0112. *Generating functions for the number of consecutive occurrences of non-overlapping patterns in permutations and cycles.* Preliminary report.

We say that a permutation $\tau \in S_j$ is non-overlapping if the smallest n for which there is a permutation $\sigma \in S_n$ such that σ has two consecutive occurrences of the pattern τ is $n = 2j - 1$. We show how one can derive the generating function for the number of consecutive occurrences of a non-overlapping permutation τ in S_n by applying appropriate homomorphisms defined on the ring of symmetric functions to a simple symmetric function identity. Our result allows us to prove a conjecture of Elizade that such generating functions depend only on the length of τ and its initial and final elements. We prove similar results for the number of consecutive cyclic occurrences of a non-overlapping permutation τ in the set of n-cycles of S_n. This joint work with Adrian Duane and Miles Jones. (Received February 15, 2010)

1058-05-223 **Bruce Sagan**, **John Shareshian*** (shareshi@math.wustl.edu) and **Michelle Wachs**. *Cyclic sieving and Eulerian quasisymmetric functions.*

For a partition λ of n, let C_λ be the conjugacy class in the symmetric group S_n consisting of all elements of cycle type λ, and set

$$A_\lambda(q) := \sum_{w \in C_\lambda} q^{maj(w) - exc(w)},$$

where maj is the major index and exc is the excedance statistic. Let $g = (12 \dots n)$, an n-cycle in S_n. Let h be a power of g having order d, and let ω_d be a primitive d^{th} root of 1. Then

$$A_\lambda(\omega_d) = |C_{S_n}(h) \cap C_\lambda|.$$

In other words, the triple $(\langle g \rangle, A_\lambda(q), C_\lambda)$ satisfies the cyclic sieving phenomenon, with the action of $\langle g \rangle$ on C_λ being by conjugation. I will explain how we proved this fact using quasisymmetric functions. (Received February 15, 2010)

1058-05-226 **Chalermpong Worawannotai*** (worawannotai@wisc.edu), Department of Mathematics, University of Wisconsin, 480 Lincoln Dr., Madison, WI 53706. *Dual polar graphs and the quantum algebra $U_q(sl_2)$.* Preliminary report.

Let $\Gamma = (X, R)$ denote a dual polar graph. Let A denote the adjacency matrix of Γ. Fix a vertex $x \in X$ and let $A^* = A^*(x)$ denote the dual adjacency matrix of Γ with respect to x. Let $T = T(x)$ denote the subalgebra of $Mat_X(\mathbb{C})$ generated by A, A^*. Let $V = \mathbb{C}^X$ denote the standard T-module. In this talk we display a $U_q(sl_2)$-module structure on V and discuss how this is related to the actions of A, A^*. (Received February 15, 2010)

1058-05-231 **Angela Hicks*** (ashicks@math.ucsd.edu), Department of Mathematics, University of California, San Diego, 9500 Gilman Dr #0112, La Jolla, CA 92093. *Two Bijections in the Theory of Parking Functions.*

In this talk we present two parking function bijections and describe their relationship to the Frobenius characteristic of the diagonal harmonics. In particular these bijections prove Dyck and Schröder paths recursions which combined with certain Hall Littlewood operators recursions proved by Garsia, Xin, and Zabrocki yield sharper versions of the q,t-Catalan and Shröder Theorems. (Received February 15, 2010)

1058-05-233 **Alex Miller*** (mill1966@math.umn.edu), School of Mathematics, Room 127 VinH 0412, 206 Church St S E, Minneapolis, MN 55455, and **Victor Reiner**. *Differential Posets and Smith Normal Forms.*

We present a conjecture asserting a strong property for the up and down maps U and D in an r-differential poset: $DU + tI$ and $UD + tI$ have Smith normal forms over $\mathbb{Z}[t]$. In particular, this would determine the integral structure of the maps U, D, UD, DU, including their ranks in any characteristic. As evidence for such a conjecture, we will focus mainly on two families: Cartesian products of Young's lattice and the r-differential generalizations of the Young-Fibonacci lattice. In particular, the conjecture has been verified in the latter family, and many of its consequences have been verified for Cartesian products of Young's lattice. (Received February 15, 2010)

1058-05-258 **Brendon Rhoades*** (brhoades@math.mit.edu), Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA 02139. *The cluster and dual canonical bases of $\mathbb{Z}[x_{11}, \dots, x_{33}]$ are equal.*

The polynomial ring $\mathbb{Z}[x_{11}, \dots, x_{33}]$ has a basis called the dual canonical basis whose quantization facilitates the study of representations of the quantum group $U_q(\mathfrak{sl}_3(\mathbb{C}))$. On the other hand, the ring $\mathbb{Z}[x_{11}, \dots, x_{33}]$ inherits

a basis from the cluster monomial basis of a geometric realization of the type D_4 cluster algebra. We prove that these two bases are equal. This extends work of Skandera and proves a conjecture of Fomin and Zelevinsky. (Received February 16, 2010)

1058-05-261 **Linyuan Lu*** (lu@math.sc.edu), Department of Mathematics, University of South Carolina, 1523 Greene Street, Columbia, SC 29208, and **Xing Peng** (pengx@mailbox.sc.edu), Department of Mathematics, University of South Carolina, 1523 Greene Street, Columbia, SC 29208. *Fractional Chromatic Number of Triangle-free Graphs with $\Delta \leq 3$.*

Let G be any triangle-free graph with $\Delta \leq 3$. Staton proved the independence number of G is at least $\frac{5}{14}n$. Heckman and Thomas conjectured that Staton's result can be strengthened into a bound on the fractional chromatic number of G; namely, $\chi_f(G) \leq \frac{14}{5}$. Recently, Hatami and Zhu proved $\chi_f(G) \leq 3 - \frac{3}{64}$. In this talk, we will present a new upper bound $\chi_f(G) \leq 3 - \frac{3}{22}$. (Received February 16, 2010)

1058-05-265 **Cristian Lenart*** (lenart@albany.edu), Department of Mathematics, State University of New York at Albany, 1400 Washington Avenue, Albany, NY 12222. *From Macdonald polynomials to a charge statistic in classical Lie types.* Preliminary report.

The charge is an intricate statistic on words, due to Lascoux and Schützenberger, which gives positive combinatorial formulas for the Kostka polynomials. These are the coefficients in the expansion of the Hall-Littlewood symmetric polynomials in terms of Schur polynomials; they are also Lusztig's q-analogue of weight multiplicities in Lie type A. It has been a long-standing problem to generalize charge to all classical types. I will present a method to address this problem based on the recent Ram-Yip formula for Macdonald polynomials. The key step is to derive from the Ram-Yip formula (at $t = 0$) a formula in terms of sequences of Kashiwara-Nakashima columns (Kashiwara-Nakashima tableaux are the natural generalization of semistandard Young tableaux to classical Lie types). I am currently working with Anne Schilling on a conjectured connection between the generalized charge and the energy function on affine crystals. (Received February 16, 2010)

1058-05-267 **André Kündgen*** (akundgen@csusm.edu), Department of Mathematics, California State University San Marcos, 333 S Twin Oaks Valley Road, San Marcos, 92096, **Sebastian Cioabă**, University of Delaware, and **Craig Timmons**, University of California San Diego. *Covering complete r-graphs with complete r-partite r-graphs.*

An *r-cut* of the complete r-uniform hypergraph K_n^r is obtained by partitioning its vertex set into r parts and taking all edges that meet every part in exactly one vertex. In other words it is the edge set of a spanning complete r-partite subhypergraph of K_n^r. An r-cut cover is a collection of r-cuts so that each edge of K_n^r is in at least one of the cuts.

While in the graph case $r = 2$ any 2-cut cover will on average cover each edge at least $2-o(1)$ times, when r is odd we exhibit an r-cut cover in which each edge is covered exactly once. When r is even no such decomposition can exist, but we can bound the average number of times an edge is cut in an r-cut cover strictly between 1 and 2. (Received February 16, 2010)

1058-05-269 **Zoltan Furedi*** (z-furedi@math.uiuc.edu), 1409 W Green Street, Urbana, IL 61801. *Decomposition of graphs into given sample graphs.* Preliminary report.

Let H be a given graph on k vertices. Wilson showed in 1975 that the edge-set of the complete graph K_n can be decomposed into edge-disjoint copies of H, whenever $n > n_0(k)$ and obvious divisibility properties hold. The case $H = K_k$ is equivalent to the existence of a Steiner system $S(n, k, 2)$.

Our aim is to extend Wilson's result to a much larger class of graphs. We show that if G is an n-vertex graph with $f(n, H)$ saturated (i.e., of degree $n - 1$) vertices then a similar decomposition theorem holds.

For a bipartite H the value of f is $o(n)$, and it is related to its Turan number. (Received February 16, 2010)

1058-05-278 **Nathan Reading*** (nathan_reading@ncsu.edu) and **David Speyer** (speyer@math.mit.edu). *A Cambrian approach to cluster algebras.*

Cambrian lattices and Cambrian fans arise from a lattice-theoretic construction on the weak order on a Coxeter group. The closely related sortable elements provide an explicit combinatorial construction of these lattices and fans. Surprisingly (a priori), the Cambrian constructions reproduce the combinatorics and polyhedral geometry of cluster algebras.

I will discuss combinatorial models for cluster algebras arising from Cambrian fans/lattices and sortable elements. I will also describe how the Cambrian approach gives new insights into the combinatorics of cluster algebras and the geometry of the **g**-vector fan. (Received February 16, 2010)

1058-05-280 **Felix Lazebnik*** (lazebnik@math.udel.edu), Department of Mathematical Sciences, University of Delaware, Newark, DE 19716, **Stefaan De Winter** (sgdwinte@cage.ugent.be), Department of Mathematics and Computer Algebr, 9000 Gent, Belgium, and **Jacques Verstraëte** (jacques@ucsd.edu), Department of Mathematics, University of California, La Jolla, CA 92093-0112. *An Extremal Characterization of Projective Planes.*

For a given integer n, consider a family of all n by n bipartite graphs with no 4-cycles. Which graphs from the family contains the greatest number of 8-cycles? We show that if $n = q^2 + q + 1 \geq 157$, the incidence graph of a projective plane of order q, when it exists, has the maximum number of cycles of length eight. This characterizes projective planes as the partial planes with the maximum number of quadrilaterals. Several generalizations of this question, and related results will be discussed. (Received February 16, 2010)

1058-05-284 **Jerrold R. Griggs*** (j@sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208, and **Wei-Tian Li** and **Linyuan Lu**. *The Lubell function and H-free families of subsets.* Preliminary report.

We consider the problem of determining the largest size $\mathrm{La}(n, H)$ of a family of subsets of $[n] := \{1, \ldots, n\}$ that contains no subposet isomorphic to a given poset H. Sperner's Theorem is the foundational result of this kind, and Katona *et al.* have made recent progress. We introduce the Lubell function $L_n(F)$ for families F of subsets of $[n]$, derived from the familiar LYM inequality, to obtain upper bounds on $|F|$ for H-free families F. This allows us to improve bounds on $\lim_{n\to\infty} \mathrm{La}(n, H)/\binom{n}{\lfloor n/2 \rfloor}$, if it exists, and to determine the limit for several posets H. (Received February 16, 2010)

1058-05-287 **Sarah K Mason*** (sarahkmason@gmail.com), Winston Salem, NC 27106, and **Aaron Lauve**, College Station, TX. *A basis for the coinvariant space for quasisymmetric polynomials.*

The coinvariant space for quasisymmetric polynomials is the quotient ring of quasisymmetric functions by symmetric func- tions. Garsia and Wallach used an algorithmic approach to prove that this ring has dimension n!, where n is the number of variables. In this joint work with Lauve, we affirm that the basis conjectured by Bergeron and Reutenauer is indeed a basis for this quotient ring, providing the first constructive proof of the Garsia-Wallach result. Our proof utilizes recent results (joint with Haglund, Luoto, and van Willigenburg) on the multiplication of quasisymmetric functions. (Received February 16, 2010)

1058-05-293 **Michael William Schroeder*** (schroede@math.wisc.edu), 480 Lincoln Dr, Madison, WI 53706, and **Richard A Brualdi** (brualdi@math.wisc.edu), 480 Lincoln Dr, Madison, WI 53706. *Symmetric Hamilton Cycle Decompositions of Graphs.*

We will define symmetric Hamilton cycle decompositions and prove some existence and non-existence results for certain families of graphs. (Received February 16, 2010)

1058-05-296 **Gregory S. Warrington*** (gwarring@cems.uvm.edu), Department of Mathematics and Statistics, University of Vermont, 16 Colchester Ave., Burlington, VT 05401, and **Nicholas A. Loehr**. *Infinitely many new partition statistics.*

Traditionally, the generating function $1/((1-tq)(1-tq^2)(1-tq^3)\ldots)$ enumerates partitions by area (the power of q) and number of parts (power of t). We give an infinite number of new interpretations for the power of t. That these new statistics are equidistributed with the length of a partition is proven via explicit bijections. These bijections involve various combinatorial constructions such as oriented trees and Eulerian tours on directed multigraphs. This is joint work with Nick Loehr. (Received February 17, 2010)

1058-05-298 **Andrew J Beveridge*** (abeverid@macalester.edu), Department of Mathematics, Macalester College, 1600 Grand Avenue, Saint Paul, MN 55105, and **Laszlo Lovasz**. *Exit frequency matrices for finite Markov chains.*

We think of a Markov chain as a random walk on a (directed) graph. If we consider such a random walk in reverse, the result is a random walk on an associated Markov chain, called the *reverse chain*. We develop a framework that describes how this duality extends to *stopping rules*. A stopping rule is an intelligent procedure which "looks where it is going" to sample exactly from any desired distribution. Fixing a target distribution τ, we consider a family of stopping rules, one from each possible starting node. We show that this family is dual to a family of rules on the reverse chain to an associated distribution τ^*. The key to unlocking this duality is to partition the random walks into *exit frequencies*, which are the expected number of exits at each node. (Received February 17, 2010)

1058-05-301 **Jacques A Verstraete*** (jacques@ucsd.edu), 9500 Gilman Drive, La Jolla, CA 92037, and **Peter Keevash** and **Benny Sudakov**. *On a conjecture of Erdos and Simonovits.* Preliminary report.

Erdős and Simonovits conjectured that if H is any bipartite graph containing a cycle, then the maximum number of edges in an n-vertex bipartite graph containing no H is asymptotically the same as the maximum number of edges in an H-free n-vertex graph with no cycles of length at most k, for a sufficiently large integer k. They verified their conjecture for $H = C_4$.

We verify their conjecture for $H = K_{3,3}$ and $H = K_{2,t}$, and in addition show that extremal C_4, C_k-free graphs are actually bipartite. Erdős also conjectured that extremal C_4, C_3-free graphs have asymptotically as many edges as extremal bipartite C_4-free graphs; we give evidence to the contrary by showing that extremal $K_{2,3}, C_3$-free graphs have substantially more edges than extremal $K_{2,3}$-free bipartite graphs. The proofs are a mix of probabilistic methods, and some algebra and number theory. (Received February 17, 2010)

06 ► Order, lattices, ordered algebraic structures

1058-06-5 **Jeffrey S Olson*** (jolson@norwich.edu), Department of Mathematics, 158 Harmon Dr., Northfield, VT 05663. *Fixed elements in involutive residuated lattices.* Preliminary report.

An involutive residuated lattice (IRL) is a lattice-ordered monoid possessing residual operations and a dualizing element d. The involution, i.e., the function $x \mapsto x\backslash d$, of an IRL induces a lattice anti-isomorphism, and is also an order-2 bijection of the underlying set. We examine which such bijections may be induced by the involution of an IRL. (Received August 01, 2009)

1058-06-9 **Kate S Owens*** (kate.s.owens@gmail.com), Department of Mathematics, Texas A&M University, Blocker 623B, College Station, TX 77843-3368. *Finite axiomatizability and commutative directoids.* Preliminary report.

An algebra is a nonempty set equipped with some finitary operations. The equational theory of an algebra is the set of all equations true in that algebra. If we can deduce all of an algebra's true equations from a finite set of equations true in the algebra, we say that the algebra's equational theory is finitely axiomatizable. Ježek and Quackenbush devised a way to convert any up-directed partially ordered set into an algebra by imposing a two-place operation on the set which always outputs a common upper bound of its inputs and, in the case of comparable inputs, will output the larger. The resulting algebras are called directoids. In this talk we examine recent work on the finite axiomatizability of the equational theory of commutative directoids. (Received November 15, 2009)

1058-06-10 **Elijah J Stines*** (ejstines@iastate.edu), 807 12th St., Boone, IA 50036. *Divisibility in Psedo Valuation Domains.*

An ideal P of an integral domain R is called strongly prime if for every $x, y \in K$, the quotient field of R, $xy \in P$ implies $x \in P$ or $y \in P$. An integral domain where P prime implies P strongly prime is called a Pseudo Valuation Domain.

In this talk I plan to give a characterization of the group of divisibility of any Pseudo Valuation Domain. I will then explain how this can be used to classify the lattice of ideals of the class of Pseudo Valuation Domains of the form $K + XF[[X]]$ for a field extension F_K. (Received November 16, 2009)

1058-06-18 **Stephen L Bloom*** (bloom@cs.stevens.edu), Department of Computer Science, Hoboken, NJ 07030, and **Zoltan Esik** (ze@inf.u-szeged.hu), Department of Informatics, University of Szeged, Szeged, Hungary. *Algebraic Linear Orderings.*

An algebraic linear ordering is a component of the initial solution of a first-order recursion scheme over the continuous categorical algebra of countable linear orderings equipped with the sum operation and the constant **1**, denoting the one point linear order. Due to a general Mezei-Wright type result, algebraic linear orderings are exactly those isomorphic to the linear ordering of the leaves of an algebraic tree. Using Courcelle's characterization of algebraic trees by deterministic context-free languages, we obtain the fact that a linear ordering is algebraic iff it can be represented as the lexicographic ordering of a deterministic context-free language. When the algebraic linear ordering is a well-ordering, its order type is an algebraic ordinal. We prove that the Hausdorff rank of any scattered algebraic linear ordering is less than ω^ω. It follows that the algebraic ordinals are exactly those less than ω^{ω^ω}. (Received December 01, 2009)

1058-06-19 **M E Adams*** (adamsm@newpaltz.edu), Department of Mathematics, State University of New York, New Paltz, NY 12561, and **Jürg Schmid** (juerg.schmid@math.unibe.ch), Institute of Mathematics, University of Bern, CH-3012 Bern, Switzerland. *Free Products of Pseudocomplemented Semilattices – Revisited.*

The structure of free products of pseudocomplemented semilattices is analyzed in terms of their skeleta and Glivenko classes by giving a rather explicit construction, complementing the description given by Katriňák and Heleyová (Semigroup Forum **60** (2000), 450 – 469). (Received December 01, 2009)

1058-06-21 **Andrew Ylvisaker*** (andrewy@iastate.edu), Department of Mathematics, 396 Carver Hall, Iowa State University, Ames, IA 50011, and **Roger D Maddux** (maddux@iastate.edu), Department of Mathematics, 396 Carver Hall, Iowa State University, Ames, IA 50011. *Constructing relation algebras from semiassociative relation algebras.* Preliminary report.

We show how to construct finitely presented semiassociative relation algebras which have quasi-projectional (hence, by Tarski's theorem, representable) relation algebras as definitional reducts. This construction allows new proofs of results by Tarski, Nemeti, and Maddux, e.g., set theory may be coded into the logic of three variables, the equational theory of semiassociative relation algebras is undecidable, and free semiassociative relation algebras are not atomic. The methods and results are directed toward the still unsolved problem of coding set theory into the equational theory of diagonal-free cylindric algebras. (Received December 01, 2009)

1058-06-25 **Fred E.J. Linton*** (flinton@wesleyan.edu), Dept. of Math/CS, Wesleyan University, Middletown, CT 06459. *Portraits of Kuratowski monoid orbits.* Preliminary report.

Some six dozen or so years ago, Kuratowski observed that, given a subset A of a topological space, if one begins with A and repeatedly applies the operations of closure and complement (resp. of closure and interior), as many as 14 (resp. 7) distinct subsets arise, but never more.

From this observation a small cottage industry has arisen, characterizing the cardinalities of these closure-and-complement (resp. closure-and-interior) monoid orbits, and finding minimal cardinalities for the finite spaces capable of realizing them.

In the same vein, we mine the possibilities of classifying the isomorphism types of these orbits as action-sets for the corresponding monoids; and we offer some portraits, in the style of Kerekjarto's famous portrait of Bessel-Hagen, of some of the finite spaces in which they occur. (Received December 01, 2009)

1058-06-29 **Jeremy F Alm*** (alm.academic@gmail.com), 1101 W. College Ave., Jacksonville, IL 62650, and **Aaron Van Winkle**, 1101 W. College Ave., Jacksonville, IL 62650. *Embedding M_ℓ in $Sub(\mathbb{Z}_n \times \mathbb{Z}_n)$.* Preliminary report.

Much work has been devoted to the problem of embedding the lattice M_ℓ as an interval in the subgroup lattice of a group, a difficult and important problem for lattice theory. In this talk, we consider the problem of embedding M_ℓ as a 0-1 sublattice of the subgroup lattice of a group, in particular of the group $\mathbb{Z}_n \times \mathbb{Z}_n$. The interest in this problem is more combinatorial than lattice-theoretic, and is related to the construction of finite projective planes and to the group-representation of relation algebras known as Lyndon algebras. We will characterize the ℓ such that M_ℓ embeds as a 0-1 sublattice of $\mathbb{Z}_n \times \mathbb{Z}_n$ but $M_{\ell+1}$ does not. (Received December 18, 2009)

1058-06-86 **Fusun Akman*** (akmanf@ilstu.edu) and **Papa Amar Sissokho** (psissok@ilstu.edu). *The lattice of finite vector space partitions and its Möbius function.* Preliminary report.

Let $V = V(n, q)$ be the vector space of dimension n over $GF(q)$. A vector space partition of V is a collection of subspaces of V such that every nonzero vector in V is contained in exactly one subspace belonging to this collection. We show that the set of all vector space partitions of V form a poset under refinement, with unique minimum and maximum elements, and introduce a lattice structure on it. Furthermore, we conjecture that the value of the Möbius function of this lattice approaches that of the lattice of set partitions of $\{1, 2, \ldots, n\}$, and that the number of vector space partitions of $V(n, q)$ approaches the number of set partitions of $\{1, 2, \ldots, n\}$, as $q \to 1$. We also compute the Möbius function of the partitions of $V(n, q)$ for small values of n. (Received February 04, 2010)

08 ► General algebraic systems

1058-08-12 **Clifford Bergman*** (cbergman@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011, and **Joel David Berman** (jberman@uic.edu), Department of Mathematics, University of Illinois at Chicago, 851 S Morgan (M/C 249), Chicago, IL 60607-7045. *On fully invariant and verbal congruences.* Preliminary report.

Let $\mathcal{V}$ be a variety and $\mathbf{A}$ an algebra of the same similarity type as $\mathcal{V}$. We define $\lambda_{\mathcal{V}}^{\mathbf{A}}$ to be the smallest congruence, θ, on $\mathbf{A}$ such that $\mathbf{A}/\theta \in \mathcal{V}$. Congruences of this form are called *verbal.* A congruence θ on $\mathbf{A}$ is called *fully invariant* if, for every endomorphism f on $\mathbf{A}$, $(a,b) \in \theta \implies \big(f(a), f(b)\big) \in \theta$.

Every verbal congruence is fully invariant. The converse fails in general. We shall discuss conditions on $\mathcal{V}$ and on $\mathbf{A}$ under which fully invariant congruences must be verbal. (Received November 24, 2009)

1058-08-13 **Jonathan D.H. Smith***, Department of Mathematics, Iowa State University, Ames, IA 50011-2064. *Lambda-rings of automorphisms.*

The set of automorphisms of a single algebra forms a group under composition. This talk considers the full set of all automorphisms of all algebra structures in a given abstract class on a fixed finite set. A lambda-ring, known as the automorphism type ring, is associated with this full set of automorphisms, and its structure is described. For certain classes (such as the variety of lattices), the full set of automorphisms is represented up to conjugation in the symmetric group by the automorphisms of a single, so-called representative algebra. In this case, the automorphism type ring is a subring of the ring of class functions on the automorphism group of the representative algebra. (Received November 28, 2009)

1058-08-14 **Zurab Janelidze*** (zurab@sun.ac.za), Department of Mathematical Sciences, Stellenbosch University, Private Bag X1, Matieland, Stellenbosch, West Cape 7602, South Africa. *Categorical terms for congruence-modularity.* Preliminary report.

The so called *categorical terms* introduced in a recent joint work of Z. Janelidze and D. Bourn, provide on the one hand, a category-theoretic approach to the theme of Mal'tsev conditions in Universal Algebra, and on the other hand, they open a possibility for a universal-algebraic style of treatment of many topics in modern Categorical Algebra. For example, the so called Mal'tsev categories can be characterized via categorical Mal'tsev terms, much in the spirit of the classical characterization of congruence-permutable varieties obtained by A. I. Mal'tsev in 1954 (see [D. Bourn and Z. Janelidze, Approximate Mal'tsev operations, Theory and Applications of Categories 21, 2008, 152-171]). The main goal of the present work is to revisit congruence-modular varieties via the categorical counterparts of Day and Gumm terms characterizing these varieties, and to investigate the connection between the corresponding categorical term condition and Gumm's shifting lemma. (Received November 28, 2009)

1058-08-15 **Joel Berman***, Department of Mathematics, University of Illinois at Chicago, 851 S. Morgan Street, Chicago, IL 60607. *Pattern operations, strict pattern operations, and varieties.* Preliminary report.

For α an equivalence relation on $\{1, ..., n\}$, for $\bar{a} \in A^n$, and $1 \leq k \leq n$ we say $\bar{a}$ has an *α-pattern* if $(i,j) \in \alpha$ implies $a_i = a_j$ and we call (α, k) a *pattern pair.* For $f : A^n \to A$ and Γ a set of pattern pairs, f is a *Γ-pattern operation* if $f(\bar{a}) = a_k$ whenever $\bar{a} \in A^n$ has an α-pattern for an $(\alpha, k) \in \Gamma$.

A set Γ of pattern pairs is *consistent* if at least one Γ-pattern operation exists. A *strict pattern operation* is defined analogously starting from the definition $\bar{a} \in A^n$ has a *strict α-pattern* precisely if $(i,j) \in \alpha$ iff $a_i = a_j$.

Familiar examples of pattern operations include n-ary near-unanimity operations and Mal'cev operations; examples of strict pattern operations are discriminator and dual-discriminator operations.

For a variety $\mathcal{V}$ generated by a set K of algebras, we investigate conditions on K and $\mathcal{V}$ that guarantee for a given n, for every consistent set Γ of [strict] pattern pairs there exists a term t_Γ for which $t_\Gamma^{\mathbf{A}}$ is a [strict] Γ-pattern operation for all $\mathbf{A} \in K$. (Received November 30, 2009)

1058-08-16 **George F. McNulty*** (mcnulty@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *A Dozen Easy Problems.*

What is the computational complexity of deciding whether a finite algebra generates a minimal variety? What is the likelihood that a random finite lattice directly decomposes into an even number of directly indecomposable lattices? Is the algebra $\langle \mathbb{N}, +, \cdot, \binom{n}{k}, !, 0, 1 \rangle$ finitely based? Is it decidable, given a finite lattice $\mathbf{L}$ and a finite algebra $\mathbf{A}$, whether $\mathbf{L}$ can be embedded into the congruence lattice of an algebra belonging to the variety generated by $\mathbf{A}$? What is the Nullstellensatz for free lattices? Which finite automatic algebras are dualizable?

These six untried problems, as well as six well-known old open problems will be discussed. (Received November 30, 2009)

1058-08-20 **Peter Mayr*** (stein@cii.fc.ul.pt), Centro de Algebra de Universidade de Lisboa, Av. Prof. Gama Pinto 2, Lisbon, 1649-003, and **Erhard Aichinger** (erhard@algebra.uni-linz.ac.at), Department of Algebra, JKU Linz, Altenberger Strasse 69, 4040 Linz, Austria. *On finitely related clones.* Preliminary report.

A clone is a collection of finitary functions on a set that contains all projection maps and is closed under composition. If a clone is determined by finitely many invariant relations, we call it finitely related. For example, on a finite set the clones containing a near-unanimity operation are finitely related by the Baker-Pixley Theorem.

In 1999 Pawel Idziak asked whether there exists a finite set with uncountably many clones containing a Mal'cev operation and all constant operations. For proving that the answer is no it would suffice to show that every such clone is finitely related. We report on recent progress on that problem and present some new classes of clones that are finitely related. (Received December 18, 2009)

1058-08-23 **Walter Taylor*** (walter.taylor@colorado.edu), Professor Walter Taylor, University of Colorado, Boulder, CO 80309-0395. *Approximate satisfaction of equations.*

For a topological algebra $\mathbf{A}$ based on a metric space $A = (A, d)$, and for Σ a set of equations, we define $\lambda_{\mathbf{A}}(\Sigma)$ to be the sup of $d(\sigma^{\mathbf{A}}(a), \tau^{\mathbf{A}}(a))$, over all $\sigma \approx \tau \in \Sigma$ and over all assignments a of A-values to variables. Then, for a metric space A, $\lambda_A(\Sigma)$ is defined as the inf of $\lambda_{\mathbf{A}}(\Sigma)$, over all topological algebras on A. $\lambda_A(\Sigma)$ measures how far the equations Σ must deviate from being satisfied on A with continuous operations.

λ_A is not a topological invariant of A, but depends heavily on the metric.

For certain A, such as a closed unit interval, we have: if $\lambda_A(\Gamma \times \Delta) < \varepsilon$, then $\lambda_A(\Gamma) < 4\varepsilon$ or $\lambda_A(\Delta) < 4\varepsilon$. This is an analog to the known result for topological algebras that if $[0, 1]$ models $\Gamma \times \Delta$, then $[0, 1]$ models Γ or $[0, 1]$ models Δ.

Let A be the realization of a finite simplicial complex, and let α be a computable real number. By simplicial approximation, the set of all finite Σ (in a fixed alphabet) such that $\lambda_A(\Sigma) < \alpha$ is recursively enumerable. (Received December 01, 2009)

1058-08-26 **Robert McGrail*** (mcgrail@bard.edu), Bard College, 30 Campus Road, Annandale-on-Hudson, NY 12504, and **James Belk** and **Japheth Wood**. *CSP Dichotomy for Idempotent, Right Quasigroups.*

We prove that if the constraint language for an idempotent, right quasigroup has no associated NP-complete constraint satisfaction problem, then all such constraint satisfaction problems over this constraint language must be tractable. It is known that under the former condition, the variety of this algebra must omit the unary type. We demonstrate that any idempotent, right quasigroup that omits the unary type must satisfy a certain strong connectivity condition. Moreover, this condition enables the construction of a Mal'cev term, which implies that all constraint satisfaction problems over the algebra must be tractable. (Received December 02, 2009)

1058-08-137 **Evelyne Hubert*** (evelyne.hubert@sophia.inria.fr), INRIA, Galaad, 06902 Sophia Antipolis, France. *Algebra of Differential Invariants.*

For a given group action, I give three algorithmic descriptions of the algebra of differential invariants as given by generators and syzygies. The normalized and edge invariants were the focus in the reinterpretation of the moving frame method by Fels & Olver (1999). My contribution here is first to exhibit a set of syzygies for the normalized invariants that can be written down with minimal information on the group action (namely the infinitesimal generators) and show its completeness. Second, I provide the adequate general concept of edge invariants (Olver 2007) and show their generating properties. The syzygies for edge invariants are obtained by applying the algorithms for differential elimination that I generalized to non-commuting derivations.

Another contribution is to exhibit the generating and rewriting properties of Maurer-Cartan invariants. Those have desirable properties from the computational point of view. They are all the more meaningful when one understands that they are the differential invariants that come into play in the moving frame method as practiced by Griffiths (1974) and differential geometers. The syzygies for the Maurer-Cartan invariants naturally follow from the structure equations for the group. (Received February 11, 2010)

11 ► Number theory

1058-11-7 **Byungchan Kim*** (bkim4@illinois.edu), 1409 W. Green St, Urbana, IL 61801, and **Jeremy Rouse** (jarouse@math.uiuc.edu), 1409 W. Green St., Urbana, IL 61801. *Explicit bounds for the number of p-core partitions.*

Let p be a prime number. The generating function for the number of p-core partitions of n is

$$\sum_{n=0}^{\infty} pc_p(n)q^n = \prod_{n=1}^{\infty} \frac{(1-q^{pn})^p}{1-q^n}.$$

We use the theory of modular forms, and the circle method of Hardy and Ramanujan to derive explicit bounds on $pc_p(n)$. As an application, we show Stanton's conjecture is true for small p's. (Received October 04, 2009)

13 ► Commutative rings and algebras

1058-13-49 **Shane P Redmond*** (shane.redmond@eku.edu), 521 Lancaster Ave., 313 Wallace Bldg., Richmond, KY 40475. *Zero-divisors, zero-divisor graphs, and cut vertices.*

Given a commutative ring with identity R, define the zero-divisor graph of R, denoted $\Gamma(R)$, to be the graph whose vertices are the non-zero zero-divisors of R and where there is an edge between vertices x and y if and only if $xy = 0$. Several features of zero-divisor graphs have been studied in the past few years, including the fact that all zero-divisor graphs (as defined here) are connected. A cut vertex of a graph is a vertex such that its removal (along with the incident edges) produces a disconnected graph. This presentation classifies when a zero-divisor graph of a finite commutative ring has a cut vertex in terms of properties of the ring. Further properties of cut vertices in zero-divisor graphs will be investigated. Finally, computations will be presented on the number of zero-divisors in a ring, including the fact that it is not possible to find a commutative ring with identity having exactly n zero-divisors for every natural number n. (Received January 25, 2010)

1058-13-50 **Nicholas R Baeth*** (baeth@ucmo.edu), WCM 213, Department of Mathematics and Computer Scienc, University of Central Missouri, Warrensburg, MO 64064, and **Silvia Saccon**. *Monoids of Modules over Rings with Infinite Representation Type.*

Given a reduced Noetherian local ring $(R, \mathfrak{m})$, $\mathfrak{C}(R)$ denotes the monoid of isomorphism classes of torsion-free R-modules (together with [0]) with operation $[M] + [N] = [M \oplus N]$. If R is complete, then the Krull-Remak-Schmidt property holds; i.e., direct-sum decompositions of finitely generated R-modules are unique. If R is not complete, then properties of the monoid $\mathfrak{C}(R)$ measure how far R is from having the Krull-Remak-Schmidt property. We give descriptions of $\mathfrak{C}(R)$ for local ring-orders with infinite representation type. Under certain hypotheses, we show that for arbitrary positive integers s and t, there exists a torsion-free R-module which can be written as $N_1 \oplus \cdots \oplus N_s \cong L_1 \oplus \cdots \oplus L_t$ for indecomposable torsion-free R-modules N_i and L_j. (Received January 25, 2010)

1058-13-58 **Dan D. Anderson*** (dan-anderson@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242. *Quasi-complete local rings.* Preliminary report.

We discuss quasi-complete local and semilocal rings and modules. Of the many equivalent ways to define a quasi-complete local ring, the simpliest is the following. Let (R,M) be a local (Noetherian) ring. Then R is quasi-complete if each element s in the M-adic completion of R has the form s=ru where r is in R and u is a unit of the completion. (Received January 28, 2010)

1058-13-70 **Jason Laska*** (laska@math.utk.edu), Department of Mathematics, 104 Aconda Court, 1534 Cumberland Avenue, Knoxville, TN 37916. *Non-unique factorization, Cohen-Kaplansky Domains, and the invariant* $\overline{\Lambda}(R)$. Preliminary report.

We investigate some of the conjectures proposed by D.F. Anderson concerning nonunique factorization and the invariant $\overline{\Lambda}(R)$. Let R be an atomic integral domain and $x \in R$. We define $l(x) = \min\{m \mid x = \alpha_1\alpha_2 \ldots \alpha_m\}$ where for each $1 \leq i \leq m$, α_i is an irreducible element of R. Additionally, define $\eta(x)$ as the number of nonassociate irreducible factorizations of x. Then $\overline{\Lambda}(R) = \lim_{n\to\infty} \frac{|\{\eta(x)|l(x)=n\}|}{n}$. Intuitively, $\overline{\Lambda}(R)$ describes the asymptotic behavior of the number of different number of nonassociate irreducible factorizations of elements with minimal length n. We show that if R is a one-dimensional analytically irreducible local FFD, then $\overline{\Lambda}(R) = 0$. (Received February 14, 2010)

1058-13-75 **Benjamin Coté**, **Caroline Ewing**, **Michael Huhn**, **Chelsea M Plaut** and **Darrin Weber*** (dmweber@millikin.edu), 3975 E. Camelot Circle Apt #304, Decatur, IL 62526. *Cut-Vertices and Cut-Sets on Zero-Divisor Graphs.*

We examine minimal sets of vertices which, when removed from a zero-divisor graph, separate the graph into disconnected subgraphs. We classify these sets for all finite commutative rings with identity. (Received February 02, 2010)

1058-13-80 **David E. Dobbs*** (dobbs@math.utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 37996-0614, and **Andrew J. Hetzel**. *Using going-up to characterize going-down domains.*

A (commutative integral) domain R is called an AGU-domain if $R \subseteq T$ satisfies the going-up property whenever T is an algebraic extension domain of R such that the natural map $\mathrm{Spec}(T) \to \mathrm{Spec}(R)$ sends the maximal spectrum $\mathrm{Max}(T)$ onto $\mathrm{Max}(R)$. Any domain of (Krull) dimension 1 is an AGU-domain, as is any absolutely injective (ai-) domain. A quasilocal domain is an AGU-domain if and only if it is a going-down domain. A partial generalization is given for rings with nontrivial zero-divisors. An example is given of a two-dimensional Prüfer (hence going-down) domain with exactly two maximal ideals which is not an AGU-domain. (Received February 03, 2010)

1058-13-84 **Jeremiah N. Reinkoester***, Department of Mathematics, 14 MacLean Hall, Iowa City, IA 52242. $\tau_{[\ ]}$*-UFD's, UCFD's, and CK-domains.* Preliminary report.

Let D be an integral domain. We define a $\tau_{[\ ]}$-atom to be any nonzero, nonunit element a of D with no proper factorization $a = a_1 \cdots a_n$ such that $[a_i, a_j] = 1$ for $i \neq j$. We then define a $\tau_{[\ ]}$-UFD to be an integral domain such that each nonzero, nonunit element a can be uniquely written, up to units, as a product of $\tau_{[\ ]}$-atoms $a = a_1 \cdots a_n$ with $[a_i, a_j] = 1$ for $i \neq j$. We explore the connection between Unique Comaximal Factorization domains (UCFD's) and $\tau_{[\ ]}$-UFD's. We also compare Cohen-Kaplansky domains with $\tau_{[\ ]}$-UFD's. (Received February 04, 2010)

1058-13-99 **Thomas G Lucas*** (tglucas@uncc.edu), Department of Mathematics & Statistics, University of North Carolina Charlotte, Charlotte, NC 28223. *Almost principal ideals in R[x].* Preliminary report.

For an integral domain R, a nonzero ideal I of the polynomial ring $R[x]$ is said to be almost principal if there is a nonconstant polynomial $f(x) \in I$ and a nonzero element $r \in R$ such that $rI \subseteq f(x)R[x]$. If such a pair $f(x)$ and r exists, then $I \cap R = (0)$ and $I \subseteq I_f := f(x)K[x] \cap R[x]$ where K is the quotient field of R. The polynomial ring $R[x]$ is said to be an almost principal ideal domain if each nonzero ideal I of $R[x]$ that contracts to the zero ideal of R is almost principal. It is known that $R[x]$ is an almost principal ideal domain if R is either integrally closed or Noetherian. In the literature, the proofs for these two cases are quite different. One of the main goals here is to provide a proof that takes care of these two cases (and many others) simultaneously. Other domains for which the corresponding polynomial ring is an almost principal ideal domain include all seminormal domains and all domains with the radical trace property. (Received February 08, 2010)

1058-13-153 **Christina Eubanks-Turner*** (ceturner@louisiana.edu), P.O. Box 41010, lafayette, LA 70504, and **Melissa Luckas** and **Serpil Saydam**. *Prime Ideals in Birational Extensions of Two-Dimensional Power Series Rings.*

In this article we describe the prime spectrum, the set of prime ideals, for certain two-dimensional polynomial and power series rings. Our main result is the characterization of those partially ordered sets that arise as prime spectra of simple birational extensions of a power series ring in one indeterminate with coefficients in a Noetherian one-dimensional integral domain that has infinitely many maximal ideals. (Received February 12, 2010)

1058-13-166 **Nicholas Werner*** (werner@math.osu.edu), Department of Mathematics, 231 West 18th Ave, Columbus, OH 43210. *Integer-valued Polynomials on Subsets of a Noncommutative Ring.*

Given an integral domain D with quotient field K and a subset $S \subseteq D$, the set $\mathrm{Int}(S, D) = \{f(x) \in K[x] \mid f(S) \subseteq D\}$ is always a ring. However, if instead we consider a noncommutative ring R contained in a division ring $\mathcal{D}$ and a subset $S \subseteq R$, then the set $\mathrm{Int}(S, R) := \{f(x) \in \mathcal{D}[x] \mid f(S) \subseteq R\}$ may or may not be a ring; it depends on S and R. We will explore this construction in the case of a particular quaterion algebra over $\mathbb{Z}$. (Received February 14, 2010)

1058-13-167 **Peter Vamos** (P.Vamos@exeter.ac.uk), Dept of Mathematics, University of Exeter, Exeter, 68502-4042, England, and **Sylvia M Wiegand*** (swiegand@math.unl.edu), 2400 Sheridan Blvd, Lincoln, NE 68502-4042. *Block diagonal matrices and sums of units over Pruefer domains.*

We discuss when a matrix is equivalent to one with blocks of bounded size along the diagonal over certain Pruefer domains. This is related to the problem of writing a square matrix as a sum of invertible matrices. (Received February 14, 2010)

1058-13-168 **Roger A. Wiegand*** (rwiegand@math.unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130, and **Sylvia M. Wiegand**. *The partially ordered set of prime ideals in a two-dimensional Noetherian domain.* Preliminary report.

Let R be a two-dimensional integral domain that is finitely generated as a $\mathbb{Z}$-algebra. Let $\mathrm{Spec}(R)$ denote the partially ordered set of prime ideals of R. R. Wiegand conjectured 25 years ago that $\mathrm{Spec}(R)$ is order-isomorphic to $\mathrm{Spec}(\mathbb{Z}[X])$. We will survey what is known about this conjecture and discuss some recent progress. (Received February 14, 2010)

1058-13-219 **Jim Coykendall*** (jim.coykendall@ndsu.edu), Department of Mathematics, North Dakota State University, Fargo, ND 58108, and **Chris Spicer** (spicer@morningside.edu), Department of Mathematical Sciences, Morningside College, Sioux City, IA 51106. *On Cohen-Kaplansky Domains.*

A Cohen-Kaplansky (CK) domain is an atomic integral domain that contains only finitely many irreducibles elements (up to associates). We augment the definition by saying that a CK-n domain is a CK domain with precisely n irreducible elements (again, up to associates). One can easily see that for every n a CK-n domain can be constructed by localizing a suitable PID at the set complement of n height-one primes. The more interesting question is "for every n, can a CK-n domain be constructed with n non-prime irreducibles?". We will consider some new constructions of CK domains and show that, given a slight strengthening of the Goldbach Conjecture, the answer to the questions is "yes". (Received February 15, 2010)

1058-13-232 **Ela Celikbas*** (s-ecelikb1@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, 326 Avery Hall, Lincoln, NE 68588, and **Christina Eubanks-Turner** (ceturner@louisiana.edu), Mathematics Department, University of Louisiana at Lafayette, 405 Maxim Doucet, Lafayette, LA 70504. *The Projective Line Over The Integers.* Preliminary report.

We analyze the partially ordered set of prime ideals of the projective line over the integers, denoted by $\mathrm{Proj}(\mathbb{Z}[h,k])$, that is, the prime ideals of $\mathbb{Z}[h,k]$ generated by homogeneous polynomials in the variables h and k over $\mathbb{Z}$ excluding the prime ideals of form (h,k,p), with p a prime integer. In 2002, Meral Arnavut described a property that would complete the characterization of $\mathrm{Proj}(\mathbb{Z}[h,k])$, if it always holds. In this talk we show her property holds in certain cases, and we give some preliminary results towards a characterization of $\mathrm{Proj}(\mathbb{Z}[h,k])$ considered as $\mathrm{Spec}(\mathbb{Z}[x]) \cup \mathrm{Spec}(\mathbb{Z}[\frac{1}{x}])$, where the intersection $\mathrm{Spec}(\mathbb{Z}[x]) \cap \mathrm{Spec}(\mathbb{Z}[\frac{1}{x}])$ is identified with $\mathrm{Spec}(\mathbb{Z}[x, \frac{1}{x}])$. (Received February 15, 2010)

1058-13-240 **Bruce Olberding*** (olberdin@nmsu.edu), Department of Mathematical Sciences, Las Cruces, NM 88003-8001. *Embedding dimension, multiplicity and Cohen-Macaulayness of subintegral extensions of local Noetherian domains.* Preliminary report.

We discuss a class of integrally closed local Noetherian domains S which admit subintegral extensions that although in one sense very remote from S (they are analytically ramified), have a number of features, such as multiplicity and embedding dimension, that can be determined in a tractable way from S. Whether the subintegral extensions are Cohen-Macaulay or Gorenstein can also be determined, as can ideal-specific properties involving Hilbert functions, reduction number and analytic spread. Many of the techniques used to study these rings are non-Noetherian in nature. (Received February 16, 2010)

1058-13-260 **K Alan Loper*** (lopera@math.ohio-state.edu), Department of Mathematics, Ohio State University Newark, 1179 University Drive, Newark, OH 43055. *Topology and integer-valued polynomials on valuation domains.* Preliminary report.

Let V be a valuation domain and S a subset. We investigate the question of conditions on S such that Int(S,V) is a Prufer domain. We make extensive use of Chabert's recent results on polynomial topology. (Received February 16, 2010)

1058-13-264 **Evan Houston*** (eghousto@uncc.edu), Dept. of Mathematics and Statistics, UNC Charlotte, Charlotte, NC 28223, **Abdeslam Mimouni** (amimouni@kfupm.edu.sa), Dept. of Mathematics and Statistics, King Faud University of Petroleum & Minerals, Dhahran, 31261, Saudi Arabia, and **Mi Hee Park** (mhpark@cau.ac.kr), Dept. of Mathematics, Chung-Ang University, Seoul, 156-756, South Korea. *Integral domains which admit only finitely many star operations.* Preliminary report.

We study integral domains which admit only finitely many star operations, paying particular attention to the Noetherian and Prüfer cases. (Received February 16, 2010)

1058-13-270 **Scott T Chapman*** (scott.chapman@shsu.edu), Sam Houston State University, Department of Mathematics and Statistics, Box 2206, Huntsville, TX 77341-2206, and **William W Smith** (wwsmith@email.unc.edu), University of North Carolina at Chapel Hill, Department of Mathematics, Phillips Hall, Chapel Hill, NC 27599-3250. *Erdős-Zaks All Divisor Sets.*

Let $\mathbb{Z}_n$ be the finite cyclic group of order n and $S \subseteq \mathbb{Z}_n$. We examine the factorization properties of the Block Monoid $\mathcal{B}(\mathbb{Z}_n, S)$ when S is constructed using a method inspired by a 1990 paper of Erdős and Zaks. For such a set S, we develop an algorithm in Section 2 to produce and order a set $\{\mathfrak{M}_i\}_{i=1}^{n-1}$ which contains all the non-primary irreducible Blocks (or atoms) of $\mathcal{B}(\mathbb{Z}_n, S)$ and use this set to argue that $\mathcal{B}(\mathbb{Z}_n, S)$ is weakly half-factorial. After developing some basic properties of the set $\{\mathfrak{M}_i\}_{i=1}^{n-1}$, we examine in Section 3 the connection between these irreducible blocks and the Erdős-Zaks notion of "splittable sets." In particular, the Erdős-Zaks notion of "irreducible" does not match the classic notion of "irreducible" for the commutative cancellative monoids $\mathcal{B}(\mathbb{Z}_n, S)$. We close with a detailed discussion of the special properties of the blocks $\mathfrak{M}_1$ with an emphasis on the case where the exponents of $\mathfrak{M}_1$ take on extreme values. (Received February 16, 2010)

1058-13-297 **Ryan E Clark*** (rclark@math.utk.edu), TN. Γ*-rings and their zero-divisor graphs.* Preliminary report.

The notion of Γ-ring, a certain generalization of ring, is defined and some history and examples of the concept are discussed. Next the definitions of zero-divisors and zero-divisor graphs for commutative Γ-rings are given, which generalize the usual definitions for commutative rings. Finally, several theorems are stated which demonstrate some structure of these generalized zero-divisor graphs. (Received February 17, 2010)

14 ► Algebraic geometry

1058-14-63 **Alexander Yong***, Math Dept, 1409 W. Green Street, Urbana, IL 61801, and **Li Li** (llpku@math.uiuc.edu), Math Dept., 1409 W. Green Street, Urbana, IL. *Some degenerations of Kazhdan-Lusztig ideals and multiplicities of Schubert varieties.*

We study Hilbert-Samuel multiplicity for points of Schubert varieties in the complete flag variety, by Groebner degenerations of the Kazhdan-Lusztig ideal. In the covexillary case, we give a positive combinatorial rule for multiplicity by establishing (with a Groebner basis) a reduced and equidimensional limit whose Stanley-Reisner simplicial complex is homeomorphic to a shellable ball or sphere. We show that multiplicity counts the number of facets of this complex. We also obtain a formula for the Hilbert series of the local ring. In particular, our work gives a multiplicity rule for Grassmannian Schubert varieties, providing alternative statements and proofs to formulae of [Lakshmibai-Weyman '90], [Rosenthal-Zelevinsky '01], [Krattenthaler '01], [Kreiman-Lakshmibai '04] and [Woo-Yong '09]. We suggest extensions of our methodology to the general case. (Received January 29, 2010)

1058-14-300 **Andrei Caldararu***, 480 Lincoln Dr., Madison, WI 53706, **Junwu Tu**, WI , and **Damien Calaque**, , France. *A conjecture of Duflo and the Ext algebra of branes.*

The Duflo theorem is a statement in Lie theory which allows us to compute the ring structure of the center of the universal enveloping algebra of a finite-dimensional Lie algebra. A categorical version of it was used by Maxim Kontsevich to give a spectacular proof of the so-called "Theorem on complex manifolds," which computes the multiplicative structure of Hochschild cohomology of a complex manifold in terms of the algebra of polyvector fields. In Lie theory there are also more general Duflo-type statements (mostly conjectural), which study the case of a pair (Lie algebra, Lie subalgebra). I will explain how these translate into conjectures about the multiplicative structure of the Ext-algebra of the structure sheaf of a complex submanifold of a complex manifold, and how from this interaction we can hope to gain new insights into both algebraic geometry and Lie theory. (Received February 17, 2010)

15 ► Linear and multilinear algebra; matrix theory

1058-15-42 **Michael S. Cavers*** (mscavers@gmail.com), Dept. of Mathematics & Statistics, University of Regina, Regina, SK S4S 0A2, Canada. *Preliminary Report on Sets of Inertias for Matrix Patterns.* Preliminary report.

An n by n matrix pattern $\mathcal{A}$ is a matrix with entries in $\{*, +, -, 0\}$. The inertia of a real matrix A is the ordered triple (a_1, a_2, a_3) of nonnegative integers where a_1 (resp. a_2 and a_3) is the number of eigenvalues of A with positive (resp. negative and zero) real part. The inertia of a matrix pattern $\mathcal{A}$ is the set of inertias of real matrices that have pattern $\mathcal{A}$. In this talk, we focus on the problem of finding sets of inertias that a pattern allows. Some techniques that appear in the literature are extended for this problem. (Received January 18, 2010)

1058-15-47 **Richard A Brualdi*** (brualdi@math.wisc.edu), Mathematics Department, 480 Lincoln Drive, University of Wisconsin, Madison, WI 53706. *(0,1)-Matrices and Nonnegative Eigenvalues.* Preliminary report.

We discuss some properties of $(0, 1)$-matrices all of whose eigenvalues are nonnegative. Nonnegativity of eigenvalues is guaranteed if the matrix is totally nonnegative (determinants of all square submatrices are nonnegative). But a $(0, 1)$-matrix all of whose eigenvalues are nonnegative need not be totally nonnegative. (This talk is based on some joint work with S. Kirkland.) (Received January 22, 2010)

1058-15-55 **Amy A Yielding*** (ayielding@eou.edu), Amy Yielding, Eastern Oregon University, One University Blvd, La Grande, OR 97850. *Complex Spectrally Arbitrary Patterns.* Preliminary report.

In this talk we discuss additional irreducible complex spectrally arbitrary zero-nonzero patterns. The discovery of the patterns occurred while studying the subgraphs of directed graphs corresponding to spectrally arbitrary patterns. Inherit cycle structure is forced upon directed graphs corresponding to real spectrally arbitrary patterns, whereas such requirements are lessened for complex spectrally arbitrary patterns. This difference is highlighted in the patterns we study. (Received January 26, 2010)

1058-15-108 **Paul M Terwilliger*** (terwilli@math.wisc.edu), Math Department, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706. *The classification of tridiagonal pairs.*

Let F denote a field and let V denote a vector space over F with finite positive dimension. We consider a pair of linear transformations $A : V \to V$ and $A^* : V \to V$ that satisfy the following conditions: (i) each of A, A^* is diagonalizable; (ii) there exists an ordering $\{V_i\}_{i=0}^d$ of the eigenspaces of A such that $A^*V_i \subseteq V_{i-1} + V_i + V_{i+1}$ for $0 \leq i \leq d$, where $V_{-1} = 0$ and $V_{d+1} = 0$; (iii) there exists an ordering $\{V_i^*\}_{i=0}^\delta$ of the eigenspaces of A^* such that $AV_i^* \subseteq V_{i-1}^* + V_i^* + V_{i+1}^*$ for $0 \leq i \leq \delta$, where $V_{-1}^* = 0$ and $V_{\delta+1}^* = 0$; (iv) there is no subspace W of V such that $AW \subseteq W$, $A^*W \subseteq W$, $W \neq 0$, $W \neq V$. We call such a pair a *tridiagonal pair* on V. We classify up to isomorphism the tridiagonal pairs over an algebraically closed field. We discuss a connection to the orthogonal polynomials from the terminating branch of the Askey-scheme. This is joint work with Tatsuro Ito and Kazumasa Nomura. (Received February 09, 2010)

1058-15-114 **Luz M. DeAlba*** (luz.dealba@drake.edu), 2507 University Avenue, Des Moines, IA 50311. *Connected Graphs with Minimum Skew Rank Equal to Four.*

The minimum skew rank of a simple graph G over the field of real numbers is the smallest possible rank among all real skew-symmetric matrices whose (i, j)-entry (for $i \neq j$) is nonzero whenever $\{i, j\}$ is an edge in G and is zero otherwise. In this presentation we classify those connected acyclic or unicyclic graph that have minimum skew rank equal to four. We also study more general graphs with the same property. (Received February 09, 2010)

1058-15-115 **Shaun M Fallat*** (sfallat@math.uregina.ca), Department of Mathematics and Statistics, Regina, Sask. S4S 0A2, Canada. *Progress on the Graph Complement Conjecture.*

The minimum rank of a discrete graph has been a compelling problem for a number of researchers over the past decade or so. One of the many unresolved questions on this topic is the so-called graph complement conjecture, which grew out of a workshop in 2006. This conjecture essentially asks for a bound on the sum of the minimum of a graph and the minimum rank of its complement. To date the presumed correct bound is two plus the order of the graph. During this talk, I will report on some recent progress on this conjecture and related variants. (Received February 10, 2010)

1058-15-118 **Yi-Fan Chen**, **Hung-Lin Fu** and **In-Jae Kim*** (in-jae.kim@mnsu.edu), 273 Wissink Hall, Mankato, MN 56001, and **Eryn Stehr** and **Brendon Watts**. *On nearly complete bipartite graphs.*

In this talk, spectral properties of a class of bipartite graphs are presented. In addition, using the properties, we list nearly complete bipartite graphs according to their spetral radius. (Received February 10, 2010)

1058-15-130 **Darren D. Row*** (ddrow@iastate.edu). *Results for improving computation of zero forcing number.* Preliminary report.

The zero forcing number of a graph is the minimum size of a zero forcing set. This parameter is useful in the minimum rank/maximum nullity problem as it gives an upper bound to the maximum nullity. Techniques to improve computation of zero forcing number for certain families of graphs are presented. (Received February 11, 2010)

1058-15-136 **Minerva Catral*** (mrcatral@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011, **Leslie Hogben**, Department of Mathematics, Iowa State University, Ames, IA 5001, **D. D. Olesky**, Department of Computer Science, University of Victoria, Victoria, BC V8W 3P6, Canada, and **P. van den Driessche**, Department of Mathematics, University of Victoria, Victoria, BC V8W 3R4. *Sign patterns that require or allow power-positivity.*

A matrix A is power-positive if some positive integer power of A is entrywise positive. A matrix A is eventually positive if A^k is entrywise positive for all sufficiently large integers k. A characterization of sign patterns that require power-positivity is presented. It is also shown that a sign pattern $\mathcal{A}$ allows power-positivity if and only if $\mathcal{A}$ or $-\mathcal{A}$ allows eventual positivity. (Received February 11, 2010)

1058-15-147 **Minerva Catral** (mrcatral@iastate.edu) and **Craig Erickson*** (craig@iastate.edu), Department of Mathematics, 396 Carver Hall, Iowa State University, Ames, IA 50011, and **Leslie Hogben** (lhogben@iastate.edu), **D. D. Olesky** (dolesky@cs.uvic.ca) and **P. van den Driessche** (pvdd@math.uvic.ca). *Strongly Eventually Nonnegative Matrices.* Preliminary report.

A matrix is called eventually nonnegative (positive) if there exists a positive integer m such that A^k is entry-wise nonnegative (positive) for all $k \geq m$. A matrix is nilpotent if $A^k = O$ for some positive integer k. The study of eventually nonnegative matrices and connections to Perron-Frobenius theory is hindered by nilpotent matrices and matrices which have powers that are reducible with a nilpotent diagonal block. This talk introduces a new class of eventually nonnegative matrices (which we call strongly eventually nonnegative) in order to avoid these issues with nilpotence. We also introduce a generalization of the Perron-Frobenius property in an attempt to extend results on eventually positive matrices to strongly eventually nonnegative matrices. We also characterize the relationships between different classes of eventually nonnegative matrices. (Received February 12, 2010)

1058-15-163 **Sivaram K. Narayan*** (sivaram.narayan@cmich.edu), Department of Mathematics, Pearce Hall 218, Central Michigan University, Mount Pleasant, MI 48859. *Lower Bounds in Minimum Rank Problems.*

The minimum rank of a graph is the smallest possible rank among all real symmetric matrices with the given graph. The minimum semidefinite rank of a graph is the minimum rank among Hermitian positive semidefinite matrices with the given graph. We explore connections between OS-sets and a lower bound for minimum rank related to zero forcing sets as well as exhibit graphs for which the difference between the minimum semidefinite rank and these lower bounds can be arbitrarily large.

This is a joint work with Lon Mitchell and Andrew Zimmer. (Received February 13, 2010)

1058-15-174 **Francesco Barioli**, **Shaun M Fallat**, **Lon H Mitchell*** (lmitchell2@vcu.edu) and **Sivaram K Narayan**. *Minimum Semidefinite Rank of Outerplanar Graphs.*

Following the work of John Sinkovic relating the minimum rank of an outerplanar graph to its path cover number, we are able to completely determine the minimum semidefinite rank of outerplanar graphs by considering coverings by trees. (Received February 14, 2010)

1058-15-210 **Louis A Deaett*** (deaett@math.uvic.ca), Dept of Mathematics and Statistics, University of Victoria, P.O. Box 3060 STN CSC, Victoria, BC V8X 2R9, Canada. *Minimum semidefinite rank and the Heawood graph.*

Assign vectors to the points and lines of the Fano plane such that a point is on a line if and only if the corresponding vectors are not orthogonal. This forms an *orthogonal representation* for the incidence graph of

the Fano plane, i.e. the Heawood graph. We investigate the smallest number of dimensions in which such a representation exists. (Received February 15, 2010)

1058-15-214 **Judith J. McDonald*** (jmcdonald@math.wsu.edu), Dept. Of Math, Box 643113, Pullman, WA 99164-3113, and **Jeff Stuart**. *Spectrally Arbitrary Ray Patterns.*

An nxn zero-nonzero, sign, or ray pattern over a given field is said to be spectrally arbitrary over that field if any monic n-th degree polynomial from that field can be realized as the characteristic polynomial of a matrix with entries from the field, so that the matrix realization matches the given pattern. In this talk we will look at spectrally arbitrary ray patterns over the field of complex numbers. (Received February 15, 2010)

1058-15-218 **Ali Godjali*** (godjali@math.wisc.edu), Department of Mathematics, Van Vleck Hall, 480 Lincoln Drive, Madison, WI 53706. *Thin Hessenberg Pairs of Linear Transformations.*

We will discuss a linear algebraic object called a thin Hessenberg pair (or TH pair). Roughly speaking, this is a pair of diagonalizable linear transformations on a nonzero finite-dimensional vector space such that each of which has eigenspaces all of dimension one and each of which acts on the eigenspaces of the other in a certain restricted way.

Given a TH pair, we display several bases for the underlying vector space, with respect to which the matrices representing the pair we find attractive. We give these matrices along with the transition matrices relating the bases. We introduce an "oriented" version of a TH pair called a TH system. We classify the TH systems up to isomorphism. (Received February 15, 2010)

1058-15-242 **Jason Grout*** (jason.grout@drake.edu), Department of Math and Computer Science, Drake University, 2507 University Avenue, Des Moines, IA 50311, and **Laura DeLoss**, **Leslie Hogben**, **Tracy McKay**, **Jason Smith**, **Geoff Tims**, **H. Tracy Hall** and **Josh Lagrange**. *Computation of Minimum Rank.*

We will describe some results and algorithms used to compute bounds on minimum rank using a computer, including a new algorithm for computing zero forcing sets. These algorithms and results will be implemented in Sage (http://www.sagemath.org) and will be freely available. (Received February 16, 2010)

1058-15-245 **Mark Kempton*** (mark.kempton@gmail.com), 1990 South 50 East, Orem, UT 84058. *Minimum Rank of Outerplanar Graphs.* Preliminary report.

Given a graph $G = (V, E)$ we define $\mathcal{S}(G)$ to be the set of symmetric matrices associated with G whose zero-nonzero pattern is given by the edges of the graph. The problem of finding the minimum rank of all such matrices has grown in interest recently. It is well known that the minimum rank of any graph is bounded above by the *clique cover number*, the minimum number of cliques needed to cover all edges of the graph. In many cases, the minimum rank is equal to the clique cover number. We generalize the idea of the clique cover number to covers using a few basic graphs whose minimum rank is known, and give a solution to the minimum rank problem for outerplanar graphs in terms of these subgraph cover numbers. A consequence of this result is that the minimum rank of an outerplanar graph is independent of the field from which the entries of the matrices are taken. (Received February 16, 2010)

1058-15-275 **Elizabeth J. Bodine*** (ebodine@math.wsu.edu), Department of Mathematics, P.O. Box 643113, Pullman, WA 99164-3113, and **Judith J. McDonald**. *Spectrally arbitrary patterns over finite fields.*

In this talk, we will explore zero-nonzero patterns that are spectrally arbitrary over finite fields. In particular, we will examine patterns that illustrate fundamental differences in the algebraic structure of different fields. (Received February 16, 2010)

1058-15-285 **John Sinkovic*** (johnsinkovic@gmail.com) and **Mark Kempton** (mark.kempton@gmail.com). *The Minimum Rank Problem for Outerplanar Graphs.* Preliminary report.

Given a simple graph $G = (V, E)$ on n vertices and a field F, let $S^F(G)$ equal the set of symmetric $n \times n$ F-valued matrices A such that $a_{ij} \neq 0$ iff $ij \in E$, $i \neq j$. The minimum rank of a graph G over F is equal to $\min\{\text{rank}(A) | A \in S^F(G)\}$. The minimum rank problem of a simple graph G over a field F is to determine the minimum rank of a matrix in $S^F(G)$. The inverse inertia problem of a simple graph G asks which inertias can be obtained by matrices in $S^{\mathbb{R}}(G)$.

A cover for a graph G is a collection of subgraphs of G such that every edge and vertex of G lie in at least one of the subgraphs in the collection. A graph G is outerplanar if there exists a planar drawing of G such that every vertex lies on the outer face of G. We discuss previous results concerning outerplanar graphs and

show that every outerplanar graph G has a clique, star, cycle cover such that the sum of the minimum ranks of the graphs in the cover is equal to the minimum rank of G. We discuss corollaries to this result which have implications for determining the positive semi-definite minimum rank and the inertia of an outerplanar graph. (Received February 16, 2010)

16 ► Associative rings and algebras

1058-16-43 **Liping Li*** (lixxx480@math.umn.edu), VinH 504, 206 Church St. S.E., Minneapolis, MN 55455. *Representation Types of Finite EI-Categories.*

The notion "finite EI categories" generalize many well-known structures such as finite groups, finite posets, etc. In this talk we introduce the representation theory of fInite EI categories and try to classify their representation types by constructing and studying their Auslander-Reiten Quivers. Some results for categories with 2 objects are described. (Received January 20, 2010)

1058-16-110 **Silvia Montarani*** (silvia.montarani@utoronto.ca), Department of Mathematics, University of Toronto, 40 St. George St., Bahen Centre Room 6290, Toronto, Ontario M5S 2E4, Canada. *Representations of Gan-Ginzburg algebras and quiver-related differential operators.* Preliminary report.

Gan-Ginzburg algebras are one-parameter deformations of the wreath product of a symmetric group with a deformed preprojective algebra of a quiver. When the quiver is extended Dynkin, these algebras are related by a Morita equivalence to the symplectic reflection algebras of Etingof and Ginzburg, which are analogs of Hecke algebras of double affine type. We will explain how to construct representations of a Gan-Ginzburg algebra starting from modules over the algebra of differential operators on a space of representations of the corresponding quiver. (Received February 09, 2010)

1058-16-116 **Nicole J. Snashall*** (njs5@mcs.le.ac.uk), Department of Mathematics, University of Leicester, University Road, Leicester, LE1 7RH, England. *Koszul self-injective algebras and their deformations.*

Koszul self-injective algebras play an important part in many aspects of the representation theory of algebras. In this talk we consider a class of such algebras which arise in the representation theory of $U_q(sl_2)$, in the Drinfeld double of generalized Taft algebras, in the study of Hopf algebras associated to infinitesimal groups and as quantum complete intersections. We describe the structure of the Hochschild cohomology ring of these algebras and their formal deformations. (Received February 10, 2010)

1058-16-144 **Anne V. Shepler** and **Sarah Witherspoon*** (sjw@math.tamu.edu), Department of Mathematics, College Station, TX 77843. *Graded Hecke algebras and deformations of crossed products.*

A crossed product of an algebra with a group of automorphisms encodes the group action in a larger algebra. In case the group acts on a polynomial ring, deformations of the crossed product include graded Hecke algebras, symplectic reflection algebras, and rational Cherednik algebras. In order to understand these deformations in a wider context, we give some results on the Gerstenhaber bracket on Hochschild cohomology of the crossed product; this bracket encodes obstructions to deforming the algebra. (Received February 12, 2010)

1058-16-177 **Tatyana S Chmutova*** (chmutova@umich.edu), University of Michigan, Department of Mathematics, 530 Church St, Ann Arbor, MI 48109. *Twisted symplectic reflection algebras.*

Given a finite group G, its symplectic representation U, and a two-cocycle ψ we will define a twisted symplectic reflection algebra. We will consider the case of noninjective U and show that it can be reduced to the injective case. In this reduction the cocycle ψ might become nontrivial even if at the beginning it was trivial. (Received February 14, 2010)

1058-16-183 **Sibylle Schroll***, Department of Mathematics, University of Leicester, LE1 7RH, UK. *From Hecke Algebras to Brauer Graph Algebras.*

Hecke algebras of finite and tame representation type can be represented as Brauer graph algebras. In this talk we will show how they fit into a larger family of Brauer graph algebras. We then give a classification up to derived equivalence of all Koszul Brauer graph algebras and present the structure of the Hochschild cohomology groups of the different families. (Received February 15, 2010)

1058-16-203 **Akaki Tikaradze***, Department of Mathematics, University of Toledo, 2801 W Bancroft avenue, Toledo, OH 43606. *Representations of Infinitesimal Hecke algebras in positive characteristic.* Preliminary report.

In this talk I will consider representations of a class of almost commutative algebras in positive characteristic, which includes some infinitesimal Hecke algebras and spherical subalgebras of symplectic reflection algebras. Connections between dimensions of irreducible representations and the geometry of the center will be emphasized. (Received February 15, 2010)

1058-16-215 **Zajj B Daugherty*** (daughert@math.wisc.edu), Dept of Mathematics, Van Vleck Hall, 480 Lincoln Dr, Madison, WI 53706. *The degenerate two-boundary Hecke algebra.* Preliminary report.

We study algebras similar to the group algebra of the symmetric group, the Brauer algebras, and the graded Hecke algebra of type A. In particular, we investigate algebras of operators which commute with the action of $\mathfrak{sl}_n$ and $\mathfrak{gl}_n$ on tensor space of the form $M \otimes N \otimes L(\omega_1)^{\otimes k}$. We use combinatorial techniques to explore the structure and representation theory of these algebras, concentrating on cases where M and N are finite dimensional modules indexed by rectangular partitions. These examples yield beautiful structure and mimic that of type C objects. (Received February 15, 2010)

1058-16-248 **Calin Ioan Chindris*** (cchindri@math.uiowa.edu). *Exceptional sequences and rational invariants for quivers.*

An orthogonal exceptional sequence of a quiver Q can be thought of as a sequence of roots of Q that satisfy certain homological conditions. In this talk, I will introduce this type of sequences, and then explain how they can be used to prove the rationality of the fields of rational invariants for tame quivers. (Received February 16, 2010)

1058-16-251 **Frederick M. Goodman*** (goodman@math.uiowa.edu), Department of Mathematics MLH, University of Iowa, Iowa City, IA , and **John Graber** (jgraber@bethelks.edu), Bethel College, North Newton, KS. *Cellularity and the Jones basic construction.*

We establish a framework for cellularity of algebras related to the Jones basic construction. Our framework allows a uniform proof of cellularity of Brauer algebras, ordinary and cyclotomic BMW algebras, and others. Our cellular bases are labeled by paths on certain branching diagrams rather than by tangles, and may be regarded as analogues of the Murphy basis of the Hecke algebra.

It is built into our construction that the cellular structures are compatible with restriction and induction of modules. In examples, it is often easy to handle Jucys–Murphy like element within our framework, although the framework does not automatically produce such elements. (Received February 16, 2010)

1058-16-271 **Rosa C Orellana*** (rosa.c.orellana@dartmouth.edu), Dartmouth College, Mathematics Department, 6188 Kemeny Hall, Hanover, NH 03755. *Hecke Algebras and Markov traces.*

Hecke algebras and BMW algebras are related to quantum groups of type A and type B respectively. Using this relation one can define and obtain formulas for Markov traces on these algebras. For Hecke algebras Markov traces yield invariants of knots.

In this talk I will discuss the connection between these algebras and the quantum groups as well as the method of obtaining the Markov traces. We will then proceed to show further generalizations. (Received February 16, 2010)

1058-16-276 **Apoorva Khare*** (apoorva.khare@yale.edu), 10 Hillhouse Avenue, Department of Mathematics, New Haven, CT 06511. *Infinitesimal Hecke algebras.*

Infinitesimal Hecke algebras are deformations of non-semisimple Lie algebras, that share many common properties with semisimple Lie algebras, including concerning their centers and their characters, primitive ideals, symplectic leaves, and quantum analogues. We survey some of the results concerning their structure and representation theory. (Received February 16, 2010)

1058-16-288 **Cathy Kriloff*** (krilcath@isu.edu), Department of Mathematics, Idaho State University, 921 S. 8th Ave., Stop 8085, Pocatello, ID 83209-8085, and **Yu Chen**. *Unitary representations of the graded Hecke algebra of type H_3.* Preliminary report.

Barbasch and Ciubotaru have described unitary representations for (crystallographic) graded Hecke algebras of classical and exceptional types, motivated by an interest in spherical unitary representations of real Lie groups. We report on progress in our description and methods of understanding the support of unitary representations of the noncrystallographic graded Hecke algebra of type H_3. Although this algebra is not associated to a Lie group,

its representations are of interest as representation theory expands to algebras associated to complex reflection groups. (Received February 16, 2010)

1058-16-294 **Emanuel I Stoica*** (immanuel@math.mit.edu), 77 Massachusetts Ave, 2-089, Cambridge, MA 02139. *Unitary Representations of Rational Cherednik Algebras and Hecke Algebras.*

In this talk I will explain the classification of unitary irreducible representations in the highest weight category of the rational Cherednik algebra of the symmetric group and how unitarity is preserved by the KZ functor, that maps highest weight modules to modules over the corresponding Hecke algebra. (Received February 16, 2010)

17 ► Nonassociative rings and algebras

1058-17-120 **Irfan Bagci*** (irfan@math.ucr.edu), Department of Mathematics, University of California at Riverside, Riverside, CA 92521. *On cohomology and support varieties for Lie superalgebras.*

We discuss finite generation of the relative cohomology rings for Lie superalgebras. We formulate a definition for detecting subalgebras and also discuss realizability of support varieties. As an application we compute the relative cohomology ring of the Lie superalgebra S(n) relative to the graded zero component $S(n)_0$ and show that this ring is finitely generated. We also compute support varieties of all simple modules in the category of finite dimensional S(n)-modules which are completely reducible over $S(n)_0$. (Received February 10, 2010)

1058-17-149 **Kenyon J Platt*** (platt@math.byu.edu), 310 TMCB, Department of Mathematics, Brigham Young University, Provo, UT 84602, and **Bobbe J Cooper**. *Nilpotent Orbit Theory and Infinitesimal Blocks of the Parabolic Category $\mathcal{O}_S$.* Preliminary report.

Let $\mathfrak{g}$ be a simple Lie algebra over the complex numbers. In the early 1980's, A. Rocha-Caridi introduced the parabolic category $\mathcal{O}_S$ of $\mathfrak{g}$-modules, which generalized the BGG category $\mathcal{O}$. Category $\mathcal{O}_S$ decomposes into subcategories containing only finitely many simple $\mathfrak{g}$-modules, called *infinitesimal blocks* of $\mathcal{O}_S$. The classification of these infinitesimal blocks in terms of the cardinality of the indecomposable modules has been ongoing since 2001. In joint work with B. Cooper, I present a conjecture for the complete classification of the infinitesimal blocks of $\mathcal{O}_S$ in terms of the nilpotent orbits of $\mathfrak{g}$. I will also present compelling evidence in favor of the conjecture. (Received February 12, 2010)

1058-17-198 **Audrey Malagon*** (malagon_al@mercer.edu), Dept. of Mathematics, Mercer University, 1400 Coleman Ave., Macon, GA 31207. *Killing Forms of Isotropic Lie Algebras.*

This paper presents a method for computing the Killing form, a quadratic form invariant, of an isotropic Lie algebra defined over an arbitrary field. The method is based on the Killing form of a subalgebra containing its anisotropic kernel. This approach allows for streamlined formulas for many exceptional Lie algebras of inner and outer type E6 and type E7 and yields a unified formula for all Lie algebras of inner type E6, including the anisotropic ones. (Received February 15, 2010)

1058-17-228 **Noah J Snyder*** (nsnyder@gmail.com). *How to recognize $U_q(\mathfrak{g}_2)$ or S_t.*

Suppose someone hands you a modular category, how do you identify whether it's an example you already knew about? One technique is to find a "small" simple object X such that $X \otimes X$ does not have too many summands. Then, following Kazhdan, Tuba, and Wenzl, you can use techniques inspired by knot theory to prove that your category must come from one of the classical quantum groups. In this talk I'll prove a similar result about G_2 extending techniques of Kuperberg. Along the way we will also see Deligne's category S_t appear. (Received February 15, 2010)

18 ► Category theory; homological algebra

1058-18-3 **Peter Webb***, University of Minnesota, School of Mathematics, 206 Church Street SE, Minneapolis, MN 55455-0100. *Representations and cohomology of categories.*

Many of the standard properties of group representations are also valid for representations of categories (which include representations of groups, of posets and of quivers). I will introduce the basic notions and then survey several areas of recent development including the Schur multiplier and central extensions of categories, Xu's counterexample to the Snashall-Solberg conjecture, and stratification of category representations and a reformulation of Alperin's weight conjecture. (Received April 22, 2009)

1058-18-122 **Nathan Geer** and **Jonathan Kujawa*** (kujawa@math.ou.edu), Dept. of Mathematics, PHSC, University of Oklahoma, Norman, OK 73019, and **Bertrand Patureau-Mirand**, Dept. of Mathematics, Universite de Bretagne-Sud, Vann. *Generalized Trace and Dimension Functions in Ribbon Categories.*

Ribbon categories are ubiquitous in representation theory. They appear as the finite dimensional representations of groups, Lie (super)algebras, and quantum (super)groups. An essential tool in studying these categories is the trace of an endomorphism and the dimension of ob ject. Using low dimensional topology we generalize these notions and prove that these functions provide new insights into representation theory. (Received February 10, 2010)

1058-18-159 **Junwu Tu*** (tu@math.wisc.edu), 505 Apt B Eagle Heights, Madison, WI 53705. *Hochschild invariants for curved algebras and Landau-Ginzburg models.*

We compute the Hochschild (co)homology of A_∞ algebras that appear in the study of matrix factorizations, as well as in the theory of Landau-Ginzburg models from physics. We find that these groups are trivial, contradicting predictions by physicists. To correct this we introduce a modification of Hochschild theory which is better suited for curved A_∞ algebras. The new invariants are in the same relationship to the old ones as compactly supported homology and Borel-Moore homology are to ordinary homology and cohomology. We compute the new invariants, arriving at the answers predicted by physics. We also present similar calculations for the case of graded matrix factorizations. (Received February 14, 2010)

1058-18-222 **Jens Fjelstad*** (jens.fjelstad@kau.se), Karlstad University, Universitetsgatan 2, 65188 Karlstad, Sweden. *Some properties of quantum representations of mapping class groups.* Preliminary report.

I will discuss two properties of the projective representations of mapping class groups provided by a TQFT based on the modular category $\mathcal{C}$.

(i) Techniques developed to describe two-dimensional rational conformal field theory can be used to construct self intertwiners of quantum representations, providing reducibility criteria formulated in terms of $\mathcal{C}$.

(ii) Invertible objects in $\mathcal{C}$ can be used to construct finite Heisenberg groups acting on quantum representations generalizing the situation in abelian theories and $\mathfrak{su}(2)$ theories where, for even levels, it implies a spin decomposition. (Received February 16, 2010)

1058-18-230 **Caroline B. Wright*** (cwright@math.arizona.edu), Department of Math University of Arizona, 617 N. Santa Rita Ave., P.O. Box 210089, Tucson, AZ 85721. *Computing Lie Algebra Cohomology for $p = 2$.* Preliminary report.

Title: Computing Lie algebra Cohomology for $p = 2$

Abstract: Let G be a simple simply connected affine algebraic group scheme defined over an algebraically closed field k of characteristic p, B be a Borel subgroup of G, and U be the unipotent radical of B. Let $\mathfrak{u} = \mathrm{Lie}(U)$. Let $F : G \to G$ be the Frobenius map and G_1 (respectively B_1, U_1) be the Frobenius kernel of G (respectively B, U). In my PhD thesis I computed $\mathrm{H}^2(U_1, k)$ when $p = 2$.

In this talk I will present how to compute the ordinary Lie algebra cohomology, $\mathrm{H}^2(\mathfrak{u}, k)$ from the restricted Lie algebra cohomology, $\mathrm{H}^2(U_1, k)$, specifically for the case when $p = 2$. (Received February 15, 2010)

20 ► Group theory and generalizations

1058-20-113 **Hendryk Pfeiffer*** (pfeiffer@math.ubc.ca), Department of Mathematics, The University of British Columbia, 121-1984 Mathematics Road, Vancouver, BC V6T 1Z2, Canada. *Fusion categories in terms of graphs and relations.*

Every fusion category $\mathcal{C}$ that is k-linear over a suitable field k, is the category of finite-dimensional comodules of a Weak Hopf Algebra H over k, the universal coend with respect to the long canonical functor $\omega\colon \mathcal{C} \to \mathbf{Vect}_k$. We show that H is a quotient $H = H[\mathcal{G}]/I$ of a Weak Bialgebra $H[\mathcal{G}]$ which has a combinatorial description in terms of a finite directed graph $\mathcal{G}$ that depends on the choice of a generator M of $\mathcal{C}$ and on the fusion coefficients of $\mathcal{C}$. The algebra underlying $H[\mathcal{G}]$ is the path algebra of the quiver $\mathcal{G} \times \mathcal{G}$, and so the composability of paths in $\mathcal{G}$ parameterizes the truncation of the tensor product of $\mathcal{C}$. The ideal I is generated by two types of relations. The first type enforces that the tensor powers of the generator M have the appropriate endomorphism algebras, thus providing a Schur–Weyl dual description of $\mathcal{C}$. If $\mathcal{C}$ is braided, this includes relations of the form '$RTT = TTR$'

where R contains the coefficients of the braiding on $\omega M \otimes \omega M$. The second type of relations removes a suitable set of group-like elements. (Received February 09, 2010)

1058-20-126 **Pramod N Achar*** (pramod@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Green functions via hyperbolic localization.* Preliminary report.

Green functions are certain polynomials that arise in the character theory of finite groups of Lie type and (following Kriloff-Ram) are closely related to the representation theory of graded Hecke algebras. The key fact for calculations is that they satisfy a certain matrix equation. I will describe a new proof of this matrix equation using Braden's hyperbolic localization functor. This approach also leads to a description of the derived category of the nilpotent cone in terms of dg-modules over the coinvariant algebra of the Weyl group. (Received February 10, 2010)

1058-20-131 **Michael W. Hero**, **Lauren Kelly Williams** and **Jeb F. Willenbring*** (jw@uwm.edu), University of Wisconsin - Milwaukee, Department of Mathematical Sciences, P. O. Box 0413, Milwaukee, WI 53201-0413. *The measurement of quantum entanglement and enumeration of graph coverings.* Preliminary report.

We provide formulas for polynomial invariants on a tensor product of defining representations of unitary groups, $U(n_1) \times \cdots \times U(n_r)$, when viewed as a real vector space. This situation has a physical interpretation, as it is the quantum analog of an r-particle classical system in which the i-th particle has n_i classical outcomes upon observation. We provide a graphical interpretation of the dimension of the polynomial invariants of a fixed degree. Specifically, we exhibit a bijection between isomorphism classes of m-fold coverings of connected simple graphs and a conjectural basis for the space of degree $2m$-polynomial invariants. The graph coverings are related to branched coverings of surfaces. (Received February 11, 2010)

1058-20-141 **David A Jordan*** (djordan@mit.edu), 405 South Huntington Ave 1R, Jamaica Plain, MA 02130. *Quantum D-modules and the DAHA.*

We describe a technique for constructing representations of the double affine Hecke algebra of type A_n from a D-module on the quantum group $U_q(gl_N)$, $(n, N \in N)$, which may be considered a higher genus analog of q-Schur-Weyl duality. Time permitting, we will discuss more recent constructions with Xiaoguang Ma, extending to root systems of type B and C. (Received February 11, 2010)

1058-20-169 **Christopher M. Drupieski*** (cdrup@math.uga.edu), Department of Mathematics, University of Georgia, Boyd Graduate Studies Research Center, Athens, GA 30602-7403, and **Daniel K. Nakano** and **Nham Ngo**. *Cohomology rings of infinitesimal unipotent algebraic and quantum groups.* Preliminary report.

Let G be a simple, simply-connected algebraic group over an algebraically closed field k of characteristic $p > 0$, B a Borel subgroup of G, and U the unipotent radical of B. Let U_1 be the first Frobenius kernel of U, and $\mathfrak{u}$ the Lie algebra of U. Friedlander and Parshall observed that for large p, there exists a filtration on the cohomology ring $\mathrm{H}^*(U_1, k)$ such that the associated graded ring is isomorphic to $S(\mathfrak{u}^*) \otimes \mathrm{H}^*(\mathfrak{u}, k)$, a polynomial ring tensored with the ordinary Lie algebra cohomology of $\mathfrak{u}$. In this talk I will discuss how, for sufficiently large p, this ring isomorphism can be lifted to $\mathrm{H}^*(U_1, k)$. This result makes critical use of Kostant's theorem for Lie algebra cohomology. I will also discuss how similar cohomology ring calculations can be carried out for quantum groups. (Received February 14, 2010)

1058-20-188 **Christopher P. Bendel**, **Daniel K. Nakano** and **Cornelius Pillen*** (pillen@jaguar1.usouthal.edu), Department of Mathematics and Statistics, University of South Alabama, Mobile, AL 36688. *Cohomology of Finite Groups of Lie Type.* Preliminary report.

A long-standing open problem of major interest for algebraists and topologists has been to determine the cohomology rings of finite groups of Lie type in the so-called defining characteristic. Little is known in general about these rings. Being far from well-understood, the cohomologies of the corresponding Lie algebras and Frobenius kernels, nevertheless, are better understood theories that can be used as a tool for investigations into the cohomology rings of finite groups. Recently developed methods and techniques in linking these theories will be presented. (Received February 15, 2010)

1058-20-200 **Stephen Doty*** (doty@math.luc.edu), Department of Mathematics and Statistics, Loyola University Chicago, Chicago, IL 60626. *Factoring tilting modules for algebraic groups.*

Let G be a semisimple, simply-connected algebraic group over an algebraically closed field of characteristic $p > 0$. We observe that the tensor product of the Steinberg module with a minuscule module is always indecomposable tilting. Although quite easy to prove, this fact does not seem to have been observed before. It has the following consequence: If a given tilting module has highest weight p-adically close to the r-th Steinberg weight, then the tilting module is isomorphic to a tensor product of two simple modules, usually in many ways. (Received February 15, 2010)

1058-20-206 **Brian Parshall*** (bjp8w@virginia.edu), Dept. of Mathematics, University of Virginia, Charlottesville, VA 22903, and **Leonard Scott** (lls2l@virginia.edu), Dept. of Mathematics, University of Virignia, Charlottesville, VA 22903. *Complexity of Kazhdan-Lusztig polynomials and Koszul structures.* Preliminary report.

Let $\mathfrak{g}$ be a semisimple, complex Lie algebra, and let $U_\zeta = U_\zeta(\mathfrak{g})$ be the associated (Lusztig) quantum enveloping algebra at an lth root of unity. Assume $l > h$, the Coxeter number of $\mathfrak{g}$, and that l is odd and prime to 3 if $\mathfrak{g}$ has a component of type G_2. For a dominant weight λ, let $L_\zeta(\lambda)$ be the irreducible, integrable, type 1 U_ζ-module of highest weight λ. For a fixed l-regular dominant weight λ, the sequence $\{\sum_\nu \operatorname{Ext}^n_{U_\zeta}(L_\zeta(\lambda), L_\zeta(\nu))\}_n$ has exponential growth. However, for arbitrary regular λ, ν, the sequence $\{\operatorname{Ext}^n_{U_\zeta}(L_\zeta(\lambda), L_\zeta(\nu))\}_n$ has polynomial growth in n. In this way, a complexity theory for U_ζ can be developed. This work is closely related to the theory of Kazhdan-Lusztig polynomials and to the authors' recent theorem stating that the Yoneda-algebra (without identity) $\mathbb{E} := \bigoplus_{\lambda,\nu \text{ reg}} \operatorname{Ext}^\bullet_{U_\zeta}(L_\zeta(\lambda), L_\zeta(\nu))$ is "locally Koszul," i. e., for idempotents e corresponding to saturated sets of weights, $e\mathbb{E}e$ is a finite dimensional Koszul algebra. (Received February 15, 2010)

1058-20-241 **Elizabeth T Beazley*** (ebeazley@umich.edu), 530 Church Street, 2074 East Hall, Ann Arbor, MI 48109. *Non-emptiness for affine Deligne-Lusztig varieties associated to dominant Weyl chambers.*

Affine Deligne-Lusztig varieties can be thought of as the affine analog of classical Deligne-Lusztig varieties, or Frobenius-twisted analogs of Schubert varieties. We will discuss affine Deligne-Lusztig varieties inside the affine flag variety and survey known results. We then provide a method for proving that non-emptiness holds whenever it is conjectured to do so for affine Deligne-Lusztig varieties associated to alcoves in the dominant Weyl chamber. Our technique involves the work of Geck and Pfeiffer on cuspidal conjugacy classees and elements of minimal length inside their conjugacy classes in finite Weyl groups. (Received February 16, 2010)

1058-20-263 **Leonard L Scott*** (lls2l@virginia.edu), Kerchof Hall, Cabell Drive, Charlottesville, VA 22903. *Ext and Donkin's tilting module conjecture.*

I will discuss recent work with Brian Parshall bounding dimensions of higher Ext groups for semisimple algebraic groups G with irreducible coefficients. In treating the small prime cases, we prove and use a stable version of a tilting module conjecture of Donkin, regarding G-module structures on injective modules for the restricted Lie algebra. In particular a direct sum of a finite number of copies of such a module with itself has a compatible G-structure. (Received February 16, 2010)

1058-20-291 **Lizhen Ji** and **Zongzhu Lin*** (zlin@math.ksu.edu), Department of Mathematics, Kansas State University, Manhattan, KS 66503. *Finite generation of cohomology rings for classes of infinite groups.*

For a finite group G, the cohomology ring with coefficient in a Noetherian commutative ring is always Noetherian. In this talk, I will discuss the same results for classes of infinite groups. These infinite groups appear in many interesting geometric and topological contexts. (Received February 16, 2010)

22 ► Topological groups, Lie groups

1058-22-73 **Dan Ciubotaru*** (ciubo@math.utah.edu), Department of Mathematics, University of Utah, 155 S 1400 E, Salt Lake City, UT 84112. *Functors for unitary representations of real groups and affine Hecke algebras.*

This talk is based on joint work with Peter Trapa. We define exact functors between certain subcategories of Harish-Chandra modules for real classical groups and categories of modules over affine graded Hecke algebras, and we study their behaviour with respect to irreducible, Hermitian, and unitary modules. (Received February 02, 2010)

1058-22-78 **Shigeo Koshitani*** (koshitan@math.s.chiba-u.ac.jp), Mathematics, Graduate School of Science, Chiba University, 1-33 Yayoi-cho, Inage-ku, Chiba, Chiba 263-8522, Japan. *An application of the Hecke algebras of permutation representations to representation theory.*

In representation theory in Algebra or Geometry no matter what is, Hecke algebras play a very important role. Here by a Hecke algebra we mean one of the most classical ones, namely, the endomorphism ring (algebra) of a permutation representation. Almost forty years ago in his celebrated paper [Trans. A.M.S. 175 (1973)] Leonard Scott announced a wonderful result which is on lifting homomorphisms between two permutation modules of a finite group from a field of prime characteristic to the ring of local integers. In particular, we can compute the Hecke algebras of permutation modules in terms of ordinary reresentations. By using his result we can give several partial positive answers to Broue's abelian defect group conjecture which is one of the most important and interesting problems or conjectures in representation theory of finite groups and the conjecture is described in terms of derived equivalences. We shall present some results as applications of the theorem by Scott. (Received February 03, 2010)

1058-22-117 **Dorin Dutkay** (ddutkay@mail.ucf.edu), **Deguang Han** (dhan@pegasus.cc.ucf.edu), **Palle Jorgensen** (jorgen@math.uiowa.edu) and **Gabriel Picioroaga*** (Gabriel.Picioroaga@usd.edu). *On Common Fundamental Domains.*

We find conditions under which two measure preserving actions of two groups on the same space have a common fundamental domain. Our results apply to commuting actions with separate fundamental domains, lattices in groups of polynomial growth, and some semidirect products. We prove that two lattices of equal co-volume in a group of polynomial growth, one acting on the left, the other on the right, have a common fundamental domain. (Received February 10, 2010)

1058-22-181 **S. N. Kitchen*** (kitchen@math.utah.edu), 155 S 1400 E Rm 233, Math Department, Salt Lake City, UT 84112. *Localization of Cohomologically Induced Modules to Partial Flag Varieties.*

The duality theorem of Hecht, Milicic, Schmidt and Wolf establishes a relationship between Harish-Chandra modules for a real reductive Lie group G that are cohomologically induced from Borels and D-modules on the complex flag variety of G. I will present the corresponding results for partial flag varieties. (Received February 15, 2010)

1058-22-238 **Rahbar Virk*** (virk@math.wisc.edu), Department of Mathematics, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706. *Soergel's character formula for tilting modules via derived equivalences.* Preliminary report.

We explain how Soergel's character formula for tilting modules (for semisimple Lie algebras) is a consequence of the existence of a family of derived equivalences which are a categorical incarnation of a braid group action on category O. (Received February 15, 2010)

28 ► Measure and integration

1058-28-107 **Thomas M Jordan*** (thomas.jordan@bris.ac.uk), The department of Mathematics, The University, of Bristol, University Walk, Clifton, Bristol, BS8 1TW, England. *Multifractal analyis for Bedford-McMullen carpets.*

Joint work with Michal Rams. In this talk we will show how it is possible to calculate the multifractal analysis for a class of self-affine measures. These are self-affine measures which are supported on the self-affine structures originally studied by Bedford-McMullen. Previous work on this subject by King, Olsen and Barral-Mensi as always required some suitable strong separation conditions. We show that such conditions are not needed. (Received February 09, 2010)

1058-28-112 **Sze-Man Ngai*** (smngai@georgiasouthern.edu), Department of Mathematical Sciences, Georgia Southern University, Statesboro, GA 30458. *Fractal Laplacians defined by iterated function systems with overlaps.*

We study spectral asymptotics of a class of Laplacians defined by iterated function systems with overlaps. We also study the computation of the eigenfunctions and eigenvalues of the Laplacians. Part of this work is joint with J. Chan, J. Chen, J. Hu, and K.-S. Lau. (Received February 09, 2010)

33 ► Special functions

1058-33-40 **Ibrahim A. Salehbhai*** (ibrahimmaths@gmail.com), Applied Mathematics and Humanities Department, S.V. National Institute of Technology, SURAT, 395007, India, and **A. K. Shukla**. *On a Hankel transform integral.*

Let x and v be complex variables, $\Gamma(x)$ the Gamma function, and $(x)_v = \frac{\Gamma(x+v)}{\Gamma(x)}$ for any complex v the generalized Pochhammer symbol. The principal aim of the paper is to investigate new integral expression

$$\int_0^\infty x^{s-1} e^{-\sigma x^2} L_m^{(\gamma,\delta)}\left(\sigma x^2\right) L_n^{(\alpha,\beta)}\left(\sigma x^2\right) J_s(xy)\, dx,$$

where α,β,γ,δ and $s \in \mathrm{C}^*$; $\mathrm{C}^* = \{x/x \in \mathrm{C}\ \&\ Re(x) > -1\}$, $\sigma \in \mathrm{C}$ with $Re(\sigma) > 0$,$y \in \mathrm{R}^+$ and

$$L_n^{(\alpha,\beta)}(x) = \frac{\Gamma(\alpha n + \beta + 1)}{\Gamma(n+1)} \sum_{k=0}^{n} \frac{(-n)_k\, x^k}{k!\Gamma(\alpha k + \beta + 1)}.$$

Some special cases have been obtained. (Received January 15, 2010)

1058-33-45 **Jyotindra C Prajapati** (jyotindra18@rediffmail.com), Department of Mathematics, Charotar University of Science and Technology, Changa, Anand, Gujarat 388421, India, **Amitkumar Dilipbhai Patel*** (p.amitkumar@ashd.svnit.ac.in), Department of Applied Mathematics and Hum., S. V. National Institute of Technology, Ichchhanath, Surat, Gujarat 395007, India, and **Ajay K Shukla** (ajayshukla2@rediffmail.com), Department of Applied Mathematics and Hum., S. V. National Institute of Technology, Ichchhanath, Surat, Gujarat 395007, India. *Generating relation for Laguerre type polynomial containing Mittag-Leffler function.*

The generating relations of classical Laguerre polynomials contain exponential function. The principal object of this paper is to introduce two parameter Laguerre type polynomials. The authors found some results of the two parameter Laguerre type polynomials. The remarkable thing of this paper is that the generating relations of the Laguerre type polynomials involving the Mittag-Leffler and the Wright functions. The relationships between Laguerre type polynomials, Mittag-Leffler function, Wright function, Bessel function, Confluent hypergeometric functions, Beta function and Gamma function are also obtained in this paper. The interesting Integral representations of the two parameter Laguerre type polynomials discussed in this paper. (Received January 22, 2010)

34 ► Ordinary differential equations

1058-34-65 **Youssef N Raffoul*** (youssef.raffoul@notes.udayton.edu), Dayton, OH 45469-2316. *Exponential Stability And Instability In Finite Delay Nonlinear Volterra Integro-differential Equations.* Preliminary report.

Lyapunov functionals are employed to obtain sufficient conditions that guarantee asymptotic stability of the nonlinear Volterra Integro-differential equation with uniformly distributed delay

$$x'(t) = -\int_{t-r}^{t} a(t,s)g(x(s))ds,$$

where the functions $a(t,s)$ and $g(x)$ are continuous on their respective domains and $r > 0$. In addition, we will obtain criteria for instability. (Received January 30, 2010)

35 ► Partial differential equations

1058-35-35 **Yangjin Kim*** (yangjink@umd.umich.edu), Department of Mathematics & Statistics, 2078 CASL Building, 4901 Evergreen Road, Dearborn, MI 48128, **Avner Friedman** (afriedman@math.ohio-state.edu), Jennings Hall, 3rd Floor, 1735 Neil Avenue, Columbus, OH 43210, **Sean Lawler** (Sean.Lawler@osumc.edu), Department of Neurological Surgery, Columbus, OH 43210, **Michal Nowicki** (Michal.Nowicki@osumc.edu), Department of Neurological Surgery, Columbus, OH 43210, and **E. Antonio Chiocca**, Department of Neurological Surgery, Columbus, OH 43210. *Pattern formation of glioma cells (brain tumor) outside the tumor spheroid core.*

Glioblastoma is a highly invasive brain tumor. This invasive behavior is responsible for low survival rate and microenvironment plays an important role in this active migration. We developed a mathematical model to

better understand the role of microenvironment in creating different invasion patterns. We analyze the migration patterns of glioma cells from the main tumor, and show that the various patterns observed in experiments can be obtained by a model's simulations, by choosing appropriate values for some of the model parameters (chemotaxis, haptotaxis, and adhesion) of the PDE model. A multi-scale model will also be presented in order to get more detailed information on cell migration. (Received January 08, 2010)

1058-35-52 **Dmitri Kuzmin*** (kuzmin@math.uh.edu), Department of Mathematics, University of Houston, 651 Philip G. Hoffman Hall, Houston, TX 77204-3008. *Flux and slope limiters for finite element approximations to convection-dominated transport equations.*

High-resolution finite element schemes are developed for convection-dominated problems with steep fronts. Algebraic and geometric design principles are reviewed in the context of scalar transport equations. The oscillatory part of a continuous Galerkin discretization is decomposed into a sum of antidiffusive fluxes. Multidimensional flux limiters are applied to control the growth of local extrema.

A new slope limiter is proposed for enforcing monotonicity in the context of discontinuous Galerkin methods. The upper and lower bounds for admissible variations are determined using the maxima/minima of centroid values over the set of elements meeting at a vertex. Within each element, the derivatives of DG solutions are limited in a hierarchical manner. The proposed limiting strategy is designed to maintain high accuracy at smooth extrema. No free parameters or troubled cell markers are involved. An evaluation of the presented limiting tools is performed for a 2D benchmark problem. (Received January 25, 2010)

1058-35-54 **Peter Hinow*** (hinow@uwm.edu), Department of Mathematical Sciences, University of Wisconsin - Milwaukee, P.O. Box 413, Milwaukee, WI 53201-0413. *Semigroup Analysis of Structured Parasite Populations.*

Motivated by structured parasite populations in aquaculture we consider a class of size-structured population models, where individuals may be recruited into the population with distributed states at birth. The mathematical model which describes the evolution of such a population is a first-order nonlinear partial integro-differential equation of hyperbolic type. First, we use positive perturbation arguments and results from the spectral theory of semigroups to establish conditions for the existence of a positive equilibrium solution of our model. Then, we formulate conditions that guarantee that the linearised system is governed by a positive quasicontraction semigroup on the biologically relevant state space. We also show that the governing linear semigroup is eventually compact, hence growth properties of the semi-group are determined by the spectrum of its generator. In the case of a separable fertility function, we deduce a characteristic equation, and investigate the stability of equilibrium solutions in the general case using positive perturbation arguments.

This is joint work with Jozsef Z. Farkas and Darren Green (University of Stirling, Scotland). (Received January 26, 2010)

1058-35-79 **Willy A Hereman*** (whereman@mines.edu), Dept. Mathematical and Computer Sciences, Colorado School of Mines, Golden, CO 80401-1887, and **Loren Douglas Poole**. *Symbolic Computation of Conservation Laws of Nonlinear Partial Differential Equations in Multiple Space Dimensions.*

A method will be presented for the symbolic computation of conservation laws of nonlinear partial differential equations (PDEs) involving multiple space variables and time.

Using the scaling symmetries of the PDE, the conserved densities are constructed as linear combinations of scaling homogeneous terms with undetermined coefficients. The variational derivative is used to compute the undetermined coefficients. The homotopy operator is used to invert the divergence operator, leading to the analytic expression of the flux vector.

The method is algorithmic and has been implemented in the syntax of the computer algebra system MATHEMATICA. The software is being used to compute conservation laws of nonlinear PDEs occuring in the applied sciences and engineering.

The software package will be demonstrated for PDEs that model shallow water waves, ion-acoustic waves in plasmas, sound waves in nonlinear media, and transonic gas flow. The featured equations include the Korteweg-de Vries and Boussinesq equations, the Navier and Kadomtsev-Petviashvili equations, and the Zakharov-Kuznetsov and Khoklov-Zabolotskaya equations. (Received February 03, 2010)

1058-35-104 **Jonatan Lenells**, **Gerard Misiolek** and **Feride Tiglay*** (feride.tiglay@gmail.com). *Integrable evolution equations on spaces of tensor densities.*

We study a family of equations defined on the space of tensor densities of weight λ on the circle and introduce two integrable PDE. One of the equations turns out to be closely related to the inviscid Burgers equation while the

other has not been identified in any form before. We present their Lax pair formulations and describe their bi-Hamiltonian structures. We prove local wellposedness of the corresponding Cauchy problem and include results on blow-up as well as global existence of solutions. We argue that there is a natural geometric framework for these equations that includes other well-known integrable equations and which is based on V. Arnold's approach to Euler equations on Lie groups (joint work with J. Lenells and G. Misiolek). (Received February 09, 2010)

1058-35-124 **Annalisa Calini** and **Thomas Ivey***, Dept. of Mathematics, College of Charleston, 66 George St., Charleston, SC 29424, and **Gloria Marí Beffa**. *Integrable Curve Flows in Centro-Affine Space.* Preliminary report.

Inspired by the well-known correspondence between the nonlinear Schrödinger equation and the vortex filament flow, we explore the relationship between certain geometric evolution equations for curves in 3-dimensional centro-affine geometry and solutions for KdV equation and a two-component system which is a 5th-order member of the Boussinesq hierarchy. (In the case of the scalar KdV, the corresponding flow in 3 dimensions was first studied by Chou-Qu and Huang-Singer.) We show that a bi-Hamiltonian structure for the 5th-order flow arises naturally from the operator that computes the evolution of the curvatures induced by a given invariant flow. We also outline how to use solutions of the scalar Lax pairs for these integrable systems to obtain evolving curves which are solutions for the corresponding flows. (Received February 10, 2010)

1058-35-145 **Jonathan P. Desi**, **Hanein H. Edrees**, **Joseph J. Price** and **Evelyn Sander*** (esander@gmu.edu), Department of Math Sci. MS-3F2, Fairfax, VA 22030, and **Thomas Wanner**. *The Dynamics of Nucleation in Stochastic Cahn-Morral Systems.* Preliminary report.

Cahn-Hilliard systems serve as models for several phase separation phenomena in metal alloys. In this talk, I will talk about the dynamical aspects of a certain type of phase separation - known as nucleation - in which the material separates into small droplets. I will present numerical studies in the context of alloys consisting of three metallic components. The numerics give a statistical classification for the distribution of droplet types as the component structure of the alloy is varied. We relate these statistics to the low-energy equilibria of the deterministic equation computing numerical bifurcation methods. (Received February 12, 2010)

1058-35-146 **Svetlana Tlupova*** (stlupova@umich.edu), Department of Mathematics, 3863 East Hall, 530 Church St., Ann Arbor, MI 48109. *Numerical Solution of Coupled Stokes-Darcy Flow.*

Many important physical and biological phenomena that occur in our daily lives involve fluids partly flowing freely and partly filtrating through a porous medium. We consider a coupled problem where the free fluid flow is governed by the Stokes equations and the flow in the porous domain is governed by the Darcy equations. The model then consists of PDEs of different orders, and the coupling conditions have to be chosen carefully. We apply a non-overlapping domain decomposition method to reduce the problem size and to overcome the limitations of the direct solution. The coupled system is then reduced to solving each problem separately by an iterative procedure using a Krylov subspace method. In each subdomain, the numerical solution is based on the boundary integral formulation with preconditioners, where we apply a regularization-correction procedure for improved accuracy. (Received February 12, 2010)

1058-35-185 **Gui-Qiang Chen** and **Weihua Ruan*** (ruanw@calumet.purdue.edu), Department of Mathematics, Computer Science, and Statistics, Purdue University Calumet, Hammond, IN 46323. *A HYPERBOLIC SYSTEM OF CONSERVATION LAWS FOR FLUID FLOWS THROUGH COMPLIANT AXISYMMETRIC VESSELS.*

We are concerned with the derivation and analysis of one-dimensional hyperbolic systems of conservation laws modelling fluid flows such as the blood flow through compliant axisymmetric vessels. Early models derived are nonconservative and/or nonhomogeneous with measure source terms, which are endowed with infinitely many Riemann solutions for some Riemann data. We derive a one-dimensional hyperbolic system that is conservative and homogeneous. Moreover, there exists a unique global Riemann solution for the Riemann problem for two vessels with arbitrarily large Riemann data, under a natural stability entropy criterion. The Riemann solutions may consist of four waves for some cases. The system can also be written as a 3×3 system for which strict hyperbolicity fails and the standing waves can be regarded as the contact discontinuities corresponding to the second family with zero eigenvalue. (Received February 15, 2010)

1058-35-202 **Dimitris Kontogiannis*** (dkontog@iastate.edu). *Homogenization of partial differential equations in random environments.*

I will present recent work on the modeling and analysis of random network structures with the use of percolation theory. Such structures model physiological microvascular networks, sea ice structures, etc. The goal of this

work is to develop the mathematical tools that lead to the homogenization of partial differential equations in such environments. (Received February 15, 2010)

1058-35-217 **Annalisa Calini*** (calinia@cofc.edu), Department of Mathematics, Robert Scott Small Bldg, Room 339, College of Charleston, Charleston, SC 29424, and **Thomas Ivey**, **Scott Keith** and **Stephane Lafortune**. *Linear stability of small-amplitude torus knot solutions of the Vortex Filament Equation.* Preliminary report.

I will discuss a framework for studying the linear stability of solutions of the Vortex Filament Equation, based on the connection between its linearization and the linearized Nonlinear Schrödinger equation. In particular, I will describe the linear stability of torus knot solutions "close" to circular filaments, and show that, contrary to what has been suggested by various authors, their stability is not related to their knot type. This talk is a preliminary report on related joint projects with Tom Ivey, Stephane Lafortune, and our former student Scott Keith. (Received February 15, 2010)

1058-35-250 **Anna L Mazzucato***, Department of Mathematics, Penn State University, University Park, PA 16802, and **Wen Cheng**, **Nicola D Costanzino** and **Victor Nistor**. *An approximate Green-function algorithm for solving Fokker-Planck equations.*

We discuss an algorithm to compute solutions of certain Fokker-Planck equations in terms of approximate Green's function, based on Dyson series, Taylor expansions, and exact commutator formulas. The algorithm gives approximate solutions that are accurate to arbitrary order in time in the short-time limit. Part of this work is also joint with Radu Costantinescu and John Liechty. (Received February 16, 2010)

1058-35-256 **Stephen Anco*** (sanco@brocku.ca), Brock University, Department of Mathematics, St Catharines, Ontario L2S3A1, Canada. *Bi-Hamiltonian geometric curve flows in semi-simple Klein geometries.* Preliminary report.

Recent work has given a general geometrical derivation of group-invariant (multicomponent) generalizations of mKdV, NLS, and SG soliton equations along with their bi-Hamiltonian structure, symmetries, and conservation laws. The derivation uses a moving frame formulation of non-stretching curve flows in semi-simple Klein geometries (i.e. Riemannian and Lorentzian symmetric spaces).

In this talk I will describe some examples of new scalar/vector soliton equations derived by this method. I will also present an explicit bi-Hamiltonian formulation of the underlying curve flows themselves, in terms of the geometric structure of a semi-simple Klein geometry. (Received February 16, 2010)

1058-35-292 **James Brannick*** (brannick@psu.edu), Department of Mathematics, Penn State University, University Park, PA 16803. *Modeling and numerical simulations of immiscible multi-phase fluids.*

We introduce a multi-phase fluid model derived via an energetic variational approach. We start with a governing energy law which describes the total energy (the kinetic and a Cahn-Hilliard mixing energy) with an additional dissipative functional. The conservative part of the non-Newtonian stress tensor is derived from the least action principle or principle of virtual work. This follows by application of Onsager's principle, which introduces the dissipative terms in the equations. We present simulations of several applications of the model, including the dynamics of a buoyant air bubble or a falling solid in a two-phase Stokesian flow. Possible slip effects at the interfaces of the multi-phase fluids are also considered. Numerical simulations will also be discussed, including adaptivity and a pressure Schur complement approach for solving the fluid system. (Received February 16, 2010)

37 ► Dynamical systems and ergodic theory

1058-37-8 **Robert L. Devaney*** (bob@bu.edu), Math Dept., Boston University, 111 Cummington St., Boston, MA 02215. *Dynamic Classification of Sierpinski Curve Julia Sets.*

Sierpinski curves (sets that are homeomorphic to the Sierpinski carpet fractal) arise in a number of different ways as Julia sets for rational maps in the family $z^n + C/z^d$. These objects are quite rich from a geometric point of view. We shall show that the dynamical behavior on these sets is also quite rich. We shall give a complete classification of the dynamics on the "escape time" Sierpinski curve Julia sets in these families. This is joint work with Kevin Pilgrim. (Received November 09, 2009)

1058-37-30 **Piotr Oprocha*** (oprocha@agh.edu.pl), Departamento de Matematicas, Universidad de Murcia, Campus de Espinardo, 30100 Murcia, Spain, and **Paweł Wilczyński** (pawel.wilczynski@uj.edu.pl), Institute of Mathematics, Jagiellonian University, ul. Łojasiewicza 6, 30-348 Kraków, Poland. *Factor maps and chaos.*

Let X, Y be compact metric spaces, let $f \in C(X), g \in C(Y)$ be continuous self-mappings and $\pi\colon X \to Y$ be a factor map between f and g.

In this talk we will present sufficient conditions on π which allow to transfer chaotic dynamics from g to f (we will mainly focus on distributional chaos and ω-chaos).

We will also comment how geometric approach (more specifically, the method of isolating segments) may help in the construction of such a π. As a testing ground, we will use Poincaré maps for the perturbations of the planar ODE of the type

$$\dot{z} = \left(1 + e^{i\kappa t}|z|^2\right)\overline{z}.$$

(Received December 20, 2009)

1058-37-68 **Adam Doliwa*** (doliwa@matman.uwm.edu.pl), Department of Mathematics and Computer Scence, University of Warmia and Mazury, Zolnierska 14, 10-561 Olsztyn, Poland. *On geometric integrability of discrete systems.*

I will report on recent advances in geometric description of integrability of partial difference equations, and the role of incidence geometry theorems in the scheme. In particular, I will present the relation of the quadrilateral lattice maps and the corresponding discrete Darboux equations with the so-called Desargues maps and the non-commutative Hirota-Miwa system. (Received February 01, 2010)

1058-37-109 **Edward D Tymchatyn*** (tymchat@math.usask.ca), Department of Mathematics and Statistics, University of Saskatchewan, Maclean Hall, Saskatoon, Sask S7N0W0, Canada, and **Ihor Stasyuk**. *Spaces of sigma finite linear measure.* Preliminary report.

Spaces of finite linear measure were characterized in the 1930's. They are subsets of metric continua in which every pair of points can be separated by each of uncountably many pairwise disjoint finite sets. We prove that a space admits a sigma finite linear measure if and only if it is the countable union of closed subsets each of which admits finite linear measure. (Received February 09, 2010)

1058-37-121 **Brian F Martensen*** (martensen@mnsu.edu), Department of Mathematics & Statistics, Wissink Hall 273, Mankato, MN 56001, and **Marcy Barge** (barge@math.montana.edu), Department of Mathematical Sciences, Montana State University, Bozeman, MT 59717. *The classification of expansive attractors on surfaces.*

We prove the conjecture of F. Rodriguez Hertz and J. Rodriguez Hertz (Erg. Thy. & Dyn. Sys., 2006) that every nontrivial transitive expansive attractor of a homeomorphism of a compact surface is a derived from pseudo-Anosov attractor.

It follows that such attractors are very nearly hyperbolic. Simply "unzipping" finitely many unstable branches and splitting finitely many periodic orbits turns such an attractor into a hyperbolic attractor that can be modeled by a substitution tiling space. As such, the dynamics of the attractor are essentially determined by its topology. (Received February 10, 2010)

1058-37-125 **Elizabeth D Russell***, Department of Mathematical Sciences, US Military Academy, West Point, NY 10996. *Complex Dynamics of Rational Maps.*

We study the dynamics of a family of rational maps, demonstrating the presence of Cantor sets of point components in the Julia set by a geometric approach and symbolic dynamics. (Received February 10, 2010)

1058-37-132 **Jean-Luc Thiffeault*** (jeanluc@math.wisc.edu), Department of Mathematics, University of Wisconsin, 480 Lincoln Dr, Madison, WI 53706, and **Sarah E. Matz** and **Kevin A. Mitchell**. *Exact topological entropy for some non-hyperbolic maps.*

In fluid mechanics, the topological entropy is a useful measure of the effectiveness of mixing devices. The entropy can be bounded from below by looking at a few periodic orbits. Moreover, there are cases where this bound appears to be sharp, based on numerical simulations. To simplify the system, we study classical "linked twist maps" to isolate features that make the bound exact. The crucial ingredient is to be the manner in which folding occurs in the map. The hope is that these observations can be applied to estimate the entropy of real physical systems. (Received February 11, 2010)

1058-37-135 **David R Stockman*** (stockman@udel.edu), Economics Dept., University of Delaware, Newark, DE 19716, and **Brian E Raines**, Mathematics Department, Baylor University, Waco, TX 76798. *Chaotic Sets and Chaos for a Class of Differential Inclusions that Arise in Economic Models.*

Some economic models may exhibit a type of indeterminacy known as Euler equation branching. The dynamics in such models are governed by a differential inclusion $\dot{x} \in H(x)$, where H is a set-valued function. In this paper, we introduce the concept of a *chaotic set* and explore its implications for Devaney chaos, Li-Yorke chaos and distributional chaos (adapted to dynamical systems generated by a differential inclusion). We show that a *chaotic set* will imply Devaney and Li-Yorke chaos, but *not* distributional chaos. We show that the existence of a steady state for a differential inclusion on the plane will generate a chaotic set and hence Devaney and Li-Yorke chaos. Though a chaotic set by itself is not sufficient for distributional chaos, we show that since the chaotic set is generated by a differential inclusion, one obtains distributional chaos as well. (Received February 11, 2010)

1058-37-143 **James A Yorke*** (yorke@umd.edu). *Comparing the period doubling cascades of two maps.*

This is joint work with Evelyn Sander. There are many papers that investigate the properties of a single period-doubling cascade that consists of infinitely many period-doublings. There has very little recognition in the literature that there are typically infinitely many cascades when there is one. Each can be characterized by the minimum period of its orbits. For example the map

$$\mu - x^2$$

has one cascade with minimum period 1; one with minimum period 3; three with minimum period 5, and so on. The theory for this map was established by Milnor and Thurston who showed that the map is "monotonic". That is as μ increases no orbits are destroyed. Given that property, which is very rarely true, a theory of cascades is simple. In this talk, we compare its behavior with maps like

$$\mu - x^2 + 1000\cos(\mu^3 + x)$$

which is a massive perturbation of the first map and does not satisfy the monotonicity property. Caveat: Our theory is for generic maps, that is, maps whose saddle-node and period-doublings bifurcations are generic. We allow inverted cascades and period-having bifurcations. Our theory also extends to systems in higher dimensions. (Received February 12, 2010)

1058-37-156 **Sina Greenwood** and **Judy A. Kennedy*** (kennedy9905@gmail.com), Dept. of Mathematics, PO Box 10047, Beaumont, TX 77710. *Pseudoarcs and generalized inverse limits.*

We show that for surjective upper semicontinuous bonding functions f on an interval I whose graphs are pseudoarcs, the generalized inverse limit space is a Cantor set. (Received February 12, 2010)

1058-37-172 **Marian Gidea*** (mgidea@neiu.edu), Department of Mathematics, 5500 N St Louis Ave, Chicago, IL 60625, and **James Meiss**, **Ilie Ugarcovici** and **Howard Weiss**. *APPLICATIONS OF KAM THEORY TO POPULATION DYNAMICS.* Preliminary report.

Computer simulations have shown that several classes of population models, including the May host-parasitoid model and the Ginzburg-Taneyhill "maternal-quality" single species population model, exhibit extremely complicated orbit structures. These structures include islands-around-islands, ad infinitum, with the smaller islands containing stable periodic points of higher period. We identify the mechanism that generates this complexity and we discuss some biological implications. (Received February 14, 2010)

1058-37-176 **Philip Boyland*** (boyland@math.ufl.edu), Mathematics Department, University of Flordia, Gainesvill, FL 32611. *Entropy Efficiency of Braids.* Preliminary report.

A braid β is said to have entropy $h(\beta)$ if that is the least topological entropy of all homeomorphisms of the disk which have a collection of periodic orbits corresponding to the braid. The braid entropy may be computed using the Thurston-Nielsen Theory. The *maximal entropy efficiency* of a finite set of braids, $\{\alpha_1, \ldots, \alpha_k\}$, is the maximum possible entropy per unit α_i of braid words made from the α_i, or

$$\sup_{m\in\mathbb{N}} \{\frac{h(\alpha_{i_i} \ldots \alpha_{i_m})}{m} : 1 \le i_j \le k\}.$$

The terminology comes from fluid mixing where the α_i correspond to simple motions of stirring rods, and the entropy of the braid gives a rough measure of how well the corresponding rod motion mixes. Thus one seeks stirring protocols with maximum mixing per simple rod motion. We discuss results on entropy efficiency for various sets of braids. (Received February 14, 2010)

1058-37-184 **E Andrei Ghenciu*** (eghenciu@ecok.edu). *Non-irreducible Gibbs States over Finite and Infinite Alphabets.*

We extend the study of Gibbs states to the case when the defining incidence matrix is not finitely irreducible anymore. We give necessary and sufficient conditions for a Gibbs state to exist when the alphabet is finite and look at the infinite case as well. Connections with Graph Directed Markov Systems will de discussed. (Received February 15, 2010)

1058-37-234 **Anne J Catlla*** (catllaaj@wofford.edu), 429 N Church St., Spartanburg, SC 29303, and **Chad M Topaz**. *Forced patterns near a Turing-Hopf bifurcation.*

We study the effect of external forcing on Turing patterns in generic two-component reaction-diffusion systems. Such patterns appear in a variety of biological systems but have been explored in greatest detail in chemical reactions. Experiments on the CDIMA chemical reaction have shown that external periodic forcing can suppress Turing patterns [Horvath, Dolnik, et al., PRL, 1999]. Using symmetry and perturbation analyses of reaction-diffusion systems near a Turing-Hopf bifurcation, we determine conditions under which forcing suppresses or enhances patterns and predict how this effect scales with forcing amplitude and frequency. We discuss these results in relation to the aforementioned chemical experiments, simulations of the Lengyel-Epstein and Brusselator models, and biological systems. (Received February 15, 2010)

1058-37-255 **Erin P. J. Pearse*** (erin-pearse@uiowa.edu), 25L MacLean Hall, Iowa City, IA 52242-1419, and **Palle E. T. Jorgensen** (jorgen@math.uiowa.edu), 25B MacLean Hall, Iowa City, IA 52242-1419. *Fractals as Boundaries.*

I will discuss a couple of recent approaches to understanding certain self-similar fractals as "boundaries". Denker and Sato constructed a Markov process for which the Sierpinski gasket is (homeomorphic to) the Martin boundary. Kaimanovich outlined a program for understanding the Sierpinski gasket as a Gromov boundary, by constructing an associated hyperbolic graph. More recently, Lau and Wang have extended Kaimanovich's construction to self-similar sets satisfying the open set condition, and Lau, Ju, and Wang have also extended Denker & Sato's work to a certain class of pcf self-similar fractals. Also, Kigami's recent preprint develops the theory of resistance analysis on trees, with the aim of providing a new approach to the theory of analysis on fractals. The idea is to begin with the Laplacian & energy form on the tree, then use potential theory to take the trace of these objects to the boundary (a totally disconnected fractal set). I will give an overview of these results and, if time permits, describe some preliminary results of the authors on this topic. (Received February 16, 2010)

1058-37-279 **Andrew J. Bernoff*** (ajb@hmc.edu), Dept. of Mathematics, Harvey Mudd College, Claremont, CA 91711, and **Andrew J. Leverentz** and **Chad M. Topaz**. *Asymptotic dynamics of attractive-repulsive swarms.*

We classify and predict the asymptotic dynamics of a class of swarming models. The model consists of a conservation equation in one-dimension describing the movement of a population density field. The velocity is found by convolving the density with a kernel describing attractive-repulsive social interactions. The kernel's first moment and its limiting behavior at the origin determine whether the population asymptotically spreads, contracts, or reaches steady-state. For the spreading case, the dynamics approach those of the porous medium equation. The widening, compactly-supported population has edges that behave like traveling waves whose speed, density and slope we calculate. For the steady states we calculate analytic expressions for the swarm density when the kernel is a Morse potential, a common model of attraction and repulsion. For the contracting case, the dynamics of the cumulative density approach those of Burgers' equation. We derive an analytical upper bound for the finite blow-up time after which the solution forms one or more δ-functions. (Received February 16, 2010)

41 ► Approximations and expansions

1058-41-227 **Kathy D. Merrill*** (kmerrill@ColoradoCollege.edu), 43981 Road L, Mancos, CO 81328. *Building fractal space GMRAs from filters.* Preliminary report.

New examples will be given of multiresolution structures in fractal spaces that are constructed from filters. (Received February 15, 2010)

42 ► Fourier analysis

1058-42-27 **Dorin Ervin Dutkay*** (ddutkay@gmail.com), Orlando, FL 32816. *Fourier frames on fractal measures.*

We present some results on frame spectra for fractal measure, i.e., sets of frequencies that yield frames of exponential functions. We show how the Hausdorff dimension of a self-affine fractal measure coincides with the Beurling dimension of its frame spectra. We give a characterization of Bessel sequences of exponentials for such measures. (Received December 13, 2009)

1058-42-46 **Peter G. Casazza*** (casazzap@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211-4100, and **Janet C. Tremain** (j.tremain@mchsi.com), **Matt Fickus** (Matthew.Fickus@afit.edu) and **Dustin Mixon** (dmixon@princeton.edu). *Kadison-Singer Meets Signal Processing.*

We will use variations of the Discrete Fourier Transform from Signal Processing to construct the first concrete counter-examples to 2-paving of projections with constant diagonal 1/2. (Received January 22, 2010)

1058-42-48 **Palle E. T. Jorgensen*** (jorgen@math.uiowa.edu), Dept of Math, MLH, University of Iowa, Iowa City, IA 52242. *Orthogonal harmonic analysis of selfsimilar measures.* Preliminary report.

Co-authors Dorin Dutkay, Keri Kornelson, Karen Shuman: An orthogonal harmonic analysis of selfsimilar measures. Our analysis involves dynamical systems and Cuntz algebras which in turn determine both the algorithmic and the analytic part of the problem. It divides up into two parts, periodic and non-periodic. The precise meaning involves a random walk-dynamical system. The periodic case is especially easy to understand in terms of a natural encoding with finite and infinite code-words. By contrast, the second case involves an intriguing family of invariant sets. They can have quite subtle fractal properties.

Cuntz algebras are infinite algebras on a finite number of generators, and on certain relations. By their nature, they are selfsimilar and they therefore ideally serve to encode iterated function systems (IFSs) and their measures. At the same time, their representations offer (in a more subtle way) a new harmonic analysis of IFS-fractal measures. Even though the Cuntz algebras initially entered into the study of operator-algebras and physics, in recent years these same Cuntz algebras, and their representation, have found increasing use in pure and applied problems, wavelets, fractals, signals. (Received January 23, 2010)

1058-42-170 **Judith A Packer*** (packer@colorado.edu), Department of Mathematics, CB 395, University of Colorado, Boulder, CO 80305. *On induced representations of Baumslag-Solitar groups and existence of wavelet sets.*

Recent investigations done in collaboration with L. Baggett, K. Merrill, and A. Ramsay will be discussed, that study representations of Baumslag-Solitar groups on Hilbert spaces built on solenoids, as first constructed using wavelet filter functions by D. Dutkay and P. Jorgensen. We remark that the existence of a wavelet-set wavelet, even in the case where the filters in question come from wavelets on inflated fractal sets, is contingent on the corresponding representation of the Baumslag-Solitar group $\mathbb{Q}_A \ltimes \mathbb{Z}$ being induced from a representation of the normal abelian subgroup $\mathbb{Q}_A$. Here $\mathbb{Q}_A = \cup_{n=0}^{\infty} A^n(\mathbb{Z}^d)$, where A is a $d \times d$ dilation matrix with integer entries. We relate our work to previous works of L.-H. Lim– J. Packer–K. Taylor, Dutkay–Jorgensen, and E. Weber. (Received February 14, 2010)

1058-42-205 **Eric S Weber*** (esweber@iastate.edu), Department of Mathematics, 396 Carver Hall, Ames, IA 50010. *Exponential Frames and Bases on the Cantor-3 set.*

Exponential bases on the Cantor-4 set considered by Jorgensen and Pedersen can be constructed in an iterative scale-by-scale manner. We discuss the possibility of doing so for frames or bases on the Cantor-3 set. (Received February 15, 2010)

1058-42-239 **Yang Wang***, 2345 Club Meridian Dr. B09, Okemos, MI 48864. *Bi-Lipschitz equivalence of dust-like Cantor sets.*

Bi-Lipschitz equivalence plays an important role in fractal geometry. But it is in general very challenging to determine whether two given Cantor sets are Lipschitz equivalent. In this talk we introduce several new criteria for bi-Lipschitz equivalence of Cantor sets. In particular we completely classify the bi-Lipschitz equivalence of Cantor sets with two branches. (Received February 15, 2010)

1058-42-253 **Fumiko Futamura*** (futamurf@southwestern.edu), 1001 E University Ave, Georgetown, TX 78626. *Frame multipliers and commutative Banach algebras.* Preliminary report.

We characterize frame multipliers (generalizations of Fourier and Gabor multipliers) through commutative Banach algebras of Riesz diagonal operators. (Received February 16, 2010)

43 ► Abstract harmonic analysis

1058-43-92 **Lawrence W. Baggett*** (lawrence.baggett@colorado.edu), **Veronika Furst**, **Kathy Merrill** and **Judith Packer**. *Abstract generalized multiresolution structures.* Preliminary report.

Let $\{V_j\}$ be a generalized multiresolution analysis relative to operators T and D. We investigate the non-standard situation in which the spectral measure μ, associated to the unitary operator T restricted to the core subspace V_0, is not Lebesgue measure. There is still a function h serving as a low-pass filter, but the "filter equation" it satisfies is not the usual one. We show that such non-standard GMRAs do indeed exist, but that the normal notion of associated wavelets no longer holds. (Received February 06, 2010)

46 ► Functional analysis

1058-46-34 **Manijeh Bahreini**, **Elizabeth Bator** and **Ioana Ghenciu*** (ioana.ghenciu@uwrf.edu), University of Wisconsin-River Falls, Departament of Mathematics, River Falls, WI 54022. *Complemented Subspaces of Linear Bounded Operators.*

We study the complementation of the space $W(X,Y)$ of weakly compact operators, the space $K(X,Y)$ of compact operators, the space $U(X,Y)$ of unconditionally converging operators, and the space $CC(X,Y)$ of completely continuous operators in the space $L(X,Y)$ of bounded linear operators from X to Y. Feder proved that if X is infinite dimensional and $c_0 \hookrightarrow Y$, then $K(X,Y)$ is uncomplemented in $L(X,Y)$. Emmanuele and John showed that if $c_0 \hookrightarrow K(X,Y)$, then $K(X,Y)$ is uncomplemented in $L(X,Y)$. Bator and Lewis showed that if X is not a Grothendieck space and $c_0 \hookrightarrow Y$, then $W(X,Y)$ is uncomplemented in $L(X,Y)$. In this paper, classical results of Kalton and separably determined operator ideals with property $(*)$ are used to obtain complementation results that yield the preceding theorems as corollaries. (Received January 07, 2010)

1058-46-56 **Hafedh Herichi*** (herichi@math.ucr.edu), Mathematics department, Surge 283., University of California, Riverside, 900 University Ave., Riverside, CA 92521. *On the spectral operator for generalized fractal strings.*

A generalized fractal string, η; viewed as a discrete or continuous measure, is the associated measure to an ordinary fractal string. The spectral operator was introduced by M. L. Lapidus and M. van Frankenhuisjen in their theory of complex dimensions in fractal geometry. It is defined as the operator mapping the counting function of a generalized fractal string η to the counting function of its associated spectral measure $\nu = \eta * h$, where $*$ is the operation convolution of measures and h is the generalized harmonic string,

$$a(f)(t) = \zeta(\partial)(f)(t) = \prod_{p \in \mathbf{P}} (1 - (\partial)^{-1})^{-1}(f)(t)\,,$$

where f is the counting function of the generalized fractal string and $\mathbf{P}$ is the set of prime numbers. It relates the spectrum of a fractal string with its geometry. The spectral operator has also an Euler product representation, which provides a counterpart to the usual Euler product expansion for the Riemann Zeta function, but convergent in the critical strip of the complex plane. During this talk we will be discussing, in details, some fundamental properties of this operator as well as its prime-factors. (Received February 12, 2010)

1058-46-282 **Dominic Donald Kramer*** (kramerd@iastate.edu), 477 Carver Hall, Iowa State University, Ames, IA 50011. *Identifying a Basis in a Frame.*

Given a frame, we present a convex optimization problem which identifies a subset of the frame which is a basis with some nice properties. This is joint work with Eric Weber and Mark Lammers. (Received February 16, 2010)

1058-46-290 **Jonas D'Andrea*** (jdandrea@westminstercollege.edu). *A Filter-based Construction for Fractal Wavelet Frames.*

D. Dutkay and P. Jorgensen developed the concept of wavelets defined on a σ-finite fractal measure space arising from an iterated function system. We demonstrate a construction for wavelet frames on Dutkay-Jorgensen fractal spaces using finite frames from $\mathbb{C}^n$ and consider potential applications. (Received February 16, 2010)

47 ► Operator theory

1058-47-91 **Akram Aldroubi*** (akram.aldroubi@vanderbilt.edu), Dept Math. SC 1520, Nashville, TN 37240, and **Ilya Krishtal**. *Slanted matrices, Banach frames and sampling.*

We present a rare combination of abstract results on the spectral properties of slanted matrices and some of their very specific applications to frame theory and sampling problems. We show that for a large class of slanted matrices boundedness below of the corresponding operator in l_p for some p implies boundedness below in l_p for all p. We use the established result to enrich our understanding of Banach frames and obtain new results for irregular sampling problems. We also present a version of a non-commutative Wiener's lemma for slanted matrices. (Received February 06, 2010)

49 ► Calculus of variations and optimal control; optimization

1058-49-274 **Robert Thompson*** (robt@umn.edu), School of Mathematics, University of Minnesota, 206 Church St SE, Minneapolis, MN 55455. *Cohomology of the Euler-Lagrange complex.*

The theory of the ordinary Euler-Lagrange (E-L) complex provides a powerful tool for studying problems in variational calculus. Because of symmetries naturally present in many variational problems, it is useful to study an invariant version of the E-L complex, blending the theory of the variational bicomplex and the theory of equivariant moving frames.

In this talk we will explain the basic construction of the invariant E-L complex and discuss its cohomology. In particular, we'll explain constructively that its local cohomology is isomorphic to the Lie algebra cohomology of the Lie group acting on the space, and discuss some geometrically interesting cohomology classes.

This is joint work with Francis Valiquette of McGill University. (Received February 16, 2010)

51 ► Geometry

1058-51-44 **Thomas W Kephart*** (tom.kephart@gmail.com), Depatment of Physics and Astro., Box 1807 Sta. B, Vanderbilt University, Nashville, TN. *Physical Knots.*

We review the universal energy spectrum of tight knots and links in classical and quantum systems. Aspects of physical world examples are discussed. (Received January 21, 2010)

52 ► Convex and discrete geometry

1058-52-28 **Jay Kangel*** (j.kangel@excite.com), 4610 Bryant Ave. S. Apt. 102, Minneapolis, MN 55419. *Necessary and Sufficient Conditions for Krein-Milman Type Conclusions.*

Convex structures and notions of extreme subsets are used to provide necessary and sufficient conditions for Krein-Milman type conclusions. Suppose that C is a convex set. We prove: 1. Any collection of pairwise disjoint, extreme subsets of C can be enlarged to a collection whose convex hull is C iff every collection $\mathcal{E}$ of pairwise disjoint, extreme subsets of C satisfies either $C = \mathsf{con}(\cup\mathcal{E})$ or there exists a nonempty extreme subset E of C that is disjoint from $\cup\mathcal{E}$. 2. Assume the parts of the previous statement hold. Then C is the convex hull of its minimal extreme subsets iff there exists a topology for C that satisfies every nonempty extreme subset of C contains a nonempty, closed, compact, extreme subset of C. 3. Assume the parts of the previous statements hold. All of the minimal extreme subsets of C are singletons iff every nonempty extreme subset of C contains a singleton that is an extreme subset of C.

Topologies are constructed in which extreme subsets are closed. If X satisfies the hypotheses of the Krein-Milman theorem then, using the collection of closed, convex(in the usual sense) subsets as a convex structure and one these topologies, we obtain the conclusion of the Krein-Milman theorem. (Received December 16, 2009)

53 ► Differential geometry

1058-53-38 **Abraham D Smith*** (adsmith@mrsi.org), The Department of Mathematics and Statistics, McGill University, Burnside Hall, Room 1242, Montreal, QC H3A 2K6, Canada. *GL(2) geometry, integrability and hyperbolicity in high dimensions.*

GL(2) geometry is a special type of conformal geometry that has recently proven extremely useful for understanding integrable systems in three independent variables. This talk is a discussion of what this geometry can tell us about integrable hyperbolic PDEs in four or more independent variables, and vice-versa. (Received January 12, 2010)

1058-53-83 **Hans-Christian Herbig**, **Srikanth Iyengar** and **Markus J Pflaum*** (markus.pflaum@colorado.edu), Department of Mathematics, University of Colorado, UCB395, Boulder, CO 80309. *Formal deformation quantizations of singular symplectically reduced spaces.*

We discuss the so-called BFV method to construct formal deformations quantizations of symplectic quotients of Hamiltonian systems. We explain that under certain conditions among which is the requirement that the Koszul complex of the moment map of the Hamiltonian system is acyclic the BFV method allows to construct deformations quantizations in the presence of singularities. We then discuss examples coming from the special case of linear Hamiltonian torus actions. (Received February 03, 2010)

1058-53-95 **Francis Valiquette*** (valiquette@math.mcgill.ca), Department of Mathematics and Statistics, McGill University, 805 Sherbrooke W., Montréal, Québec H3A 2K6, Canada. *Solving Equivalence Problems with the Equivariant Moving Frame Method.* Preliminary report.

I will explain how to use the method of equivariant moving frames to solve local equivalence problems. The result is a method which avoids Cartan's iterative loop solution, does not require absorption of torsion and offers other distinctive advantages. (Received February 07, 2010)

1058-53-102 **Theresa C Anderson*** (tcanderson2@wisc.edu), 480 Lincoln Dr., Madison, WI 53706. *The Light Cone and the Conformal Sphere: Differential Invariants and their Relations.*

Here we employ the normalization technique of Fels and Olver to construct group-based moving frames for star-shaped curves in the light cone and the conformal 2-sphere, and we use the moving frame to find the differential invariants. Surprisingly, curves in these different geometries are not only connected via a projectivization map, but, with the appropriate choices of normalization constants, the invariants and invariant evolutions are related as well. We will prove that when we reparameterize star-shaped curves in the light cone with respect to centro-arc-length, the differential invariants are in a one-to-one correspondence with the conformal differential invariants under the projectivization. (Received February 08, 2010)

1058-53-127 **Robert B. Kusner*** (kusner@math.umass.edu,robkusner@gmail.com), GANG: Geometry, Analysis, Numerics & Graphics, Department of Mathematics, University of Massachusetts, Amherst, MA 01003. *Knots and Links as Collections of Annuli with Minimal Modulus.*

Any knot or link K in $\mathbf{R}^3$ can be represented as a collection of disjoint embedded annuli which immerse into the unit sphere S^2: a"thick" spherical diagram of K. Now regard S^2 as the Riemann sphere $\mathbf{C} \cup \infty$. The Riemann mapping theorem implies that any annulus in S^2 is conformal to either the punctured plane $\mathbf{C}^* = \mathbf{C} \setminus \{0\}$ or to $A_m = \{z \in \mathbf{C} : m < |z| < 1\}$. Call $m \in [0, 1)$ the *modulus* of this annulus A_m. The unknot is represented by (an annulus conformal to) A_0 (as well as by $\mathbf{C}^*$). Every other K (without trivial components) has a minimal modulus representation by annuli with $m > 0$. We report on some preliminary computations of minimal modulus knots and links (if K has more than one component, minimize the the sum of moduli for each of the representative annuli). Some of these computations exploit the classical representation of higher genus Riemann surfaces as branched covers over the Riemann sphere, making use of (disjoint collections of) embedded annuli with minimal (total) modulus on these Riemann surfaces, and leading to some (interesting?!) connections with Teichmüller theory. (Received February 10, 2010)

1058-53-142 **Joseph M Burdis** (jmburdis@ncsu.edu) and **Irina A Kogan*** (iakogan@ncsu.edu), Department of Mathematics, North Carolina State University, Campus Box 8205, Raleigh, NC 27695. *Object-image correspondence for curves under central and parallel projections.* Preliminary report.

We provide criteria for deciding whether a given planar curve is an image of a given spatial curve, obtained by a central or a parallel projection. These criteria reduce the projection problem to a certain variation of the equivalence problem of planar curves under affine and projective transformations. The latter problem can be addressed using Cartan's moving frame method. This leads to an algorithmic solution of the projection problem for curves. The same approach can be used to decide whether a given finite set of ordered points on a plane image of a given finite ordered set of points in $\mathbf{R}^3$. (Received February 11, 2010)

1058-53-193 **Chuu-Lian Terng*** (cterng@math.uci.edu), Department of Mathematics, University of California at Irvine, Irvine, CA 92697-3875, and **Gudlaugur Thorbergsson** (gthorbergsson@mi.uni-koeln.de), Mathematisches Institut, Universität zu Köln Weyertal, 86-90 5093 Koln, Germany. *Integrable curve flows in flat space.* Preliminary report.

We construct curve flows in flat spaces whose geometric invariants give solutions of soliton equations associated to rank one symmetric spaces. These curve flows also admit bi-Hamiltonian structures. (Received February 15, 2010)

1058-53-216 **Jeanne N. Clelland*** (Jeanne.Clelland@colorado.edu), Dept. of Mathematics, 395 UCB, University of Colorado, Boulder, CO 80309-0395. *Totally quasi-umbilic timelike surfaces in* $\mathbb{R}^{1,2}$. Preliminary report.

For a regular surface in Euclidean space $\mathbb{R}^3$, umbilic points are precisely the points where the Gauss and mean curvatures K and H satisfy $H^2 = K$; moreover, it is well-known that the only totally umbilic surfaces are planes and spheres. But for timelike surfaces in Minkowski space $\mathbb{R}^{1,2}$, it is possible to have $H^2 = K$ at a non-umbilic point; we call such points *quasi-umbilic*. In this talk I will discuss the classification of totally quasi-umbilic timelike surfaces in $\mathbb{R}^{1,2}$; these surfaces turn out to be much more plentiful than totally umbilic surfaces, and their classification features a surprise appearance by Liouville's equation! (Received February 15, 2010)

1058-53-259 **Jason Cantarella*** (cantarella@math.uga.edu), University of Georgia, Mathematics Department, Athens, GA 30602, and **Ted Ashton**, **Michael Piatek** and **Eric Rawdon**. *Lessons from the* `ridgerunner` *collection of tight knots.*

Suppose we tie a knot in a rope of fixed circular cross section and pull the knot tight. The resulting shape is the result of a complex interaction between the geometry and topology of the knot. What information can we extract from these shapes?

Over the past several years, we have developed a numerical simulation of the knot-tightening process, based on the method of constrained gradient descent. The result code, called `ridgerunner`, is a very effective knot tightener. This spring, we released the first large-scale publicly available collection of coordinates for tight knots, covering all knots with ≤ 10 crossings and all links with ≤ 9 crossings. This talk presents a short "guided tour" of this dataset, revealing some interesting features of tight knots.

Among other discoveries, we present some explicit examples of local minima for tight knots, discuss the role of curvature constraints in tight knots (tight knots and links seem to almost always be "kinked"), and consider various conjectures about the writhe of tight knot shapes. The talk will include a brief movie of the tightening process. (Received February 16, 2010)

54 ► General topology

1058-54-134 **Alex Karasev** and **Murat Tuncali*** (muratt@nipissingu.ca), Nipissing University, 100 College Drive, North Bay, Ontario P1B 8L7, Canada, and **Vesko Valov**. *Finite-to-one Maps into Euclidean Manifolds and Spaces with Disjoint Disks Properties.*

In this talk, some recent results on the existence of finite-to-one mappings onto Euclidean manifolds will be presented. (Received February 11, 2010)

1058-54-160 **Barry A. Peratt*** (bperatt@winona.edu), Department of Mathematics & Statistics, Winona State University, 175 West Mark Street, Winona, MN 55987, and **Judy A. Kennedy** (kennedy9905@gmail.com), Department of Mathematics, Lamar University, 4400 MLK Blvd., P.O. Box 10009, Beaumont, TX 77710. *The Topology of Tank Stirring.*

We examine the topology of stirring in a cylindrical tank with a centrally located impeller and a recycle loop. In constrast to the usual approaches involving partial differential equations or statistical mechanics, we consider an idealized mathematical model which consists of a geometrically motivated discrete time process. Our numerical studies indicate the existence of invariant tori, corresponding to periodic orbits, within which no mixing occurs. In addition to rigorously proving the existence of such tori, we prove that, under certain mild conditions, the topological structure which evolves is a "Sierpinski-like" curve $\times S^1$. (Received February 13, 2010)

55 ► Algebraic topology

1058-55-128 **J. Scott Carter*** (carter@jaguar1.usouthal.edu), Department of Mathematics and Statistics, ILB 325, Mobile, AL 36688, and **Alissa Crans**, **Mohamed Elhamdadi** and **Masahico Saito**. *Categorical Quandles and Knots.*

Categorical quandles are defined as a category object in the category of quandles, following the construction called internalization, and the resulting category is called a strict 2-quandle. The definition is motivated by that of a strict 2-group, which is well-known to be equivalent to a crossed module. Taking conjugation is shown to induce a functor from strict 2-groups to strict 2-quandles. Other explicit and interesting examples are presented. (Received February 11, 2010)

1058-55-289 **Robert G. Scharein*** (blomalfur@gmail.com), Department of Mathematics, Thornton Hall 937, 1600 Holloway Ave, San Francisco, CA 94132. *Minimal step number of cubic lattice knots in thin slabs.*

We present provisional data on the minimal step number of cubic lattice knots confined to a thin slab. In particular, we investigate thin slabs of thickness 1, 2 and 3. For most knot types, several ergodicity classes are found, often with dramatically different minimal step numbers. We discuss the number of distinct minimal step embeddings found within each class. Finally, we examine recurring patterns across the entire database of minimal step knots, both in thin slabs and for the unconstrained case. (Received February 16, 2010)

57 ► Manifolds and cell complexes

1058-57-2 **Vladimir Turaev***, Indiana University. *From monoidal categories to 3-manifold invariants and back.*

The lecture will explore connections between Topological Quantum Field Theory (TQFT) in dimension 3 and the theory of monoidal categories. We will discuss two main constructions of 3-dimensional TQFTs from categories and outline a connection between them. This circle of questions is motivated by Witten's Chern-Simons TQFT and the Ponzano-Regge model of 3-dimensional quantum gravity. (Received April 22, 2009)

1058-57-6 **Charles D Frohman*** (moss1956@gmail.com), The Deparment of Mathematics, The University of Iowa, Iowa City, IA 52242, and **Joanna M Kania-Bartoszynska** (jkaniaba@nsf.gov), National Science Foundation, 4201 Wilson Bvd, Arlington, VA 22230. *Reidemeister Torsion and the A-polynomial.*

We define a seminorm on the coordinate ring of the pillowcase using Reidemeister torsion. If the character variety of the knot is sufficiently nonsingular it detects the character variety of the knot complement. We derive a formula for the seminorm that makes it look like a limit of quantum invariants. (Received August 14, 2009)

1058-57-31 **Ren Guo***, Vincent Hall, 206 Church St. SE, Minneapolis, MN 55455, and **Xiaobo Liu**, No.55 Zhongguancun East Road, Beijing, Peoples Rep of China. *Quantum Teichmüller space and Kashaev algebra.*

Kashaev algebra associated to a surface is a noncommutative deformation of the algebra of rational functions of Kashaev coordinates. For two arbitrary complex numbers, there is a generalized Kashaev algebra. The relationship between the shear coordinates and Kashaev coordinates induces a natural relationship between the quantum Teichmüller space and the generalized Kashaev algebra. (Received December 20, 2009)

1058-57-39 **Dorothy Buck***, Dept of Mathematics, Imperial College London, London, sw7 2az, England, and **Ken Baker** and **Andrew Lobb**. *A Topological Model of Protein-Mediated Localized DNA Transformations.*

Many protein-DNA interactions, such as site-specific recombination and (type II) topoisomerase-mediated unknotting and unlinking, act by cutting and resealing (double-stranded) DNA segments in a localized way. These enzymatic reactions can be modelled in terms of tangles, 3-dimensional balls with two properly embedded arcs, each representing a segment of DNA. The action of the protein can be thought of as removing one tangle and replacing it with another – e.g. a topoisomerase-initiated crossing change as replacing a (+1) tangle with a (-1) tangle – leaving the rest of the DNA unchanged. This replacement can be straightforward (as in the topoisomerase example above) or quite complex.

Because of the plectonemic supercoiling of DNA, 'rational tangles' (formed by an alternating series of horizontal and vertical twists) are the most biologically relevant. We classify all possible rational tangles that can replace – in any prescribed manner – a given rational tangle, thus elucidating all possible protein-mediated localized changes of DNA. (Received January 14, 2010)

1058-57-71 **Qi Chen*** (chenqi@wssu.edu), Department of Mathematics, Winston-Salem State University, Winston Salem, NC 27110. *The Integrality of the Quantum SU(2) Invariant of 3-manifolds.*

We will show that the quantum SU(2) invariant τ_r of 3-manifolds is always an algebraic integer if r is coprime to the order of the first homology group of the 3-manifold. The proof is based on a relationship between τ_r and the Hennings invariant. (Received February 02, 2010)

1058-57-74 **Patricia Cahn*** (patricia.cahn@dartmouth.edu), 6188 Kemeny Hall, Dartmouth College, Hanover, NH 03755. *A Generalization of the Turaev Cobracket and the Minimal Self-Intersection Number.* Preliminary report.

Goldman and Turaev constructed a Lie bialgebra structure on the free $\mathbb{Z}$-module generated by free homotopy classes of loops on a surface. The Turaev cobracket $\Delta(\alpha)$ gives a lower bound on the minimal number of self-intersection points of a loop in a given homotopy class. Chas found examples which prove that this lower bound is not sharp. In particular, she constructed a class α with $\Delta(\alpha) = 0$, but which is not realized by a power of a simple loop. This disproves Turaev's conjecture that $\Delta(\alpha) = 0$ if and only if α can be realized by a power of a simple loop. We introduce an operation μ, defined in the spirit of the Andersen-Mattes-Reshetikhin algebra of chord diagrams. The Turaev cobracket factors through μ, and μ also gives a lower bound on the minimal number of self-intersection points of a loop in a given homotopy class. We show that this lower bound is sharp for homotopy classes α such that $\alpha \neq \beta^i$ for $|i| > 1$. We also show that $\mu(\alpha) = 0$ if and only if α can be realized by a power of a simple loop, thus showing that a statement similar to Turaev's conjecture is true. (Received February 02, 2010)

1058-57-90 **Patrick M Gilmer*** (gilmer@math.lsu.edu) and **Gregor Masbaum**. *Maslov index, Lagrangians, Mapping Class Groups and TQFT.*

Given a mapping class f of an oriented surface Σ and a lagrangian λ in the first homology of Σ, we define an integer $n_\lambda(f) \pmod 4$. We use $n_\lambda(f)$ to describe a universal central extension of the mapping class group of Σ as an index-four subgroup of the extension constructed from the Maslov index of triples of lagrangian subspaces in the homology of the surface. We give two formulas for $n_\lambda(f)$. One is topological using surgery, the other is homological and builds on work of Turaev and work of Walker. Some applications to TQFT are discussed. (Received February 05, 2010)

1058-57-98 **Kenneth C Millett*** (millett@math.ucsb.edu), Department of Mathematics, UCSB, Santa Barbara, CA 93106, and **E. Panagiotou** and **S. Lambropoulou**. *The linking number and writhe of uniform random walks and polygons in confined spaces.*

Random walks and polygons are used to model polymers. We consider the extension of the writhe, self-linking number and linking number to open chains. We then study the average writhe, self-linking and linking number of random walks and polygons over the space of configurations as a function of their length. We show that the mean squared linking number, the mean squared writhe and the mean squared self-linking number of oriented uniform random walks or polygons of length n, in a convex confined space, are of the form $O(n^2)$. Moreover, for a fixed simple closed curve in a convex confined space, we prove that the mean absolute value of the linking number between this curve and a uniform random walk or polygon of n edges is of the form $O(\sqrt{n})$. Our numerical studies confirm those results. They also indicate that the mean absolute linking number between any two oriented uniform random walks or polygons, of n edges each, is of the form $O(n)$. Equilateral random walks

and polygons are used to model polymers in θ-conditions. We use numerical simulations to investigate how the self-linking and linking number of equilateral random walks scale with their length. (Received February 08, 2010)

1058-57-101 **Stu Whittington*** (swhittin@chem.utoronto.ca), University of Toronto, 80 St George Street, Toronto, Ontario M5S 3H6, Canada. *Knotted 2-spheres in tubes in Z^4.* Preliminary report.

We consider 2-spheres in a tube in Z^4 and prove a pattern theorem using transfer matrix techniques. This implies that all except exponentially few such 2-spheres are knotted. This is joint work with Chris Soteros and De Witt Sumners. (Received February 08, 2010)

1058-57-106 **Elizabeth Denne*** (edenne@smith.edu), Department of Mathematics & Statistics, Smith College, Northampton, MA 01063, and **John M Sullivan** and **Nancy Wrinkle**. *Flat Ribbon Links in $\mathbb{R}^2$.*

Knots and links are modeled as flat ribbons immersed in $\mathbb{R}^2$ without folding. This is a 2-dimensional analogue of thick knots and the new work grew out of the theory of ropelength criticality studies by the second and third authors (and others). This talk will give examples of flat ribbon links, definitions and a discussion of the technicalities involved - that moving from 3 to 2 dimensions does not necessarily simplify the mathematics. (Received February 09, 2010)

1058-57-111 **De Witt Sumners*** (sumners@math.fsu.edu), Department of Mathematics, Florida State University, Tallahassee, FL 32306. *Are large codimension 2 spheres knotted with high probability?* Preliminary report.

We would like to prove that almost all sufficiently large (in area) 2-spheres in the 4-dimensional cubic lattice are knotted, and have results for sufficiently large 2-spheres in tubes (see abstract of S.G. Whittington for this special session). I will discuss the problem of constructing knotted 2-spheres in the 4d lattice, and the general problem of detecting knots among randomly generated polyhedral 2-spheres in 4-space. This is joint work with Stu Whittington and Chris Soteros. (Received February 09, 2010)

1058-57-139 **Maciej Niebrzydowski** and **Jozef H. Przytycki*** (przytyck@gwu.edu), Department of Mathematics, George Washington University, Monroe Hall, Room 240 2115 G Street NW, Washington, DC 20052. *The second quandle homology of odd Takasaki quandles and exterior algebra.* Preliminary report.

We are partially computing the second quandle homology of a finite connected Takasaki quandles. For an abelian group G the Takasaki quandle (or Kei), $T(G)$, is defined using the binary operation $*$ by $a * b = 2a - b$. A finite Takasaki quandle is connected iff $|G|$ is odd. Greene showed that $H_2^Q(T(Z_k)) = 0$ for k odd. We show that $H_2^Q(T(Z_k \oplus Z_k)) = Z_k$, k odd. Furthermore, we construct the epimorphism $H_2^Q(T(Z_k^n)) \to Z_k^{\binom{n}{2}}$, k odd. More generally, we prove that for an abelian group G of odd rank, there is an epimorphism from $H_2^Q(T(G))$ to $\Lambda^2(ZG)$ where Λ is the exterior tensor algebra. We analyze when this epimorphism is an isomorphism. Our precise result is that for G of odd rank, $H_2^Q(T(G))$ is isomorphic to $Z(G \times G)$ modulo relations: $(a, b) = -(b, a)$ and $(x, z) + (z, y) = (x, x + z - y) + (x + z - y, y)$. (Received February 11, 2010)

1058-57-152 **Charles D Frohman** and **Joanna Kania-Bartoszynska*** (jkaniaba@nsf.gov), 4201 Wilson Blvd., Arlington, VA 22230. *Quantum form of the Reidemeister torsion of a knot complement.*

J. Dubois defined a torsion invariant for knot complements. We will give an integral formula for this invariant that looks like a limit of quantum invariants. (Received February 12, 2010)

1058-57-154 **Hao Wu*** (haowu@gwu.edu), Math Department, GWU, Monroe Hall, Room 240, 2115 G Street, NW, Washington, DC 20052. *Colored $\mathfrak{sl}(N)$-homology for links and its deformations.*

I will introduce a homology that categorifies the $\mathfrak{sl}(N)$-polynomial of links colored by wedge powers of the defining representation. The construction is based on matrix factorizations associated to MOY graphs. I will also discuss deformations of this homology.

This work is a generalization of the Khovanov-Rozansky homology. (Received February 12, 2010)

1058-57-155 **Nathan Geer*** (nathan.geer@usu.edu), Utah State University, Math, Logan, UT 84322-3900, and **Bertrand Patureau**, Université de Bretagne-Sud. *Polynomial 6j-Symbols and States Sums on Triangulated 3-Manifolds.*

Following V. Turaev and O. Viro, I will discuss a construction which leads to information about the topology of a 3-manifold from one of its triangulation. This construction is based on algebraic tools which are 6-parameter quantities called 6j-symbols. I will give the formulas of a new family of such 6j-symbols, coming from nilpotent representations of quantum sl(2) at a root of one. This is joint work with B. Patureau and V. Turaev. (Received February 12, 2010)

1058-57-173 **Yuanan Diao** and **Claus Ernst***, Department of Mathematics, and Computer Science, Bowling Green, KY 42101, and **Uta Ziegler**. *On the square writhe of a minimal alternating knot diagram.* Preliminary report.

Given a knot diagram D with n crossings. If we assume that the over and underpass at each crossing is assigned at random then the expected value of the square writhe $E(wr^2(D)) = n$. If D is an alternating minimal knot diagram with n crossings then one expects that $E(wr^2(D)) > n$. We provide numerical evidence collected to support this expectation and give an exact analysis of $E(wr^2(D))$ for some knot families. (Received February 14, 2010)

1058-57-186 **Oleg Viro*** (oleg.viro@gmail.com), Stony Brook, NY 11794-3660. *How to obtain invariants of linked surfaces in the 4-space from a link homology theory.* Preliminary report.

The question posed in the title will be discussed. At least, one construction giving a non-trivial invariant will be presented. (Received February 15, 2010)

1058-57-187 **Kenneth C. Millett** and **Eric J. Rawdon*** (ejrawdon@stthomas.edu), Department of Mathematics, University of Saint Thomas, 2115 Summit Ave, Saint Paul, MN 55105, and **Andrzej Stasiak** and **Vy Tran**. *Symmetry-breaking in cumulative measures of shapes of polymer models.* Preliminary report.

Using numerical simulations we investigate shapes of random polygons, one of the simplest models of freely fluctuating circular polymers in a solution. We are interested in the 3D density distribution of our modeled polymers where the polymers have been aligned with respect to their three principal axes of inertia. This type of approach was pioneered by Theodorou and Suter in 1985. The approach of Theodorou and Suter results in a shape which is symmetric with respect to the xy, xz, and yz planes. This high order of symmetry is somewhat troubling as it is maintained even for chiral sets of data. By taking advantage of asymmetries within the modeled polymers, we modify the procedure of aligning independent configurations in such a way that shows their asymmetry. This approach reveals, for example, that the 3D density distribution for left-handed trefoil knots has a chiral structure that is mirror symmetric to the equivalent 3D density distribution obtained for right-handed trefoil knots. The symmetry breaking approach reveals more information than the traditional, symmetrical 3D density distributions originally introduced by Theodorou and Suter. (Received February 15, 2010)

1058-57-190 **Francis Bonahon**, Department of Mathematics, University of Southern California, Los Angeles, CA 90089, and **Helen Wong***, Department of Mathematics, Carleton College, Northfield, MN 55057. *The Kauffman bracket skein algebra and the quantum Teichmuller space.*

The Kauffman bracket skein algebra of Turaev and Przytycki-Sikora, and the quantum Teichmüller space of Chekhov-Fock and Kashaev, were both introduced as quantizations of the representation variety of surface groups into $\mathrm{PSL}_2(\mathbb{C})$. The first one has a combinatorial definition, whereas the second one is motivated by hyperbolic geometry. We construct a natural map between these two quantizations, relating the two points of view. (Received February 15, 2010)

1058-57-201 **R Trapp*** (rtrapp@csusb.edu), Department of Mathematics, 5500 University Pkwy, San Bernardino, CA 92373, and **S. Sadjadi**, **J. Alley** and **C. Mathes**. *On the Ropelength of Alternating Conformations.* Preliminary report.

It has been conjectured that the ropelength of alternating knots is at least linear in the crossing number. We show that for alternating conformations this is the case. One consequence is the fact that if the ropelength of an alternating knot is less than four times its crossing number, then minimizing conformations do not admit alternating projections. We then introduce the notion of a paired conformation, and extend the results to paired and almost-paired conformations. (Received February 15, 2010)

1058-57-212 **Louis H. Kauffman*** (kauffman@uic.edu), Math UIC, 851 South Morgan Street, Chicago, IL 60607-7045. *Topological Quantum Information, Khovanov Homology and the Jones Polynomial.*

In this paper we give a quantum statistical interpretation for the bracket polynomial state sum $< K >$ and for the Jones polynomial. We use this quantum mechanical interpretation to give a new quantum algorithm for computing the Jones polynomial. This algorithm is useful for its conceptual simplicity, and it applies to all values of the polynomial variable that lie on the unit circle in the complex plane. Letting $C(K)$ denote the Hilbert space for this model, there is a natural unitary transformation U from $C(K)$ to itself such that $< K >=< \phi|U|\phi >$ where $|\phi >$ is a sum over basis states for $C(K)$. The quantum algorithm arises directly from this formula via the Hadamard Test. We then show that the framework for our quantum model for the bracket polynomial is a natural setting for Khovanov homology. (Received February 15, 2010)

1058-57-224 **Uwe Kaiser*** (kaiser@math.boisestate.edu), Department of Mathematics, 1910 University Drive, Boise, ID 83725-1555. *Commutative Frobenius Algebras and 3-dimensional Compression Bordisms.* Preliminary report.

Given a commutative Frobenius algebra V over a commutative ring R with 1 we construct certain $V^{\otimes j}$-module categories $V[j]$ for $j \geq 0$. Let (M, α) be an oriented 3-manifold with a closed oriented 1-manifold α in its boundary. Then there are defined natural functors from a category of oriented surfaces in M bounding α and morphisms defined by *compression bordisms in* $M \times I$, taking values in $V[|\alpha|]$. (Here a compression bordism $S_1 \to S_2$ is a 3-dimensional manifold with corners, properly embedded in $M \times I$, which is a product over α, and with only embedded 2-handles and 3-handles attached to $S_1 \times I$, considered up to isotopy through those bordisms). The colimit of this functor is the Bar-Natan skein module defined for (M, α) and the Frobenius algebra V. Moreover, a glueing theorem can be proven for this functor. The above construction can be twisted with a $(3 + 1)$-dimensional TQFT over R to define functors on a category with the morphisms embedded in oriented 4-manifolds. We discuss the above constructions and some conjectures related to it. (Received February 15, 2010)

1058-57-243 **Victor A Nicholson***, vnichols@kent.edu. *Laundry Embedded Surfaces and Protein Folding.*

Linking and turn are invariants associated with laundry embedded surfaces. These invariants are necessary and sufficient conditions for the surfaces to be equivalent by ambient isotopy. A consequence is that the crossings of the strings of a tennis racquet (a laundry embedded chordal graph) can only be changed by chord rotation. An application of laundry surfaces is as augmented ribbon models of single domain protein. The model describes the native state, the unfolded state and a folding pathway in space as a single mathematical entity. (Received February 16, 2010)

1058-57-249 **Sergei Chmutov*** (chmutov@math.ohio-state.edu), 1680 University Drive, Mansfield, OH 44906. *Virtual linking numbers and the Conway polynomial.* Preliminary report.

We generalize to virtual link well known theorems of Hosokawa, Hartley, and Hoste which state that for an m-component link L the coefficients $c_i(L)$ of the Conway polynomial of L vanish when $i \leq m - 2$ and the coefficient $c_{m-1}(L)$ depends only on the linking numbers $l_{ij}(L)$ between the i-th and j-th components of L. This coefficient is equal to the determinant of a certain matrix composed of the linking numbers. This determinant can be computed using the matrix-tree theorem from graph theory.

For virtual links there are two different types of the linking number and two Conway polynomials, ascending and descending. We generalize the theorem above to virtual links. In this case the determinant representing $c_{m-1}(L)$ is related to the oriented version of the matrix-tree theorem. This is a joint work with my students Z.Cheng, T.Dokos, and J.Lindquist. (Received February 16, 2010)

1058-57-273 **Marta Asaeda*** (marta@math.ucr.edu), UC Riverside, Mathematics, 900 Big Springs Dr, Riverside, CA 92521. *Tensor functors on a certain category constructed from spherical categories.*

We construct functors from a certain algebraic category Alg , defined by Hopf algebra generators and relations, to the category of vector spaces, based on spherical categories. The category Alg is proposed by Habiro to be isomorphic to the cobordism category of once-punctured surfaces. If the proposal is proved valid, the result of this paper would imply a construction of a TQFT functor based on a spherical category. (Received February 16, 2010)

1058-57-277 **Jason Cantarella** and **Jason Parsley*** (parslerj@wfu.edu), Department of Mathematics, Box 7588, Wake Forest University, Winston-Salem, NC 27109-7588. *Intrinsic symmetries of knots and links.*

For oriented knots, the question of whether a knot is invertible (isotopic to itself with the opposite orientation) and/or chiral (not isotopic to its mirror image) have great implications in mathematics and in other sciences. We consider the case of oriented links and ask similar questions: if we invert one or more components, is this isotopic to our original link? What if we permute components? Or take a mirror image? The group of transformations of this type which can be realized by an isotopy of the link is called the "intrinsic" symmetry group of that link. We present the first computations of the intrinsic symmetry groups of links with 8 and fewer crossings.

The traditional definition of the symmetry group of a link is the mapping class group $MCG(S^3, L)$ of the pair S^3, L. Our symmetry groups are the images of the traditional symmetry groups of links under the natural homomorphism from $MCG(S^3, L)$ onto $MCG(S^3) \times MCG(L)$.

This is joint work with many students. (Received February 16, 2010)

58 ► Global analysis, analysis on manifolds

1058-58-88 **Juha Pohjanpelto*** (juha@math.oregonstate.edu), Department of Mathematics, Oregon State University, Corvallis, OR 97331. *Symmetries, conservation laws, and variational principles in classical field theories.*

Noether's theorem associates to every symmetry of a variational problem a conservation law for the corresponding Euler-Lagrange equations. Noether's second theorem, in turn, asserts that infinite dimensional Lie symmetry pseudogroups correspond to differential constraints among the Euler-Lagrange equations.

These classical theorems suggest the following problem first enunciated by Takens in 1977: Suppose that a system of differential equations is invariant under a given pseudogroup of transformations and that the system admits the conservation laws and is subject to the differential identities corresponding to these symmetries. Does it then follow that the system can be written as the Euler-Lagrange equations of some Lagrangian? Besides its intrinsic mathematical interest, Takens' question has far-reaching ramifications in physical field theories where symmetries and conservation laws are of primary importance in determining the form of the field equations.

In this talk I will review my recent joint work with G. Manno and R. Vitolo on Takens' problem for non-abelian gauge theories and with Ian Anderson on Takens' problem for metric field theories, involving the infinite dimensional symmetry pseudogroups of gauge transformations and of local diffeomorphisms, respectively. (Received February 04, 2010)

60 ► Probability theory and stochastic processes

1058-60-246 **Iddo Ben-Ari**, **Khalid Boushaba**, **Anastasios Matzavinos** and **Alexander Roitershtein*** (roiterst@iastate.edu), 420 Carver Hall, Iowa State University, Ames, IA 50011. *Stochastic analysis of the motion of DNA nanomechanical bipeds.*

We formulate and analyze a Markov process modeling the motion of DNA nanomechanical walking devices. We consider a molecular biped restricted to a well-defined one-dimensional track and study its asymptotic behavior. Our analysis allows for the biped legs to be of different molecular composition and thus to contribute differently to the dynamics. Our main result is a functional central limit theorem for the biped with an explicit formula for the effective diffusivity coefficient in terms of the parameters of the model. A law of large numbers, a recurrence/transience characterization and large deviations estimates are also obtained. Our approach is applicable to a variety of other biological motors such as myosin and motor proteins on polymer filaments.

The talk is based on a joint work with Iddo Ben Ari, Khalid Boushaba, and Anastasios Matzavinos. (Received February 16, 2010)

65 ► Numerical analysis

1058-65-53 **Robert Krasny*** (krasny@umich.edu), Mathematics Department, 530 Church Street, University of Michigan, Ann Arbor, MI 48109-1043, and **Hualong Feng**, **Leon Kaganovskiy** and **Lei Wang**. *Some Recent Developments in Particle Methods.*

Particle methods are related to the Green's function approach for solving differential equations and they represent an alternative to the traditional methods of scientific computing such as finite-difference, finite-element, and

spectral methods. Here some recent developments in particle methods will be discussed. First I'll present a treecode algorithm for multiquadric radial basis functions which reduces the operation count from $O(N^2)$ to $O(NlogN)$, where N is the number of nodes in the system. Our approach uses Cartesian Taylor expansions as opposed to the Laurent expansions used by previous investigators. Second I'll discuss Lagrangian particle simulations of vortex sheet roll-up in 3D fluid flow. The Lagrangian approach tracks the flow map and we employ special techniques such as kernel smoothing for stability, adaptive interpolation for accuracy, and a treecode for efficiency. We present simulations of vortex ring dynamics. (Received January 25, 2010)

1058-65-69 **James A Rossmanith*** (rossmani@math.wisc.edu), 480 Lincoln Drive, Madison, WI 53706. *Discontinuous Galerkin Methods for Magnetohydrodynamics.*

Standard shock-capturing numerical methods fail to give accurate solutions to the equations of magnetohydrodynamics (MHD). The essential reason for this failure is that by ignoring the divergence-free constraint on the magnetic field, these methods can be shown to be entropy unstable. In this talk we will briefly review the entropy stability theorem for discontinuous Galerkin (DG) methods. We will then present a class of constrained transport (CT) methods that we will give both stable and accurate results on several test cases. The proposed CT approach can be viewed as a predictor-corrector method, where an approximate magnetic field is first predicted by a standard DG method, and then corrected through the use of a magnetic potential. Finally, we will briefly describe efforts to extend this approach to Hall MHD and genuinely two-fluid plasma models. (Received February 01, 2010)

1058-65-89 **Dominik M Schoetzau*** (schoetzau@math.ubc.ca), University of British Columbia, Department of Mathematics, 1984 Mathematics Road, Vancouver, BC V6T 1Z2, Canada. *Exponential convergence of hp-version DG methods for linear elliptic PDEs in three dimensions.*

We introduce and analyze *hp*-version discontinuous Galerkin (DG) finite element methods for the numerical approximation of linear second-order elliptic boundary-value problems in three dimensional polyhedral domains. In order to resolve possible corner-, edge- and corner-edge singularities, we consider hexahedral meshes that are geometrically and anisotropically refined towards the corresponding neighborhoods. Similarly, the local polynomial degrees are increased linearly and possibly anisotropically away from singularities. We design interior penalty DG methods on such *hp*-meshes and prove that they are stable and well-defined under the proposed *hp*-refinements. We then establish exponential rates of convergence in the number of degrees of freedom for problems with piecewise analytic data. (Received February 05, 2010)

1058-65-197 **Gerard Awanou***, NIU/Mathematical Sciences, Dekalb, IL 60115. *Numerical methods for fully nonlinear elliptic equations.* Preliminary report.

While the theory of second order fully nonlinear equations has received considerable attention, there is a paucity of numerical methods, especially finite element methods, for these equations. As it is not in general possible to weaken the order of the equations through integration by parts, spaces of C^1 spline functions form an appropriate framework to approximate the solution of these equations. We introduce a general framework for numerical solution of these equations and illustrate the performance of the approach with numerical experiments using the spline element method. We treat the examples of the Monge-Ampère and Pucci equations and discuss the convergence of our algorithms. (Received February 15, 2010)

1058-65-204 **Hengguang Li**, **Anna Mazzucato** and **Victor Nistor***, Mathematics Department, McAllister Bldg., University Park, PA 16802. *Analysis of transmission and mixed boundary value problems with applications to the Finite Element Method.*

We study theoretical and practical issues in the Finite Element Method for a strongly elliptic second order equation with jump discontinuities in its coefficients on a polygonal domain Ω with cracks. More precisely, we consider the equation $-\operatorname{div}(A\nabla u) = f \in H^{m-1}(\Omega)$ with mixed boundary conditions, where the matrix A has variable, piecewise smooth coefficients. We establish regularity and Fredholm results. When the interface is smooth and no two adjacent edges have natural boundary conditions, we also establish well-posedness in weighted Sobolev spaces. In general, we obtain well-posedness in an augmented space Sobolev space. The theoretical analysis yields interpolation estimates that are then used to construct improved graded meshes recovering the (quasi-)optimal rate of convergence for piecewise polynomials of degree $m \geq 1$. We present several numerical tests. (Received February 15, 2010)

1058-65-229 **Yassine Boubendir*** (boubendi@njit.edu), Maths. Sci dept. Univ. Heights, 323 Dr. M. L. King Jr Blvd., Newark, NJ 07102. *Local adaptive radiation condition and overlapping domain decomposition methods for Helmholtz equation.*

The model problem addressed in this paper concerns the analysis and computation of a radiated or scattered time-harmonic acoustic solution, where the obstacle is composed of dielectric and metal. A new adaptive radiation condition method, that localizes the artificial interface only around the dielectric object, is introduced. An appropriate algorithm coupling finite and boundary element methods is solved iteratively using an overlapping domain decomposition method. Convergence and stability of the resulting algorithm are established. Numerical results are presented validating the theoretical results. (Received February 15, 2010)

1058-65-237 **Fernando Miranda-Mendoza*** (fermirme@iastate.edu), Department of Mathematics, 396 Carver Hall, Iowa State University, Ames, IA 50011. *Numerical Solution of Stochastic Partial Differential Equations using Wiener-Ito Chaos Expansions.*

In many complex physical, economical, and biological phenomena, the large scale dynamics can be modeled by deterministic laws, while the small scale effects can be naturally modeled with stochastic processes. This combination usually results in partial differential equations with either random coefficients, random initial or boundary conditions, or random forcing terms.

I will describe the Wiener-Ito chaos expansion of a stochastic function defined on the white noise probability space and the applications of this series expansion to the numerical solution of stochastic PDEs. I will also make some observations about the importance of the concepts of white noise terms, Wick products, and stochastic distributions when modeling with stochastic PDEs. (Received February 15, 2010)

1058-65-252 **Peter B Monk*** (monk@math.udel.edu), Department of Mathematical Sciences, Newark, DE 19716. *The Interior Transmission Problem in Acoustics.*

As a result of studies of the far field pattern of the scattered wave for time harmonic acoustic and electromagnetics, a new class of interior problem arises termed the "Interior Transmission Problem" (ITP). The ITP is not a standard elliptic problem, and a study of the solvability of this problem gives rise to a non-standard eigenvalue problem for the ITP. The proof of existence and properties of these eigenvalues is not straightforward. I shall survey the ITP and its properties in acoustics, and describe numerical schemes for computing transmission eigenvalues. Remarkably, transmission eigenvalues can be observed from far field data, and the resulting eigenvalues can be used to estimate properties of the scatterer. The interior transmission problem has similarities with problems involving negative index of refraction. (Received February 16, 2010)

1058-65-257 **Sheng Zhang*** (sheng@math.wayne.edu), Department of Mathematics, Wayne State University, Detroit, MI 48202. *Some numerical methods for shell models.* Preliminary report.

We present some numerical methods for the models of elastic shells. The methods are devised by using the discontinuous Galerkin approach and mixed finite element methods methodology. We show that the methods are stable and free of membrane/shear locking. (Received February 16, 2010)

1058-65-266 **Hengguang Li*** (hli19@syr.edu), Department of Mathematics, Syracuse University, Syracuse, NY 13244. *The FEM for axisymmetric elliptic PDEs.*

Let $\mathcal{L} := -r^{-2}(r\partial_r)^2 - \partial_z^2$. We consider the equation $\mathcal{L}u = f$ on a bounded polygonal domain with suitable boundary conditions, derived from the three-dimensional axisymmetric Poisson's equation. We establish the well-posedness, regularity and Fredholm results in weighted Sobolev spaces, for possible singular solutions caused by the singular coefficient of the operator $\mathcal{L}$, as $r \to 0$, and by non-smooth points on the boundary of the domain. In particular, our estimates show that there is no loss of regularity of the solution in these weighted Sobolev spaces. By analyzing the convergence property of the finite element solution, we provide a construction of improved graded meshes, such that the *quasi-optimal* convergence rate can be recovered on piecewise linear functions for singular solutions. The introduction of a new projection operator from the weighted space to the finite element subspace, certain scaling arguments, and a calculation of the index of the Fredholm operator, together with our regularity results, are the ingredients of the finite element estimates. (Received February 16, 2010)

1058-65-295 **Alexander Alekseenko*** (alexander.alekseenko@csun.edu), Department of Mathematics, Cal. State University Nortridge, 18111 Nordhoff St., Northridge, CA 91330. *Application of Discontinuous Galerkin Methods to Kinetic Problems with Gas-Surface Interaction.* Preliminary report.

Gas flows in micro and nano-devices, high-speed flows and high-altitude flight, are known to deviate from thermodynamic equilibrium, that is the distributions of molecular velocities in these flows differ significantly from the

Maxwellian distribution. Non-equilibrium flows exhibit many peculiar gas-surface interaction features, including velocity slip, temperature jump, thermal creep, and viscous heating. These features are often undesirable as they may interfere with device operation, and their inaccurate estimation may lead to unexpected device failures. In some instances, however, the principle of operation of a novel device may be based on non-equilibrium effects. For example, the action of a Knudsen compressor is based on the effect of thermal creep. Accurate modeling of gas-surface interaction is difficult. Numerical methods often lose of accuracy when surface effects are strong. The difficulty seems to be the weak regularity of the solution in the so-called Knudsen layer next to the surface. We are interested in the design of methods that can capture the discontinuity in the solution without losing high order convergence. We consider applications of discontinuous Galerkin methods to the solution of problems with gas-surface interactions. (Received February 17, 2010)

1058-65-299 **Jie Shen***, Department of Mathematics, Purdue University, West Lafayette, IN 47906. *A New Spectral-Galerkin Method for High-Dimensional PDEs.*

Many scientific, engineering and financial applications require solving high-dimensional PDEs. However, traditional tensor product based algorithms suffer from the so called "curse of dimensionality". We shall present a new spectral-Galerkin method for non-periodic problems and/or in the whole space. The method is based on two basic ingredients: (i) Choosing the frequencies of the trial functions from the "hyperbolic cross"; (ii) Developing a fast transform between the "hyperbolic cross" and a suitable sparse grid. We shall present rigorous error estimates as well as numerical algorithms which make it possible to solve a class of PDEs in moderately high dimensions. (Received February 17, 2010)

74 ► Mechanics of deformable solids

1058-74-37 **Mihaela Blanariu*** (mblanariu@colum.edu), 623 S. Wabash Ave., room 224, Chicago, IL 60605-1996, and **B J Spencer**. *Asymptotic Analysis of the Shape and Composition of Alloy Islands in Epitaxial Solid Films.*

We consider the formation of solid drops ("islands") occurring in the growth of strained solid films. Beginning from a detailed model for the growth of an alloy film that incorporates the coupling between composition, elastic stress and the morphology of the free boundary, we develop an asymptotic description of the shape and compositional non-uniformity of small alloy islands grown at small deposition rates. A key feature of the analysis is a "thin domain" scaling in the island which enables recasting the free boundary problem into a set of integrodifferential equations for the shape and composition profile. The system can be decomposed into two parts: one part gives a single integrodifferential equation for the shape analogous to that obtained for a single-component island determined by Shanahan and Spencer (2002), and the other part gives the composition profile in terms of the shape. The shape of an alloy island is identical to that of a single-component island with the same system parameters, but with a non-uniform composition that depends on the stress-composition coupling and alloy solution thermodynamics. We describe the structure and magnitude of the compositional non-uniformity and interpret our theoretical results in the context of SiGe films. (Received January 11, 2010)

76 ► Fluid mechanics

1058-76-207 **Yuen-Yick Kwan** (tkwan@tulane.edu) and **Jinhae Park*** (park196@math.purdue.edu), 150 N. University Street, Purdue University, West Lafayette, IN 47906, and **Jie Shen** (shen@math.purdue.edu), Purdue University. *A study of incompressible flow with surfactant monolayer.* Preliminary report.

A mathematical model is used to study the effect of surfactant concentration on the motion of an incompressible fluid in a cylinder. The presence of surfactant gives rise to coupling terms in the governing equations for such a system. With physically relevant boundary conditions, we discuss existence of solutions and investigate the motions of the fluid and surfactant by means of fast-spectral methods. (Received February 15, 2010)

78 ► Optics, electromagnetic theory

1058-78-129 **Gang Bao**, **Shui-Nee Chow**, **Peijun Li*** (lipeijun@math.purdue.edu) and **Haomin Zhou**. *An Inverse Random Source Problem for the Helmholtz Equation in One Dimension.* Consider the wave propagation in the one-dimensional stochastic Helmholtz equation with the source function driven by the Wiener process. To determine the random wave field, the direct problem is equivalently formulated as a two-point stochastic boundary value problem. This problem is shown to have pathwise existence and uniqueness of a solution. Furthermore the solution is explicitly deduced with a compact form using the integrated solution method. Since the source and hence the radiated field are stochastic, the inverse problem is to reconstruct the statistical structure, such as the mean value and variance, of the source function from physically realizable measurements of the radiated field. Based on the constructed solution for the direct problem, explicit formulas are derived to connect the mean value and variance of the random source to the Fourier transform of the measurements, which can be efficiently implemented by the fast Fourier transform. Numerical examples will be presented to demonstrate the validity and effectiveness of the proposed method. (Received February 11, 2010)

81 ► Quantum theory

1058-81-236 **Spencer D Stirling***, 115 South 1400 East, Salt Lake City, UT 84112, and **Yong-Shi Wu**. *Second Quantization of Categorical Quantum Mechanics.* Preliminary report.
joint work with Yong-Shi Wu (Received February 15, 2010)

1058-81-254 **Alexander Kirillov, Jr** (kirillov@math.sunysb.edu) and **Benjamin Balsam*** (balsam@math.sunysb.edu). *Turaev-Viro Invariants as an Extended TQFT.* Preliminary report.
In this talk, we will describe a extension of Turaev-Viro invariants, defined for an arbitrary spherical fusion category $\mathcal{C}$, to 3-manifolds with corners. We will show that this gives an extended (3-2-1) TQFT which coincides with the Reshetikhin-Turaev TQFT associated to $\mathcal{Z}(\mathcal{C})$, the Drinfeld center of $\mathcal{C}$. This is joint work with Sasha Kirillov. (Received February 16, 2010)

82 ► Statistical mechanics, structure of matter

1058-82-162 **Jim Evans***, Ames Laboratory & Dept. of Mathematics, 315 Wilhelm Hall, Iowa State University, Ames, IA 50011, and **Da-Jiang Liu** and **Xiaofang Guo**. *Stochastic Model for Spatial Epidemics: Quadratic Contact Process.*
We analyze the quadratic contact process for a population of individuals distributed on an infinite square lattice. Individuals are either sick or healthy. Sick individuals recover spontaneously at rate p. Healthy individuals are infected by *two* or more sick neighbors. (Also, neighbors can also switch places at rate h.) We find the existence of a diseased steady-state for p (=0.0944 for h=0), with a discontinuous transition to an all-healthy (absorbing) state for p. However, a finite patch of the epidemic can only survive for p (=0.0869 for h=0). One finds "generic two-phase coexistence" for p between, i.e., stable diseased and all-healthy regions coexist [1], contrasts a Durrett-postulate [2] of equal pf andf pe. The phenomenon reflects an orientation-dependence of the "equistability value" of p for stationary planar interfaces separating all-healthy and diseased states. Analysis of both steady-state behavior and interface propagation is achieved via Kinetic Monte Carlo simulation and by approximation to the exact master equations (producing discrete RDE's).

[1] Liu, Guo, Evans, Phys Rev Lett 98 (2007) 050601; Physica A 387 (2008) 177; J Chem Phys. 130 (2009) 074106.

[2] R. Durrett, SIAM Rev. 41 (1999) 677. (Received February 13, 2010)

1058-82-179 **Jonathan K Simon*** (jonathan-simon@uiowa.edu), Department of Mathematics, University of Iowa, Iowa City, IA 52240, and **Eric J Rawdon** and **Robert G Scharein**. *Using tangling to distinguish polymer packing.*
The "average crossing number" (ACN) and "average over-pass number" (ABN) are measures of entanglement for a polymer or other filament. We can use these measures to recognize different kinds of spatial packing, in particular to distinguish between models representing different kinds of spatially dense packing: a "crumpled globule" vs. a more inter-penetrated globule.

We also investigate a variety of protein shapes using these tangle measures. (Received February 14, 2010)

1058-82-213 **Marc L. Mansfield*** (marc.mansfield@stevens.edu), Dept. of Chemistry, Stevens Institute of Technology, Hoboken, NJ 07030. *Transport properties of knotted polymers and DNA.*

There has been interest in predicting the transport properties of knotted polymers ever since it was first observed that the electrophoretic mobility of DNA corrrelates with knot complexity. Many of these calculations have been based on dilute-solution hydrodynamic theory, which is most likely inadequate for gel electrophoresis. Nevertheless, we have computed transport properties of knotted ring polymers by a relatively new, versatile path-integration technique that is capable of determining dilute-solution properties even of bodies of complex shape. Although our results are consistent with the existence of asymptotic scaling laws, we find that mass-scaling for the transport properties fails at all accessible molecular weights. Interestingly, knotted polymers and DNA at accessible molecular weights appear to be in a "double-crossover." One crossover is attributed to knot localization, which does not develop fully until the chains are very long. The other is the "draining" crossover, or the very slow convergence of hydrodynamic properties to their asymptotic behavior. In particular, we find that stiff chains, such as DNA, exhibit an exceptionally strong draining effect. (Received February 15, 2010)

1058-82-262 **Chris Soteros*** (soteros@math.usask.ca), 106 Wiggins Road, Saskatoon, SK S7N 5E6, Canada. *Knotting statistics after a local strand passage in self-avoiding polygons on $\mathbb{Z}^3$.*

On the macroscopic scale, circular DNA can be viewed simply as a ring polymer. Experimental studies of enzyme action on DNA have inspired investigation of the following question about polygon models of ring polymers: Given a polygon with a fixed knot type, how does the distribution of knots after a "local" strand passage depend on the polygon's initial knot type, its length and on the specific details of the strand passage such as where it occurs and the number of edges altered in the strand passage? In 2000 Szafron proposed the first self-avoiding polygon (SAP) lattice model for investigating this. In the model, a SAP is used to model a ring polymer in dilute solution for which it is assumed that two segments of the polymer have already been brought close together to enable a local strand passage. Such a SAP, called a Θ-SAP, contains a specific pattern Θ at the strand passage site. Recent results obtained with Dr. M. Szafron about this model will be presented. In particular, numerical evidence that the after-strand-passage knot probabilities depend on the structure around the strand passage site will be provided. These results are consistent with the findings of Liu *et al* (2006-2010) for another polygon model of local strand passage. (Received February 16, 2010)

92 ► Biology and other natural sciences

1058-92-1 **Charles Doering***, University of Michigan, Complex System, Math and Physics, Ann Arbor, MI 48109-1109. *Fluctuations versus Spatial Variation in the Competition between Fast and Slow Dispersers.*

Dispersal is an important strategy employed by populations to locate and exploit favorable habitats. Given competition in a spatially heterogeneous landscape, what is the optimal rate of dispersal? Continuous population models predict that, all other features the same, a species with a lower dispersal rate always drives a competing species to extinction in the presence of spatial variation of resources. But the introduction of intrinsic demographic fluctuations can reverse this conclusion. We present a simple model in which competition between the exploitation of resources and population birth-death fluctuations leads to victory by either the faster or slower of two species depending on the environmental parameters. A simplified limiting case of the model, analyzed by closing the moment and correlation hierarchy, quantitatively predicts which species will win in the complete model under given parameters of spatial variation and average carrying capacity. This is joint work with Jack N. Waddell and Leonard M. Sander of the University of Michigan. (Received April 22, 2009)

1058-92-41 **Yangjin Kim*** (yangjink@umd.umich.edu), Department of Mathematics & Statistics, 2078 CASL Building, 4901 Evergreen Road, Dearborn, MI 48128, **Avner Friedman** (afriedman@math.ohio-state.edu), Jennings Hall, 3rd Floor, 1735 Neil Avenue, Columbus, OH 43210, **Julie Wallace** (wallace.395@osu.edu), 810 Biomedical research Tower, 460 W. 12th Ave, Columbus, OH 43210, **Fu Li** (Fu.Li@osumc.edu), 810 Biomedical research Tower, 460 W. 12th Ave, Columbus, OH 43210, and **Michael Ostrowski** (Michael.Ostrowski@osumc.edu), 810 Biomedical research Tower, 460 W. 12th Ave, Columbus, OH 43210. *Role of microenvironment in cancer progression : A mathematical model.*

Cancer is a complex, multiscale process, in which genetic mutations occurring at a sub-cellular level manifest themselves as functional changes at the cellular and tissue scale. Both the immediate microenvironment (cell-cell

or cell-matrix interactions) and the extended microenvironment (e.g. vascular bed) are considered to play crucial roles in tumour progression as well as suppression. Stroma is known to control tumor growth and invasion to surrounding tissue. However, it also prohibits therapeutics from accessing the tumor cells, thus causing drug resistance. Therefore, a thorough understanding of the microenvironment would provide a foundation to generate new strategies in therapeutic drug development. A mathematical model based on experiments has been developed in order to understand this complex relationship between tumor cells and host tissue. (Received January 15, 2010)

1058-92-51 **chuan xue***, 1735 Neil Ave Rm 378, Columbus, OH 43210. *Mathematical models of pattern formation in baterium Proteus mirabilis colonies.*

Proteus mirabilis cells can grow, move and colonize hard surfaces after they are inoculated. During the expansion of the colony, they form radial and spiral streams moving inward toward the inoculation site and a number of other complex patterns. To understand the underlying mechanism of these complicated patterns, we developed a hybrid cell-based model which incorporates a simplified single cell signal transduction model with both the adaptation and excitation components. By assuming that swimmer cells respond to a chemoattractant that they produce, we are able to predict the formation of radial streams as a result of the modulation of the local attractant concentration by the cells. We further predict the spiral streams by incorporating a swimming bias of the cells near the surface of the medium. The hybrid cell-based model becomes computationally expensive because of the large number of cells due to cell division, therefore a higer level description is needed. We also present a moment-closure method for deriving macroscopic evolution equations from the hybrid cell-based model using perturbation analysis, and compare the solutions of the cell-based model and the derived continuum model.

Joint work with Hans Othmer and Elena Budrene-Kac. (Received January 25, 2010)

1058-92-76 **chuan xue*** (cxue@mbi.osu.edu), 1735 Neil Ave 3rd Floor, Columbus, OH 43210. *Modeling ischemic cutaneous wounds.*

Chronic wounds represent a major public health problem affecting 6.5 million people in the United States. Ischemia, primarily caused by peripheral artery diseases, represents a major complicating factor in cutaneous wound healing. In this talk, we present a mathematical model of ischemic dermal wounds. The model consists of a coupled system of partial differential equations in the partially healed region, with the wound boundary as a free boundary. The extracellular matrix (ECM) is assumed to be viscoelastic, and the free boundary moves with the velocity of the ECM at the boundary. The model equations involve the concentration of oxygen, PDGF and VEGF, the densities of macrophages, fibroblasts, capillary tips and sprouts, and the density and velocity of the ECM. Simulations of the model demonstrate how ischemic conditions may limit macrophage recruitment to the wound-site and impair wound closure. The results are in general agreement with experimental findings.

* Joint work with Professor Avner Friedman and Dr. Chandan Sen (Received February 02, 2010)

1058-92-77 **Lynn Zechiedrich*** (elz@bcm.edu), One Baylor Plaza, Mail-stop BCM-280, Houston, TX 77030, and **Jonathan M. Fogg**, **Daniel J. Catanese, Jr.**, **Donald Schrock**, **Brian Gilbert**, **Nianxi Zhao** and **Youli Zu**. *Supercoiled DNA minicircles.*

To study DNA supercoiling and DNA topoisomerases, we created a way to make milligram quantities of minicircle DNAs of a few hundred base pairs. These DNAs have been extremely useful for this purpose. I will present data showing that supercoiled minicircles are useful for studying DNA structure and are superior vectors for delivering DNA into human cell types that no other DNA vector has been previously able to penetrate. In cells, DNA sequence is transcribed from these minicircles into small RNAs that regulate gene expression. Even small genes can be expressed from supercoiled minicircles. Supercoiled minicircles resist shear forces associated with gene therapy delivery and are significantly less susceptible to the nucleases in human serum than normal plasmid DNA vectors of a few thousand base pairs. (Received February 02, 2010)

1058-92-87 **Maria E. Gracheva*** (gracheva@clarkson.edu), 8 Clarkson Avenue, Potsdam, NY 13699, and **Irina V. Dokukina**. *A model of fibroblast motility with substrate rigidity sensing.*

To function efficiently in the body, the biological cells must have the ability to sense the external environment. Mechanosensitivity towards the extracellular matrix was identified as one of such sensing mechanisms that affects cell behavior. It was shown experimentally that a fibroblast cell has preference for locomoting over the stiffer substrate when given a choice between a softer and a stiffer substrate. We develop a discrete model of a fibroblast motility with substrate rigidity sensing. Our model allows to understand the interplay between the cell-substrate sensing and the cell bio-mechanics. The model cell exhibits experimentally observed substrate rigidity sensing which allows us to gain additional insights into the cell mechanosensitivity. (Received February 04, 2010)

1058-92-93 **Isabel K. Darcy*** (isabel-darcy@uiowa.edu), Department of Mathematics, 14 MacLean Hall, Iowa City, IA 52242-1419. *Tangle analysis of protein-DNA complexes.* Preliminary report.

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. 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? Topological 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 February 06, 2010)

1058-92-96 **Magdalena A Stolarska*** (mastolarska@stthomas.edu), 2115 Summit Ave., Mail # OSS 201, St. Paul, MN 55105. *A model of cellular movement and its effect on substrate traction patterns.*

Mechanical interactions between a cell and the substrate are vital for cell migration and are involved in various cellular processes, such as wound healing, embryonic development, and metastasis of cancerous tumors. As a result, understanding the nature of force generation by single cells and the mechanical interaction of a cell with the substrate is extremely important, and mathematical models are being used in furthering this understanding. In this talk, we present a continuum model of the mechanics of single cell motility in which the stresses that result from the active deformation of the cell are transmitted to a deformable substrate via adhesion sites that are modeled as either fixed connections or frictional interaction between the cell and the substrate. A finite element implementation of this model is used to numerically examine the nature of the stresses generated by the cell and the resulting traction patterns that occur at the substrate. We use the model to better understand what are the local active deformation profiles and the adhesion types necessary to replicate experimentally observed motion and traction patterns of different cell types. (Received February 07, 2010)

1058-92-105 **Hans G. Othmer*** (othmer@math.umn.edu), School of Mathematics, University of Minnesota, 270 Vincent Hall, Minneapolis, MN 55455. *Robustness of Pattern Formation in Development.*

Pattern formation during development of an adult organism requires precise spatio-temporal control of gene expression, which involves complex signal transduction and control networks. In this talk we will address the question of robustness of such complex systems under various disturbances, and in particular, analyze mechanisms for scale-invariant pattern formation. (Received February 09, 2010)

1058-92-140 **Maria R D'Orsogna*** (dorsogna@csun.edu), California State University at Northridge, Los Angeles, CA 90405. *Two dimensional swarming patterns: from discrete to continuum descriptions.*

Schools of fish, flocks of birds and swarms of insects arise in response to external stimuli or by direct interaction, and are able to fulfill tasks much more efficiently than single agents. How do these patterns arise? What are their properties? How are individual characteristics linked to collective behaviors? In this talk we discuss various aspects of biological swarming. Starting from a non-linear system of self propelled discrete agents that interact via pairwise attractive and repulsive potentials we predict aggregation morphologies, such as flocks and mills. We also relate the interaction potential to the collapsing or dispersing behavior of aggregates as the number of constituents increases. Finally, we discuss passage to the continuum, via kinetic and hydrodynamic equations. (Received February 11, 2010)

1058-92-161 **Wen Zhou*** (riczw@iastate.edu), 396 Carver Hall, Department of Mathematics, Iowa State University, Ames, IA 50010. *Mathematical modeling of MHC class II mediated immune responses in tissues.*

MHC class II mediated immunity, which is managed by $CD4^+$ T cells, plays essential role in immune response against infectious diseases. Motivated by Dr. Zinkernagel's postulate that the immune response is determined by the dynamics of antigen load, we developed a self-regulated functional mathematical framework to model MHC class II mediated immune response.

To recapitulate realistic scenarios, we have carefully modeled immune cells' movement by concepts of homogenization, B cell activation in the lymph nodes, helper T cell subtype activation and switch, and various type of activation of professional phagocytes. A framework to capture distinct types of pathogens is also introduced. We demonstrate using numerical simulations that the model can successfully respond to broad classes of pathogens. A highly skewed T_H1 response is generated against some virtual pathogens (e.g. Mycobacterium tuberculosis, Leishmania major etc.) and granuloma formation is observed, other virtual pathogens lead to an unskewed or

mixed response (e.g. Leishmania mexicana etc.) and some virtual pathogens lead to a T_H1 to T_H2 switch (e.g. M. avium paratuberculosis), and a T_H2 responses is generated against sole extracellular pathogens (e.g. parasitic worms such as nippostrongylus etc.). (Received February 13, 2010)

1058-92-195 **Hye Won Kang*** (hkang@math.umn.edu), 127 Vincent Hall, 206 Church St SE, Minneapolis, MN 55455, and **Likun Zheng** and **Hans Othmer**. *The maximal compartment size in stochastic modeling of chemical reaction-diffusion networks.*

In this talk, I will discuss how to discretize space for the stochastic spatially-discrete model for chemical reaction-diffusion networks. A system with reaction and diffusion is modeled using a continuous time Markov jump process. Diffusion is described as a jump to the neighboring compartments with proper spatial discretization. Considering the measure defined by steady-state first and second moments of each species in each compartment, the maximal compartment size for spatial discretization will be suggested. Then, I will show conditions for the exponential convergence of concentration to the uniform solution in the corresponding deterministic spatially-continuous model for chemical reaction-diffusion networks. Conditions obtained from the deterministic model estimate the maximal compartment size for space discretization from the stochastic model well. This is a joint work with Hans Othmer and Likun Zheng. (Received February 15, 2010)

1058-92-211 **Stephen D Levene*** (sdlevene@utdallas.edu), Departments of Molecular and Cell Biology, and Physics, University of Texas at Dallas, Richardson, TX 75080. *Mechanics and Energetics of DNA Loops in Complex Nucleoprotein Assemblies.*

Formation of DNA loops mediated by proteins bound at distant sites along a single molecule is an essential mechanistic aspect of many biological processes including gene regulation, DNA replication, and recombination. These processes are closely coupled to the topological state of DNA domains through supercoiling, knotting, and linking. Moreover, DNA looping is facilitated by an abundance of architectural proteins in cells such as HU, IHF, and HMGs, which bend the intervening DNA between cognate protein-binding sites. The complex interplay between DNA topology, expression of architectural DNA-bending proteins, and the regulation of DNA transactions remains poorly understood. We discuss numerical approaches for computing the free energies of DNA loop formation that account for intrinsic DNA properties such as bends or regions of altered flexibility, as well as global properties such as supercoiling. The objective of these approaches is to obtain the effective local concentration of loop ends, the generalization of the J factor in DNA cyclization, for topologically defined domains of complex nucleoprotein structures. Applications to lac-repressor-mediated gene regulation and the effects of architectural DNA-bending proteins on loop-mediated regulation will be discussed. (Received February 15, 2010)

1058-92-221 **Javier Arsuaga*** (jarsuaga@sfsu.edu), 1600 Holloway Avenue, Mathematics Department, Thronton 936, San Francisco, CA 94132, and **Yuanan Diao** (ydiao@uncc.edu), Department of Mathematics and Statistics, University of North Carolina at Charlotte, Charlotte, NC 28223. *DNA knotting in bacteriophage spooling like conformations.*

A number of idealized models have been proposed to explain the long range organization of the DNA in bacteriophages. However few can account for the distributions of complex knots found when examining DNA extracted from bacteriophage P4 capsids. Furthermore these models do not consider possible chirality biases in the arrangement of the DNA molecule inside the capsid. In this talk we address these two issues by proposing a randomized version of one of the most popular models: the coaxially spooled model. We present analytical and numerical results for the properties of the random polygons (knots) generated using this model. We show that such model can easily generate complex knotted conformations and although it accounts for some chirality of the organization of the DNA molecules inside bacteriophage capsids does not fully explain the experimental data. (Received February 15, 2010)

1058-92-225 **Sijia Liu*** (sijialiu@iastate.edu), 485 Carver Hall, Iowa State University, Ames, IA 50010. *Novel clustering methods for the analysis of biological data.*

The need to interpret and extract possible inferences from high-dimensional datasets has led over the past decades to the development of dimensionality reduction and data clustering techniques. In this talk, we present a family of novel fuzzy spectral clustering algorithms that combine seamlessly the strengths of existing spectral approaches to clustering with various desirable properties of fuzzy methods. We discuss examples of biological datasets for which the developed methodology outperforms other frequently used algorithms. (Received February 16, 2010)

1058-92-235 **Chad M. Topaz*** (ctopaz@macalester.edu), Macalester College, Dept. of Math, Statistics & Computer Science, 1600 Grand Ave., St. Paul, MN 55105, and **Andrew J. Bernoff**, **Sheldon Logan** and **Wyatt Toolson**. *Locust swarms: Discrete models, homogenization, and variational minimization.*

We construct a high-dimensional ODE model of desert locust swarms. The model incorporates social interactions, gravity, wind, and the effect of the impenetrable boundary formed by the ground. The dynamics of the group depend crucially on whether the underlying statistical mechanics are H-stable or catastrophic. Catastrophic swarms can form a rolling "bubble" with grounded locusts, airborne locusts, and an unpopulated center. The rolling pattern is similar to that observed by biologists, and includes a takeoff zone, a landing zone, and a stationary zone where grounded locusts can rest and feed. To further understand this structure, we formulate a one-dimensional continuum problem describing a vertical slice of the swarm. Using variational methods, we derive a Fredholm integral equation for locust density and find exact solutions which agree closely with simulations of the discrete problem. (Received February 15, 2010)

1058-92-244 **Paul A Milewski*** (milewski@math.wisc.edu), 480 Lincoln Dr, Madison, WI 53706, and **Julie Simons** (simons@math.wisc.edu), Madison, WI 53706. *The Volcano Effect in Bacterial Chemotaxis.*

Chemotaxis is the directed motion towards a chemical attractant. Many bacteria chemotax by iteratively swimming in a randomly chosen direction and biasing their swim lengths to lengthen if the environment is improving in the current direction. At a macroscopic level this biased random walk has been modeled by the Keller-Segel (K-S) equations which are conservation laws that have a bacterial flux biased in the direction of increasing attractant concentration. The K-S equations predict that bacteria will aggregate at the maxima of the attractant concentration, and this is not always observed: for rapidly varying concentration gradients, the peak in bacterial concentration is some distance away, lying on a ring. This is the "volcano effect". Our work, starting from a simplified biochemical description of each bacterium and then extracting population level models, shows how to bridge these two regimes (K-S and volcanic). The results are verified against stochastic simulations of virtual bacteria. We also discuss applications to the more complex chemotactic process where the bacteria are themselves producing the chemoattractant. (Received February 16, 2010)

1058-92-247 **Mark B Campanelli***, Dept. of Mathematics and Computer Science, Southwest Minnesota State University, 1501 State Street, Marshall, MN 56258-1136. *A multicellular mathematical model for the initiation of gene-expression waves during somitogenesis.*

Somitogenesis is a process common to all vertebrate embryos in which repeated blocks of cells arise from the presomitic mesoderm (PSM) to lay a foundational pattern for trunk and tail development. Somites form in the wake of passing waves of periodic gene expression that originate in the tailbud and sweep posteriorly across the PSM. Previous work has suggested that the waves result from a spatiotemporally graded control protein that affects the oscillation rate of clock-gene expression. With a minimally constructed mathematical model, the contribution of two control mechanisms to the initial formation of the gene-expression wave has been examined.

A system of delay differential-algebraic equations tracks the level of mRNA and protein for both a clock and signaling gene in each cell, with a non-diffusive coupling mechanism between nearest neighbors and a non-autonomously prescribed control protein level. Four biologically motivated model scenarios have been tested, with either one or two clock protein transcription binding sites and with or without differential decay rates for clock protein monomers and dimers.

Results indicate that only the model scenario with both multiple binding sites and differential decay rates is able to reproduce experimentally observed waveforms. (Received February 16, 2010)

1058-92-268 **Hans G Othmer*** (othmer@math.umn.edu), School of Mathematics, University of Minnesota, 270 Vincent Hall, Minneapolis, MN 55455. *Multi-scale analysis of chemical reaction networks.* Preliminary report.

In many complex reaction networks the reactions occur on vastly different time scales, but the usual form of the evolution equations does not lend itself to identification of slow and fast variables. In this talk we show how they can be identified in deterministic systems and we will discuss recent work on stochastic multi-scale analysis of reaction networks. (Received February 16, 2010)

1058-92-281 **Mariel Vazquez*** (mariel@math.sfsu.edu), Mathematics Department, San Francisco State University, 1600 Holloway Avenue, San Francisco, CA 94132, and **Javier Arsuaga** (jarsuaga@math.sfsu.edu) and **Robert Scharein** (scharein@shaw.ca). *DNA unknotting, topoisomerases and bacteriophages.*

Type II topoisomerases simplify DNA knots and links efficiently by performing strand-passage on DNA strands. Experimental studies have shown that these enzymes simplify the topology of DNA very efficiently, however the key to this efficiency is yet to be revealed. Motivated by these experimental observations, we study random transitions of knotted polygonal chains of fixed length. We use Monte Carlo computer simulations and computational knot theory methods to model strand-passage, with and without topological biases. Unknotting patterns can assist knot identification. We propose to apply these methods in the study of the DNA knots extracted from bacteriophage P4 capsids. (Received February 16, 2010)

1058-92-283 **Eirikur Palsson*** (epalsson@sfu.ca), Dept of Biology, Simon Fraser University, 8888 Unviersity DR, Burnaby, BC V5A1S6, Canada. *A cAMP Signaling Model Explains the Benefit of Maintaining Two Forms of Phosphodiesterase in Dictyostelium.*

Dictyostelium cells respond chemotactically to waves of the chemoattractant cAMP that guides cell aggregation towards a signaling center. This process is responsible for the recruitment of many cells resulting in the formation of large aggregation territories. An important component of the signaling system, the enzyme PdsA phosphodiesterase (PDE) that breaks down the external cAMP, can be either membrane-bound or secreted. I use a cell-based model of the cAMP signaling system to show that by utilizing both forms of PDE, *Dictyostelium* can extend the range of cell densities where cAMP waves can propagate, and thus where aggregation can be successful. This could confer an adaptive advantage and suggests why both forms have been maintained through evolution. The model indicates that membrane-bound PDE reduces the likelihood that the aggregation territory breaks up into many smaller territories as the cell density increases, while secreted PDE is important for wave propagation at low cell densities. These findings have implications for other excitable media with similar features of spatially discrete "release" and "degradation" sites. Examples of such systems are Ca^{2+} propagation in cardiac cells and propagation of electrical excitation in nerve axons. (Received February 16, 2010)

1058-92-286 **Sayanti Banerjee** and **Janet Best*** (jbest@math.ohio-state.edu), Dept of Mathematics, 100 Math Tower, 231 West 18th Ave, Columbus, OH 43210, and **Jung Eun Kim**. *Mixed Mode Oscillations in a Neuroendocrine Cell Model.*

Mixed mode oscillations (MMOs) are patterns involving an inter-mixing of large- and small-amplitude oscillations. For neurons, MMOs are typically mixtures of spikes and subthreshold oscillations. MMOs have been observed both in experimental data and in mathematical neuron models and have recently been a very active area of mathematical research. In this talk, I will discuss MMOs arising in a model for Gonadotropin-releasing hormone neurons. I will describe the use of dynamical systems theory to understand the mechanisms underlying MMOs in the model and how these compare to known mechanisms for generating MMOs. I will also explore possible physiological functions of MMOs. (Received February 16, 2010)

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1058-97-32 **Semail ULGEN YILDIRIM*** (sulgen@math.northwestern.edu), Northwestern University 2033 Sheridan Rd, Lunt Hall 223, Evanston, IL 60208. *Calculus Students: Learn from Others' Mistakes.* Preliminary report.

This project is about a new method which will facilitate Calculus learning. Indeed, it is very simple. Instructor prepares handouts where the questions are solved, however there are mistakes in the solutions. Students are required to find these mistakes and correct the mistakes if they could. The questions and solutions are taken from old midterms and finals where the real students made the real mistakes. We claim that this type of work will improve the success of a student a lot. We do not know how much. We will do the research on our students and present the results. (Received December 22, 2009)

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ABSTRACTS

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