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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
1049	April 25–26, 2009	San Francisco, CA	March 3	Vol 30, No. 3
1050	April 25–26, 2009	Worcester, MA	March 3	Vol 30, No. 3
1051	October 16–18, 2009	Waco, TX	August 25	Vol 30, No. 4
1052	October 24–25, 2009	University Park, PA	September 1	Vol 30, No. 4
1053	October 30–November 1, 2009	Boca Raton, FL	September 8	Vol 30, No. 4
1054	November 7–8, 2009	Riverside, CA	September 15	Vol 30, No. 4
1055	December 16–20, 2009	Seoul, South Korea	TBA	TBA
1056	January 13–16, 2010	San Francisco, CA	September 22	Vol 31, No. 1

URBANA, IL, March 27–29, 2009

Abstracts of the 1047th Meeting.

00 ► General

1047-00-2 **Gilles Pisier***, Texas A & M University amd Université Paris VI. *Complex interpolation between Hilbert, Banach and operator spaces.*

Let $B(X,Y)$ denote the Banach space of bounded operators between two Banach spaces X, Y. We describe the complex interpolation spaces

$$(B(\ell_{p_0}), B(\ell_{p_1}))^\theta \text{ or } (B(L_{p_0}), B(L_{p_1}))^\theta$$

for any pair $1 \le p_0, p_1 \le \infty$ and $0 < \theta < 1$. In the same vein, given a locally compact Abelian group G, let $M(G)$ (resp. $PM(G)$) be the space of complex measures (resp. pseudo-measures) on G equipped with the usual norm $\|\mu\|_{M(G)} = |\mu|(G)$ (resp.

$$\|\mu\|_{PM(G)} = \sup\{|\hat{\mu}(\gamma)| \mid \gamma \in \widehat{G}\}).$$

We describe similarly the interpolation space $(M(G), PM(G))^\theta$. Various extensions and variants of this result will be given, e.g. to Schur multipliers on $B(\ell_2)$ and to operator spaces. Motivated by a question of Vincent Lafforgue, we study the Banach spaces X satisfying the following property: there is a function $\varepsilon \to \Delta_X(\varepsilon)$ tending to zero with $\varepsilon > 0$ such that every operator $T\colon\ L_2 \to L_2$ with $\|T\| \le \varepsilon$ that is simultaneously contractive (i.e. of norm ≤ 1) on L_1 and on L_∞ must be of norm $\le \Delta_X(\varepsilon)$ on $L_2(X)$. We show that $\Delta_X(\varepsilon) \in O(\varepsilon^\alpha)$ for some $\alpha > 0$ iff X is isomorphic to a quotient of a subspace of an ultraproduct of θ-Hilbertian spaces for some $\theta > 0$ where θ-Hilbertian is meant in a slightly more general sense than in our previous work. (Received May 27, 2008)

1047-00-19 **Stewart E Brekke*** (stewabruk@aol.com), 2900 Maple Ave, Downers Grove, IL 60515. *Geometric Figures as Sets of Convergent, Divergent and Parallel Lines and Surfaces.* Preliminary report.

Plane figures such as angles, triangles and polygons, to name a few,can be thought of as sets of convergent, divergent and parallel lines. A plane angle can be considered as a set of two convergent and/or divergent lines interwsecting a a point of convergence or divergence. A triangle can be considered as a set of three convergent and/or divergent lines having three vertices of convergence and/or divergence points. A dihedral angle can be thought of as a set of two divergent or convergent planes inetersecting at a line of convergence or divergence. Also, a square based pyramid can be thought of as a set of five convergences and/or divergences as vertices with two sets of parallel lines as the base. The Law of Convergence states that the smaller the angle between two or more lines or surfaces, the greater the convergence. The Law of Divergence states that the greater the angle of divergence between two or more lines or surfaces , the greater the divergence. Covergences and divergences may be quantified as the measure of the angle of convergence or divergence. (Received November 18, 2008)

1047-00-116 **Andrew J. Hanson*** (hansona@indiana.edu), Computer Science Department, Lindley Hall 215, Indiana University, Bloomington, IN 47405. *Experiencing the Fourth Dimension.* Preliminary report.

Human interaction with the 3D world is responsible for grounding our understanding of our environment. We learn from this experience, for example, how to correctly interpret 2D images of the 3D world. A wide variety of methods that produce 2D experiences of 3D worlds can be extended to simulate 3D experiences of 4D worlds. We explore recent progress in simulating and interacting with 4D worlds. Examples include interactive volume rendering of 3-manifolds and thickened 2-manifolds embedded in 4D and projected to a 3D image, interactive adjustment of complex thickening features to provide additional richness to renderings of embedded 2-manifolds, and in general how to exploit the latest GPU techniques to assist 4D visualization. Other examples include the possibility of 3D touch-based interaction with (simulated) physically colliding 4D objects, and the challenges of extending interactive graphics approaches to 4-manifolds such as the K3 surface. (Received January 23, 2009)

01 ► History and biography

1047-01-103 **Colin B. P. McKinney*** (cbmckinn@math.uiowa.edu), Department of Mathematics, 14 MacLean Hall, Iowa City, IA 52242-1419. *Archytas of Tarentum: Savior to the Delians.*

It is well known to modern mathematicians that the problem of constructing a cube double a given cube, using only straightedge and compass alone, is impossible. However, the problem is solvable with additional techniques. Many examples date to antiquity, and may be found in Netz' recent translation of Eutocius' commentaries on Archimedes' *On the Sphere and the Cylinder*. One such solution is due to Archytas of Tarentum, who flourished in the early 4th century BCE. In this talk, I will discuss a brief history of the problem, its equivalence to the problem of finding two means proportional, and my work on a 3D visualization of Archytas' solution. (Received January 21, 2009)

1047-01-159 **C. Huneke**, Department of Mathematics, University of Kansas, Lawrence, KS 66045, **D. Katz*** (dlk@math.ku.edu), Department of Mathematics, University of Kansas, Lawrence, KS 66045, and **J. Validashti**, Department of Mathematics, University of Kansas, Lawrence, KS 66045. *Uniform equivalence of symbolic and adic topologies.*

Let (R, m) be a local ring. We study the question of when there exists a positive integer h such that for all prime ideals $P \subseteq R$, the symbolic power $P^{(hn)}$ is contained in P^n, for all $n \geq 1$. We show that such an h exists when R is a reduced isolated singularity such that R either contains a field of positive characteristic and R is F-finite or R is essentially of finite type over a field of characteristic zero. This partially generalizes previous work by Ein-Lazarsfeld-Smith and Hochster-Huneke. (Received January 27, 2009)

03 ► Mathematical logic and foundations

1047-03-29 **Vinicius Cifu Lopes*** (vinicius@alumni.illinois.edu). *The Grothendieck semiring of the group of complex roots of unity.*

We focus on the category of definable sets and functions in the group of complex roots of unity. We define and present its Grothendieck semiring, which is isomorphic to the semiring of nonnegative polynomials over the integers. This is the same semiring for vector spaces over any division ring; however, contrarily to the latter case, the universal Euler characteristic for this category does not enjoy the Fubini property; more strongly, the category itself does not enjoy definable triviality. (This material is part of the speaker's doctoral thesis under supervision of Lou van den Dries.) (Received December 06, 2008)

1047-03-64 **Henry P Wynn***, London School of Economics, Houghton Street, London, WC2A 2AE, England. *Self-avoiding generating sequences for Fourier lattice designs.*

This continues work by Riccomagno, Schwabe and Wynn (Ann. of Statist., 1997) and other papers on d-dimensional Fourier regression. Good designs, that is set of sampling points, for multidimensional regression are based on integer lattices whose positive integer generators $\{g_1, \ldots, g_d\}$ have special self-avoiding properties. These properties lead to generalisations of the Nyquist sampling theorem in that to realise solutions to these properties the sample size must exceed a minimal value, which we may call the generalised Nyquist value. The self-avoiding property can be converted to a statement about the existence of integer vectors $g = (g_1, \ldots, g_d)^T$ which do *not* satisfy a special set of linear equation $A_d g = 0$. It transpires that some "greedy" solutions are derived from certain sequences of intrinsic interest such as Sidon sets, the Thue-Morse sequence and constructions

based on Cantor sets. Minimal solutions can be found using methods from computational algebraic geometry. (Received January 11, 2009)

1047-03-100 **Roger D Maddux*** (maddux@iastate.edu), Department of Mathematics, 396 Carver Hall, ISU, Ames, IA 50011. *Relational relevance algebras.*

Relational relevance algebras are algebras in which the elements are binary relations and the operations are intersection, union, composition, and converse-complimentation.

A relational relevance algebra is dense (transitive) if every relation in it is dense (transitive), and commutative if the operation of composition is commutative.

Relational relevance algebras provides semantics for relevance logic, just as Boolean algebras of sets provide semantics for classical propositional calculus.

The class of commutative dense relational relevance algebras is sound but not complete for the system of relevance logic known as R.

The class of transitive commutative dense relational relevance algebras is both sound and complete for the system of relevance logic known as RM, also called R-mingle. This follows from another result, that all normal Sugihara algebras are isomorphic to relational relevance algebras. (Received January 21, 2009)

1047-03-121 **Richard L Kramer*** (ricardo@iastate.edu), Department of Mathematics, 396 Carver Hall, Ames, IA 50011. *Birelativized relation algebras.* Preliminary report.

We consider a variety of relation-type algebras that contains all proper relation algebras and is closed under relativizations from both the top and the bottom. (Received January 23, 2009)

1047-03-158 **Ross Willard*** (rdwillar@uwaterloo.ca), Pure Math Department, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada. *The complexity of pp-definability.* Preliminary report.

It is known (Friedman, unpublished; Bergman, Juedes and Slutzki, IJAC '99) that the clone membership problem for finite algebras is EXPTIME-complete. The computational complexity of the analogous *relational clone membership problem* for finite relational structures is not yet determined. This problem accepts as input a finite set $\mathcal{R}$ of finitary relations on a finite set A, together with another relation s on A, and asks if s is in the relational clone generated by $\mathcal{R}$ (equivalently, if s is definable by a primitive positive (pp) formula in the structure $\langle A; \mathcal{R}\rangle$). This problem is known in the theoretical computer science community as the existential inverse satisfiability problem ($\exists$-$INVSAT$). We call it the pp-definability problem.

The standard proof connecting clones and relational clones via the usual Galois connection places the pp-definability problem in co-NEXPTIME. Last year at a meeting at AIM, I provided a lower bound by showing that the problem is EXPTIME-hard. In this lecture I will sketch these results and report on efforts aiming to resolve the precise complexity of pp-definability. (Received January 27, 2009)

1047-03-170 **Jeremy F Alm*** (alm.academic@gmail.com), 1101 W College Ave, Jacksonville, IL 62650. *Relation algebras from group actions.* Preliminary report.

Suppose a group G acts on a set A. Let A_G be the unary algebra

$$\langle A, \{g \cdot (\,\cdot\,) : A \to A \mid g \in G\}\rangle$$

Then the collection $Rel(A_G)$ of compatible relations on A_G is a proper relation algebra (endowed with the usual operations). We consider representable relation algebras which arise as algebras of compatible relations in this way. (Received January 27, 2009)

1047-03-395 **Petar Markovic**, **Ralph McKenzie** and **Matthew Nickodemus*** (matthew.nickodemus@vanderbilt.edu), Vanderbilt University, Department of Mathematics, 1326 Stevenson Center, Nashville, TN 37240. *Algebras of Bounded Width.*

In this talk I will present an algorithm used to solve the constraint satisfaction problem over certain algebras. Algebras for which this algorithm works are called algebras of bounded width. This talk is related to the talks of McKenzie and Markovic. (Received February 02, 2009)

05 ► Combinatorics

1047-05-25 **YiHuang Shen*** (yshen@math.purdue.edu), Department of Mathematics, Purdue University, 150 North University Street, West Lafayette, IN 47907. *Stanley decompositions and squarefree monomial ideals.* Preliminary report.

For a finitely generated $\mathbb{Z}^n$-graded module M over the polynomial ring $k[x_1, \ldots, x_n]$, one can consider its Stanley decompositions and Stanley depth. Stanley conjectured that $sdepth(M) \geq depth(M)$. The conjecture has been confirmed in several cases, but still remains open. One obstacle of verifying this conjecture lies in the difficulty of computing the Stanley depth. Using a recent method due to Herzog, Vladoiu and Zheng, we studied the Stanley depths for several classes of squarefree monomial ideals. We will report these interesting results. (Received November 28, 2008)

1047-05-28 **Anthony B Evans*** (anthony.evans@wright.edu), Department of Mathematics and Statistics, Wright State University, 3640 Colonel Glenn Highway, Dayton, OH 45435. *Mutually orthogonal latin squares based on groups.* Preliminary report.

Given the multiplication table of a finite group, we can construct sets of mutually orthogonal latin squares (MOLS), by permuting its columns. A natural question: how large a set of MOLS can we construct in this way?

The existence of a pair of MOLS based on a group is completely determined by the structure of the group's Sylow-2 subgroup. But, beyond this, very little is known for most classes of groups. We will study possible ways to improve on lower bounds for the largest number of squares possible in sets of MOLS based on groups. (Received December 04, 2008)

1047-05-35 **T Abualrub**, **A Ghrayeb**, **N Aydin*** (aydinn@kenyon.edu) and **I Siap**. *On the Construction of Skew Quasi-Cyclic Codes.* Preliminary report.

Cyclic codes have an important place in algebraic coding theory. There have been many generalizations of cyclic codes. In this work we study a recent generalization of cyclic codes known as skew QC codes. This set of codes is constructed using a non-commutative ring called the skew polynomial ring $F[x;\theta]$. Skew QC codes are left submodules of the ring $R_s^l = (F[x;\theta]/(x^s - 1))^l$. Our search in this class of codes resulted in the construction of several new codes with Hamming distances exceeding the Hamming distances of the previously best known linear codes with comparable parameters. (Received December 09, 2008)

1047-05-39 **Wesley Pegden*** (pegden@math.rutgers.edu), 110 Frelinghuysen Rd, Piscataway, NJ 08540. *Thue-type games and highly nonrepetitive sequences.*

A theorem of J. Beck, proved with the Lovász Local Lemma, asserts that there is an infinite binary sequence in which any long identical blocks are exponentially far apart. We prove that an analagous result can be achieved even with only limited control over the sequence—that is, we prove that if two players take turns selecting binary digits to form an unending sequence, Player 1 has a strategy to ensure exponential distance between any long identical blocks. The existence of Player 1's winning strategy is proved probabilistically, via an extension of the Local Lemma which can dramatically reduce the number of edges needed in a dependency graph when there is an ordering underlying the significant dependencies of events. The same method allows us to prove other theorems with the same theme; for example, we show that for sufficiently large base c (*e.g.,* $c \geq 37$), Player 1 has a strategy which avoids repetition of any blocks of lengths ≥ 2 in the c-ary sequence game, giving a natural game-theoretic analog to Thue's original theorem on nonrepetitive sequences. These results represent the first successful application of a Local Lemma to games. (Received December 10, 2008)

1047-05-52 **Ralph Faudree*** (rfaudree@memphis.edu), Office of Provost, 360 Administration Building, University of Memphis, Memphis, TN 38152. *Saturation Numbers.*

A graph G is an H-saturated graph if G does not contain H as a subgraph, but $G \cup \{e\}$ contains a copy of H for any edge e not in G. The *saturation number* of H, denoted by $sat(H, n)$, is the minimum number of edges in an H-saturated graph G of order n. A survey of some of the classical results on saturation numbers will be presented, also with a comparison of the saturation number $sat(H, n)$ with the Turán extremal number $ex(H, n)$. However, the focus will be on some recent results on saturation numbers. This will include saturation numbers for disjoint union of complete graphs, generalized fans, books and generalized books, and special classes of trees. (Received January 05, 2009)

1047-05-71 **Jeremy F. Alm**, **Roger D. Maddux** and **Jacob Manske*** (jmanske@iastate.edu).
Chromatic Graphs, Ramsey Numbers, and the Flexible Atom Conjecture.

Let K_N denote the complete graph on N vertices with vertex set $V = V(K_N)$ and edge set $E = E(K_N)$. For $x, y \in V$, let xy denote the edge between the two vertices x and y. Let L be any finite set and $\mathcal{M} \subseteq L^3$. Let $c : E \to L$. Let $[n]$ denote the integer set $\{1, 2, \ldots, n\}$.

Briefly, $\mathcal{M}$ can be thought of as a set of colored triangles. Every triangle that is in $\mathcal{M}$ is *mandatory* and every triangle that is not in $\mathcal{M}$ is *forbidden*. We try to color the edges of K_N so that every colored triangle in $\mathcal{M}$ appears (and no forbidden triangle appears) and so that if a color is part of a triangle in $\mathcal{M}$, then every edge with that color participates in that triangle.

We investigate for which sets of triangles there exist colorings which obey these conditions as well as connections to relation algebras. We discuss our proof of a special case of the flexible atom conjecture which states that every finite relation algebra with one flexible atom is representable on a finite set, continuing the work of Jipsen, Maddux, and Tuza in 1995. This represents a joint work with J. Alm and R. Maddux. (Received January 14, 2009)

1047-05-96 **Jacob Fox** and **Po-Shen Loh*** (ploh@princeton.edu), Mathematics Department, Princeton University, Princeton, NJ 08544-1000, and **Benny Sudakov**. *Large induced trees in K_r-free graphs.*

For a graph G, let $t(G)$ denote the maximum number of vertices in an induced subgraph of G that is a tree. We study the problem of bounding $t(G)$ for graphs which do not contain a complete graph K_r on r vertices. This problem was posed twenty years ago by Erdős, Saks, and Sós. Substantially improving earlier results of various researchers, we prove that every connected triangle-free graph on n vertices contains an induced tree of order $\sqrt{n}$. When $r > 3$, we also show that $t(G) > \frac{1}{4} \log_r n$ for every connected K_r-free graph G of order n. Both of these bounds are tight up to small multiplicative constants, and the first one disproves a recent conjecture of Matoušek and Šámal. (Received January 20, 2009)

1047-05-97 **Luis G Serrano*** (lserrano@umich.edu), 2082 East Hall, 530 Church St., Ann Arbor, MI 48109-1043. *The shifted plactic monoid.*

We introduce a shifted analog of the plactic monoid of Lascoux and Schützenberger, the *shifted plactic monoid*. It can be defined in two different ways: via the *shifted Knuth relations*, or using Haiman's mixed insertion.

Applications include: a new combinatorial derivation (and a new version of) the shifted Littlewood-Richardson Rule; similar results for the coefficients in the Schur expansion of a Schur P-function; and a shifted counterpart of the Lascoux-Schützenberger theory of noncommutative Schur functions in plactic variables. (Received January 20, 2009)

1047-05-101 **Ronald J. Gould*** (rg@mathcs.emory.edu), Department of Mathematics and Computer Scienc, Emory University, Atlanta, GA 30322. *On Saturation Numbers.*

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? This is called the saturation number of H and is denoted by $sat(n, H)$.

In this talk we survey some of the basic facts about saturated graphs and recent results on the saturation number for a variety of classes of graphs, including the union of cliques, books, cycles, and trees. (Received January 21, 2009)

1047-05-104 **Jie Ma** and **Xingxing Yu*** (yu@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30084. *K_5-subdivisions in 5-connected nonplanar graphs.*

A well known theorem of Kuratowski states that a graph is planar iff it contains no subdivision of K_5 or $K_{3,3}$. It is also known that any 3-connected nonplanar graph other than K_5 contains a subdivision of $K_{3,3}$. Seymour and Kelmans independently conjectured that every 5-connected nonplanar graph contains a subdivision of K_5. We establish this conjecture for graphs containing K_4^-. (Received January 21, 2009)

1047-05-111 **Tao Jiang*** (jiangt@muohio.edu), Department of Mathematics and Statistics, Miami University, Oxford, OH 45056. *Compact topological cliques in sparse graphs.* Preliminary report.

Let ϵ be any real number such that $0 < \epsilon < 1$. Answering a question of Paul Erdős, Kostochka and Pyber (1988) showed that for large n, every n-vertex graph with at least $4^{t^2} n^{1+\epsilon}$ edges contains a subdivision of K_t in which each edge of K_t is subdivided at most $c \log t/\epsilon$ times, where c is an absolute constant.

Here we prove a complementary (and in some sense stronger) result by eliminating the dependency on t. For each t and sufficiently large n, we show that every n-vertex graph with at least $a(t)n^{1+\epsilon}$ edges, where $a(t)$ is a constant depending on t, contains a subdivision of K_t in which each edge of K_t is subdivided at most $c \log(1/\epsilon)/\epsilon$ times, where c is an absolute constant. Note that the number of times each edge is subdivided depends only on ϵ and does not depend on t. (Received January 23, 2009)

1047-05-114 **John Roger Schmitt*** (jschmitt@middlebury.edu), Mathematics Department, Middlebury College, Middlebury, VT 05753, and **Michael Ferrara**, **Michael Jacobson** and **Mark Siggers**. *Potentially H-bigraphic sequences.*

We extend the notion of a potentially H-graphic sequence as follows. Let A and B be nonnegative integer sequences. The sequence pair $S = (A, B)$ is said to be *bigraphic* if there is some bipartite graph $G = (X \cup Y, E)$ such that A and B are the degrees of the vertices in X and Y, respectively. If S is a bigraphic pair, let $\sigma(S)$ denote the sum of the terms in A.

Given a bigraphic pair S, and a fixed bipartite graph H, we say that S is *potentially H-bigraphic* if there is some realization of S containing H as a subgraph. We define $\sigma(H, m, n)$ to be the minimum integer k such that every bigraphic pair $S = (A, B)$ with $|A| = m, |B| = n$ and $\sigma(S) \geq k$ is potentially H-bigraphic. In this paper, we determine $\sigma(K_{s,t}, m, n)$, $\sigma(P_t, m, n)$ and $\sigma(C_{2t}, m, n)$. (Received January 23, 2009)

1047-05-117 **Michael J Rowell*** (rowell@pacificu.edu), Pacific University, 2043 College Way, Forest Grove, OR 97116. *A Combinatorial Interpretation of a General Case of a Fine Identity.*

We introduce a combinatorial map which leads to general forms and finite versions of an elegant q-series identity. It is with these results that we present many new identities analogous to the first. We close with a discussion of the path taken and future possibilities. (Received January 23, 2009)

1047-05-118 **Jozsef Balogh**, **Tom Bohman** and **Dhruv Mubayi*** (mubayi@math.uic.edu). *Random Erdos-Ko-Rado.*

We prove the analogue of the Erdos-Ko-Rado theorem for the random k-uniform hypergraph for various ranges of p, k, n. Along the way, we prove that every nontrivial intersecting k-uniform hypergraph can be covered by $k^2 - k + 1$ pairs, which is sharp as evidenced by projective planes. This improves upon a result of Sanders. Several open questions remain. (Received January 28, 2009)

1047-05-126 **Jennifer Vandenbussche*** (jvandenb@spsu.edu), Southern Polytechnic State University, Department of Mathematics, 1100 S. Marietta Pkwy, Marietta, GA 30060, and **Douglas B. West**, University of Illinois at Urbana-Champaign. *Independence number of 2-factor-plus-triangles graphs.*

A *2-factor-plus-triangles graph* is the union of two 2-regular graphs G_1 and G_2 with the same vertices, such that G_2 consists of disjoint triangles. Let $\mathcal{G}$ be the family of such graphs. These include the famous "cycle-plus-triangles" graphs shown to be 3-choosable by Fleischner and Stiebitz. In this talk, we explore the independence ratio of graphs in $\mathcal{G}$. The independence ratio of a graph in $\mathcal{G}$ may be less than 1/3, but achieving the minimum value 1/4 requires each component to be isomorphic to a single 12-vertex graph. We present constructions to show that (1) $\mathcal{G}$ contains infinitely many connected graphs with independence ratio less than 4/15; and (2) for each odd g there are infinitely many connected graphs in $\mathcal{G}$ such that G_1 has girth g and the independence ratio of G is less than 1/3. (Received January 23, 2009)

1047-05-129 **Molly Dunkum** and **Peter Hamburger*** (peter.hamburger@wku.edu), 1906 College Heights Blvd#11078, Bowling Green,, KY 42101, and **Attila Pór**. *On the Chudnovsky, Seymour, and Sullivan's conjecture.*

For a simple directed graph G, let $\beta(G)$ be the size of the smallest subset $X \in E(G)$ so that $G \backslash X$ has no directed cycles, and let $\gamma(G)$ denote the number of unordered pairs of nonadjacent vertices in G. Chudnovsky, Seymour, and Sullivan showed that $\beta(G) \leq \gamma(G)$, and conjectured that $\beta(G) \leq \frac{\gamma(G)}{2}$. We show that $\beta(G) < \gamma(G)$. (Received January 24, 2009)

1047-05-141 **Guantao Chen*** (gchen@gsu.edu), Department of Mathematics and Statistics, Georgia Sate University, Atlanta, GA 30303, **Katsuhiro Ota**, Department of Mathematics, Keio University, Yokohama, Japan, **Akita Saito**, Department of Computer Science, Nihon University, Tokyo, Japan, and **Yi Zhao**, Department of Mathematics and Statistics, Georgia State University, Atlanta, GA. *On Even Square of Hamilton Cycles.* Preliminary report.

Let G be a graph. A subgraph H of G is called an *even square hamiltonian cycle* (ESHC) if it contains a hamiltonian cycle $C = v_0v_1 \dots v_{n-1}v_0$ of G and chord v_iv_{i+3} for each $0 \le i \le n-1$. Clearly, if G has an ESHC then G contains all possible 2-factors with even components. We prove that there is a positive integer N such that, for a graph G of order n, if n is even and minimum degree $\delta(G) \ge \frac{1}{2}(n + 614)$ then G contains an ESHC. The condition that n is even is necessary. (Received January 25, 2009)

1047-05-154 **Daniel W Cranston*** (dcransto@dimacs.rutgers.edu), DIMACS Center/CoRE Building/4th Floor, Rutgers University, 96 Frelinghuysen Road, Piscataway, NJ 08854-8018, and **Seog-Jin Kim** and **Gexin Yu**. *Injective colorings of sparse graphs.*

Let $\mathrm{mad}(G)$ denote the maximum average degree (over all subgraphs) of G and let $\chi_i(G)$ denote the injective chromatic number of G (in an injective coloring, vertices must receive distinct colors if they have a common neighbor). If Δ denotes the maximum degree of G, then clearly $\chi_i(G) \ge \Delta$. We study upper bounds on $\mathrm{mad}(G)$ that imply $\chi_i(G) \le \Delta + c$ for $c \in \{0, 1, 2\}$. In particular, we have the following results.

If $\mathrm{mad}(G) < \frac{14}{5}$ and $\Delta \ge 4$, then $\chi_i(G) \le \Delta + 2$. When $\Delta = 3$, we show that $\mathrm{mad}(G) < \frac{36}{13}$ implies $\chi_i(G) \le 5$; in contrast, we give a graph G with $\Delta = 3$, $\mathrm{mad}(G) = \frac{36}{13}$, and $\chi_i(G) = 6$.

If $\mathrm{mad}(G) \le \frac{5}{2}$, then $\chi_i(G) \le \Delta + 1$; similarly, if $\mathrm{mad}(G) < \frac{42}{19}$, then $\chi_i(G) \le \Delta$. When G is a planar graph with $\Delta \ge 4$, we have the following improvements. If $\mathrm{girth}(G) \ge 9$, then $\chi_i(G) \le \Delta + 1$; similarly, if $\mathrm{girth}(G) \ge 13$, then $\chi_i(G) = \Delta$. (Received January 26, 2009)

1047-05-181 **Michael Gekhtman*** (mgekhtma@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46530, and **Michael Shapiro** and **Alek Vainshtein**. *Poisson Geometry of Directed Networks.*

Recently, Postnikov used weighted directed planar graphs in a disk to parametrize cells in Grassmannians. We investigate Poisson properties of Postnikov's map from the space of edge weights of a planar directed network into the Grassmannian. We show that this map is Poisson if the space of edge weights is equipped with a representative of a 6-parameter family of universal quadratic Poisson brackets and the Grasmannian is viewed as a Poisson homogeneous space of the general linear group equipped with an appropriately chosen R-matrix Poisson-Lie structure. We also prove that Poisson brackets on the Grassmannian arising in this way are compatible with the natural cluster algebra structure.

Next, we generalize Postnikov's construction by defining a map from the space of edge weights of a directed network in an annulus into a space of loops in the Grassmannian. We then show that universal Poisson brackets induce a family of Poisson structures on rational-valued matrix functions and on the space of loops in the Grassmannian. In the former case, this family includes, for a particular kind of networks, the Poisson bracket associated with the trigonometric R-matrix. (Received January 28, 2009)

1047-05-183 **Laszlo A Szekely*** (szekely@math.sc.edu), Department of Mathematics, USC, Columbia, SC 29208. *Phylogenetic combinatorics.*

A phylogenetic tree is a binary tree in which the leaves are labelled with different labels. A binary subtree of a phylogenetic tree is obtained by selecting a subset of the leaf vertices, taking their spanning subtree, and in the spanning subtree contracting recursively edges, in which at least one endvertex has degree 2.

A well-known fact is, that given two different phylogenetic trees with there should be a 4-leaf binary tree, which is a binary subtree of one of the phylogenetic trees, but not of the other.

A version of the Maximum Agreement Subtree Problem asks how large common binary subtree must be always there for two phylogenetic trees with n leaves each, using the same label set.

In general, the question is what kind of structures should be shared by any two different phylogenetic trees and what kind of different structures should there be in any two different phylogenetic trees.

These problems show analogy with Ramsey theory and come up naturally in phylogeny reconstruction, and in related questions about testing phylogenetic trees. I'll discuss results on phylogeny reconstruction and phylogeny testing in the framework of the Cavender-Farris-Neyman model.

This is joint work with Mike Steel, Elchanan Mossell and others. (Received January 28, 2009)

1047-05-190 **Cun-Quan Zhang*** (cqzhang@math.wvu.edu), Dept. Mathematics, POBox 6310, Morgantown, WV 26506-6310. *Cycle covers – minimal contra pairs, Petersen chain and Hamilton weights.*

Let G be a bridgeless cubic graph and w be an eulerian weight $w : E(G) \mapsto \{1, 2\}$. A faithful circuit cover of the ordered pair (G, w) is a family F of circuits if every edge e of G is contained in precisely $w(e)$ members of F. A circuit C of (G, w) is removable if the graph obtained from G by deleting all weight 1 edges contained in C remains bridgeless. An ordered pair (G, w) is a contra pair if it has no faithful circuit cover, and a contra pair is minimal if (G, w) has no removable circuit and for every weight 2 edge e, the ordered pair $(G - e, w)$ has a faithful circuit cover.

Let (G, w) be a minimal contra pair. It is proved by Alspach, et al (Tran. AMS 1994) that if (G, w) is a minimal contra pair, then the graph G must contain a Petersen minor. It is further conjectured by Fleischner and Jackson that G must be the Petersen graph. We show that this conjecture is true if Hamilton weight conjecture is true.

Note, an ordered pair (G, w) is a Hamilton weight pair if every faithful circuit cover of (G, w) is a pair of Hamilton circuits. And Hamilton weight conjecture states that if every 3-connected Hamilton weight pair is constructed from K_4 via a series of $Y - \Delta$-operations. (Received January 28, 2009)

1047-05-191 **Eva Czabarka*** (czabarka@math.sc.edu), **Laszlo A Szekely** and **Todd J Vision**. *Minimizing the number of episodes on a species tree - an extension of Gallai's theorem on intervals.* Preliminary report.

In 1996 Guigo et al. posed the following problem: for a given species tree and a number of gene trees, what is the minimum number of duplication episodes, where several genes can undergo duplication together to generate the observed situation (gene order is neglected, but duplication of genes could have happened only on segments associated with particular genes on the species tree). We study two versions of this problem, one of which was solved recently by Bansal and Eulenstein. We provide min-max theorems for both versions that generalize Gallai's archetypal min-max theorem on intervals. These theorems lead to algorithms that find a feasible location for these episodes on the tree. (Received January 28, 2009)

1047-05-213 **Hong-Jian Lai*** (hjlai@math.wvu.edu), 320 Armstrong Hall, West Virginia University, Morgantown, WV 26506-6310, **Yanting Liang** (lyt814@math.wvu.edu), 320 Armstrong Hall, West Virginia University, Morgantown, WV 26506-6310, and **Yehong Shao** (shaoy@ohio.edu), Arts and Science, Ohio University Southern, Ironton, OH 45638. *On s-hamiltonian connected line graphs.*

A graph G is hamiltonian-connected if any two of its vertices are connected by a Hamilton path (a path including every vertex of G); and G is s-hamiltonian-connected if the deletion of any vertex subset with at most s vertices results in a hamiltonian-connected graph. In this paper, we prove that the line graph of a $(t+4)$-edge-connected graph is $(t+2)$-hamiltonian-connected if and only if it is $(t+5)$-connected, and for $s \geq 2$ every $(s+5)$-connected line graph is s-hamiltonian-connected. (Received January 29, 2009)

1047-05-239 **Maria Chudnovsky*** (mchudnov@columbia.edu) and **Paul Seymour**. *Rao's degree sequence conjecture and well-quasi-ordering tournaments by immersion.*

In the 1980's Rao conjectured that in every infinite set of degree sequences of graphs, there are two degree sequences with graphs one of which is an induced subgraph of another. Recently we proved this conjecture, and we will sketch the main ideas of proof. It turns out that Rao's conjecture is related to the problem of ordering certain families of digraphs by immersion. In particular, we were able to show that the set of tournaments is well-quasi-ordered by immersion. (Received January 29, 2009)

1047-05-244 **Ken-ichi Kawarabayashi** and **Gexin Yu*** (gyu@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23185. *Graph Minors and graph linkages.* Preliminary report.

A graph G contains a graph H as a subdivision if there exists a subgraph of G isomorphic to a subdivision of H. A graph G is said to be H-linked if every injective mapping from the vertices of H to the vertices of G can be extended to an H-subdivision, where the edges of H are associated with internally vertex disjoint paths of G. For a graph H with k edges, H-linked graphs generalize the notions of k-linked, k-ordered and k-connected graphs.

It is well-known that if a graph is $2k$-connected and has certain dense minors, then it is k-linked. In this talk, we will follow this kind of idea to explore conditions for a graph to be H-linked when H contains few edges. This is a joint work with Ken-ichi Kawarabayashi. (Received January 29, 2009)

1047-05-245 **Andrew J. Radcliffe*** (aradcliffe1@math.unl.edu), Department of Mathematics, 203 Avery Hall, University of Nebraska-Lincoln, Lincoln, NE 68502, and **Jonathan Cutler** (jonathan.cutler@montclair.edu). *A simple entropy proof of the Kahn-Lovasz theorem.*

We give a simple entropy proof of the Kahn-Lovasz theorem, which states that the number of perfect matchings in a simple graph G is at most

$$\prod_{v \in V(G)} (d(v)!)^{1/d(v)}.$$

(Received January 29, 2009)

1047-05-255 **Eric A. Swartz*** (eswartz@math.ohio-state.edu), Department of Mathematics, The Ohio State University, 231 West 18th Avenue, Columbus, OH 43202. *A Construction of an Infinite Family of 2-Arc Transitive Polygonal Graphs of Arbitrary Odd Girth.*

A near-polygonal graph is a graph Γ which has a set $\mathcal{C}$ of m-cycles for some positive integer m such that each 2-path of Γ is contained in exactly one cycle in $\mathcal{C}$. If m is the girth of Γ then the graph is called polygonal. Up until now, the only examples of 2-arc transitive polygonal graphs with arbitrarily large valency had girth no larger than seven, and the 2-arc transitive polygonal graph with largest girth had valency five and girth twenty-three (in fact, even with no restrictions on the automorphism group, there were no examples of polygonal graphs with odd girth greater than twenty-three). We provide a construction of an infinite family of polygonal graphs of arbitrary odd girth with 2-arc transitive automorphism groups. (Received January 29, 2009)

1047-05-256 **József Balogh** and **Ryan Martin*** (rymartin@iastate.edu), 396 Carver Hall, Department of Mathematics, Iowa State University, Ames, IA 50010. *On Avoider-Enforcer games.*

Positional games are two-player games in which both players have perfect information and alternately choose elements from a set. In the Avoider-Enforcer game on the complete graph K_n, the players (Avoider and Enforcer) each take one edge in turn. Given a graph property $\mathcal{P}$, Enforcer wins the game if Avoider's graph has the property $\mathcal{P}$. An important parameter is $\tau_E(\mathcal{P})$, the smallest integer t such that Enforcer can win the game against any opponent in t rounds.

In this talk, let $\mathcal{F}$ be an arbitrary family of graphs and $\mathcal{P}$ be the property that a member of $\mathcal{F}$ is a subgraph or is an induced subgraph. We determine the asymptotic value of $\tau_E(\mathcal{P})$ when $\mathcal{F}$ contains no bipartite graph and establish that $\tau_E(\mathcal{P}) = o(n^2)$ if $\mathcal{F}$ contains a bipartite graph.

The proof uses the game of JumbleG and Szemerédi's regularity lemma. (Received January 29, 2009)

1047-05-260 **Rahil Baber**, **J Robert Johnson** and **John Talbot*** (talbot@math.ucl.ac.uk), Department of Mathematics, UCL, Gower Street, London, WC1E 6BT, England. *Extremal problems for multipartite graphs.*

Bondy, Shen, Thomassé and Thomassen showed that any tripartite graph with all edge densities greater than the golden ratio must contain a triangle and that this is best possible. We will consider some related problems: in particular given a tripartite graph with prescribed edge densities how many triangles must it contain? (Received January 30, 2009)

1047-05-263 **William T. Trotter*** (trotter@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Partitioning Subset Lattices into Intervals.* Preliminary report.

Motivated by a question involving the Stanley depth of modules, Jürgen Herzog asked us whether it is always possible to find a partition $\mathcal{P}_n$ of the non-empty subsets of $\{1, 2, \ldots, n\}$ into intervals with $|Y| \geq n/2$ for each interval $[X, Y]$ in $\mathcal{P}_n$. We answer Herzog's question in the affirmative by first embedding it in a stronger result and then providing two elegant proofs, using entirely different methods. In this talk, we outline the first of these proofs. This is joint work with Csaba Biró, David M. Howard, Mitchel T. Keller and Stephen J. Young (Received January 30, 2009)

1047-05-266 **Bela Csaba*** (bela.csaba@wku.edu), Dept. of Mathematics, 1906 College Heights Blvd., Bowling Green, KY 42101, **Ali Shokoufandeh** (ashokouf@cs.drexel.edu), Department of Computer Science, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, and **Jeff Abrahamson** (jeffa@cs.drexel.edu), Dept. of Computer Science, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104. *Optimal Random Matchings on Trees and Applications.*

We consider tight upper- and lower-bounds on the expected total length of the optimal matching between two random point sets distributed among the leaves of a hierarchically separated tree. Specifically, given two n

element sets of points $R = \{r_1, ..., r_n\}$ and $B = \{b_1, ..., b_n\}$ distributed uniformly and randomly on the m leaves of a λ-Hierarchically Separated Tree with branching factor b such that each one of its leaves are of depth δ, we prove that the expected total length of the optimal matching between R and B is $\Theta(\sqrt{nb}\sum_{k=1}^{h}(\sqrt{b}\lambda)^k)$, for $h = \min(\delta, \log_b n)$. This result allows us to provide bounds on the expected total length on other metric spaces via approximate embeddings into hierarchically separated trees. In particular, we reproduce the results concerning the expected optimal transportation cost in $[0,1]^d$ (except for $d = 2$) and prove bounds on self-similar sets, e.g., the Cantor set, and various fractals. (Received January 30, 2009)

1047-05-267 **Philippe R Di Francesco*** (philippe.di-francesco@cea.fr), CEA Saclay/ IPhT, 91191 Gif sur Yvette, France. *Q-systems and Cluster Positivity.*

Q-systems are integrable systems of recursion relations first introduced in the study of quantum spin chains based on Lie groups. These were interpreted recently [Kedem07]-[DiFrancesco-Kedem07] as mutation relations for certain cluster algebras. The latter were introduced by Fomin and Zelevinsky as discrete dynamical systems describing the evolution by mutation of (cluster) variables, with the built-in property that any mutated variable may be expressed as a Laurent polynomial of any other cluster variable. It was conjectured that the corresponding Laurent polynomials have non-negative integer coefficients.

In the present work [DiFrancesco-Kedem08], we prove this positivity property for the cluster algebras associated to the A_r Q-systems. This is done with the help of integrability by giving an explicit combinatorial expression for the cluster variables as partition functions for positively weighted paths on finite target graphs. Cluster mutation can then be understood as continued fraction rearrangements for the corresponding generating functions. We also present an alternative formulation in terms of domino tilings of plane domains, including possible defects. (Received January 30, 2009)

1047-05-273 **Maria Axenovich*** (axenovic@iastate.edu), 412 Carver Hall, Department of Mathematics, Ames, IA 50011, and **JiHyeok Choi** and **Perry Iverson**. *On colorings avoiding both monochromatic and rainbow subgraphs.*

An edge-coloring of a graph is called (G, H)-good if it does not contain a monochromatic copy of G and it does not contain a rainbow (totally multicolored) copy of H. Except for a small class of graphs G, H, a (G, H)-good coloring of a complete graph exists. For such graphs we consider $maxR(n; G, H)$, the maximum number of colors in a (G, H)-good coloring of K_n. We determine the value of $maxR(n; G, H)$ for wide classes of graphs and formulate several open problems. One of such problems is to determine the largest number of colors used on the edges of K_n such that each copy of K_4 is neither monochromatic nor rainbow. (Received January 30, 2009)

1047-05-276 **Jonathan Cutler*** (cutlerjo@mail.montclair.edu), Montclair State University, Dept. of Mathematical Sciences, One Normal Avenue, Montclair, NJ 07030, and **A. J. Radcliffe**. *Extremal problems for counting homomorphisms.*

There is a close connection between graph homomorphisms and a variety of natural graph theoretic notions: independent sets, colorings, etc. There has been some progress recently concerning extremal problems for counting graph homomorphisms. We will discuss some of this work, including the interesting behavior of a specific extremal problem. (Received January 30, 2009)

1047-05-278 **Marina Langlois**, **Dhruv Mubayi**, **Robert H. Sloan** and **Gyorgy Turan*** (gyt@uic.edu), Univ. of Illinois at Chicago, Dept. Math., Stat. and Comp.Sci., Chicago, IL 60607-7045. *Combinatorial problems from and for Horn formulas.* Preliminary report.

We consider some combinatorial problems related to propositional Horn formulas. We give an algorithmic version of the Kovari-Sos-Turan argument for the existence of large balanced complete bipartite graphs in dense graphs. This leads to algorithmic versions of previous results on the decomposition of arbitrary graphs and bipartite graphs into complete bipartite graphs, where the complexity of a decomposition is measured by the sum of the number of vertices. This, in turn, is used in an approximate Horn minimization algorithm. We also consider some extremal and phase transition problems for directed hypergraphs corresponding to Horn formulas. (Received January 30, 2009)

1047-05-280 **Victor Reiner** and **Alexander Woo*** (woo@stolaf.edu), MSCS Department, St. Olaf College, 1520 St. Olaf Ave., Northfield, MN 55057, and **Alexander Yong**. *Presenting the cohomology of a Schubert variety.*

We extend the short presentation of the cohomology ring of a generalized flag manifold, originally due to Borel, to a relatively short presentation of the cohomology of any of its Schubert varieties. Our result is stated in a root-system uniform manner, by introducing the essential set of a Coxeter group element, generalizing and giving a new characterization of Fulton's definition for permutations. Bounds for the number of generators can then

be obtained in terms of Kazhdan-Lusztig polynomials for the essential set. Further refinements are obtained in type A_n, which specialize to an improvement upon Gasharov and Reiner's generators for the class of Schubert varieties defined by inclusions (of which smooth Schubert varieties are a subclass). (Received January 30, 2009)

1047-05-281 **Hao Li*** (li@lri.fr), LRI, UMR 6823 CNRS-Univercite Paris-sud 11, Bat.490, 91405 Orsay, France, and **Yan Zhu** (zhu@lri.fr), LRI, UMR 6823, CNRS-Universite Paris-sud 11, bat. 490, 91405 Orsay, France. *Cyclable sets of vertices in 3-connected graphs.*

A subset of vertices S is cyclable if there is a cycle C containing all vertices of S. Clearly it is a generalization of hamiltonicity since a graph is hamiltonian if the set of all its vertices is cyclable. Beginning from a result of Dirac in 1952, many results on sufficient conditions that relate to degree sum and neighborhood of vertices for hamiltonicity and cyclability, have been obtained. We give a new sufficient condition on degree sum, neighborhood union and neighborhood intersections of any four independent vertices in the graph. We also study the extremal cases of this condition. (Received January 30, 2009)

1047-05-283 **Ye Dong*** (dye@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26506. *Pfaffian Orientations in Cubic Polyhex Graphs on the Torus and the Klein Bottle.*

Let G be a graph admitting a perfect matching. A circuit of even size C is *central* if $G-C$ has a perfect matching. Given an orientation to G, an even circuit C is *oddly oriented* if along either direction of traversal around C, the number of edges of C with the direction as the same as the traversal direction is odd. An orientation of G is *Pfaffian* if every central circuit of G is oddly oriented. A graph G is *Pfaffian* if it has a Pfaffian orientation. A brace is a 2-extendable bipartite graph. A complete characterization Pfaffian braces was obtained by Robertson, Seymour and Thomas, and independently by McCuaig.

A polyhex graph is a cubic graph embedded on a surface with only hexagonal facial circuits. By the Euler's formula, the surface can be only the torus or the Klein bottle. C. Thomassen gave a classification for polyhex graphs. Every polyhex graph on the torus is bipartite. But a polyhex graph on the Klein bottle is not necessary bipartite. We show that a cubic polyhex graph on the torus is pfaffian if and only if it is planar, or isomorphic to the Heawood graph. For a polyhex graph on the Klein bottle, we show that it is Pfaffian if and only if it is planar or non-bipartite. (Received January 30, 2009)

1047-05-292 **André E. Kézdy*** (kezdy@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Hunter Snevily**. *On the degree of regularity of a specific linear equation.* Preliminary report.

An equation is r-regular if, for every r-coloring of the positive integers, the equation has a monochromatic solution. If an equation is not r-regular for all positive integers r, then its *degree of regularity* is the maximum r such that it is r-regular. This talk focuses on the equation

$$\sum_{i=1}^{n} x_i - \sum_{i=1}^{n} y_i = b_n, \qquad (*)$$

where b_n is a positive integer (depending on n). Fox and Kleitman have shown that the degree or regularity of (*) is at most $2n-1$ and conjecture that, for every n, some choice of b_n achieves this bound. This talk describes partial results on this conjecture. (Received January 31, 2009)

1047-05-307 **Jozsef Solymosi*** (solymosi@math.ubc.ca), 1984 Mathematics Road, Vancouver, BC. V6T1Z2. *On the sum-product problem.* Preliminary report.

An old conjecture of Erdős and Szemerédi states that if A is a finite set of integers then the sum-set or the product-set should be large. The sum-set of A is $A+A=\{a+b|a,b\in A\}$, and the product set is defined in a similar way, $A\cdot A=\{ab|a,b\in A\}$. Erdős and Szemerédi conjectured that the sum-set or the product set is almost quadratic in the size of A, i.e. $\max(|A+A|,|A\cdot A|)\geq c|A|^{2-\delta}$ for any positive δ. In this talk we review some recent developments on this conjecture. (Received February 03, 2009)

1047-05-310 **Kathrin Bringmann*** (kbringma@math.uni-koeln.de), Weyertal 86-90, Cologne, Germany. *Multiplicative q-hypergeometric series arising from real quadratic fields.*

Andrews, Dyson, and Hickerson showed that 2 q-hypergeometric series, going back to Ramanujan, are related to real quadratic fields, which explains interesting properties of their Fourier coefficients. There is also an interesting relation of such series to automorphic forms. Here we construct more such examples. (Received February 01, 2009)

1047-05-312 **Dwight Duffus*** (dwight@mathcs.emory.edu), Math & CS Dept, Emory University, Altanta, GA 30322, **Peter Frankl**, Tokyo, Japan, and **Vojtech Rodl**, Math & CS Dept, Emory University, Atlanta, GA 30322. *Maximal Independent Sets in Adjacent Levels of the Cube.*

The original motivation of this work is estimation of the asymptotic value of the logarithm of the number of maximal antichains in the Boolean lattice. This is the same as estimating the maximal independent sets in the comparability graph of the Boolean lattice.

In joint work with Peter Frankl and Vojtech Rodl, we have considered the following related estimation problem. For integers k < n, let mis(n,k) denote the number of maximal independent sets in the bipartite graph defined by the k and k+1 levels of the Boolean lattice of all subsets of an n-set. If k/n tends to 0 as n grows, it is easy to determine the asymptotic value of log mis(n,k). Our most substantial result for k a fixed proportion of n is the upper bound:

log mis(n,k) < 1.3563 (1 + o(1)) C(n-1,k)

where o(1) tends to 0 as n grows and C(n-1,k) is the binomial coefficient. (Received February 01, 2009)

1047-05-313 **Pavlo Pylyavskyy*** (pavlo@umich.edu) and **Thomas Lam**. *Total positivity in loop groups I: whirls and curls.*

We develop a theory of total positivity for loop groups. In this work, we completely describe the totally nonnegative part of the polynomial loop group, and for the formal loop group we describe the totally nonnegative points which are not totally positive. Furthermore, we make the connection with networks on the cylinder. Our approach involves the introduction of distinguished generators, called whirls and curls, and we describe the commutation relations amongst them. These matrices play the same role as the poles and zeroes of the Edrei-Thoma theorem classifying totally positive functions (corresponding to our case n=1). We give a solution to the "factorization problem" using limits of ratios of minors. This is in a similar spirit to the Berenstein-Fomin-Zelevinsky Chamber Ansatz where ratios of minors are used. (Received February 01, 2009)

1047-05-314 **Maria Chudnovsky** and **Paul Seymour*** (pds@math.princeton.edu), Math Dept, Princeton University, Fine Hall, Washington Rd, Princeton, NJ 08540. *Packing seagulls.*

Let G be a graph with $\alpha(G) < 3$ ($\alpha(G)$ denotes the size of the largest stable set in G). If G has n vertices, then its chromatic number is at least $\lceil n/2 \rceil$, and so Hadwiger's conjecture implies that there should be $\lceil n/2 \rceil$ disjoint connected subgraphs in G, pairwise joined by edges. This is far from being proved.

If G also contains a clique of cardinality at least $n/3$, then the disjoint subgraphs exist; this is a consequence of our main result and generalizes two earlier theorems of Blasiak. Our main result answers when a graph G with $\alpha(G) < 3$ contains k vertex-disjoint seagulls (a *seagull* is an induced three-vertex path). We give five necessary conditions, and the union of these five conditions is sufficient. We also answer the analogous question for fractional packing of seagulls, and give a polynomial-time algorithm to test whether there are k disjoint seagulls.

This all depends on the hypothesis that $\alpha(G) < 3$; for general graphs a result of Dor and Tarsi implies that testing whether there are k disjoint seagulls is NP-complete. (Received February 01, 2009)

1047-05-318 **Vladimir Nikiforov***, vnikifrv@memphis.edu. *New bounds in the Zarankiewicz problem.* Preliminary report.

Given positive integers m,n,s,t, let z(m,n,s,t) be the maximum number of ones in a (0,1)-matrix of size m-by-n that does not contain an all ones submatrix of size s-by-t. A generic bound on z(m,n,s,t) is given that implies the known bounds of Kövari, Sós and Turán, and of Füredi. As a consequence, the best upper bound on the spectral radius of the adjacency matrix of a graph of order n with no complete bipartite s-by-t subgraph is obtained. (Received February 01, 2009)

1047-05-320 **Mark Ellingham*** (mark.ellingham@vanderbilt.edu) and **Xiaoya Zha**. *Symmetries of* $(3,6)$*-fullerenes.* Preliminary report.

$(3,6)$-fullerenes are cubic plane graphs in which all faces are hexagons, except for four faces that are triangles. There is a standard way of representing these graphs by folding a plane hexagonal lattice onto a suitable tetrahedron. Fowler and Cremona showed how to determine the automorphism group from this representation, but the conditions are complicated. By viewing the construction slightly differently we obtain simple conditions to determine the automorphism group and other structural information. We use this to address some conjectures of Déza and Dutour on "tight" graphs of this kind, and to describe the projective-planar cubic graphs with all faces hexagons except for two faces that are triangles. (Received February 01, 2009)

1047-05-328 **Alexander Berkovich*** (alexb@math.ufl.edu), Mathematics Department, University of Florida, Little Hall 496, Gainesville, FL 32611. *The GBG-Rank , 4-cores and 3-cores.* Preliminary report.

I will provide an elegant combinatorial explanation of some amazing formulas for 4-cores due to M.Hirshhorn and J. Sellers. I will discuss analogous new results for 3-cores. (Received February 01, 2009)

1047-05-334 **Jozsef Balogh**, **Bela Bollobas** and **Miklos Simonovits*** (miki@renyi.hu). *New results in Erdos-Frankl-Rodl theory.*

The lecture will describe some new results in the Erdős-Frankl-Rödl theory, in which, for a family $\mathcal{L}$ of forbidden graphs, we describe the typical structure of the n-vertex graphs not containing any $L \in \mathcal{L}$. The work itself is mostly joint work with J. Balogh and B. Bollobás. In our earlier works first we improved earlier estimates on the number of $\mathcal{L}$-free graphs, then, improving these results, we described the typical structure of $\mathcal{L}$-free graphs. Here we improve our earlier results in some particular cases, providing in some sense absolutely sharp results for the typical structure of $\mathcal{L}$-free graphs, in some particular cases.

We also formulate several related conjectures, open problems.

Here, in the Abstract we mention two important particular cases, one of them is the Octahedron Graph $O_6 = K(2, 2, 2)$, the other being the Petersen graph.

We shall also provide some more general results, containing the above two cases.

Among others, we prove the following results.

The vertex set of almost every O_6-free graph can be partitioned into two classes of almost equal sizes, U_1 and U_2, where the graph spanned by U_1 is a C_4-free and that by U_2 is P_3-free. (Received February 01, 2009)

1047-05-339 **Jozsef Balogh** and **Wojciech Samotij*** (samotij2@illinois.edu). *Counting graphs without a fixed subgraph.*

A graph is called H-free if it contains no copy of H. Denote by $f_n(H)$ the number of (labeled) H-free graphs on n vertices. Since every subgraph of an H-free graph is also H-free, it immediately follows that $f_n(H) \geq 2^{ex(n,H)}$. Erdős conjectured that, provided H contains a cycle, this trivial lower bound is in fact tight, i.e.

$$f_n(H) = 2^{(1+o(1))\, ex(n,H)}.$$

The conjecture was resolved in the affirmative for graphs with chromatic number at least 3 by Erdős, Frankl and Rödl (1986), but the case when H is bipartite remains wide open. We will give an overview of the results in case $\chi(H) = 2$, and talk about a few related problems and recent progress in the area. (Received February 02, 2009)

1047-05-341 **S. Ole Warnaar*** (o.warnaar@maths.uq.edu.au), Mathematics, The University of Queensland, Brisbane, Australia. *The sl_3 Selberg integral.*

In 2000 Mukhin and Varchenko conjectured the existence of a Selberg integral for each simple Lie algebra g provided certain representation theoretic spaces are one-dimensional. In this talk I will discuss an approach based on Macdonald polynomials to tackle the conjecture. I will mainly focus on the simplest non-trivial case, and present an explicit Selberg integral evaluation for $g = sl_3$. (Received February 02, 2009)

1047-05-353 **Nathan Reading*** (nathan_reading@ncsu.edu), North Carolina State University. *Noncrossing partitions and the shard intersection order.*

I will discuss the shard intersection order $(W, \preceq)$ on a finite Coxeter group W. This poset is a lattice and has the noncrossing partition lattice $\mathrm{NC}(W)$ as a sublattice. This new construction of $\mathrm{NC}(W)$ yields a new proof that $\mathrm{NC}(W)$ is a lattice. The shard intersection order is graded and atomic. Its rank generating function is the W-Eulerian polynomial. Many order-theoretic properties of $(W, \preceq)$, like Möbius number, number of maximal chains, etc., are analogous to corresponding properties of $\mathrm{NC}(W)$.

The shard intersection order is most naturally defined in terms of the polyhedral geometry of the reflecting hyperplanes of W, and in particular certain codimension-1 polyhedral cones called shards. The reflecting hyperplanes are cut into shards according to a simple rule. Shards were originally defined as a way of understanding lattice congruences of the weak order on W. The collection of arbitrary intersections of shards forms a lattice under reverse containment. Arbitrary intersections of shards are in bijection with elements of W, so the lattice of shard intersections defines a partial order "$\preceq$" on W. I will illustrate the definitions and results with a running example, taking W to be the symmetric group S_4. (Received February 02, 2009)

1047-05-354 **Penny Haxell***, Combinatorics and Optimization, University of Waterloo, Waterloo, ON N2L 3G1, Canada, and **Subir Ghosh**. *Packing and covering tetrahedra.*

For a graph G, we denote by $\nu(G)$ the maximum size of a set of edge-disjoint triangles in G. The parameter $\tau(G)$ is the minimum size of an edge cover of the triangles of G, that is, a set C of edges such that $G-C$ is triangle-free. An old unsolved conjecture of Tuza states that $\tau(G) \leq 2\nu(G)$ for every graph G. As proved by Tuza, the conjecture is true (and best possible) for planar graphs. We consider geometric generalisations of this problem, in particular we prove that the result of Tuza can be generalised to a best possible bound for d-uniform hypergraphs as follows. Let H be a d-uniform hypergraph whose associated simplicial complex has a geometric realisation in $\mathbf{R}^d$. Then $\tau(H) \leq (\lceil d/2 \rceil + 1)\nu(H)$. Here $\nu(H)$ is the maximum size of a set of edge-disjoint copies of the complete hypergraph K^d_{d+1} in H, and $\tau(H)$ is the minimum size of an edge cover of the K^d_{d+1}'s in H. (Received February 02, 2009)

1047-05-365 **Sujith Vijay*** (sujith@math.uiuc.edu), 1409 W Green St, Urbana, IL 61801. *On a Variant of van der Waerden's Theorem.*

A *quasi-progression* of diameter n (and *low-difference* d) is a sequence $(x_1, x_2, \ldots, x_k)$ with

$$d \leq x_{j+1} - x_j \leq d + n, \quad 1 \leq j \leq k-1$$

Let $Q_n(k)$ be the least integer for which any 2-coloring of $\{1, 2, \ldots, Q_n(k)\}$ yields a monochromatic k-term quasi-progression of diameter n. It follows from van der Waerden's theorem that $Q_n(k)$ exists for all n and k. Bruce Landman has shown that $Q_1(k) \geq 2(k-1)^2 + 1$. I will show how this can be improved to an exponential lower bound, using basic probabilistic techniques and some linear algebra. (Received February 02, 2009)

1047-05-366 **David Offner*** (offner@cmu.edu), Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213. *Turán type problems and polychromatic colorings on the hypercube.*

For a fixed graph G, let $c(G)$ denote the proportion of edges which must be deleted to kill all copies of G in any n-dimensional hypercube Q_n. This problem has been studied extensively for choices of G including even cycles and hypercubes of fixed dimension.

Let $p(G)$ denote the largest number of colors with which the edges of any Q_n can be colored so that every copy of G contains every color. For many choices of G, the best bounds on $c(G)$ come from $p(G)$, since $c(G) \leq 1/p(G)$. We discuss techniques for finding bounds on $p(G)$, what is known, and some open problems. (Received February 02, 2009)

1047-05-368 **Yezhou Wu*** (yzwu@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26506, **Wenan Zang** (wzang@maths.hku.hk), Department of Mathematics, University of Hong Kong, Hong Kong, Hong Kong, and **Cun-Quan Zhang** (cqzhang@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26506. *A Characterization of Almost CIS Graphs.*

A graph G is called CIS if each maximal clique intersects each maximal stable set in G, and is called almost CIS if it has a unique disjoint pair (C, S) consisting of a maximal clique C and a maximal stable set S. While it is still unknown if there exists a good structural characterization of all CIS graphs, in this note we prove the following Andrade-Boros-Gurvich conjecture: A graph is almost CIS if and only if it is a split graph with a unique split partition. (Received February 02, 2009)

1047-05-374 **Fan Chung**, **Paul Horn** and **Linyuan Lu*** (lu@math.sc.edu), Department of Mathematics, University of South Carolina, 1501 Greene Street, Columbia, SC 29208. *Diameter of random spanning trees in a given graph.*

We show that a random spanning tree formed in a general graph G (such as a power law graph) has diameter much larger than the diameter of G. We show, with high probability the diameter of a random spanning tree of G is shown to be between $c\sqrt{n}$ and $c'\sqrt{n}\log n$, where c and c' depend on the spectral gap of G and the ratio of the moments of the degree sequence. For the special case of regular graphs, this result improves the previous lower bound by Aldous by a factor of $\log n$. (Received February 02, 2009)

1047-05-375 **Kyungyong Lee** (kyungl@purdue.edu) and **Li Li*** (llpku@math.uiuc.edu), Mathematics Department, University of Illinois at Urbana-Champaign, Urbana, IL 61801. *On a minimal set of generators for the ideal of the diagonal locus of $(C^2)^n$.*

The ideal I of the diagonal locus of the affine space $(\mathbb{C}^2)^n$ is a very interesting object in algebra, combinatorics and geometry, for example it is used to define the t,q-Catalan numbers. It has been studied in detail by Haiman in process of proving Macdonald positivity conjecture. Haiman posed the question to find a rule to determine a set of minimal generators of the ideal I. As a partial answer to the question, we provide explicit generators

for the ideal I of certain bi-degrees. We also discover a relation between t,q-Catalan numbers and partition numbers as a corollary. (Received February 02, 2009)

1047-05-376 **V. Reiner**, 206 Church St. SE, Minneapolis, MN 55455, and **D. Stanton***, 206 Church St. SE, MInneapolis, MN 55455. *The negative q-binomial.* Preliminary report.

Interpretations for the negative q-binomial coefficient are given. Two positivity conjectures in a (q, t)-universe are proposed. (Received February 02, 2009)

1047-05-378 **Stephen G. Hartke*** (hartke@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588-0130, and **A. J. Radcliffe** and **Raghunath Tewari**. *The sign of a permutation of a multiset and Lozanić's Triangle.* Preliminary report.

The sign of a permutation π of a set is the parity of the number of transpositions needed to sort π. We analogously define the sign of a permutation σ of a *multiset* to be the parity of the minimum number of transpositions needed to sort σ. We develop a closed-form formula for the number of even and odd permutations of a multiset, and show its relation to Lozanić's Triangle, a classical combinatorial sequence similar to Pascal's Triangle. (Received February 02, 2009)

1047-05-397 **Attila Por*** (attila.por@wku.edu), Department of Mathematics, Western Kentucky University, Bowling Green, KY 42101, and **Tobias Muller** and **Jean-Sebastian Sereni**. *Graphs with four boundary vertices and the Frame of a graph.*

A vertex v of a graph G is a *boundary vertex* if there exists a vertex u such that the distance in G from u to v is at least the distance from u to any neighbour of v. We give a full description of all graphs that have exactly four boundary points, which answers a question of Hasegawa and Saito. To this end, we introduce the concept of frame of a graph. It allows us to construct, for every positive integer b and every possible "distance-vector" between b points, a graph G with exactly b boundary vertices such that every graph with b boundary points and the same distance-vector between them is an induced subgraph of G. (Received February 02, 2009)

1047-05-401 **H. A. Kierstead*** (kierstead@asu.edu), Department of Mathematics and Statistics, Arizona State University, Tempe, AZ , and **A. V. Kostochka** (kostochk@math.uiuc.edu), Department of Mathematics, University of Illinois, Urbana, IL 61801. *Graph Packing, Game Coloring and* 2*-Coloring Number.*

The game coloring number $\mathrm{gcol}(G)$ of a graph G is the least k such that if two players take turns choosing the vertices of a graph then either of them can insure that every vertex has less than k neighbors chosen before it, regardless of what choices the other player makes. Clearly $\mathrm{gcol}(G) \leq \Delta(G)+1$. Sauer and Spencer proved that if two graphs G_1 and G_2 on n vertices satisfy $2\Delta(G_1)\Delta(G_2) < n$ then they pack, i.e., there is an embedding of G_1 into the complement of G_2. We improve this by showing that if $(\mathrm{gcol}(G_1)-1)\Delta(G_2)+(\mathrm{gcol}(G_2)-1)\Delta(G_1) < n$ then G_1 and G_2 pack. To our knowledge this is the first application of such coloring games to a non-game problem. (Received February 03, 2009)

1047-05-407 **SuHo Oh*** (suho@mit.edu), 70 Pacific #446B, Cambridge, MA 02139, and **Alexander Postnikov** and **Hwanchul Yoo**. *Bruhat order, smooth Schubert varieties, and hyperplane arrangements.*

Our aim is to link Schubert varieties in the flag manifold with hyperplane arrangements. For a given element of any finite Weyl group, we can construct a certain hyperplane arrangement. Postnikov conjectured that the generating function for regions of this arrangement coincides with the Poincare polynomial of the corresponding Schubert variety if and only if the Schubert variety is rationally smooth. We prove this conjecture for Type A case. We give an explicit combinatorial formula for the Poincare polynomial. (Received February 02, 2009)

1047-05-412 **Gregg Musiker**, **Ralf Schiffler** and **Lauren Williams*** (lauren@math.harvard.edu), Department of Mathematics, 1 Oxford Street, Cambridge, MA 02138. *Positivity results for cluster algebras.*

We give combinatorial formulas for cluster variables for cluster algebras coming from various surfaces, as well as some cluster algebras obtained by "folding." In particular, this proves the positivity conjecture of Fomin and Zelevinsky for cluster algebras of classical types. (Received February 02, 2009)

1047-05-414 **Luis A Goddyn*** (goddyn@math.sfu.ca), Mathematics, Simon Fraser University, Burnaby, BC V5A 1S6, Canada. *The rank-chromatic number and the rank-flow number.* Preliminary report.

A new family of graph chromatic numbers and flow numbers arises as a restriction to graphs of a natural matrix optimization problem. For any graph G and positive integer k we define the *k-rank-flow number* of G to be

$$\phi_k(G) = \min_{\vec{G}} \max_{P} \frac{d(P)}{d^+(P)} \ \in \ \mathbb{Q} \cup \{\infty\}.$$

Here $\vec{G}$ ranges over the orientations of G, and P ranges over the ordered partitions $(V_0, V_1, \ldots, V_k)$ of $V(\vec{G})$ into $k+1$ parts. Also $d(P)$ is the number of arcs of $\vec{G}$ whose ends lie in distinct parts of P, and $d^+(V)$ is the number of those arcs, say uv with $u \in V_i$, $v \in V_j$, for which $i < j$.

Dually, we may define the *k-rank-chromatic number*, in terms of strong orientations P of all the subgraphs of G having Betti number k (details omitted).

Then $\phi_1(G)$ is just the circular flow index of G, and $\chi_1(G)$ is just the circular chromatic number of G. The *rank-chromatic sequence* $[\chi_1(G), \chi_2(G), \ldots, \chi_{n-1}(G)]$ carries significantly more information than the ordinary chromatic number does, and similary for the *rank-flow sequence*. I will describe the connection to geometry, and determine some values and bounds for these invariants. (Received February 02, 2009)

1047-05-434 **László Babai*** (laci@cs.uchicago.edu), **Igor Gorodezky** and **Allie Shapiro**. *It's a long way to recurrence - an extremal problem in the Abelian Sandpile Model.*

The Abelian Sandpile Model is a diffusion process on graphs, the analysis of which has fascinated physicists, mathematicians, and computer scientists for two decades. We study the evolution of the process as it moves from the empty state through *transient* states to a *recurrent* state. Our main question is the maximum number $f(m)$ of steps this process can take as a function of m, the number of edges of the underlying graph. We show that $f(m)$ grows as c^m where c is at least the golden ratio. (Received February 03, 2009)

1047-05-436 **Jan Kratochvil*** (honza@kam.mff.cuni.cz), KAM MFF UK Charles University, Malostranske nam 25, 11800 Praha 1, Czech Rep. *Teledomination in special graph classes: A survey of algorithmic and complexity results.*

Given two sets σ and ρ of nonnegative integers (as parameters of the problem), a set S of vertices of a graph is called *(σ, ρ)-dominating* if the number of S-neighbors of any vertex of S (of $V - S$) is an element of σ (of ρ, respectively). This notion of generalized domination was introduced by Jan Arne Telle in 1990's and has been investaigated by Telle, Proskurowski, Heggernes, Miller, Golovach, Fomin, Kratsch, and others. In particular, it is known that for any pair of finite nonempty sets σ and ρ (such that $0 \notin \rho$), already the existence of a (σ, ρ)-dominating set in an input graph is NP-complete. We survey recent results in this area, including the computational complexity of (σ, ρ)-domination in special graph classes, exact exponential time algorithms for general graphs, and a related question of bounding the number of (σ, ρ)-dominating sets in a connected graph. (Received February 03, 2009)

1047-05-441 **Kevin P Costello*** (kcostell@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30332-0160. *Bilinear and Quadratic Variants on the Littlewood-Offord Problem.*

Let f be a polynomial dependent on a large number of independent random inputs. Two natural questions to ask are

(1) As the number of inputs increases, what is the maximum concentration that f can have on any one value, assuming all (or most) of the coefficients are non-zero?

(2) If f is a polynomial which comes close to this maximum, what can be said about the structure of the coefficients of f?

In the linear case, this is a question first investigated by Littlewood and Offord and answered by Erdős: The maximum concentration of $O(n^{-1/2})$ occurs when all of the nonzero coefficients of f are equal. Here we will give near-sharp bounds in the case where f is a bilinear or quadratic form. (Received February 03, 2009)

1047-05-456 **Jerrold R. Griggs*** (j@sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *Diamond-free families of subsets.* Preliminary report.

We consider the problem of determining the maximum size $\mathrm{La}(n, H)$ of a family $\mathcal{F}$ of subsets of the set $\{1, 2, \ldots, n\}$, subject to the condition that a certain subposet H is excluded. For instance, Sperner's Theorem solves the problem for H being a two-element chain P_2, giving $\mathrm{La}(n, P_2) = \binom{n}{\lfloor \frac{n}{2} \rfloor}$. We survey results of this kind, and focus on the newest bounds on $\mathrm{La}(n, H)/\binom{n}{\lfloor \frac{n}{2} \rfloor}$ when H is the four-element diamond poset B_2 (joint with Linyuan Lincoln Lu). (Received February 03, 2009)

1047-05-467 **André Kündgen*** (akundgen@csusm.edu), Department of Mathematics, California State University San Marcos, 333 S Twin Oaks Valley Road, San Marcos, CA 92096, **Michael Pelsmajer**, Illinois Institute of Technology, and **Radhika Ramamurthi**, California State University San Marcos. *Finding minors in graphs with a given path structure.*

A *routing* of a graph H in a graph G with $V(H) \subseteq V(G)$ is a collection of $|E(H)|$ paths, consisting of one u, v-path in G for each edge uv in H. An H-subdivision corresponds to a routing in which the paths are internally vertex disjoint, whereas an H-immersion corresponds to a routing in which the paths are edge-disjoint.

The study of H-routings that force G to have an H-minor naturally leads to H-immersions with the additional property that all paths in the routing that contain the same vertex must have a common endpoint. If H has the property that every graph G with such an H-immersion contains an H-minor, then we call H *routing contractible*.

We show that K_4, $K_{2,3}$, trees and cycles are routing contractible, but that complete graphs on more than 6 vertices as well as many subdivisions of $K_{2,3}$ are not routing contractible. (Received February 03, 2009)

1047-05-471 **Tibor Szabo*** (szabo@math.mcgill.ca), **Philipp Zumstein** and **Stefanie Zuercher**. *On the minimum degree of minimal Ramsey graphs.*

A graph G is called H-Ramsey if any two-coloring of the edges of G contains a monochromatic copy of H. An H-Ramsey graph is called H-minimal if no proper subgraph of it is H-Ramsey. We investigate the minimum degree of H-minimal graphs, a problem initiated by Burr, Erdős, and Lovász. We determine the smallest possible minimum degree of H-minimal graphs for numerous bipartite graphs H, including bi-regular bipartite graphs and forests. We also make initial progress for graphs of larger chromatic number. (Received February 03, 2009)

1047-05-473 **Jeno Lehel*** (jlehel@memphis.edu), The University of Memphis, Department of Mathematics, Memphis, TN 38152. *k-fold list colorings with Hall's condition.*

We consider proper colorings of the vertices of a graph with k-element subsets of colors taken from some subset of at least t available colors at each vertex. We are interested in the smallest length t of those color lists that in addition satisfy a natural necessary condition for the existence of such k-fold list colorings. Results and questions on cycles will be presented based on joint work with M.M. Cropper, A.J.W. Hilton, M.S. Jacobson, and P.D. Johnson. (Received February 03, 2009)

1047-05-474 **Hasan Coskun*** (hasan_coskun@tamu-commerce.edu), Department of Mathematics, 2600 S Neal St, Commerce, TX 75429. *A Multiple Weak Bailey Lemma and Some Applications.* Preliminary report.

I will present a multiple analogue of the weak Bailey Lemma and some interesting multiple q-series identities that result from the lemma. (Received February 03, 2009)

1047-05-481 **Jacques A Verstraete*** (jacques@ucsd.edu), 9500 Gilman Drive, La Jolla, CA 92037. *Independent dominating sets in graphs of girth five.*

It is well-known that a graph on n vertices with minimum degree d contains a dominating set of size at most roughly $n(\log d)/d$, and this result is one of the standard examples of the probabilistic method. Furthermore, a random d-regular graph on n vertices almost surely has no smaller dominating set. In this talk, I will show that if a d-regular n-vertex graph has girth at least five, then it has an independent dominating set of size at most roughly $n(\log d)/d$. Since the graph consisting of $n/(2d)$ disjoint copies of the complete bipartite graph $K_{d,d}$ has no independent dominating set of size less than $n/2$, the girth condition cannot be relaxed. The d-regularity also cannot be relaxed, as will be shown using random graphs with varying degrees. The proof of this result is probabilistic and also yields an alternative proof of a recent result of Alon, Kim and Spencer on matchings in hypergraphs.

Join work with Ararat Harutyunyan and Paul Horn. (Received February 03, 2009)

1047-05-493 **Sun Kim*** (sunkim2@uiuc.edu), 1409 W. Green St, Urbana, IL 61801. *Bijective proofs for some partition identities involving parity.*

Recently, G.E. Andrew posed open questions regarding parity in partition identities. Some of them are connected with partition identities of Rogers, Ramanujan and Gordon. In this talk, we give bijective proofs for some of them. (Received February 04, 2009)

06 ► Order, lattices, ordered algebraic structures

1047-06-41 **George Metcalfe*** (george.metcalfe@vanderbilt.edu), Mathematics Department, 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240. *Interpolation and Amalgamation for Ordered Algebraic Structures.*

In this talk I will explain how the logical property of interpolation can be used as a stepping stone to the algebraic property of amalgamation. In particular, I will give a simple proof of the so-called deductive interpolation property for abelian l-groups that implies not only the amalgamation property but also decidability and generation of the variety by the integers Z. Moreover, the approach can be modified to establish the amalgamation property for the variety of MV-algebras, the algebraic semantics for Lukasiewicz logic. (Received December 15, 2008)

1047-06-45 **Aditya K Nagrath*** (adnagrat@du.edu), 7255 E. Quincy Ave. #307, Denver, CO 80237. *A Stone-Type Duality for Meet Semilattices.*

We generalize Priestley duality to arrive at a duality for an interesting category of bounded meet semilattices with two natural properties. The dual objects of the meet semilattices are a category of topological spaces endowed with a ternary relation called betweenness. As with Priestley duality, our duality results from what is known categorically as a full duality between the two categories in question. (Received January 19, 2009)

1047-06-268 **J. B. Nation*** (jb@math.hawaii.edu), Department of Mathematics, University of Hawaii, Honolulu, HI 96822, and **Tristan Holmes**, **Dayna Kitsuwa** and **Sheri Tamagawa**. *Lattices of theories in languages without equality.*

We consider lattices of theories in a language that may not include equality. Lattices of atomic theories (the analog of equational theories) are isomorphic to the lattice of order ideals of an ordered set. Lattices of implicational theories (the analog of quasi-equational theories) are isomorphic to the congruence lattice of a semilattice with operators. (Received January 30, 2009)

1047-06-306 **Kira V Adaricheva*** (adariche@yu.edu), 245 Lexington Ave., New York, NY 10016. *Observations about perfect lattices.* Preliminary report.

We call a complete lattice perfect if it can embedded into a lattice of algebraic subsets of an algebraic lattice. The problem about the description of perfect lattices is connected to Birkhoff-Maltsev problem of description of lattices of subquasivarieties of a quasivariety. We show that any algebraic lattice join-generated by completely join-irreducible elements and satisfying some form of Jónsson condition is perfect. (Received February 01, 2009)

08 ► General algebraic systems

1047-08-40 **Peter Mayr*** (peter.mayr@jku.at), Altenberger Strasse 69, Linz, 4040. *Affine complete G-sets.* Preliminary report.

For a permutation group G on a set X, we call the algebra (X, G) a G-set. Hence G-sets are simply the algebraic structures that model group actions. If every unary congruence preserving function on a G-set is either constant or in G, we say that it is 1-affine complete.

We present some families of affine complete G-sets, like for example, regular actions of non-abelian groups that are generated by involutions. In general, whether a G-set is affine complete is not determined by the isomorphism type of its congruence lattice alone. Still we can show that certain lattices – including all distributive lattices – do not occur as congruence lattices of affine complete G-sets. (Received January 17, 2009)

1047-08-57 **Keith A. Kearnes*** (kearnes@euclid.colorado.edu), Department of Mathematics, University of Colorado, Boulder, CO 80309-0395, and **Ross D. Willard**. *Residually finite varieties.* Preliminary report.

Let V be a variety of algebras in a finite language. We show that if V satisfies a nontrivial congruence identity and is residually finite, then V is generated by a single finite algebra. This extends earlier results of Olshanskii for groups, McKenzie for associative rings, and Premet and Semenov for Lie algebras. (Received January 07, 2009)

1047-08-109 **Clifford Bergman*** (cbergman@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011. *Categorical Equivalence of Unary Algebras.* Preliminary report.

For an algebra $\mathbf{A}$, let $\mathcal{V}(\mathbf{A})$ represent the variety generated by $\mathbf{A}$, viewed as a category. We say that algebras $\mathbf{A}$ and $\mathbf{B}$ are *categorically equivalent* if there is an equivalence of categories $F\colon \mathcal{V}(\mathbf{A}) \to \mathcal{V}(\mathbf{B})$ such that $F(\mathbf{A}) = \mathbf{B}$.

We shall consider the question of characterizing those algebras that are categorically equivalent to a finite algebra, all of whose operations are unary.

In one special case the answer is known. Let $\mathbf{B}$ be a finite algebra with no nullary operations. Then $\mathbf{B}$ is categorically equivalent to an algebra all of whose operations are (unary) permutations if and only if, for every $n > 0$, the lattice $\mathrm{Sub}(\mathbf{B}^n)$ is boolean. (Received January 22, 2009)

1047-08-145 **Joel Berman*** (jberman@uic.edu), Dept. of Mathematics (m/c 249), University of Illinois at Chicago, 851 S. Morgan, Chicago, IL 60607. *Free algebras and hereditarily closed families.* Preliminary report.

Let K be either the set of all positive integers or some initial segment of them. Suppose $\mathcal{K} = \{\mathbf{A}_k \mid k \in K\}$ is a family of pairwise nonisomorphic algebras, all of the same similarity type, indexed by K. We say $\mathcal{K}$ is *hereditarily closed* if for each $k \in K$ every subalgebra of $\mathbf{A}_k$ is isomorphic to $\mathbf{A}_p$ for some $p \in K$ with $1 \leq p \leq k$. Let $m(k, p)$ denote the number of subalgebras of $\mathbf{A}_k$ that are isomorphic to $\mathbf{A}_p$.

Suppose $\mathcal{V}$ is any locally finite variety generated by some hereditarily closed family of algebras. We provide an upper bound for the cardinality of the n-generated free algebra for $\mathcal{V}$ based on the values of the $m(k, p)$ and we characterize those varieties for which the upper bound is obtained. We also present several illustrative examples of how this upper bound may be computed and applied. (Received January 26, 2009)

1047-08-146 **Jonathan D.H. Smith*** (jdhsmith@math.iastate.edu), Department of Mathematics, 396 Carver Hall, Iowa State University, Ames, IA 50011-2064. *Comparing the complexity of hyperequivalent operations.* Preliminary report.

Let A be an algebra. Let S be a set of operations on A. Suppose that S forms a single orbit under a group of hypersubstitutions. How large is the variation in the complexity of the operations from S on A? Examples taken from hyperquasigroups exhibit variation from polynomial to rational and from rational to algebraic. For unary hyperquasigroups, variation over complexity classes would demand a one-way function. Other examples of significant variation are provided by (complete) lattices such as subalgebra lattices, where (according to the algebra structure) there is variation between the meet and join. (Received January 26, 2009)

1047-08-153 **Ralph N McKenzie*** (rn.mckenzie@vanderbilt.edu), Mathematics Department, 1326 Stevevson Center, Vanderbilt University, Nashville, TN 37240, and **Petar Markovic** and **Matthew Nickodemus**. *Algebra applied to the study of constraint satisfaction problems produces spectacular results both in universal algebra and on the side of computational complexity: a survey of recent work.*

The constraint satisfaction dichotomy conjecture of Feder and Vardi has been equivalently reformulated as a conjecture about the algorithmic problems $\mathrm{CSP}(\mathbf{A})$ associated with finite idempotent algebras $\mathbf{A}$. It is now known that each of two very weak assumptions about $\mathbf{A}$ implies that $\mathrm{CSP}(\mathbf{A})$ is polynomial time solvable. These results combined appear to subsume all known tractable instances of the CSP. These results and related ones will be examined and discussed in the talk. (Received January 26, 2009)

1047-08-173 **Agnes E. Szendrei*** (szendrei@euclid.colorado.edu), Department of Mathematics, University of Colorado, Boulder, CO 80309-0395, and **Erkko Lehtonen**. *Clones with finitely many relative $\mathcal{R}$-classes.* Preliminary report.

We define an analog of Green's $\mathcal{R}$-relation relative to any clone. We report on research into the problem of determining for which clones there are only finitely many relative $\mathcal{R}$-classes. (Received January 27, 2009)

1047-08-174 **Steve Seif*** (swseif01@louisville.edu), University of Louisville, Mathematics Department, Louisville, KY 40292. *Constrained Eden: Algebras in parallel.*

Cellular automaton over a finite alphabet are examined as finite algebraic structures with one basic operation. A computational complexity problem, Constrained Eden, a finitary version of the Garden of Eden problem, is described. Two main results:

1. Constrained Eden provides the first examples of NP-complete problems associated with 1-dimensional cellular automata over a 2-element alphabet.

2. Constrained Eden problems are log-space equivalent to constraint satisfaction problems, and conversely.

Also considered are variations of Constrained Eden, in connection with decision problems involving solutions to systems of equations over a finite algebra. (Received January 27, 2009)

1047-08-304 **Petar Markovic*** (pera@im.ns.ac.yu), Department of Mathematics and Informatics, University of Novi Sad, Trg Dositeja Obradovica 4, 21000 Novi Sad, Serbia, and **Ralph McKenzie** and **Matthew Nickodemus**. *Algebraic conditions forcing NP-completeness of the Constraint Satisfaction Problem.*

The fixed-template constraint satisfaction problem is the following problem: given a fixed finite relational structure $\mathcal{A}$ (called the *template*), it is the membership problem for the class of all similar finite relational structures $\mathcal{B}$ which admit a homomorphic map into the template. This trivially reduces to the case when the template is a *core*, that is all of its endomorphisms are automorphisms.

All known cases when the fixed-template Constraint Satisfaction Problem is NP-complete, with template a core, are such that the algebra **A** of idempotent polymorphisms of $\mathcal{A}$ generates a variety which admits type **1**. In this talk, I will review the older equivalent conditions for this, and also present a few new ones. Posible applications towards proving the Algebraic Dichotomy Conjecture, that when the algebra of polymorphisms of the core template generates a variety which omits type 1, then the Constraint Satisfaction Problem is tractable, will also be discussed. (Received February 01, 2009)

11 ► Number theory

1047-11-1 **Akshay Venkatesh***, New York University-Courant Institute. *L-functions: Identities and estimates.*

Y. Motohashi discovered a remarkable identity relating the fourth power of the Riemann zeta function to (among other things) eigenvalues of the Laplacian operator on a certain hyperbolic surface. Other interesting identities of a related nature were foundby Kuznetsov. I will discuss these identities and their role in analytic number theory. This talk will report on my joint work with Philippe Michel, as well as on thework of Andrei Reznikov. (Received May 27, 2008)

1047-11-4 **Jeffrey C. Lagarias*** (lagarias@umich.edu), Dept. of Mathematics, University of Michigan, 530 Church Street, Ann Arbor, MI 48109-1043. *From Apollonian circle packings to Fibonacci numbers.*

Apollonian circle packings are infinite packings of circles, constructed recursively from a initial configuration of four mutually touching circles by adding circles externally tangent to triples of such circles. If the initial four circles have integer curvatures, then so do all the circles in the packing. If in addition the circles have rational centers, then so do all the circles in the packing. This talk describes results in number theory and group theory arising from such packings. In particular, the integer curvatures in a packing are determined by the orbit of an integer vector under the action of an integer matrix group. Recently, strong results on factorization and primality of these integers were obtained by Bourgain, Gamburd and Sarnak. We contrast these properties with those of Fibonacci and Lucas numbers, which are also describable by an orbits of an integer vectors under a different integer matrix group. (Some results presented were obtained with Ron Graham, Colin Mallows, Allan Wilks, Catherine Yan, and Jon Bober.) (Received July 10, 2008)

1047-11-6 **Hung-ping Tsao*** (hptsao@hotmail.com), 1151 Highland Drive, Novato, CA 94949. *Powered sum formulas via term-wise integrations: a geometric point of view.*

We shall apply the established method for the natural sequence to more general cases such as S(2n-1;k), the k-powered sum of 1,2,4,5,7,8,...,3n-2 and S(2n;k), the k-powered sum of 1,2,4,5, 7,8,...,3n-2,3n-1, where S(2n-1;1)=[3,-3,1], the quadratic polynomial with coeffcients 3,-3,1 and S(2n;1)=[3,0,0]. Let I(S(2n-1;k)) and I(S(2n;k)) be the integrals of S(2n-1;k) and S(2n;k) with respect to n, respectively. Then we can use mathematical induction to prove that S(2n-1;2)=6I(S(2n-1;1)+cn+d and S(2n;2)=6I(S(2n;1))+cn (d=0, in the case that the 1-powered sum is a quadratic polynomial without constant term), where c and d can be determined by taking different values of n. Thus we can obtain S(2n-1;2)=[6,-9,6+c,d], where c and d can be determined by solving 1=6-9+6+c+d and 1+4+16=48-36+12+2c+d so that S(2n-1;2)=[6,-9,5,-1]. Likewise, S(2n;2)=[6.0.-1,0]. We can then obtain S(2n-1;3)=9I(S(2n-1;2))+[c,d]=[13.5,-27,22.5,-9,1] and S(2n;3)=9I(S(2n;2))+[c,0]=[13.5,0,-4.5,0,0]. The most general sequences that this method can be applied to is when the sum of the first an+b terms of which is a quadratic polynomial, because it is equivalent to term-wise integrations justifiable by the fact that the volume of a k dimensional cube is the integral of its surface area with respect to the side. (Received September 19, 2008)

1047-11-9 **Susil Kumar Jena*** (susil_kumar@yahoo.co.uk), Professor, Dept. of Electronics and Telecom. Engineering, KIIT University, Bhubaneswar, Orissa 751024, India. *Method of Infinite Ascent applied on* $2^p.A^6 + B^3 = C^2$.

In the VII-th Joint Meeting of the American Mathematical Society and the Sociedad Matematica Mexicana held in Zacatecas, Mexico, during May 23-26, 2007, in a talk titled: Method of Infinite Ascent applied on $A^6 + n.B^3 = C^2$, I introduced a method of regenerating infinite number of co-prime integral solutions for (A, B, C) for a class of integers n. This time, I wish to apply the Method of Infinite Ascent to the title equation to prove that for any positive integer p, when $p = 6k - 5$ or $p = 6k - 3$ with k being a positive integer, the equation, $2^p.A^6 + B^3 = C^2$ has infinitely many co-prime integral solutions for (A, B, C).The method, being constructive, will help us to generate any number of co-prime integral solutions of the same. I will provide my latest findings on this interesting Diophantine equation for the other uncovered values of p only at the meeting. (Received October 23, 2008)

1047-11-11 **Greg Martin*** (gerg@math.ubc.ca), Dept. of Mathematics, UBC, Room 121, 1984 Mathematics Road, Vancouver, BC V6T 1Z2, Canada. *Dense Egyptian fractions.*

An Egyptian fraction is a sum of reciprocals of distinct positive integers. How many terms can we have in an Egyptian fraction that sums to 1, for example, if we limit the size of the denominators? It can be shown that the number of terms can be extremely large; in fact, we will see the best possible result about the density of the set of denominators. Consider also the following problems posed by Erdős and Graham: the set of integers that cannot be the largest denominator of an Egyptian fraction representation of 1 is infinite - what is its order of growth? How about those integers that cannot be the second-largest (third-largest, etc.) denominator of such a representation? We will see the answers to these questions as well, including the one theorem I have ever proved that I think would have surprised Paul Erdős. All these results extend to representations of any positive rational number in place of 1. (Received October 24, 2008)

1047-11-12 **Melvyn B. Nathanson*** (melvyn.nathanson@lehman.cuny.edu), Department of Mathematics, Lehman College (CUNY), Bronx, NY 10468. *Phase transitions in infinitely generated groups, and a problem in additive number theory.*

Let A be an infinite set of generators for a group G, and let $S_A(r)$ denote the set of elements of G whose word length with respect to A is exactly r. There are two cases. In the first case, the set $S_A(r)$ is infinite for all $r \geq 1$. In the second case, there is a positive integer r such that $S_A(r')$ is infinite for all $r' < r$ and $S_A(r') = \emptyset$ for all $r' > r$, and $S_A(r)$ is nonempty, possibly finite. Let s denote the number of elements in $S_A(r)$. The ordered pair (r, s) is called the *phase transition* of the group G with respect to A, and $S_A(r)$ is called the *transition set*. Given a group G, it is an open problem to determine the possible phase transitions and transition sets associated with infinite generating sets for G. This problem is solved for finite transition sets for the additive group $\mathbf{Z}$ of integers, and some results are known about infinite transition sets of integers. A classification of phase transitions and transition sets is not available even for the group $\mathbf{Z} \times (\mathbf{Z}/2\mathbf{Z})$. (Received October 29, 2008)

1047-11-23 **Thomas J Tucker*** (tjtucker@gmail.com), Math Department, University of Rochester, Rochester, NY 14610. *Dynamical Mordell-Lang problems.*

The Mordell-Lang conjecture, proved by Faltings and Vojta, states that a finitely generated subgroup of a semiabelian variety intersects any subvariety of that semiabelian variety in a union of finitely many translates of subgroups. It seems natural to ask if such a theorem holds when the finitely generated subgroup is replaced by a finitely generated semigroup of morphisms of a general variety; for example, one might take a semigroup of endomorphisms of a semiabelian variety. We will prove that this is true in many cases when the semigroup is cyclic and also give counterexamples in the more general case, some simple and some more complicated. (Received November 23, 2008)

1047-11-42 **D. A. Goldston** (goldston@math.sjsu.edu), San Jose State University, San Jose, CA 95192, **S. W. Graham*** (graha1sw@cmich.edu), Central Michigan University, Mount Pleasant, MI 48859, **J. Pintz**, Renyi Mathematical Institute, Hungarian Academy of Sciences, Budapest, Hungary, and **C. Y. Yıldırım**, Bogazici University, Istanbul, Turkey. *Some Conjectures of Erdős on Consecutive Integers.*

In 1952, Erdős and Mirsky conjectured that there are infinitely many integers n such that $d(n) = d(n + 1)$. This conjecture was proved by Heath-Brown in 1985. The same proof shows that $\Omega(n) = \Omega(n + 1)$ infinitely often, where $\Omega(n)$ is the number of prime power divisors of n. In 2001, Schlage-Puchta proved the corresponding conjecture that $\omega(n) = \omega(n + 1)$ infinitely often, where $\omega(n)$ denotes the number of prime divisors of n.

We recently proved that in any system of three linear forms satisfying obvious local necessary conditions, there are at least two forms that are infinitely often products of exactly two prime factors. Using this result, we are able to give proofs of the above results that are both simpler and sharper. For example, we can prove that there are infinitely many integers n that simultaneously satisfy

$$\omega(n) = \omega(n+1) = 4, \Omega(n) = \Omega(n+1) = 5 \text{ and } d(n) = d(n+1) = 24$$

We can also prove similar results with n replaced by $n+b$ for an arbitrary positive integer b. (Received December 16, 2008)

1047-11-43 **Kevin A Broughan*** (kab@waikato.ac.nz), Department of Mathematics, University of Waikato, Hamilton, 3216, New Zealand. *Gram lines and the average of the real part of the Riemann zeta function.*

By considering the dynamical system $\dot{s} = \zeta(s)$ it was discovered, then proved, that the contours $\Im\Lambda(s) = 0$ of the function which satisfies $\zeta(1-s) = \Lambda(s)\zeta(s)$ cross the critical strip on lines which are almost horizontal and straight, and cut the critical line alternately at Gram points and points where $\zeta(s)$ is imaginary. The real part of $\zeta(s)$, when averaged in a modified manner, for fixed values of σ over the values on the "Gram lines", satisfies a relation which extends a theorem of Titchmarsh giving the average of $\zeta(s)$ over the Gram points as 2, to the entire right hand side of the critical strip. (Received December 16, 2008)

1047-11-46 **Tsz Ho Chan*** (tchan@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152, and **Ervin Gyory** and **Andras Sarkozy**. *On sequences of integers no one of which divides the product of three others.*

Erdős estimated the maximal number of integers selected from $\{1, 2, ..., N\}$ so that no one of them divides the product of two others. In this talk, we generalize it to no one of them divides the product of k others, particularly when $k = 3$. Combinatorial results and a more refined classification of integers through their factorizations are used. (Received December 23, 2008)

1047-11-56 **Kevin A Broughan*** (kab@waikato.ac.nz), Department of Mathematics, University of Waikato, Hamilton, 3216. *Flat Primes and Thin Primes.*

Flat primes and thin primes are primes where the shift by ± 1 has a restricted form, namely a power of 2 or that times a square free number or odd prime respectively. They arise in the study of multi-perfect numbers. Here we show that the flat primes have asymptotic density relative to that of the full set of primes given by twice Artin's constant, that more than 50% of the primes are both lower and upper flat, and that the series of reciprocals of thin primes converges. (Received January 06, 2009)

1047-11-61 **Alex V Kontorovich*** (alexk@math.brown.edu), Department of Mathematics, Brown University, 151 Thayer Street, Providence, RI 02912, and **Hee Oh**. *Apollonian Circle Packings and Horospherical Flows on Hyperbolic 3-Manifolds.*

We prove an asymptotic formula for the number of circles in an Apollonian packing of bounded curvature. Using the affine linear sieve, we give sharp upper bounds for the number of circles of prime curvature, and the number of "twin prime" tangent circles. The main ingredient of our proof is the equidistribution of long horospherical flows in the unit tangent bundle of an infinite volume hyperbolic 3-manifold, under the assumption that the Hausdorff dimension of its limit set exceeds one. (Received January 08, 2009)

1047-11-73 **Robert L. Benedetto*** (rlb@cs.amherst.edu), Dept of Mathematics, Amherst College, Amherst, MA 01002. *(Non)-uniform bounds for rational preperiodic points in arithmetic dynamics.*

Let K be a global field, and let $f(z) \in K(z)$ be a rational function defined over K of degree at least two. Clearly f maps K-rational points to K-rational points. In 1950, Northcott proved that f has only finitely many K-rational preperiodic points. In fact, Northcott's result holds for morphisms of $\mathbb{P}^N$ for arbitrary dimension N. In 1994, Morton and Silverman formulated their broad Dynamical Uniform Boundedness Conjecture, stating that the number of K-rational preperiodic points in K is bounded by a constant depending only on K, the degree of f, and the dimension N. In this expository talk, we will describe various partial results and non-uniform bounds proven in the past fifteen years, especially in the case that f is a polynomial. (Received January 14, 2009)

1047-11-81 **Machiel van Frankenhuijsen*** (vanframa@uvu.edu), Utah Valley University, Department of Mathematics, 800 West University Parkway, Orem, UT 84058-5999. *The Multiplication-Convolution Dynamical System.* Preliminary report.

Functions on the adeles of a curve over a finite field have two kind of products: multiplication and convolution. The operator algebra generated by these two kinds of operators has an action of the ideles, which gives a

noncommutative quotient space with an action of the idele class group. We will explain how this noncommutative dynamical system may provide the framework for Connes' idea for the Riemann hypothesis, and hence yield a new proof of Weil's theorem. (Received January 16, 2009)

1047-11-87 **Ken Ono*** (ono@math.wisc.edu), Dept. Mathematics, U. Wisconsin, Madison, WI 53706.
Generalized Borcherds products and Ramanujan's mock theta function $\omega(q)$.

The theory of modular forms is a standard tool for proving congruences in partition theory. Hecke operators, twists of modular forms, and finite dimensionality are the usual suspects in most proofs. Here we prove congruences for the coefficients of Ramanujan's mock theta function $\omega(q)$ by making use of a completely new method. Here we use the theory of generalized Borcherds products (as developed by the author and Bruinier) and the theory of p-adic modular forms with Heegner divisors to obtain our results. (Received January 18, 2009)

1047-11-88 **Amanda Folsom*** (folsom@math.wisc.edu) and **Riad Masri** (masri@math.wisc.edu).
The error term in Rademacher's formula for the partition function.

Let $p(n)$ denote the number of partitions of a positive integer n. In this paper we study the asymptotic distribution of $p(n)$ using Galois orbits of Heegner points on the modular curve $X_0(6)$. We obtain an asymptotic formula for $p(n)$ with an effective error term, which significantly sharpens the error bounds obtained by Hardy-Ramanujan, Rademacher, and D. H. Lehmer. (Received January 19, 2009)

1047-11-89 **Byungchan Kim*** (bkim4@illinois.edu), 1409 West green street, Urbana, IL 61801. *On the subpartitions of the ordinary partitions.*

Let $a_1 \geq a_2 \geq \cdots \geq a_\ell$ be an ordinary partition. A subpartition with gap d of an ordinary partition is defined as the longest sequence satisfying $a_1 > a_2 > \cdots > a_s$ and $a_s > a_{s+1}$, where $a_i - a_j \geq d$ for all $i < j \leq s$. This is a generalization of the Rogers-Ramanujan subpartition which was introduced by L. Kolitsch. In this talk, we will present various properties of the subpartition and as an application, we will give a combinatorial proof of two entries which are in Ramanujan's lost notebook. (Received January 19, 2009)

1047-11-99 **Maria J Monks*** (monks@mit.edu), 290 Massachussets Avenue, Cambridge, MA 02139.
Number theoretic properties of generating functions related to Dyson's rank for partitions into distinct parts.

Let $Q(n)$ denote the number of partitions of n into distinct parts. We show that Dyson's rank provides a combinatorial interpretation of the well-known fact that $Q(n)$ is almost always divisible by 4. This interpretation gives rise to a new false theta function identity that reveals surprising analytic properties of one of Ramanujan's mock theta functions, which in turn gives generating functions for values of certain Dirichlet L-functions at non-positive integers. (Received January 21, 2009)

1047-11-131 **Krishnaswami Alladi*** (alladik@math.ufl.edu), Department of Mathematics, 358 Little Hall, University of Florida, Gainesville, FL 32611. *A partial theta identity of Ramanujan and its number theoretic interpretation.*

One of the most celebrated results in the theory of partitions and q-series is Euler's Pentagonal Numbers Theorem whose interpretation is that when the set of partitions into distinct parts of an integer n is split according to the parity of the number of parts, then the two subsets are of equal size except when n is a pentagonal number, in which case the difference is 1. We will interpret a Ramanujan partial theta identity in a similar fashion, but here we are considering partitions into distinct parts with smallest part odd. Ramanujan's identity has an extra parameter which makes it quite deep. We will give a novel proof of this and interpret it as a weighted partition theorem. George Andrews recently showed me another representation for the Ramanujan partial theta series. We will interpret this other representation as a partition theorem and discuss connections with Ramanujan's identity and several fundamental results in the theory of partitions and q-series. Our work has connections with some recent work of Berndt, B. Kim and Yee who drew my attention to the Ramanujan partial theta identity. (Received January 24, 2009)

1047-11-156 **Khang Tran*** (khangdtran@gmail.com), Mathematics Department, University of Illinois, 1409 W. Green, Urbana, IL 61801, and **Kenneth B Stolarsky** (stolarsk@illinois.edu), Mathematics Department, University of Illinois, 1409 W. Green, Urbana, IL 61801.
Multidimensional polynomial iterations and Ismail's q-discriminants. Preliminary report.

Ismail defined a natural q-analogue of the discriminant and used it to produce elegant q-analogues of the classical formulas for the discriminants of Jacobi polynomials. These are recovered upon letting q tend to 1. We calculate the Ismailian q-analogue of the discriminant of the cubic $1 + a * x + b * x^2 + x^3$ and examine how it factors over the integers. The factorization of this polynomial in a, b, and q is intimately tied to a certain multidimensional

polynomial iteration scheme that generalizes a classical one-dimensional quadratic map, namely an iteration taking x to $h * x^2 - k$. Asymptotic questions about the iteration lead to some specific real numbers we cannot yet identify in terms of standard constants. (Received January 27, 2009)

1047-11-157 **Carl Pomerance*** (carl.pomerance@dartmouth.edu), Department of Mathematics, Dartmouth College, Hanover, NH 03755. *A 1935 Erdős paper on prime numbers and Euler's function.*

Written at the age of 21, the 1935 *Quarterly* paper of Erdős, "On the normal number of prime factors of $p-1$ and some related problems concerning Euler's φ-function," is a treasure-trove of ideas. In this 9-page paper, he established the normal order of the number of prime factors of a shifted prime, he found the broad order of magnitude for the distribution of the range of Euler's function φ, and he gave a startling result on very popular values of φ. After outlining the main ideas in the paper, I will talk about some new developments (joint with Florian Luca) on the range of the iterated Euler function and the range of Carmichael's function λ. (Received January 27, 2009)

1047-11-187 **Darrin M. Doud*** (doud@math.byu.edu), Department of Mathematics, Brigham Young University, Provo, UT 84602. *LLL reduction and a conjecture of Gunnells.*

Paul Gunnells has developed an algorithm for computing actions of Hecke operators on arithmetic cohomology below the cohomological dimension. His algorithm relies on a conjecture concerning LLL-reduced matrices. We prove this conjecture for dimensions 2 through 5, and disprove it for all higher dimensions. (Received January 28, 2009)

1047-11-206 **Amy Glen*** (amy.glen@gmail.com), The Mathematics Institute, Reykjavik University, Kringlan 1, 103 Reykjavik, Iceland. *Palindromic properties of infinite sequences with applications to Number Theory.*

I will briefly survey some old and new results concerning palindromic properties of infinite words with connections to Number Theory, highlighting the rich interplay between Theoretical Computer Science, Combinatorics on Words, Dynamical Systems, and Diophantine Approximation. (Received January 29, 2009)

1047-11-250 **Richard J. McIntosh*** (mcintosh@math.uregina.ca), Department of Mathematics and Statistics, University of Regina, Regina, Sask. S4S0A2, Canada. *Asymptotics and transformations of some Mordell integrals.*

In his last letter to Hardy, Ramanujan used asymptotic expansions to define mock theta functions. The asymptotic expansion of a mock theta involves the asymptotic expansion of certain Mordell intergrals. I will show how to obtain the asymptotic expansion and modular transformation of the Mordell integrals

$$J_c(r,\alpha)=\int_0^\infty e^{-\alpha x^2}\,\frac{\cosh r\alpha x}{\cosh \alpha x}\,dx \quad\text{and}\quad J_s(r,\alpha)=\int_0^\infty e^{-\alpha x^2}\,\frac{\sinh r\alpha x}{\sinh \alpha x}\,dx\,.$$

The transformation laws are:

$$\sqrt{\frac{\alpha^3}{\pi^3}}J_c(r,\alpha)=2\cos\Big(\frac{\pi r}{2}\Big)\int_0^\infty e^{-\beta x^2}\,\frac{\cosh \beta x}{\cos \pi r+\cosh 2\beta x}\,dx$$

and

$$\sqrt{\frac{\alpha^3}{\pi^3}}J_s(r,\alpha)=\sin(\pi r)\int_0^\infty \frac{e^{-\beta x^2}}{\cos \pi r+\cosh 2\beta x}\,dx$$

for $|r|<1$, where $\beta=\pi^2/\alpha$. (Received January 29, 2009)

1047-11-251 **Karl Mahlburg*** (mahlburg@math.mit.edu), 2-173 Department of Mathematics, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, MA 02139, and **Kathrin Bringmann** and **Rob Rhoades**. *Asymptotics for cranks and ranks of partitions.*

We find the first two asymptotic terms for the moments of the partitions crank and rank functions. We prove that the two moment functions share the same main asymptotic term, and that the second term for the crank is larger than that of the rank. This (essentially) proves a stronger form of a conjecture due to Garvan in which he suggested that the crank moments are always strictly larger than the rank moments. (Received January 29, 2009)

1047-11-257 **Alex Iosevich**, **Igor Shparlinski** and **Maosheng Xiong*** (xiong@math.psu.edu), Dept. Math, Pennsylvania State University, State College, PA 16802. *Sets with Integral Distance in Finite Fields.*

This is recent joint work with Shparlinski and Iosevich. Given a positive integer n, a finite field F_q of q elements (q odd), and a non-degenerate quadratic form Q on F_q^n, we study the largest possible cardinality of subsets

$E \subseteq F_q^n$ with pairwise integral Q-distance, that is, for any two vectors $x = (x_1, \ldots, x_n), y = (y_1, \ldots, y_n)$ of E, one has

$$Q(x - y) = u^2$$

for some $u \in F_q$. (Received January 29, 2009)

1047-11-284 **Vitaly Bergelson*** (vitaly@math.ohio-state.edu), Department of Mathematics, Ohio State University, Columbus, OH 43210. *Polynomial extensions of Szemeredi's theorem on arithmetic progressions and ergodic theory.*

Polynomial Szemeredi theorem (joint result with A. Leibman) states that if p_i, i=1,2,...,k are polynomials with integer coefficients which satisfy $p_i(0)$=0, then any set A in N which has positive upper density contains "many" polynomial configurations of the form a, a+p_1(n), a+p_2(n),...,a+p_k(n). (The classical Szemeredi theorem corresponds to the case where p_i(n)= in, i=1,2,...,k).

We will discuss two new extensions of the Polynomial Szemeredi Theorem.

One of these extensions (joint work with A. Leibman and E. Lesigne) establishes necessary and sufficient conditions for a set of polynomials to satisfy the Polynomial Szemeredi Theorem.

Another extension (joint work with R. McCutcheon) deals with the "upgrade" of the Polynomial Szemeredi Theorem to the so called generalized polynomials, namely functions which are obtained from regular polynomials via iterated use of the floor function. (Received January 30, 2009)

1047-11-285 **Michael J. Mossinghoff*** (mimossinghoff@davidson.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *Wieferich pairs and Barker sequences.*

A Barker sequence is a finite sequence of integers $\{a_i\}$, each ± 1, for which every sum $\sum_i a_i a_{i+k}$ with $k \neq 0$ is -1, 0, or 1. It is unknown if any Barker sequences exist with length $n > 13$, although a number of necessary conditions on their existence have been established, so restrictive in fact that no value of $n > 13$ was even known that satisfied all of the requirements. We describe a large computational investigation that significantly improves the best known lower bound on the length of a long Barker sequence. The computation involves a large search for Wieferich prime pairs (q, p), which are defined by the property that $q^{p-1} \equiv 1 \bmod p^2$. We also describe some connections between these quantities and some problems of Erdős in number theory and analysis. (Received January 30, 2009)

1047-11-286 **Michael Filaseta*** (filaseta@math.sc.edu), Mathematics Department, University of South Carolina, Columbia, SC 29208. *Open Problems on Covering Systems.* Preliminary report.

Covering systems of the integers have received some recent attention in the literature. This talk will present a variety of open problems on the subject, some sparked by this recent activity. As an example, one topic to be surveyed is that of Sierpiński numbers, positive odd integers k with the property that $k \cdot 2^n + 1$ is composite for all positive integers n. We will, for example, consider a still open problem posed by P. Erdős to determine whether every such positive integer k can be obtained from an appropriate covering system of the integers. Formulating this more accurately leads to yet other interesting questions. Much of this talk will center on recent results of the speaker obtained with Carrie Finch, Mark Kozek, Charles Nicol and John Selfridge. (Received January 30, 2009)

1047-11-343 **Alain Togbe*** (atogbe@pnc.edu), 1401 S. U.S. 421, Westville, IN 46391. *Variants the Diophantine equation $x! + 1 = y^2$.*

We study variants of the Brocard-Ramanujan Diophantine equation $n! + 1 = y^2$. In 1935, Erdős and Obláth showed that the Diophantine equation

$$y^d \pm 1 = n!$$

has no positive integer solutions (y, d, n) with $y > 1$ and $d \geq 3$. Recently, Berend and Harmse proved that the equation $n! = y^r(y + 1)$ has only finitely many positive integer solutions (n, y) when $r \geq 4$ is a fixed integer. In this talk, we will discuss the recent progress and the variants of the problem. We will also show how we find all the integer solutions of this equation when $r = 2, 3$ under the additional assumption that $y + 1$ is squarefree or cubefree respectively. (Received February 02, 2009)

1047-11-350 **Ernie Croot***, Georgia Institute of Technology, School of Math, 103 Skiles, Atlanta, GA 30332. *Sums and Products in C[x].*

Suppose that A is a set of monic polynomials in $\mathbb{C}[x]$. A polynomial analogue of a conjecture of Erdos and Szemeredi says that either the set of sums $f(x) + g(x)$ or set of products $f(x)g(x)$ of polynomials chosen from A, must be at least $|A|^{2-o(1)}$, where the $o(1)$ tends to 0 as $|A|$ tends to infinity. In this talk we will present

some results that are a good step towards proving this conjecture. This is joint with Derrick Hart. (Received February 02, 2009)

1047-11-356 **William D Banks*** (bbanks@math.missouri.edu), Department of Mathematics, University of Missouri, 202 Math Sciences Bldg., Columbia, MO 65211. *On Carmichael and Giuga numbers.*

In this talk, I shall describe several recent results obtained (by myself and others) on Carmichael numbers and Giuga numbers, and I shall pose some open problems. (Received February 02, 2009)

1047-11-359 **Pace P. Nielsen*** (pace-nielsen@uiowa.edu), 15 MLH, Iowa City, IA 52242. *Covering systems old and new.* Preliminary report.

We give a brief overview of covering systems, including the methods used in the construction of a covering system whose smallest modulus is 40. We discuss methods, both old and new, developed with regards to existence questions for odd, square-free covering systems. Finally, we present evidence for a new conjecture on minimal growth for square-free covers. (Received February 02, 2009)

1047-11-362 **Jaebum Sohn*** (jsohn@yonsei.ac.kr), 134 Shinchon-dong, Seodaemun-gu, Department of Mathematics, Yonsei University, Seoul, 120-749, South Korea, and **Pyo Lim**. *1 mod k lecture hall partition.*

A Lecture Hall Partition of length n is a sequence $(b_1, b_2, \ldots, b_n)$ of nonnegative integers satisfying $\frac{b_1}{n} \geq \frac{b_2}{n-1} \geq \cdots \geq \frac{b_n}{1} \geq 0$. M. Bousquet-Mélou and K. Eriksson showed that there is an one to one correspondence between the set of all lecture hall partitions of length n and the set of all partitions of N into n odd parts less than $2n$. G. E. Andrews also proved this result by using MacMahon's Ω operator.

In this talk, we compute a generating function of the 1 mod k Lecture Hall Partition of length n satisfying the condition $\frac{b_1}{1+(n-1)k} \geq \frac{b_2}{1+(n-2)k} \geq \cdots \geq \frac{b_n}{1} \geq 0$. We utilize MacMahon's Ω operator to prove our result and then give some partition interpretation. (Received February 02, 2009)

1047-11-367 **Ognian Trifonov*** (trifonov@math.sc.edu), Department of Mathematics, LeConte College, 1523 Greene Street, University of South Carolina, Columbia, SC 29208. *Lattice Points Close to a Smooth Curve and Applications.*

We review the recent progress on estimating the number of lattice points close to a smooth curve and present two new applications.
(I) We show that there exists an absolute constant $C > 0$ such that for every positive integer n, there exist a prime $p < Cn^{1/5}(\log n)^2$ such that $n + p$ is a squarefree number (joint work with M. Filaseta and S. Graham).
(II) J.-P. Serre has shown that the largest possible number of $\mathbb{F}_q$ rational points on curves of small genus over a finite field $\mathbb{F}_q$ of q elements depends on the property $p| \left[2q^{1/2}\right]$, where p is the characteristic of $\mathbb{F}_q$. Recently, F. Luca and I. Shparlinski obtained upper bound on the number of $q \leq Q$ which satisfy the above condition. We improve the Luca-Shparlinski bound (joint work with D. Baczkowski). (Received February 02, 2009)

1047-11-370 **Peter Paule*** (ppaule@risc.uni-linz.ac.at), Research Institute for Symbolic Computation, (RISC), Johannes Kepler University Linz, A-4040 Linz, Austria. *A Proof of Sellers' Conjecture.*

In 1984 G.E. Andrews published an AMS Memoir on generalized Frobenius partitions. Based on an elegant product representation for the generating function, Andrews proved a congruence relation modulo 5 for 2-colored Frobenius partitions. In 1994 J. Sellers extended Andrews' result to a congruence conjecture modulo arbitrary powers of 5. In 2002 J. Sellers and D. Eichhorn proved the conjecture for the powers 1, 2, 3, and 4. This talk reports on joint work with Silviu Radu (RISC) who found a computational way to settle Sellers' conjecture for all powers of 5. (Received February 02, 2009)

1047-11-371 **Frank G Garvan*** (fgarvan@math.ufl.edu), Department of Mathematics, University of Florida, PO Box 118105, Gainesville, FL 32611-8105. *Rank and crank partition congruences.* Preliminary report.

We consider the problem of congruences for the rank of partitions, the crank of partitions and Andrews's smallest parts partition function. How common are such congruences? Are they related? (Received February 02, 2009)

1047-11-373 **Florin P Boca*** (fboca@illinois.edu), Department of Mathematics, University of Illinois, 1409 W Green Street, Urbana, IL 61801. *The distribution of the free path length of the linear flow in a honeycomb.* Preliminary report.

Some asymptotic results concerning, in particular, the distribution of the free path length of the linear flow in a honeycomb lattice, with pockets of radius r->0, will be presented. Both cases where the starting point is the center of the hexagon, and when it is randomly chosen, will be discussed. The first part is joint work with R. Gologan. (Received February 02, 2009)

1047-11-391 **Jonathan Sondow*** (jsondow@alumni.princeton.edu), 209 West 97th St Apt 6F, New York, NY 10025. *Ramanujan Primes and Bertrand's Postulate.*

The nth Ramanujan prime is the smallest natural number R_n such that if $x \geq R_n$, then there are at least n primes in the interval $(x/2, x]$. Bertrand's postulate is $R_1 = 2$. Ramanujan proved that R_n exists and gave the first five values as 2, 11, 17, 29, 41. In this talk, we prove that $2n \log 2n < R_n < 4n \log 4n$ for all n, and that R_n is asymptotic to the $2n$th prime. We also estimate the length of the longest string of consecutive Ramanujan primes among the first n primes, explain why there exist more twin Ramanujan primes than expected, and make three conjectures. Our paper is to appear in the Monthly. (Received February 02, 2009)

1047-11-394 **Rafe Jones*** (rjones@holycross.edu), College of the Holy Cross, Worcester, MA 01610. *Critical orbits in arithmetic dynamics.*

In real and complex dynamics, the critical orbit of a quadratic polynomial lives up to its billing as "critical", since its properties determine global dynamical behavior to a large extent. In arithmetic dynamics, a similar statement turns out to hold: the critical orbit gives information about arithmetic properties of all integer orbits. This occurs because the critical orbit controls the ramification in field extensions generated by preimages of zero. In this talk I'll discuss this link and give some cases where one can prove results about the arithmetic of all integer orbits. I'll also briefly review results from the real and complex settings, in particular how the Mandelbrot set illustrates the dependence of global complex dynamics on the critical orbit. (Received February 02, 2009)

1047-11-396 **Tim Huber*** (huber@iastate.edu), Department of Mathematics, 369 Carver Hall, Ames, IA 50011. *Applications of differential equations for Eisenstein series on level two subgroups of the modular group.* Preliminary report.

On pages 188 and 369 of his lost notebook, Ramanujan provides expansions for the series

$$T_{2k}(q) := 1 + \sum_{n=1}^{\infty} (-1)^n \left\{ (6n-1)^{2k} q^{n(3n-1)/2} + (6n+1)^{2k} q^{n(3n+1)/2} \right\} \quad \text{and}$$

$$F_{2k}(q) := \sum_{n=0}^{\infty} (-1)^n (2n+1)^{2k+1} q^{n(n+1)/2}$$

in terms of Eisenstein series on the full modular group. Ramanujan's ideas were extended by H. H. Chan, S. Cooper and P. C. Toh to represent a wider class of series as polynomials in Eisenstein series. In each derivation, a fundamental role is played by the coupled system of nonlinear first-order differential equations satisfied by the Eisenstein series. A similar set of differential equations exist for Eisenstein series on $\Gamma_0(2)$ and each conjugate subgroup of level two. We will employ these differential equations to obtain representations for analogous series in terms of level two Eisenstein series. Applications of these identities and further analogues corresponding to additional subgroups will be discussed as time permits. (Received February 02, 2009)

1047-11-422 **Song Heng Chan*** (chansh@ntu.edu.sg), Division of Mathematical Sciences, Nanyang Technological University, 21 Nanyang Link, Singapore, 637371, Singapore, and **Ae Ja Yee**. *RANKS FOR A FUNCTION RELATED TO OVERPARTITIONS.*

In a recent paper, K. Bringmann and J. Lovejoy investigated the role that the rank of overpartition pairs plays in the congruence properties of overpartitions. Rank differences and congruences for overpartition pairs modulo 3 were established. In another paper by Lovejoy and R. Osburn, interesting results for rank differences for overpartitions modulo 3 and 5 were presented.

In this talk, we discuss a function that is closely related to the overpartitions. Similar properties exists for the associated ranks. (Received February 02, 2009)

1047-11-430 **Dan Goldston*** (goldston@math.sjsu.edu), Department of Mathematics, San Jose State University, San Jose, CA 95192. *The Hardy-Littlewood Prime Tuple Conjecture and Gaps Between Consecutive Primes.* Preliminary report.

Gallagher proved that an appropriate form of the Hardy-Littlewood prime tuple conjecture implies that the primes are Poisson distributed around their average. Work of Brent, Erdős-Straus, and Odlyzko-Rubinstein-Wolf showed that by inclusion-exclusion one can use the Hardy-Littlwood conjectures to suggest asymptotics for the differences between consecutive primes in various ranges. The purpose of this talk is to describe preliminary work to determine more precisely how strong uniform versions of the Hardy-Littlewood conjectures can be used to answer questions on gaps between consecutive primes. This is joint work with Andrew Ledoan. (Received February 03, 2009)

1047-11-432 **Stephen C. Milne*** (milne@math.ohio-state.edu), Department of Mathematics, The Ohio State University, 231 West 18-th Avenue, Columbus, OH 43210-1174. *Sums of squares, Schur functions, and multiple basic hypergeometric series.* Preliminary report.

We first discuss how we used multiple basic hypergeometric series, Gustafson's C_ℓ nonterminating ${}_6\phi_5$ summation theorem, Andrews' basic hypergeometric series proof of Jacobi's 2, 4, 6, and 8 squares identities, and symmetry and Schur function techniques to prove the existence of explicit exact non-trivial closed formulas for the number of ways of writing a positive integer N as a sum of $4n^2$ or $4n(n+1)$ squares of integers, respectively, without using coefficients of cusp forms. We sketch how we obtained similar results for n^2 or $n(n+1)$ squares, and for $2n(2n-1)$ or $2n(2n+1)$ squares, respectively. The $n=1$ case is classical. We first computed the explicit $n=2$, and/or $n=3$ cases by the aid of Mathematica. With these results as motivation, in our more recent work, we used combinatorial/elliptic function methods to actually derive these explicit exact non-trivial closed formulas for $4n^2$ or $4n(n+1)$ squares of integers, respectively. (Received February 03, 2009)

1047-11-433 **Soon-Yi Kang*** (s2kang@kaist.ac.kr), Department of Mathematical Sciences, Korea Advanced Institute of Science and Tech, 373-1 Guseong-dong, Yuseong-g, Daejeon, 305-701, South Korea. *Partition identities that arise from the universal mock theta functions.*

All 22 of classical mock theta functions can be written in terms of cetain q-series so called universal mock theta functions. We show certain linear sums of the universal mock theta functions are theta quotients and discuss their partition interpretations. (Received February 03, 2009)

1047-11-445 **Xander Faber** and **Benjamin Hutz*** (bhutz@amherst.edu), Dept. of Mathematics & Computer Science, Amherst College, Box 2239, P.O. 5000, Amherst, MA 01002. *On the Number of Rational Pre-Images of the Origin Under Quadratic Dynamical Systems.*

We study the number of rational pre-images of a rational number a under the quadratic polynomial map $f_c(x) = x^2 + c$. We state the existence of a uniform bound (uniform over the family of maps $f_c(x)$) on the number of rational pre-images. We determine conditionally an explicit bound on the number of $\mathbb{Q}$-rational pre-images for $a = 0$ and $c \in \mathbb{Q}$. This uses methods from rational points on curves, Falting's Theorem, height functions, and the theory of elliptic curves. (Received February 03, 2009)

1047-11-454 **Paul Pollack*** (pppollac@illinois.edu), 1409 West Green Street, Department of Mathematics, MC-382, University of Illinois at Urbana-Champaign, Urbana, IL 61801. *Some problems concerning the fraction $\sigma(n)/n$.*

Let $\sigma(n)$ denote the sum of the divisors of the natural number n. The ratio $\sigma(n)/n$ has been of interest ever since the ancient Greeks, who classified numbers as *deficient*, *perfect*, or *abundant* according as $\sigma(n)/n$ is less than, equal, or greater than 2 (respectively). We survey what is known about this ratio, paying particular attention to the contributions of Erdős. We also describe some new results of the speaker concerning the amount of cancellation when $\sigma(n)/n$ is put in lowest terms. These results are connected with some 50-year old claims of Erdős. (Received February 03, 2009)

1047-11-455 **Dimitris Koukoulopoulos*** (dkoukou2@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, Urbana, IL 61801. *Generalized multiplication tables.*

Fix $k \geq 2$. For $N_1, \dots, N_k$ integers consider the k-dimensional multiplication table formed by taking all products $n_1 \cdots n_k$ with $n_i \leq N_i$, $1 \leq i \leq k$. Let $A_k(N_1, \dots, N_k)$ be the number of distinct integers that appear in this table. We seek bounds on $A_k(N_1, \dots, N_k)$. In 2004 Ford established the order of magnitude of $A_2(N, N)$. We generalize Ford's result by determining the order of magnitude of $A_k(N, \dots, N)$ when $k > 2$. Finally, we investigate how $A_3(N_1, N_2, N_3)$ behaves when the sizes of N_1, N_2, N_3 start varying. (Received February 03, 2009)

1047-11-477 **Kevin O'Bryant*** (obryant@gmail.com), Building 1S, 2800 Victory Boulevard, Staten Island, NY 10314. *Dense sets of integers without long arithmetic progressions.*

In 1946, Behrend gave a construction of dense finite sets of integers that do not contain 3-term arithmetic progressions. In 1961, Rankin generalized Behrend's construction to sets avoiding k-term arithmetic progressions, and in 2008 Elkin refined Behrend's 3-term construction. In this work, we combine Elkin's refinement and Rankin's generalization. Arithmetic progressions are handled as a special case of polynomial progressions. (Received February 03, 2009)

12 ► Field theory and polynomials

1047-12-65 **Gregory C Verchota***, Dept. of Mathematics, Syracuse University, 215 Carnegie, Syracuse, NY 13244. *Noncoercive sums of squares in* $\mathbb{R}[x_1, \ldots, x_n]$.

Positive definite forms $f \in \mathbb{R}[x_1, \ldots, x_n]$ which are sums of squares of forms of $\mathbb{R}[x_1, \ldots, x_n]$ are constructed to have the additional property that the members of any collection of forms whose squares sum to f must share a nontrivial complex root in $\mathbb{C}^n$. (Received January 12, 2009)

1047-12-76 **Erich Kaltofen*** (kaltofen@math.ncsu.edu), Dept. Mathematics, North Carolina State University, Raleigh, NC 27695-8205, and **Bin Li**, **Zhengfeng Yang** and **Lihong Zhi**. *Exact certification in global polynomial optimization via sums-of-squares of rational functions with rational coefficients.*

We present a hybrid symbolic-numeric algorithm for certifying a polynomial or rational function with rational coefficients to be non-negative for all real values of the variables by computing a representation for it as a fraction of two polynomial sum-of-squares (SOS) with rational coefficients. Our new approach turns the earlier methods by Peyrl and Parrilo at SNC'07 and ours at ISSAC'08 both based on polynomial SOS, which do not always exist, into a universal algorithm for all inputs via Artin's theorem.

Furthermore, we scrutinize the all-important process of converting the numerical SOS numerators and denominators produced by block semidefinite programming into an exact rational identity. We improve on our own Newton iteration-based high precision refinement algorithm by compressing the initial Gram matrices and by deploying rational vector recovery aside from orthogonal projection. We successfully demonstrate our algorithm on 1. various exceptional SOS problems with necessary polynomial denominators from the literature and on 2. very large (thousands of variables) SOS lower bound certificates for Rump's model problem (up to $n = 17$, factor degree $= 16$). (Received January 15, 2009)

1047-12-162 **Kenneth B Stolarsky*** (stolarsk@illinois.edu), Mathematics Department, University of Illinois, 1409 W. Green Street, Urbana, IL 61801. *Positivity properties of Schoenberg's quadratic forms - a recurrent theme.* Preliminary report.

Recently some physicists studying eigenvalues of certain random distance matrices have rediscovered results, including positivity results, concerning Schoenberg's quadratic forms related to Cayley-Menger determinants. These results are well-known in the metric embedding community, but apparently this knowledge is not universal. We indicate how the Schoenberg quadratic forms are reappearing in a type of problem that originated long ago and in fact from the physics community (distribution of points on spheres). (Received January 27, 2009)

1047-12-331 **Salma Kuhlmann*** (skuhlman@math.usask.ca), Center for Algebra, Logic and Computation, Department of Maths & Stats, McLean Hall, 106 Wiggins Road, Saskatoon, SK S7N 5E6, Canada, and **J. Cimpric** and **M. Marshall**. *Positivity in power series rings.*

Let $A = \mathbb{R}[x] := \mathbb{R}[x_1, \cdots, x_n]$ be the ring of polynomials in n variables with real coefficients. A preordering of A is a subset which contains all f^2 for $f \in A$, and is closed under addition and multiplication. For a finite subset $S = \{g_1, \cdots, g_s\}$ of A, we write $T = T_S$ for the preordering of A finitely generated by S, and $K = K_S$ for the set of all $x \in \mathbb{R}^n$ satisfying $g_i(x) \geq 0$ for $i = 1, \cdots, s$ (the basic closed semialgebraic set defined by S). We write Psd(K) for the set of all polynomials that are nonnegative on K. The preordering T is said to be saturated if T = Psd(K). Finitely generated saturated preorderings are particularly interesting since in this case, every nonnegative polynomial on the semialgebraic set has a concrete representation using sums of squares and the defining polynomials $\{g_1, \cdots, g_s\}$. In this talk we investigate what geometric properties of S imply that T is saturated. We know that T is never saturated if $\dim(K) \geq 3$. The case $\dim(K) \leq 1$ is well understood. We focus here on the 2- dimensional compact case. (Received February 01, 2009)

1047-12-415 **Amir Ali Ahmadi** and **Pablo A. Parrilo*** (parrilo@mit.edu), Massachusetts Institute of Technology, 77 Massachusetts Ave., Room 32D-726, Cambridge, MA 02139. *A convex polynomial that is not SOS-convex.*

A multivariate polynomial $p(x)$ is sos-convex if its Hessian $H(x)$ can be factored as $H(x) = M^T(x)M(x)$ with a possibly nonsquare polynomial matrix $M(x)$. It is easy to see that sos-convexity is a sufficient condition for convexity of $p(x)$. Moreover, the problem of checking sos-convexity of a polynomial can be cast as the feasibility of a semidefinite program, which can be solved efficiently in polynomial time. Motivated by this computational tractability, it has been recently speculated whether sos-convexity is also a necessary condition for convexity of polynomials. We give a negative answer to this question by presenting an explicit example of a trivariate homogeneous polynomial of degree eight that is convex but not sos-convex. Interestingly, our example is found with software using sum of squares programming techniques and duality theory of semidefinite optimization. (Received February 02, 2009)

1047-12-428 **Charles N. Delzell*** (delzell@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *A new, simpler finitary construction of the real closure of a discrete ordered field.* Preliminary report.

We give a new, simple, finitary construction of the real closure R of a discrete (roughly, computable) ordered field $(K, \geq)$, as the set of equivalence classes of (ι-terms involving) uniquely satisfiable formulae with one free variable in the first-order language of ordered rings $(+, -, \cdot, 0, 1, \geq)$ with equality, augmented by a constant symbol c_r for each element $r \in K$. It is routine to verify, finitarily, that this R satisfies the axioms of real closed, ordered fields, with the exception of the axiom $0 \neq 1$, for which the verification is difficult, and depends on (and is equivalent to) a finitary proof of the consistency of the theory of real closed ordered fields augmented by the (atomic) diagram of $(K, \geq)$. (Received February 03, 2009)

1047-12-464 **R. Patrick Morton*** (pmorton@math.iupui.edu), Dept. of Mathematical Sciences, IUPUI, LD 270, 402 N. Blackford St., Indianapolis, IN 46202. *Galois theory of iterated Euclidean constructions.*

Galois groups related to specific iterated Euclidean constructions will be discussed. Iterating the tritangent center construction of elementary geometry yields a sequence of points in the plane, whose coordinates generate abelian extensions of the base field defined by the coordinates of the vertices of the initial triangle. The construction is valid over arbitrary fields of characteristic not 2. (Received February 03, 2009)

13 ► Commutative rings and algebras

1047-13-83 **Satya Mandal*** (mandal@math.ku.edu), Department of Mathematics, University of Kansas, Lawrence, KS 66045, and **Albert Sheu**. *Real affine varieties and obstruction theories.*

Let $X = Spec(A)$ be a real smooth affine variety with $\dim X = n \geq 2$, $K = \wedge^n \Omega_{A/\mathbb{R}}$ and L be a rank one projective $A-$module. Let $E(A, L)$ denote the Euler class group and M be the manifold of X. (For this talk we assume M is compact.) Recall that any rank one projective $A-$module L induces a bundle of groups $\mathcal{G}_L$ on M associated to the corresponding line bundle on M. In this talk, we establish a cannonical homomorphism

$$\zeta : E(A, L) \to H_0(M, \mathcal{G}_{LK^*}) \overset{iso}{\to} H^n(M, \mathcal{G}_{L^*}),$$

where the notation H_0 denotes the 0^{th} homology group and H^n denotes the $n^{th}-$cohomology group with local coefficients in a bundle of groups. Further, we prove that this homomorphism ζ factors through an isomorphism

$$E(\mathbb{R}(X), L \otimes \mathbb{R}(X)) \overset{iso}{\to} H_0(M, \mathcal{G}_L)$$

where $\mathbb{R}(X) = S^{-1}A$ and S is the multiplicative set of all $f \in A$ that do not vanish at any real point of X. (Received January 24, 2009)

1047-13-122 **Javid Validashti*** (jvalidas@math.ku.edu), Department of Mathematics, 405 Snow Hall, The University of Kansas, Lawrence, KS 66045. *Relative Multiplicities of Graded Algebras.*

Let R be a Noetherian local ring and $A \subset B$ standard graded Noetherian R-algebras. We define a sequence of relative multiplicities for the pair $A \subset B$ and we study the properties of these numbers to give numerical criteria for integrality and birationality of the extension $A \subset B$, specially when A and B are Rees algebras of a pair of modules. (Received January 23, 2009)

1047-13-123 **Bart Snapp*** (snapp@coastal.edu), Department of Mathematics, Coastal Carolina University, P.O. Box 261954, Conway, SC 29528. *Free summands of syzygies and Cohen-Macaulay rings.*

We will discuss a criterion for rings to be Cohen-Macaulay. While this criterion follows from the Improved New Intersection Conjecture (INIC), we prove a special case of our criterion whose validity is independent of the INIC. (Received January 23, 2009)

1047-13-135 **Yongwei Yao*** (yyao@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303. *Uniform test exponents for rings of finite F-representation type.*

Let R be a Noetherian ring of prime characteristic p. Then, for every R-module M and every $q = p^e$ with $e \in \mathbb{N}$, there is a derived R-module structure on $\langle M, + \rangle$ whose scalar multiplication $\cdot$ is defined by $r \cdot m = r^{p^e} m$. We denote the derived module structure by ${}^eM$. We say M has *finite F-representation type* (FFRT for short) if there exist finitely many finitely generated R-modules, say $N_1, \ldots, N_r$, such that for every $q = p^e$, there are $n_{q,1}, \ldots, n_{q,r} \in \mathbb{N}$ with

$$ {}^eM \cong N_1^{\oplus n_{q,1}} \oplus N_2^{\oplus n_{q,2}} \oplus \cdots \oplus N_r^{\oplus n_{q,r}}$$

as R-modules. For example, polynomial rings of finitely many variables over F-finite (e.g., perfect) fields have FFRT.

It is known that if there exists a finitely generated R-module M with FFRT such that $\operatorname{Supp}(M) = \operatorname{Spec}(M)$, then tight closure commutes with localization. In this talk, we show that, under the same assumption as above, there are uniform test exponents (for tight closure) for all R-modules. (Received January 25, 2009)

1047-13-147 **Juan C. Migliore*** (migliore.1@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556, and **Rosa Miro-Roig** (miro@ub.edu) and **Uwe Nagel** (uwenagel@ms.uky.edu). *Monomial ideals with interesting properties.*

We describe joint work with Rosa Miró-Roig and Uwe Nagel. Let R be a polynomial ring over a field K with the usual grading. An Artinian graded algebra has the Weak Lefschetz Property (WLP) if multiplication by a general linear form, from any component to the next, has maximal rank. In characteristic zero it's known that monomial complete intersections in any number of variables have WLP, as does *every* complete intersection in three variables. Migliore and Miró-Roig asked if every almost complete intersection has WLP. This was answered negatively, for characteristic zero, by Brenner and Kaid (BK) with a simple monomial example, again in three variables. Both results in three variables were obtained by studying the corresponding syzygy bundles. Here we describe a different approach that does not require characteristic zero, and we generalize the BK results in two directions: first, a directly analogous example in any number of variables is shown to fail WLP, regardless of the choice of the field K. Second, we study monomial almost complete intersections, especially in the level case, for three variables. We reduce the WLP question to one of the vanishing of a certain determinant, and as a result the characteristic of the ground field plays a surprising role. (Received January 26, 2009)

1047-13-161 **Karl E. Schwede*** (kschwede@umich.edu), 2529 Miller Ave, Ann Arbor, MI 48103, and **Wenliang Zhang** (wlzhang@umich.edu), Department of Mathematics, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *Discreteness and rationality of F-thresholds on rings with singularities.*

In characteristic zero, the multiplier ideal $\mathcal{J}(X, f^t)$ changes (as t varies) at a discrete set of rational numbers. Since the test ideal $\tau(R, f^t)$ is a characteristic p analogue of the multiplier ideal, it is natural to ask whether it also changes (as t varies) at a discrete set of rational numbers. Blickle, Mustaţă and Smith proved this when R is regular (another proof was obtained by Katzman, Lyubeznik and Zhang).

I will discuss recent work with Zhang where we prove that the $\tau(R, f^t)$ jumps at a discrete set of rational numbers where R is not assumed to be regular (essentially, we require the same conditions on R as are assumed in characteristic zero). (Received January 27, 2009)

1047-13-163 **Stephen Fienberg** and **Sonja Petrović*** (petrovic@math.uic.edu), Department of Mathematics, Stat, Comp Sci, 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60607, and **Alessandro Rinaldo**. *Algebraic statistics of p1 random graph models.*

In a seminal 1981 paper, Holland and Leinhardt described what they referred to as the p_1 model for describing dyadic interactions in a social network summarized in the form of a directed graph. Their model which is log-linear in form, allows for effects due to differential attraction (popularity) and expansiveness, as well as an additional effect due to reciprocation. Fienberg and Wasserman re-represented the p_1 model in contingency table

form and gave it a log-linear representation in that setting. Here we reconsider the p_1 model using the tools of algebraic statistics. In particular, we describe Markov bases for these models, and briefly describe their use in the study of possible generalizations to the class of p^* models. The p_1 models admits a concise combinatorial description in terms of some well-known varieties in algebraic geometry. (Received January 27, 2009)

1047-13-171 **Andrew R. Kustin***, Mathematics Department, University of South Carolina, Columbia, SC 29210. *Socle degrees, Resolutions, and Frobenius powers.*

Let $(R, \mathfrak{m})$ be a Noetherian graded algebra over a field of positive characteristic p, with maximal homogeneous ideal $\mathfrak{m}$, J be an $\mathfrak{m}$-primary homogeneous ideal in R, and $q = p^e$. We have observed that, sometimes, if the socle degrees of $R/J^{[q]}$ and R/J are related "correctly", then the resolutions of $R/J^{[q]}$ and R/J share the same tail. This work has been carried out with Adela Vraciu, Bernd Ulrich, and Hamid Rahmati. (Received January 27, 2009)

1047-13-179 **Jason McCullough*** (jmccullo@math.uiuc.edu), Department of Mathematics, UIUC, 273 Altgeld Hall, MC-382, 1409 W. Green Street, Champaign, IL 61801-2975. *On the Strong Direct Summand Conjecture.*

Let R be a regular local ring and let A be a module-finite extension of R. Ranganathan's Strong Direct Summand Conjecture states that for every regular parameter $x \in R$ and every height one prime ideal Q in A lying over xR, the map $xR \to Q$ splits as a map of R-modules. In this talk I will discuss how the Strong Direct Summand Conjecture relates to the other Homological Conjectures. I will also present some special cases of this conjecture and the related Strong Monomial Conjecture. (Received January 28, 2009)

1047-13-193 **Mordechai Katzman** and **Gennady Lyubeznik*** (gennady@math.umn.edu), 206 Church Street, S.E., Department of Mathematics, University of Minnesota, Minneapolis, MN 55455, and **Wenliang Zhang**. *On the discreteness and rationality of F-jumping coefficients.*

The F-jumping coefficients of a principal ideal of an excellent local ring of characteristic $p > 0$ are all rational and form a discrete subset of the real numbers. This sharpens a result of Blickle, Mustata, and Smith. Our proof uses a novel idea, namely, instead of D-modules we use the Frobenius action on the injective hull of the residue field of the ring. (Received January 28, 2009)

1047-13-259 **Livia M Hummel*** (hummell@uindy.edu), Department of Mathematics, and Computer Science, 1400 E. Hanna Ave, Indianapolis, IN 46227. *Coherent Gorenstein Rings.*

Removing the Noetherian assumption, Bertin (1971) defined a ring to be regular if every finitely generated ideal has finite projective dimension. Answering a question posed by Glaz, Hamilton and Marley (2007) developed a theory of non-Noetherian Cohen-Macaulay rings for which coherent regular rings are Cohen-Macaulay. How does Gorenstein fit into this structure for coherent rings? The answer requires an extension of Gorenstein dimension to the non-Noetherian case and leads to a generalization of the Auslander-Bridger formula. In this talk I will introduce a theory of (non-Noetherian) Gorenstein rings such that coherent regular rings are Gorenstein, and coherent Gorenstein rings are Cohen-Macaulay. (Received January 30, 2009)

1047-13-265 **Sean Sather-Wagstaff*** (Sean.Sather-Wagstaff@ndsu.edu). *Semidualizing modules and Bass numbers.* Preliminary report.

Huneke has asked whether a local Cohen-Macaulay ring R whose Bass numbers are eventually constant must be Gorenstein. We will show how the existence of a nontrivial semidualizing R-module implies that the Bass numbers of R must grow at least linearly; moreover, the existence of a chain of $d+1$ semidualizing modules yield a degree-d polynomial lower bound for the Bass numbers of R. Furthermore, we show how information about the first few Bass numbers of R yields information about the structure of the class of semidualizing R-modules. (Received January 30, 2009)

1047-13-272 **H. Ananthnarayan*** (ananth@math.ku.edu), Department of Mathematics, 1460 Jayhawk Blvd, University of Kansas, Lawrence, KS 66045. *3-Standardness of the Maximal Ideal.* Preliminary report.

Let R be a Cohen-Macaulay local ring with infinite residue field. Let J be a minimal reduction of the maximal ideal $\mathfrak{m}$. P. Valabrega and G. Valla show that the condition $\mathfrak{m}^n \cap J = J\mathfrak{m}^{n-1}$ holds for all n if and only if the associated graded ring of the maximal ideal is Cohen-Macaulay. We investigate conditions under which the equality $J \cap \mathfrak{m}^3 = J\mathfrak{m}^2$, (i.e., the maximal ideal is 3-standard; in general, if $J \cap \mathfrak{m}^k = J\mathfrak{m}^{k-1}$ for all $k \leq n$, we say that $\mathfrak{m}$ is n-standard) holds and give some applications when it does hold. This is a preliminary report. (Received January 30, 2009)

1047-13-315 **David Jorgensen**, **Graham J Leuschke*** (gjleusch@math.syr.edu) and **Sean Sather-Wagstaff**. *Dualizing modules and Gorenstein presentations.* Preliminary report.

It is well known that a Cohen-Macaulay local ring admits a dualizing module if and only if it is a homomorphic image of a Gorenstein ring. We augment this result by showing that such a ring admits a nontrivial semidualizing module if and only if it admits a Gorenstein presentation Q/I such that the ideal I has a nontrivial decomposition. (Received February 01, 2009)

1047-13-329 **Dana T Weston*** (weston@math.missouri.edu), 120 Math Sciences Bldg, Department of Mathematics, University of Missouri, Columbia, MO 65211. *Examples of Some Henselian Rings.*

We provide an example of an analytically normal, local domain A such that for every positive integer n and every non-principal divisorial $\widehat{A}$ -ideal $\mathfrak{a}$, the $\widehat{A}$ -module $\overset{n}{\oplus}\mathfrak{a}$ does not descend to an A-module. (Received February 01, 2009)

1047-13-337 **C-Y. Jean Chan*** (chan1cj@cmich.edu), Department of Mathematics, PE 214, Central Michigan University, Mt. Pleasant, MI 48859. *Hilbert-Kunz Functions without the Normal Condition.* Preliminary report.

Let R be an excellent local ring of characteristic p, $\dim R = d$ and with a perfect residue field. Huneke, McDermott and Monsky (Math. Res. Lett. **11** (2004) 539-546) proved that if in addition R is normal, then there exists a constant β such that the Hilbert-Kunz function is $eq^d + \beta q^{d-1} + O(q^{d-2})$ for $n \gg 0$ in $\mathbb{Z}$ and $q = p^n$.

We will discuss the possibility of obtaining this result when R is assumed with a condition weaker than normal by applying some properties of cycle classes in the Chow group (Received February 01, 2009)

1047-13-338 **Hamid Kulosman*** (h0kulo01@louisville.edu), Department of Mathematics, University of Louisville, #328 Natural Science Building, Louisville, KY 40292. *Monomial c-sequences.* Preliminary report.

Let $a_1, a_2, \dots, a_n$ be elements in a commutative ring R and I the ideal they generate. A sequence $\langle a_1, a_2, \dots, a_n \rangle$ is a c-sequence if

$$[I_{i-1}I^k : a_i] \cap I^k = I_{i-1}I^{k-1}$$

for $i = 1, 2, \dots, n$ and $k \geq 1$. These sequences are interesting because they generate ideals of linear type, even though they are a weaker notion than d-sequences. Every initial subsequence of a c-sequence is a c-sequence. We talk about a characterization of monomial c-sequences. (Received February 01, 2009)

1047-13-379 **S Dale Cutkosky*** (cutkoskys@missouri.edu), Dept. Math., University of Missouri, Columbia, MO 65211, and **Juergen Herzog** and **Hema Srinivasan**. *Asymptotic Growth of Algebras Associated to Powers of Ideals.*

We study generalized symbolic powers and form ideals of powers and form ideals, and compare their growth with the growth of ordinary powers, and we discuss the question of when the graded rings attached to symbolic powers or to form ideals of powers are finitely generated. (Received February 02, 2009)

1047-13-380 **Jinjia Li*** (jinjiali@mtsu.edu), Department of Mathematical Sciences, Middle Tennessee State University, MTSU box 34, Murfreesboro, TN 37132. *Some observations on rigidity of Frobenius endomorphism.*

Avramov and Miller proved that over complete intersections, the Frobenius endomorphism (regarded as a module) is always rigid. In general, this cannot be generalized to the Gorenstein case. Explicit examples of nonrigid Frobenius endomorphism will be constructed. On the other hand, it is not clear to which extent one can generalize Avramov and Miller's result. Some partial results in this regard will also be discussed. Part of this work is joint with Claudia Miller. (Received February 02, 2009)

1047-13-383 **Hamid Rahmati***, Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Contracting endomorphisms and Gorenstein modules.*

A finite module M over a noetherian local ring $(R, \mathfrak{m}, k)$ is said to be Gorenstein if $\mathrm{Ext}^{\mathrm{i}}_{\mathrm{R}}(\mathrm{k}, \mathrm{M}) = 0$ for all $i \neq \dim R$. An endomorphism $\varphi\colon R \to R$ of rings is called contracting if $\varphi^i(\mathfrak{m}) \subseteq \mathfrak{m}^2$ for some $i \geq 1$. Letting S denote the R-module R with action induced by φ, we prove: A finite R-module M is Gorenstein if and only if $\mathrm{Hom}_{\mathrm{R}}(\mathrm{S}, \mathrm{M}) \cong \mathrm{M}$ and $\mathrm{Ext}^{\mathrm{i}}_{\mathrm{R}}(\mathrm{S}, \mathrm{M}) = 0$ for $1 \leq i \leq \mathrm{depth}\, R$. (Received February 02, 2009)

1047-13-385 **Hema Srinivasan*** (srinivasanh@missouri.edu), Department of Mathematics, University of Mossouri, Columbia, MO 65211. *Generators of the defining ideals of monomial curves.* Preliminary report.

Let $I = I(a_0, a_1, \cdots a_n)$ be the ideal of the monomial curve parametrized as $(t^{a_0}, \cdots, t^{a_n})$. It is well known the ideal I is generated by binomials and that the number of generators of I is 2 or 3 if $n = 2$. We will discuss some results on the number of minimal generators of I and the structure of the free I for general n. (Received February 02, 2009)

1047-13-399 **Inês Bonacho dos Anjos Henriques*** (ihenriques@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, 203 Avery Hall, P.O. Box 880130, Lincoln, NE 68588, and **Liana M. Şega** (segal@umkc.edu), Department of Mathematics and Statistics, University of Missouri, Kansas City, MO 64110. *Koszul modules over short Gorenstein local rings.*

We identify a class of local rings $(R, \mathfrak{m})$ with $\mathfrak{m}^4 = 0$, exhibiting the Koszul-like property that $\mathrm{H}_R(-t)\,\mathrm{P}^R_M(t)$ is a polynomial in $\mathbb{Z}[t]$ for all finite R-modules M. This class includes generic graded Gorenstein algebras of socle degree 3. We show that minimal free resolutions of finite modules over such rings admit Koszul syzygy modules. (Received February 02, 2009)

1047-13-424 **Christopher Jacques Hillar*** (chillar@msri.org), 17 Gauss Way, Berkeley, CA 94120. *Rational sums of squares and applications.*

Do rational certificates always exists for sum of squares problems? For instance, is every rational polynomial that is a sum of squares also a rational sum of squares (Sturmfels)? This is an especially important question given the rise of numerical and seminumerical algorithms. We discuss recent results and then propose some open problems and conjectures that arise naturally in the context of semidefinite programming and sums of squares. (Received February 03, 2009)

1047-13-442 **Neil Epstein*** (neilme@umich.edu), University of Michigan, 2074 East Hall, 530 Church St., Ann Arbor, MI 48109, and **Yongwei Yao**, Georgia State University, Atlanta, GA. *A numerical criterion for tight closure of arbitrary ideals.*

Let (R, m) be a quasi-unmixed Noetherian local ring of prime characteristic $p > 0$. Given two ideals $J \subseteq I$, where J is m-primary, I and J have the same tight closure iff they have the same Hilbert-Kunz multiplicity. A more general theorem holds, due to Hochster and Huneke, when I/J has finite length. But what if I/J isn't a finite-length module? We have defined an extension of Hilbert-Kunz multiplicity to all ideal pairs $J \subseteq I$, which is a kind of analogue of j-multiplicity, which gives a sufficient condition for the tight closures of J and I to agree. In some cases, the condition is also necessary. (Received February 03, 2009)

1047-13-475 **Terry Gannon*** (tgannon@math.ualberta.ca), Math Dept, U of Alberta, Edmonton, Alberta T6G 2G1, Canada. *Fusion rings over finite fields.*

The Hasse principle tells us that insight into the global is gained through the local. We will apply this to fusion rings, a simple algebraic structure arising in conformal field theory which includes e.g. representation rings of quantum groups at roots of 1, and Drinfeld doubles of finite groups. We will explain how their classification can be determined by an analogous (and more accessible) one over the finite fields. (Received February 03, 2009)

1047-13-476 **Mats Boij**, **Juan C Migliore**, **Rosa M Miró-Roig** and **Uwe Nagel*** (uwenagel@ms.uky.edu), University of Kentucky, Department of Mathematics, 715 Patterson Office Tower, Lexington, KY 40506, and **Fabrizio Zanello**. *The shape of a pure O-sequence.* Preliminary report.

Pure O-sequences can be defined as h-vectors of pure order ideals or of level algebras with monomial relations. They arise in various contexts. For example, f-vectors of pure simplicial complexes are pure O-sequences, and an open conjecture of Stanley says that h-vectors of matroid complexes are also pure O-sequences. We construct examples showing that pure O-sequences whose length is at least 5 may not be unimodal and we establish various results on the growth of O-sequences. However, a complete characterization of pure O-sequences remains elusive. We propose a more manageable interval conjecture that gives structural information and that we establish in various cases, most importantly for all pure O-sequences of length 4. (Received February 03, 2009)

14 ► Algebraic geometry

1047-14-60 **Murray A. Marshall*** (marshall@math.usask.ca), 106 Wiggins Road, Saskatoon, SK S7N5E6, Canada. *Polynomials non-negative on the strip.*

Any real polynomial $f(x,y)$ which is non-negative on the strip $[0,1]\times\mathbb{R}$ is expressible as $f(x,y)=\sigma(x,y)+\tau(x,y)x(1-x)$ where $\sigma(x,y),\tau(x,y)$ are real polynomials which are sums of squares of real polynomials. There are various equivalent formulations of the result. The proof will appear in the Proceedings of the AMS. See the author's webpage for the pdf file. This provides an affirmative answer to the so-called Strip Conjecture. In terms of preorderings the result asserts that the preordering of the polynomial ring $\mathbb{R}[x,y]$ generated by $x(1-x)$ (or equivalently, by x and $1-x$) is saturated. Scheiderer proved earlier in [Manuscripta Math. 119, 395-410, 2005] that the preordering of $\mathbb{R}[x,y]$ generated by $x, 1-x, y$ and $1-xy$ is saturated. In these two examples the associated basic closed semialgebraic set is not compact. These are the only examples known so far of saturated finitely generated preorderings in the 2-dimensional non-compact case. In contrast to this, in the 2-dimensional compact case many examples are known, see [Scheiderer, Manuscripta Math. 119, 395-410, 2005] and [Cimpric, Kuhlmann and Marshall, Advances in Geometry, to appear]. (Received January 08, 2009)

1047-14-70 **Ilpo Laine*** (ilpo.laine@joensuu.fi), Department of Mathematics, University of Joensuu, P.O. Box 111, FI-80101 Joensuu, Finland. *Tropical Nevanlinna theory.*

In this talk, we shall consider a max-plus semi-ring structure in the real line, with - ∞ included, endowed with tropical addition, equivalent to the usual maximum operation, and tropical multiplication, equivalent to the usual addition. In this framework, tropical Nevanlinna theory describes value distribution of continuous piecewise linear functions of a real variable, whose one-sided derivatives are integers at every point. Such functions are called tropical meromorphic functions.

In this talk, we shortly describe tropical counterparts of the first main theorem, the lemma of logarithmic differences and the classical Clunie lemma.

This is a joint work with C.-C. Yang (Hong Kong University of Science and Technology). (Received January 13, 2009)

1047-14-77 **Mounir Nisse*** (nisse@math.jussieu.fr), Université Pierre et Marie Curie-Paris 6, IMJ, Labo: Analyse Algébrique, Office: 7C14, 175, rue du Chevaleret, 75013, Paris, France, Paris, France. *Amoebas and coamoebas, relationships and similarities.*

Let V be an algebraic hypersurface in $(\mathbb{C}^*)^n$. We show that the complement components of the coamoeba of V in the flat torus $(S^1)^n$ have a similar properties as the complement components of the amoeba of V in $\mathbb{R}^n$. More precisely, if $co\mathcal{A}_V$ is the coamoeba of V, then we prove that the connected components of $(S^1)^n\setminus\overline{co\mathcal{A}_V}$ are convex and their number cannot exceed $n!\mathrm{Vol}(\Delta)$, where Δ is the Newton polytope of the polynomial defining V, and $\overline{co\mathcal{A}_V}$ is the closure of $co\mathcal{A}_V$ in the real torus $(S^1)^n$. In addition, we prove that the area of the coamoeba of a complex algebraic plane curve counted with multiplicity cannot exceed $2\pi^2\mathrm{Area}(\Delta)$, and the equality hold if and only if the curve is a Harnack, possibly with ordinary real isolated double points. In the same way, we show that a polynomial f defining a Harnack curve is dense i.e., its support is $\Delta\cap\mathbb{Z}^2$. Using a geometric properties of the coamoebas and the logarithmic Gauss map, we give a second proof of Passare-Rullgård's conjecture, that the amoeba of a complex algebraic hypersurface defined by a maximally sparse polynomial is solid. (Received January 15, 2009)

1047-14-82 **Mohan N Kumar*** (kumar@wustl.edu), Campus Box 1146, Washington University, One Brookings Drive, Saint Louis, MO 63130. *Arithmetically Cohen-Macaulay bundles on hypersurfaces.*

The talk is based on some joint work with A. P.Rao and G. V. Ravindra. The relevant preprints are available at xxx.arXiv.org/abs/math.AG/0507161 and arXiv:math/0611620. The first appeared in Commentari Math. Helv and the second in IMRN.

A vector bundle on a polarized projective variety (X,L) is called Arithmetically Cohen-Macaulay if all its middle cohomologies in all twists by powers of L vanish. A famous criterion of G. Horrocks states that a vector bundle on projective space is a direct sum of line bundles if and only if it is arithmetically Cohen-Macaulay (with respect to the usual polarization). It is well known that this criterion fails for other varieties, in particular for hypersurfaces in projective spaces. In my talk I will discuss the following results proved in the above articles. Any rank two arithmetically Cohen-Macaulay vector bundle on a general hypersurface of degree at least three in $\mathbb{P}^5$ or on a general hypersurface of degree at least six in $\mathbb{P}^4$ must be split. (Received January 17, 2009)

1047-14-142 **Matthew M Szczesny*** (szczesny@math.bu.edu). *Moduli problems and localization functors in orbifold CFT.*

Conformal field theory (CFT) yields a mechanism for producing interesting D-modules on the moduli of curves and bundles. We consider localization functors which arise in orbifold CFT, where the above geometric objects are replaced with analogues possessing discrete symmetries. (Received January 25, 2009)

1047-14-151 **David Ben-Zvi** and **David Nadler*** (nadler@math.northwestern.edu), Department of Mathematics, Northwestern University, Evanston, IL 60208. *Character sheaves.*

I will describe joint work with David Ben-Zvi devoted to understanding Lusztig's character sheaves in the framework of 3d topological field theory. (Received January 26, 2009)

1047-14-155 **Joel Kamnitzer*** (jkamnitz@math.toronto.edu) and **Pierre Baumann**. *MV polytopes and components of quiver varieties.*

A number of interesting bases exist for the upper half of the universal envelopping algebra of a semisimple Lie algebra. One such basis is Lusztig's semicanonical basis which is indexed by components of quiver varieties. Another interesting basis is indexed by Mirkovic–Vilonen cycles which lead to the combinatorics of MV polytopes. In this talk, I will explain a natural bijection between the components of quiver varieties and the MV polytopes. (Received January 26, 2009)

1047-14-246 **Carla Fidalgo*** (cfidalgo@isec.pt), Rua Pedro Nunes, Quinta da Nora, 3030-199 Coimbra, Portugal, Coimbra, Portugal, and **Alexander Kovacec** (kovacec@mat.uc.pt), P-3001-454 Coimbra, Coimbra, Portugal. *Diagonal minus tail forms and Lasserre's sufficient conditions for sums of squares.*

By a *diagonal minus tail* form (of even degree) we understand a real homogeneous polynomial $F(x_1, ..., x_n) = F(\underline{x}) = D(\underline{x}) - T(\underline{x})$, where the *diagonal* part $D(\underline{x})$ is a sum of terms of the form $b_i x_i^{2d}$ with all $b_i \geq 0$ and the *tail* $T(\underline{x})$ a sum of terms $a_{i_1 i_2 \ldots i_n} x_1^{i_1} \ldots x_n^{i_n}$ with $a_{i_1 i_2 \ldots i_n} > 0$ and at least two $i_\nu \geq 1$. We show that an arbitrary change of the signs of the tail terms of a positive semidefinite diagonal minus tail form will result in a sum of squares (sos) of polynomials. The work uses Reznick's theory of agiforms [Re] and gives easily tested sufficient conditions for a form to be sos; one of these is piecewise linear in the coefficients of a polynomial and reminiscent of Lassere's recent conditions [La] but proved in completely a different manner.

[La] J. B. Lasserre, Sufficient conditions for a polynomial to be a sum of squares, Arch. Math. 89, 390-398 (2007).

[Re] B. Reznick, Forms derived from the arithmetic geometric inequality, Math. Ann. 283, 431-464, (1989). (Received January 29, 2009)

1047-14-254 **Prabhu Venkataraman*** (prabhu@eureka.edu), 300 E College Ave, Eureka, IL 61530. *The 2-Lien of a 2-Gerbe.*

Principal bundles have a well-known description in terms of nonabelian cocycles of degree 1 with values in a sheaf. A more general notion than that of a sheaf on a space X is that of a lien on X. A lien on X is an object that is locally defined by a sheaf of groups, with descent data given up to inner conjugation. Equivalences classes of gerbes with a given lien L are classified by nonabelian degree 2 cocycles. In his work, Lawrence Breen has given a similar classification of 2-gerbes using nonabelian degree 3 cocycles that take values in a family of group stacks. We define the notion of a 2-lien on a space X. It is an object that is given locally by a group stack, with 2-descent given up to inner equivalence. We present some theorems about 2-liens of 2-gerbes which correspond to well known results about liens of gerbes. Also, Deligne has shown that any strict Picard stack $\mathcal{G}$ corresponds to a 2-term complex of abelian sheaves $K^\cdot = [K^0 \xrightarrow{d} K^1]$. In this case we prove that $\check{H}^3(X, \mathcal{G})$ is isomorphic to the hypercohomology group $\check{H}^3(X, K^\cdot)$. (Received January 29, 2009)

1047-14-300 **Christopher Brav*** (brav@math.toronto.edu). *The projective McKay correspondence.*

Alexander Kirillov Jr. has described a McKay correspondence for finite subgroups of $PSL_2(\mathbb{C})$ which associates to each 'height' function an affine Dynkin quiver, together with a derived equivalence between equivariant sheaves on $\mathbb{P}^1$ and representations of this quiver. The equivalences for various height functions are related by reflection functors for quiver representations.

We develop an analogous story for the cotangent bundle of $\mathbb{P}^1$, in which each height function gives a derived equivalence between equivariant sheaves on the cotangent bundle and modules over the preprojective algebra of an affine Dynkin quiver. These various equivalences are related by the spherical twists of Seidel-Thomas, which take the place of the reflection functors for $\mathbb{P}^1$. (Received January 31, 2009)

1047-14-323 **Alexei Oblomkov*** (oblomkov@math.princeton.edu), Fine Hall, Washington Rd, Princeton, NJ 08544, and **Andrei Okounkov**, Fine Hall, Washington Rd, Princeton, NJ 08544. *On GW/DT correspondence with descendants.* Preliminary report.

We present the exact statement of the conjectural correspondence between the gravitational descendants of GW theory of the threefold and the integrals of the characteristic classes of the universal ideal sheaf over the DT virtual cycle of the threefold. The conjecture is known to hold for some classes of P^1 fibrations (joint with A. Okounkov) (Received February 01, 2009)

1047-14-325 **Holger Brenner**, **Jinjia Li** and **Claudia Miller*** (clamille@syr.edu). *Concerning limit Hilbert-Kunz multiplicities.*

We investigate cases when a more naive limit turns out to give the limit Hilbert Kunz multiplicity. The main case is that of ideals in the affine cone of smooth nonsingular curves; the proof involves more careful estimates of bounds of Brenner and Trivedi (independently) on the ranks of the cohomologies of twists of the syzygy bundle as the characteristic p goes to infinity. Another case is that of maximal ideals in diagonal hypersurfaces. This is joint work with Holger Brenner and Jinjia Li (Received February 01, 2009)

1047-14-344 **Victoria Powers*** (vicki@mathcs.emory.edu), Dept. of Mathematics and Computer Science, Atlanta, GA 30322. *Pólya's Theorem, Applications and Generalizations.* Preliminary report.

Pólya's Theorem says that if a form (homogeneous polynomial) $p \in \mathbb{R}[X_1, \ldots, X_n]$ is strictly positive on the standard n-simplex $\{(x_1, \ldots, x_n) \in \mathbb{R}^n \mid x_i \geq 0, \sum x_i = 1\}$, then for a sufficiently large exponent N, all of the coefficients of $(X_1 + \cdots + X_n)^N p$ are positive. This elegant and beautiful result has many applications, both in pure and applied mathematics. In this talk we discuss applications of Pólya's Theorem as well as generalizations, in particular to noncommutative settings. (Received February 02, 2009)

1047-14-381 **Mari F. Castle*** (mfc7379@kennesaw.edu), 1000 Chastain Road, #1204, Kennesaw, GA 30144-5591, **Victoria Powers** (vicki@mathcs.emory.edu), 400 Dowman Dr., W401, Atlanta, GA 30322, and **Bruce Reznick** (reznick@math.uiuc.edu), 1409 W. Green Street, Urbana, IL 61801-2975. *Pólya's Theorem with Zeros.*

Let $\mathbb{R}[X] = \mathbb{R}[X_1, \ldots, X_n]$ and let Δ_n denote the standard n-simplex $\{(x_1, \ldots, x_n) \in \mathbb{R}^n \mid x_i \geq 0, \sum_i x_i = 1\}$. Pólya's Theorem says that if a form (homogeneous polynomial) $p \in \mathbb{R}[X]$ is positive on Δ_n, then for sufficiently large $N \in \mathbb{N}$, the coefficients of $(X_1 + \cdots + X_n)^N p$ are positive. In this talk, we discuss a generalization of Pólya's Theorem to form which are allowed to have zeros in the simplex. We give a characterization of forms which satisfy the conclusion of Pólya's Theorem (with "positive coefficients" replaced by "nonnegative coefficients") and give a bound for the N needed. (Received February 02, 2009)

1047-14-390 **Bruce Reznick*** (reznick@math.uiuc.edu), 1409 W. Green St., Urbana, IL 61801. *On Hilbert's theorem for psd ternary sextics.* Preliminary report.

In 1893, Hilbert proved that if p is a psd ternary sextic form, then there exists a ternary quadratic form h with the property that hp is a sum of three squares of ternary quartic forms. We plan to discuss explicit instances of this theorem. (Received February 02, 2009)

1047-14-398 **Parsa Bakhtary*** (pbakhtar@math.purdue.edu), 216 N. 4th St., Lafayette, IN 47901. *On the Cohomology of a Simple Normal Crossings Divisor and its Dual Complex.*

We establish a formula which decomposes the cohomologies of various sheaves on a simple normal crossings divisor (SNC) D in terms of the simplicial cohomologies of the dual complex $\Delta(D)$, constructed combinatorially using only incidence information of the components of D, with coefficients in a presheaf of vector spaces. This presheaf consists precisely of the corresponding cohomology data on the components of D and on their intersections. We use this formula to give a Hodge decomposition for SNC divisors and show how it simplifies in the toric setting. We also conjecture the existence of such a formula for effective non-reduced divisors with SNC support, and show that this would imply the vanishing of the higher simplicial cohomologies of the dual complex associated to the exceptional SNC divisor of a resolution of an isolated rational singularity. (Received February 02, 2009)

1047-14-400 **Saugata Basu*** (sbasu@math.purdue.edu), Purdue University, Department of Mathematics, 150 N. University St., West Lafayette, IN 47907, and **Thierry Zell**. *Polynomial hierarchy, Betti numbers and a real analogue of Toda's theorem.*

We study the relationship between the computational hardness of two well-studied problems in algorithmic semi-algebraic geometry – namely the problem of deciding sentences in the first order theory of reals with a constant number of quantifier alternations, and that of computing Betti numbers of semi-algebraic sets. We obtain a

polynomial time reduction of the compact version of the first problem to the second. As a consequence we obtain an analogue of Toda's theorem from discrete complexity theory for real Turing machines (in the sense of Blum, Shub and Smale). (Received February 02, 2009)

1047-14-421 **Rina Anno*** (anno@math.uchicago.edu), 5734 S University Ave, University of Chicago Math Department, Chicago, IL 60637. *Stability conditions, Springer fibers and braids with multiplied threads.*

This talk is based on a joint work with Roman Bezrukavnikov. Let g be a semisimple Lie group of type ADE, B the flag variety, and U the Grothendieck-Springer resolution for g. Using the affine braid group action on $D^b_B(U)$, we describe a locally closed submanifold in the space of Bridgeland's stability conditions for this triangulated category. The construction of the braid group action involves functors between derived categories for resolutions of different Slodowy slices. The induced maps on the spaces of stability conditions give a stratification of these submanifolds. This geometric picture may be described combinatorially in terms of some version of tangle calculus. (Received February 02, 2009)

1047-14-470 **Julianna Tymoczko*** (tymoczko@math.uiowa.edu), Department of Mathematics, University of Iowa, 14 MacLean Hall, Iowa City, IA 52242. *The geometry and combinatorics of some special subvarieties of the flag variety.*

Subvarieties of the flag variety like Springer varieties and their generalizations, Hessenberg varieties, arise naturally in representation theory. We describe natural combinatorial characterizations of the geometry in some special cases, and how it relates to representation theory. (Received February 03, 2009)

1047-14-483 **Sheldon H Katz*** (katz@math.uiuc.edu), Department of Mathematics, University of Illinois, 1409 W. Green Street, Urbana, IL 61801. *BPS invariants of Calabi-Yau threefolds.* Preliminary report.

I will geometrically describe BPS (or Gopakumar-Vafa) invariants of Calabi-Yau threefolds in low genus and give evidence for their expected relationship to stable pair invariants. (Received February 03, 2009)

16 ► Associative rings and algebras

1047-16-31 **Ryan Kinser*** (kinser@umich.edu). *Rank functions and quiver representations.*

A quiver is a finite directed graph, and a representation of a quiver is an assignment of a vector space to each vertex and linear map to each arrow. I will discuss the "rank" of a quiver representation, which is a numerical invariant generalizing the rank of a linear map, and some applications. (Received December 08, 2008)

1047-16-98 **Victor Reiner** (reiner@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455, and **Dumitru I. Stamate*** (dumitru.stamate@imar.ro), Institute of Mathematics "Simion Stoilow", of the Romanian Academy, P.O. BOX 1-764, 014700 Bucharest, Romania. *Koszul incidence algebras, affine semigroups, and Stanley-Reisner ideals.*

We prove a theorem unifying three results from combinatorial homological and commutative algebra, characterizing the Koszul property for incidence algebras of posets and affine semigroup rings, and characterizing linear resolutions of squarefree monomial ideals.

The characterization in the graded setting is via the Cohen-Macaulay property of certain posets or simplicial complexes, and in the more general nongraded setting, via the sequential Cohen-Macaulay property. (Received January 21, 2009)

1047-16-177 **Calin Ioan Chindris*** (calin-chindris@uiowa.edu). *Cluster fans for quivers.*

Given a quiver without oriented cycles, one can construct its cluster algebra, and hence, its cluster fan. In fact, the underlying combinatorics of such a cluster algebra is governed by its cluster fan. In this talk, I will give an interpretation of the cluster fan of a quiver Q without oriented cycles in terms of the stability conditions and the domains of semi-invariants of Q. (Received January 27, 2009)

1047-16-384 **Steffen Oppermann** (Steffen.Oppermann@math.ntnu.no), Institutt for matematiske fag, NTNU Gløshaugen, 7034 Trondheim, Norway, and **Hugh Thomas*** (hthomas@unb.ca), Department of Mathematics and Statistics, University of New Brunswick, Fredericton, NB E3B 5A3, Canada. *Higher Auslander algebras, cyclic polytopes, and analogues of tropical cluster algebras.* Preliminary report.

Consider two simple models for the A_n cluster complex: triangulations of an $n+3$-gon, and tilting objects for the path algebra of a linearly-oriented A_{n+1} quiver. We show that there are higher-dimensional analogues of both these sets of objects, and that they are naturally in bijection. These higher dimensional analogues are: triangulations of a cyclic polytope of dimension $2d$ with $n+2d+1$ vertices, and basic tilting objects over the $d-1$-fold higher Auslander algebra of the path algebra of the linearly-oriented A_{n+1} quiver (satisfying an additional condition). The analogue of the cluster variables are the internal d-dimensional simplices of the polytope and the non-projective-injective summands of the tilting objects. While we do not have anything like a cluster algebra on this set of variables, we show the existence of an analogue of the tropical cluster algebra structure associated to a lamination. (Received February 02, 2009)

17 ► Nonassociative rings and algebras

1047-17-63 **Nicolas Guay*** (nguay@math.ualberta.ca), University of Alberta, Department of Mathematics, 632 CAB, Edmonton, Alberta T6G 2G1, Canada. *Representations of double affine Lie algebras and finite groups.*

There is no general theory for matrix Lie algebras over non-commutative rings, but there are some interesting examples to consider. Motivated by Cherednik algebras and symplectic reflection algebras, one is led to the study of $\mathfrak{sl}_n$ over rings such as $\mathbb{C}[u,v] \rtimes \Gamma$, where Γ is a finite subgroup of $SL_2(\mathbb{C})$, $A_1 \rtimes \Gamma$ where A_1 is the first Weyl algebra, and $\Pi(Q)$, the preprojective algebra of a quiver Q. I will present some results regarding integrable modules, Weyl modules and quasifinite highest weight modules when Γ is a cyclic group. One can hope that some of these results can be generalized to affine Yangians and new families of quantum algebras called deformed double current algebras. (Received January 11, 2009)

1047-17-333 **Bogdan Ion*** (bion@pitt.edu). *Charge=Height.*

The charge statistic of Lascoux and Schutzenberger describes the exponents that appear in the Kostka-Foulkes polynomials of type A. It is a long standing open problem to find similar (positive) formulas for Kostka polynomials for other root systems. I will explain how this could be achieved. The statistic involved is the height of some special weights, called quasi-dominant weights. (Received February 01, 2009)

1047-17-449 **Alistair Savage*** (alistair.savage@uottawa.ca), Department of Mathematics & Statistics, University of Ottawa, 585 King Edward Ave, Ottawa, Ontario K1N 6N5, Canada. *Quiver Grassmannians.* Preliminary report.

We introduce the notion of a quiver Grassmannian, which is the space of graded, invariant subspaces of a fixed representation of a quiver. We will discuss connections of the quiver Grassmannian with the representation theory of Kac-Moody algebras and combinatorial representation theory. (Received February 03, 2009)

18 ► Category theory; homological algebra

1047-18-106 **Lucian Miti Ionescu*** (LMIones@ilstu.edu), Mathematics Department, Illinois State University, School Street, Normal, IL 61790-4520. *Deformation Theory as a generalization of Lie Theory.*

Deformation theory is presented as a pair of adjoint functors, analog to Lie Theory: the universal Maurer-Cartan solution of Stasheff-Huebshaman playing the role of the exponential, with Kuranishi functor its inverse, as the logarithm. This leads to connections with Connes-Kreimer algebraic renormalization, to be explored. (Received January 22, 2009)

19 ► K-theory

1047-19-69 **Semail Ulgen Yildirim*** (sulgen@math.northwestern.edu), 2033 Sheridan Rd Lunt Hall 223, EVANSTON, IL 60208. *Tilings, Modified Bellissard Algebra and K-theory.* Preliminary report.

We work on crossed product C^*-algebras such as the C^*-algebra $A = C(\Omega) \rtimes \mathbb{R}^d$ where $\mathbb{R}^d$ acts on $C(\Omega)$ by translations. Here Ω is a compact space formed by translations of a given tiling τ. Indeed, J. Bellissard defined the notion of a hull $(\Omega, \mathbb{R}^d, T)$ to model aperiodic solids. The hull $(\Omega, \mathbb{R}^d, T)$ is a dynamical system with group $\mathbb{R}^d$ acting by homeomorphisms on a compact metrizable space Ω. In the case of a perfect crystal, with translation group G, the hull $\Omega = \mathbb{R}^d/G$ is homeomorphic to $\mathbb{T}^d$. In fact, with any dynamical system, there is a canonical C^*-algebra, namely the crossed product C^*-algebra $A = C(\Omega) \rtimes \mathbb{R}^d$. We modify this algebra a little bit by enlarging the hull Ω after including rotational symmetry in addition to translational symmetry on tiles, in particular on aperiodic tilings and call it the modified Bellissard Algebra. In the periodic case one can study the K-theory of this modified C^*-algebra and try to detect the type of the crystal. (Received January 12, 2009)

20 ► Group theory and generalizations

1047-20-148 **Josh Wiscons*** (wiscons@colorado.edu), Department of Mathematics, Campus Box 395, Boulder, CO 80309-0395. *Moufang sets of finite Morley rank.*

We show that under certain restrictions the little projective group of an infinite Moufang set of finite Morley rank with abelian root groups is either a split sharply two-transitive group or is isomorphic to $\mathrm{PSL}_2(K)$ for K an algebraically closed field. Additionally, we review past results illustrating the role that Moufang sets of finite Morley rank may play in addressing the Cherlin-Zil'ber conjecture. (Received January 26, 2009)

1047-20-189 **John C. Meakin*** (jmeakin@math.unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588. *Subgroups of free idempotent-generated semigroups.*

We provide a concrete example of a non-free subgroup of an idempotent-generated semigroup freely generated on a biordered set, and we discuss some open problems about the structure of groups that can arise this way. This is joint work with M. Brittenham and S. Margolis. (Received January 28, 2009)

1047-20-195 **Daniel P. Groves*** (groves@math.uic.edu), MSCS, UIC, 322 SEO, M/C 249, 851 S. Morgan St., Chicago, IL 60607. *Classifying surface bundles.*

Let S be an orientable surface of finite type, and B a reasonable space (CW complex, or manifold). The set of isomorphism classes of S-bundles over B is naturally parametrized by the set of conjugacy classes of homomorphisms from the fundamental group of B to Mod(S), the mapping class group of S.

I'll describe some work in progress which gives a general structure theory for this set, for an arbitrary B with finitely generated fundamental group. (Received January 28, 2009)

1047-20-196 **Yuri A. Bahturin** and **Alexander Y. Olshanskii*** (alexander.olshanskiy@vanderbilt.edu), 1326 Stevenson Center, Department of Mathematics, Vanderbilt University, Nashville, TN 37240. *Actions of Maximal Growth.*

We study acts and modules of maximal growth over finitely generated free monoids and free associative algebras as well as free groups and free group algebras. The maximality of the growth implies some other specific properties of these acts and modules that makes them close to the free ones; at the same time, we show that being a strong "infiniteness" condition, the maximality of the growth can still be combined with various finiteness conditions, which would normally make finitely generated acts finite and finitely generated modules finite-dimensional. (Received January 28, 2009)

1047-20-238 **Mark Sapir*** (markvs@gmail.com), SC1522, Department of Mathematics, Vanderbilt University, Nashville, TN 37221. *Geometry of groups, random walks, and polynomial maps over finite fields.*

I will show how to prove that most 1-related groups are residually finite. Although the result is purely algebraic, the proof employs methods from very diverse areas of mathematics: from analysis (Brownian motion) to algebraic geometry (properties of quasi-fixed points of polynomial maps over finite fields and p-adics, related to a Deligne conjecture). (Received January 29, 2009)

1047-20-252 **Sean Cleary** (cleary@sci.ccny.cuny.edu), Department of Mathematics, The City College of New York, The City University of New York, New York, NY 10031, **Susan Hermiller*** (shermiller2@math.unl.edu), Department of Mathematics, 203 Avery Hall, University of Nebraska, Lincoln, NE 68588-0130, **Melanie Stein**, Department of Mathematics, Trinity University, Hartford, CT 06106, and **Jennifer Taback**, Department of Mathematics, Bowdoin College, Brunswick, ME 04011. *Tame combings for groups.* Preliminary report.

Connections between various scales of tameness of 1-combings and of almost convexity for groups are known for the most restrictive variants of these properties. For example, a group is almost convex with respect to a constant function iff the group has a tame 1-combing admitting the identity as a radial tameness function. In this talk I will describe two tame combings, for Thompson's group F and for the Baumslag-Solitar BS(1,64) group. From these, we show that a linear radial tameness function does not imply even the minimal almost convexity condition. (Received January 29, 2009)

1047-20-262 **Tadeusz Januszkiewicz*** (tjan@math.ohio-state.edu). *Some quotients of Coxeter groups.* Preliminary report.

Let (W, S) be a Coxeter group; let $\mathfrak{m}$ be an ideal in the ring of algebraic integers spanned by the coefficients of the Tits representation of W; let $\mathcal{F}$ be a family of subsets of S. Denote $W_{\mathfrak{m}}(\mathcal{F})$ the group obtained by reducing mod $\mathfrak{m}$ all subgroups spanned by subsets of S belonging to $\mathcal{F}$.

We study groups $W_{\mathfrak{m}}(\mathcal{F})$, where W is a Coxeter group of large type (all $m_{st} \geq 3$, and finite), and $\mathcal{F}$ is a family of 3 element subsets of S.

For almost all ideals $\mathfrak{m}$, these groups act on systolic spaces. This allows to understand several geometric properties such as hyperbolicity, isoleted flats property, being virtually torsion free. (Received January 30, 2009)

1047-20-322 **J F Manning***, Department of Mathematics, SUNY at Buffalo, Buffalo, NY 14260, and **E Martínez-Pedroza**. *Combination and separation.*

Let G be a relatively hyperbolic group with ERF (extended residually finite) peripheral subgroups. We study the separability of relatively quasiconvex subgroups of G. A combination result of Martínez-Pedroza is used to reduce to the separability of quasiconvex subgroups of certain hyperbolic quotients of G. Combining with results of Agol, Groves, and Manning, we can deduce: If all hyperbolic groups are residually finite, G as above must be QCERF. In particular, if all hyperbolic groups are residually finite, all Kleinian groups are LERF. (Received February 01, 2009)

1047-20-324 **Vladimir Shpilrain*** (shpil@groups.sci.ccny.cuny.edu), Department of Mathematics, The City College of New York, New York, NY 10031. *Search problems in group theory.* Preliminary report.

Decision problems are problems of the following nature: given a property $\mathcal{P}$ and an object $\mathcal{O}$, find out whether or not the object $\mathcal{O}$ has the property $\mathcal{P}$. On the other hand, search problems are of the following nature: given a property $\mathcal{P}$ and an object $\mathcal{O}$ with the property $\mathcal{P}$, find a proof (sometimes called a "witness") of the fact that $\mathcal{O}$ has the property $\mathcal{P}$. This is a substantial shift of paradigm, and in fact, studying search problems often gives rise to new research avenues in mathematics, very different from those prompted by addressing the corresponding decision problems. To give just a couple of examples from different areas of mathematics, we can mention (1) the isoperimetric function that can be used to measure the complexity of a proof that a given word is trivial in a given group; (2) Reidemeister moves that can be used to measure the complexity of a proof that two given knot diagrams are those of two isotopic knots.

In this talk, we are going to discuss various search problems in group theory, some of them motivated by cryptography. (Received February 01, 2009)

1047-20-335 **Kevin Wortman*** (wortman@math.utah.edu), Salt Lake City, UT. *Dehn functions of solvable groups.*

We'll show that members of a certain family of linear groups have polynomial Dehn functions. (Received February 01, 2009)

1047-20-364 **Eric M Freden*** (freden@suu.edu), Dept of Comp Science and Information Systems, Southern Utah University, Cedar City, UT 84720, and **Jared Adams**. *Growth in Baumslag-Solitar groups: Asymptotics.* Preliminary report.

The Cayley 2-complex of the Baumslag-Solitar group $BS(p, q)$ in the standard presentation $\langle b, t \mid tb^p t^{-1} = b^q \rangle$,$1 < p < q$, is homeomorphic to a tree cross line. We show that the exponent of growth for this presentation

depends only on the tree (which is the Bass-Serre tree). We consider a formal language-theoretic approach to computing these exponents of growth for various p and q. (Received February 02, 2009)

1047-20-369 **Lev Glebsky*** (glebsky@cactus.iico.uaslp.mx), Department of Math., University of Illinois at Urbana-Champaign, 1409 West Green Street, Urbana, IL 61801, and **L.M. Rivera**. *Sofic groups and profinite topology on free groups.*

The notion of sofic groups was introduced by M. Gromov in relation with the "surjunctivity" problem of cellular automata due to Gottschalk. It is an open question if there is a non-sofic group. We show the relation of sofic groups with the profinite topology on a free group.

We give a definition of weakly sofic groups (w-sofic groups). Our definition is a rather natural extension of the definition of sofic groups where instead of the Hamming metric on symmetric groups we use general bi-invariant metrics on finite groups. Let F be a finitely generated free group and $N \lhd F$. Then F/N is w-sofic if and only if for any finite sequence $g_1, g_2, ..., g_k \in N$ one has $\overline{[g_1]^F[g_2]^F...[g_k]^F} \subseteq N$. Where $\overline{X}$ denotes the closure of X in the profinite topology on F. (Received February 02, 2009)

1047-20-392 **Larsen E Louder***, Department of Mathematics, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48103. *Krull dimension for limit groups.*

There is one-to-one correspondence between limit groups and irreducible varieties defined over the free group, objects which are fundamental in the study of the first order theory of free groups. I will discuss their finite Krull dimension, with an emphasis on iteratively adjoining roots to limit groups and finitely generated freely decomposable groups without 2-torsion, via uniform finiteness of Haken hierarchies of limit groups in terms of their ranks. (Received February 02, 2009)

1047-20-418 **Volodymyr Nekrashevych*** (nekrash@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843. *Combinatorial models of Julia sets and Group Theory.* Preliminary report.

We will show how iterated monodromy groups can be used to construct polyhedral models of Julia sets of hyperbolic dynamical systems. Examples from complex dynamics in several variables (and from Teichmueller theory) will be presented. (Received February 02, 2009)

1047-20-429 **Zoran Sunic*** (sunic@math.tamu.edu). *Frobenius Problem and dead ends in integers.*

Let a and b be positive, relatively prime integers. We show that the following are equivalent: (i) d is a dead end in the (symmetric) Cayley graph of Z with respect to a and b, (ii) d is a Frobenius value with respect to a and b (it cannot be written as a non-negative or non-positive integer linear combination of a and b), and d is maximal (in the Cayley graph) with respect to this property. In addition, for given integers a and b, we explicitly describe all such elements in Z. We show that every finitely generated group has a generating set with respect to which dead ends exist. (Received February 03, 2009)

1047-20-435 **Enric Ventura*** (enric.ventura@upc.edu), EPSEM - UPC, Av. Bases de Manresa 61-73, 08242 Manresa, Barcelona, Spain. *Characterizing the solvability of the conjugacy problem in free-by-free and [free abelian]-by-free groups.*

(this is joint work with O. Bogopolski and A. Martino)

A classical construction due to Miller gave the first examples of free-by-free groups with unsolvable conjugacy problem. In this talk we shall give a characterization of the solvability of this problem within this family of groups: "a free-by-free group has solvable conjugacy problem if and only if its action group is orbit decidable". As a corollary, we obtain the solvability of the conjugacy problem for free-by-cyclic groups; and lots of new examples of free-by-free groups with unsolvable conjugacy problem.

Our characterization extends to a bigger family of groups, including [free abelian]-by-free. In this direction, we find the first known examples of [free abelian]-by-free (more concretely, Z^4-by-free) groups with unsolvable conjugacy problem. In contrast, we also prove that every Z^2-by-free group has solvable conjugacy problem. The case of Z^3-by-free is open. (Received February 03, 2009)

1047-20-461 **D. B. McReynolds***, 5734 S. University, Chicago, IL , and **Larsen Louder**. *Ranks of subgroups of free groups.*

In this talk, I will discuss a topological model that is useful for computing ranks of subgroups of free groups. This is joint with Larsen Louder. (Received February 03, 2009)

1047-20-468 **G Christopher Hruska*** (chruska@uwm.edu), Dept. of Mathematical Sciences, University of Wisconsin–Milwaukee, PO Box 413, Milwaukee, WI 53201, and **Daniel T Wise**. *Packing subgroups and relative hyperbolicity.*

A subgroup H of a countable group G has bounded packing if there is a finite upper bound on the number of left cosets that are pairwise close in G. Bounded packing has natural connections with actions on CAT(0) cube complexes. I will explain some basic properties of bounded packing and give many examples; for instance, every subgroup of a countable virtually nilpotent group has bounded packing.

Our main result establishes the bounded packing of quasiconvex subgroups of a relatively hyperbolic group, under mild hypotheses. As an application we prove that such subgroups have bounded height and width, properties that substantially restrict the way conjugates of the subgroup can intersect. (Received February 03, 2009)

22 ► Topological groups, Lie groups

1047-22-303 **Kobi Kremnizer*** (kremnize@math.uchicago.edu). *Localization for singular weights and finite W-algebras.*

I will describe Beilinson-Bernstein type localization theorems for semisimple Lie algebras at a singular weight and for finite W-algebras. (Received January 31, 2009)

1047-22-484 **Peter Magyar*** (magyar@math.msu.edu), Dept of Math, Wells Hall, Michigan State University, East Lansing, MI 48824. *Fusion of affine Grassmannians.* Preliminary report.

We will discuss relations between the Beilinson-Drinfeld Grassmannian, the fusion (twisted convolution) of affine Grassmannians, and various forms of factorization. (Received February 03, 2009)

26 ► Real functions

1047-26-298 **Grigoriy Blekherman*** (grrigg@gmail.com), 2352 East 3rd St, Brooklyn, NY 11223. *Optimizing Polynomials via Low Dimensional Restrictions.* Preliminary report.

Let p be a homogeneous polynomial in n variables of degree d. We will discuss approximating various quantities associated with p, such as its average and largest absolute value on the unit sphere by restricting p to low dimensional subspaces; the dimension of subspaces should be typically logarithmic in n. We will show that the average value of p over a subspace concentrates around the average value of p and we will discuss our progress in showing the same concentration for the maximum absolute value.

We will also discuss a class of polynomials we call "needle-like" polynomials where the computation of the maximum absolute value should be possible by optimizing over a low dimensional subspace and then rescaling properly. (Received January 31, 2009)

28 ► Measure and integration

1047-28-55 **A. Eduardo Gatto*** (aegatto@depaul.edu), 2320 N. Kenmore, 5th floor, Chicago, IL 60015. *Boundedness on inhomogeneous Lipschitz spaces of fractional integrals, singular integrals and hypersingular integrals associated to non-doubling measures.*

In the context of a finite measure metric space whose measure satisfies a growth condition, we prove "T1" type necessary and sufficient conditions for the boundedness of fractional integrals, singular integrals, and hypersingular integrals on inhomogeneous Lipschitz spaces. We also indicate how the results can be extended to the case of infinite measure. Finally we show applications to Real and Complex Analysis (Received January 06, 2009)

1047-28-75 **Anna Vershynina*** (aver@math.ucdavis.edu), Department of Mathematics, University of California Davis, One Shields Ave, Davis, CA 95616, and **Qinglan Xia**. *On the dimension of measures.*

In this talk I will talk about dimension of measures. As we know, dimension of the set may be defined in many meaningful ways: Hausdorff dimension, Minkowski dimension, etc. These definitions agree when the set is nice enough, but not necessarily agree when the set is not that nice. Which dimension is geometrically more meaningful? In this talk we introduce a new metric, called the dimensional distance, between measures. An intresting result is that the distance under this new metric between the measure and a Dirac mass is the dimension of this measure. We also show that the dimension of the measure is bounded above by the Minkowksi

dimesion and below by the Hausdorff dimension of the a set the measure is concentrated on. (Received January 14, 2009)

1047-28-112 **Joseph Rosenbaltt*** (rosnblt@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green St, 273 Altgeld Hall, Urbana, IL 61801. *Determining transformations by averaging methods.* Preliminary report.

There is a duality between transformations and sequences of averaging methods. This duality gives rise to a topology on the class of transformations being considered. This allows us to describe in topological terms when we can distinguishing transformations by averaging methods. The nature of this duality, the topology that arises, results, and open questions will be presented. (Received January 23, 2009)

1047-28-240 **Raanan Schul*** (schul@math.ucla.edu). *Towards Uniform Rectifiability in a metric space setting.*

We will present some progress in the development of the theory of Uniformly Rectifiable sets lying in a general metric space. (Received January 29, 2009)

1047-28-411 **Jasun Gong*** (jasun@pitt.edu), Department of Mathematics, University of Pittsburgh, 301 Thackeray Hall, Pittsburgh, PA 15260. *Rigidity of Derivations on the Plane and Applications.*

We will discuss the structure of doubling measures that admit weak (1,p)-Poincare inequalities on metric spaces. In particular, we will address two conjectures about such measures in the case of the Euclidean plane. The proofs will mainly use techniques from two areas: (1) N. Weaver's theory of derivations on measure spaces, and (2) the structure of null sets on the plane, as studied by G. Alberti, M. Csornyei, and D. Preiss. (Received February 02, 2009)

1047-28-425 **Chris Camfield*** (camfieldc@kenyon.edu), Department of Mathematics, Kenyon College, Gambier, OH 43022. *Comparison of BV Norms in Weighted Euclidean Spaces.*

We will examine functions of bounded variation and sets of finite perimeter as defined by Baldi in weighted Euclidean spaces and also by Miranda Jr. in metric measure spaces. Since weighted Euclidean spaces are metric measure spaces, it is natural to ask whether these two definitions are equivalent or comparable. We will give conditions that ensure the two definitions are equivalent and provide examples of weights for which they are not even comparable. (Received February 03, 2009)

1047-28-448 **Hrant Hakobyan*** (hhakob@math.toronto.edu), University of Toronto, Department of Mathematics, 40 St. George street, Toronto, Ontario M5S 2E4, Canada, and **Ilia Binder** (ilia@math.toronto.edu), University of Toronto, Department of Mathematic, 40 St. George str., Toronto, Ontario M5S 2E4. *Modulus of measures and conformal dimension.* Preliminary report.

Conformal diemnsion of a metric space X – Confdim$X$, is the infimum of quasisymmetric images of X. Tyson showed that curve families in X of positive modulus give lower bounds for Confdim$X$. We show that families of measures of positive modulus supported on certain Cantor sets in X also give lower bounds for Confdim$X$. This allows us to obtain new lower bounds for many self-affine spaces. (Received February 03, 2009)

1047-28-486 **Marshall Williams*** (mcwill@umich.edu). *Metric currents and differentiable structures.*

In 2000, Ambrosio and Kirchheim defined currents in metric spaces, generalizing the earlier theory of Federer and Fleming in $\mathbb{R}^n$. Around the same time, Cheeger showed that a large class of spaces admit a generalized form of Rademacher's differentiation theorem. We will discuss the implications of Cheeger's theorem for the metric currents of Ambrosio and Kirchheim, including an application to Heisenberg groups. (Received February 03, 2009)

30 ► Functions of a complex variable

1047-30-22 **P C Fenton** and **John F Rossi*** (rossij@vt.edu). *A reverse Denjoy theorem.*

Suppose that C_1 and C_2 are two simple curves joining 0 to ∞, non-intersecting in the finite plane except at 0 and enclosing a domain D which has angular measure at most 2α $(0 < \alpha < \pi)$ for all large r. Suppose also that u is a non-constant subharmonic function in the plane such that $u(z) = B(|z|, u) := \sup\{u(z) : |z| = r\}$ for all large $z \in C_1 \cup C_2$. Let $A_D(r, u) = \inf\{u(z) : z \in D \cap \{|z| = r\}\}$. It is shown that if $A_D(r, u) = O(1)$ then $\liminf_{r\to\infty} B(r, u)/r^{\pi/(2\alpha)} > 0$. (Received November 20, 2008)

1047-30-90 **Leonid V. Kovalev*** (lvkovale@syr.edu), Department of Mathematics, Syracuse University, 215 Carnegie Building, Syracuse, NY 13244-1150, and **Jani Onninen**. *On invertibility of Sobolev mappings.* Preliminary report.

We prove local and global invertibility of Sobolev solutions of differential inclusions $Df(x) \in K$ a.e., where K is a certain set of $n \times n$ matrices. This result is new (and sharp) even for quasiregular mappings in two dimensions. (Received January 19, 2009)

1047-30-127 **Kai Rajala*** (kirajala@maths.jyu.fi), University of Jyvaskyla, Department of Mathematics and Statistics, P.O. Box 35 (MaD), 40014 Univ. of Jyvaskyla, Finland, and **Jani Onninen** (jkonnine@syr.edu), Department of Mathematics, Syracuse University, Syracuse, NY 13244. *Quasiregular mappings to generalized manifolds.*

We present some basic properties of quasiregular maps with metric space targets, such as the excellent package constructions of Semmes. (Received January 24, 2009)

1047-30-137 **David H Hamilton*** (davidhhamilton@mac.com), 1077 30th ST NW Apt 503, Washington, DC 20007. *Julia (Limit) Sets in Curves.*

J is Julia (or Limit L_G) Set contained in a Jordan curve Γ. By Hamilton (or Bowen) $if J = \Gamma$ and $\dim(\Gamma) \leq 1$ then Γ is a circle/line (O). However if $J \subsetneqq \Gamma$ then this can fail (Hamilton), indeed for rectifiable Γ. Never the less Eremenko et al show (O) if Γ is smooth. We improve this to Zygmund smooth. Furthermore if Γ is invariant than NOT (O) implies there is E with $\dim(E) > 0$ on which Γ is not Zymund Smooth. (Similarly for quasifushsian groups). (Received January 25, 2009)

1047-30-143 **Kenneth D Koenig*** (koenig@math.ohio-state.edu), Department of Mathematics, Ohio State University, Columbus, OH 43210, and **Loredana Lanzani** (lanzani@uark.edu), Department of Mathematics, University of Arkansas, Fayetteville, AR 72701. *Bergman versus Szegö via conformal mapping.*

The study of holomorphic functions and their boundary values is a fundamental part of complex analysis, so it is natural to compare the Bergman and Szegö projections associated to a given domain and gauge how closely they are related to each other. After a brief overview of known results in one and several complex variables for domains with C^∞ boundary, this talk will focus on (bounded) simply connected planar domains that are not C^∞ smooth. For such domains with Hölder continuous boundary, the difference between these projections gains a derivative in an appropriate range of Sobolev or Lipschitz norms. (Received January 26, 2009)

1047-30-144 **Ngin-Tee Koh*** (nkoh@uiuc.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green St, Urbana, IL 61801. *Univalence Criteria, Quasiconformal Mappings and Approximable Quasidisks.*

We give a brief survey of some conditions that imply the univalence of a locally univalent function f. We also discuss related conditions that imply that f has a quasiconformal extension to the Riemann sphere. Finally, we discuss the concept of an approximable quasidisk, first introduced by Anderson and Hinkkanen. (Received January 26, 2009)

1047-30-169 **Rich L Stankewitz*** (rstankewitz@bsu.edu), Dept. of Mathematics, Muncie, IN 47306. *Repelling fixed points are dense in the Julia set of a Rational or Entire Semigroup.*

We briefly survey several methods of proof that the Julia set of a rational or entire function is the closure of the repelling cycles, in particular, focusing on those methods which can be extended to the case of semigroups. We then present an elementary proof that the Julia set of either a non-elementary rational or entire semigroup is the closure of the set of repelling fixed points. (Received January 27, 2009)

1047-30-176 **Pekka J. Pankka*** (pankka@umich.edu), University of Michigan, Department of Mathematics, 530 Church Street, Ann Arbor, MI 48109-1043. *Finite distortion, value distribution, and cohomology.*

The Mattila-Rickman equidistribution theorem yields that geometrically controlled branched covering mappings (quasiregular mappings) into closed manifolds must visit every set as often as their relative size indicates. We will discuss an equidistribution theorem of Mattila-Rickman type in the context of more general branched covering mappings (mappings of finite distortion). The result is one of the key ingredients in a proof of a cohomological boundedness theorem of Bonk-Heinonen type for closed manifolds admitting entire mappings of bounded mean distortion. (Received January 27, 2009)

1047-30-201 **Arthur A. Danielyan*** (adaniely@math.usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 E. Fowler Avenue, PHY114, Tampa, FL 33620-5700. *Bounded approximation on open and closed subsets of the complex plane.*

Suppose U is an open bounded set of the complex plane and A is a set of bounded analytic functions on U. The problem of description of bounded analytic functions on U which are limits of bounded sequences of functions in A converging pointwise in U has been investigated by Davie, Gamelin, Garnett, Rubel, Shields, and other mathematicians. In case A is the set of all polynomials, the problem was solved by a classical theorem of Rubel and Shields. In this case one can assume that U is the set of interior points of a compact set K which does not separate the plane. A similar pointwise bounded approximation problem on the whole K (including the boundary) has been considered in particular by Keldysh, Lavrentiev, and Mergelyan. The talk presents a new general approach for pointwise bounded approximations either on U or on an arbitrary compact set, and in particular a (necessary and sufficient) description of approximable functions defined on U. (Received January 28, 2009)

1047-30-241 **Zhuan J Ye*** (ye@math.niu.edu), Department of Mathematics, Northern Illinois Univ, DeKalb, IL 60115. *On the differential independence of the Riemann Zeta Function and the Euler Gamma Function.* Preliminary report.

We prove that the Riemann ζ-function and the Euler Γ-function cannot satisfy a class of algebraic differential polynomial equations whose coefficients are in $\mathbf{C}$ (joint work with Bao Qin Li). (Received January 29, 2009)

1047-30-249 **Michael T. Lacey** (lacey@math.gatech.edu), School of Mathematics, 686 Cherry Street, Georgia Institute of Technology, Atlanta, GA 30332-0160, **Eric T. Sawyer** (sawyer@mcmaster.ca), Department of Mathematics & Statistics, Hamilton Hall, Room 218, McMaster University , 1280 Main Street West, Hamilton, Ontario L8S 4K1, Canada, and **Ignacio Uriarte-Tuero*** (ignacio@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Astala's conjecture on Hausdorff measure distortion under planar quasiconformal mappings.*

In his celebrated paper on area distortion under planar quasiconformal maps (Acta 1994), K. Astala proved that a compact set E of Hausdorff dimension d is mapped under a K-quasiconformal map f to a set fE of 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 if $d' = 0$ (obvious), $d' = 2$ (Ahlfors), and recently $d' = 1$ (Astala, Clop, Mateu, Orobitg and UT, Duke 2008.) The approach in the last mentioned paper does not generalize to other dimensions.

Astala's conjecture was shown to be sharp (if it was true) in the class of all Hausdorff gauge functions by UT (IMRN, 2008).

Finally, we (the 3 named authors) jointly proved completely Astala's conjecture in all dimensions. The ingredients of the proof come from Astala's original approach, geometric measure theory, and some 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 (not yet fully understood) removability problems for various classes of quasiregular maps.

The talk will be self-contained. (Received January 29, 2009)

1047-30-297 **Melkana A Brakalova*** (brakalova@fordham.edu), 441 East Fordham Road, Mathematics Department, JMH 417, Fordham University, Bronx, NY 10458. *Circle-like homeomorphisms and homogeneity at a point.*

A homeomorphism is circle-like at a point if its circular dilatation is 1. A special case of circle-like homeomorphisms are those that are conformal at a point or homogeneous at a point (asymptotic homogeneity).

Using modules of ring domains Teichmüller (1938) developed methods (e.g. the Modulsatz) to study conformality at a point for K-quasiconoformal mappings. Later B. Rodin and S. Warshawskii (1976) applied some of these methods to study the boundary behavior of conformal maps and to attack a famous question concerning existence of an angular derivative at a boundary point. Gutlyanskii and Ryazanov (1995) proved deep results concerning asymptotic homogeneity for K-quasiconformal mappings using different methods.

We build on the methods developed in the above works of Teichmüller, Rodin, Warshawskii to provide sufficient and necessary conditions for homeomorphic solutions of the relaxed (degenerate) Beltrami equation to be circle-like at a point. These results are applied to obtain geometric and analytic conditions for homogeneity at a point, that relate to the works of Gutlyanskii and Ryazanov. The geometric conditions are in terms of modules

of families of curves and the analytic conditions are in terms of the complex dilatation. (Received January 31, 2009)

1047-30-326 **David Drasin*** (drasin@math.purdue.edu), Dept. of Mathematics, 150 N. University Street, West Lafayette, IN 47907-2067. *Entire functions of the class $\mathcal{S}$ of irregular growth.*

An entire or meromorphic function $w = f(z)$ of the class $\mathcal{S}$ is one whose points of ramification lie over at most finitely many points $\{a_1, \ldots, a_q\}$ of the Riemann sphere. This class occupies an intermediate status between rational functions and general meromorphic functions; for example Sullivan's theorem on no wandering domains applies to (iterates of) entire function of $\mathcal{S}$.

Displaying pathology for entire functions in this class seems far more difficult than with the analogous class of meromorphic functions. S. Merenkov has produced entire function in $\mathcal{S}$ of arbitrarily rapid growth, and here we find an entire function $f \in \mathcal{S}$ of preassigned order $\rho \leq \infty$ and lower order $\mu \geq 1/2$. Open problems will be raised. (Received February 01, 2009)

1047-30-382 **Linda R. Sons*** (sons@math.niu.edu), Dept. Mathematical Sciences, Northern Illinois University, DeKalb, IL 60115. *A special class of functions in the unit disc as coefficients for differential equations.* Preliminary report.

Let f be an analytic function in the unit disc D . If T denotes the Nevanlinna characteristic function, let a(f) be the limit superior of T(r,f)/(-log (1-r)) as r approaches one. Let S be the class of analytic functions in D for which a(f) is finite, but a(g) is infinite where g' = f . We explore characteristics of the solutions of differential equations in D for which functions in S are coefficients. (Received February 02, 2009)

1047-30-389 **Olena Ostapyuk*** (ostapyuk@math.ksu.edu), 138 Cardwell Hall, Manhattan, KS 66506. *Convergence of backward-iteration sequences with bounded hyperbolic step in higher dimension.* Preliminary report.

I consider a holomorphic self-map f of the unit ball in $\mathbb{C}^N$, of hyperbolic type (with a dilatation coefficient $c < 1$ at the Denjoy-Wolff point of f). I have shown that any backward-iteration sequence with bounded hyperbolic step must converge to some point on the boundary other than the Denjoy-Wolff point and stay in a Koranyi region. The proof is based on the multi-dimensional version of Julia's lemma. When $N = 1$ these limit points are known to be boundary repelling fixed points for f. For $N > 1$, I will discuss possible generalizations. (Received February 02, 2009)

1047-30-402 **Mario Bonk*** (mbonk@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Uniformization of Sierpinski carpets.*

Let S be a Sierpinski carpet in the Riemann sphere whose peripheral circles are uniform quasicircles and are uniformly relatively separated. Then there exists a quasisymmetry thats maps S to a "round" Sierpinski carpet, i.e., one whose complementary components are round disks. Ingredients in the proof of this theorem are Koebe's circle uniformization theorem and Schramm's notion of transboundary extremal length. I will also discuss metric space versions of this statement and possible applications in geometric group theory. (Received February 02, 2009)

1047-30-406 **David M Freeman*** (freemadd@email.uc.edu), Department of Mathematical Sciences, University of Cincinnati, PO Box 210025, Cincinnati, OH 45221-0025. *Unbounded Bilipschitz Homogeneous Jordan Curves.*

This talk will describe recent results concerning unbounded bilipschitz homogeneous Jordan curves. In particular, such curves in the Euclidean plane are quasicircles, quantitatively. The quantitative aspect of this result improves an analogous result of Bishop concerning bounded bilipschitz homogeneous Jordan curves. We shall also discuss a new characterization of Jordan curves that satisfy a fractal chordarc condition, and a characterization of unbounded Jordan curves that are bilipschitz homogeneous under the inner diameter distance. (Received February 02, 2009)

1047-30-444 **M. A. Snipes***, UM Department of Mathematics, 530 Church Street, Ann Arbor, MI 48109-1043. *Wolfe's theorem in Banach spaces.*

In Euclidean space, Wolfe's theorem states that the space of flat differential forms is dual to the space of geometric objects called flat chains. We will discuss a generalization of this theorem to the Banach space setting. (Received February 03, 2009)

1047-30-460 **David Minda*** (David.Minda@math.uc.edu), Old Chem 819D, Department of Mathematics, University of Cincinnati, Cincinnati, OH 45221-0025. *The hyperbolic metric and real affine mappings.* Preliminary report.

The hyperbolic metric is invariant under conformal and anti-conformal mappings. We investigate the pull-back of the hyperbolic metric by a real affine mapping. In general this is only a Riemannian metric, not a conformal metric, but is bounded above and below by conformal metrics that can be compared to the hyperbolic metric. This extends (modestly) recent work of Bañuelos and Carroll. (Received February 03, 2009)

1047-30-482 **Alexander Yu. Solynin*** (alex.solynin@ttu.edu), Texas Tech University, Department of Mathematics and Statistics, Lubbock, TX 79409. *A variant of Schwarz lemma for meromorphic functions and estimates for the hyperbolic metric.*

I will discuss a generalization of the Schwarz lemma for the class of meromorphic functions $f(z)$ mapping the unit disk $\mathbb{D}$ onto Riemann surfaces $\mathcal{R}$ with bounded in mean radial distances from $f(0)$ to the boundary of $\mathcal{R}$. Our variant of the Schwarz lemma implies a stronger form of the Landau-Toeplitz theorem, which extends the classical Schwarz lemma for the class of analytic functions $f(z)$ such that the diameter of $f(\mathbb{D})$ does not exceed 2. A new variant of the Schwarz lemma will be also given for the Carathèodory class of analytic functions having positive real part in $\mathbb{D}$. Our results lead to several improved estimates for the hyperbolic metric. (Received February 03, 2009)

1047-30-489 **Jani Onninen*** (jkonnine@syr.edu), Department of Mathematics, Syracuse University, 215 Carnegie Building, Syracuse, NY 13244, and **Tadeusz Iwaniec** and **Leonid V Kovalev**. *Dynamics of quasiconformal fields.*

A uniqueness theorem is established for autonomous systems of ODEs, $\dot{x} = f(x)$, where f is a Sobolev vector field with additional geometric structure, such as delta-monoticity or reduced quasiconformality. Specifically, through every non-critical point of f there passes a unique integral curve. (Received February 03, 2009)

1047-30-497 **Edmund Y. M. Chiang***, Department of Mathematics, Hong Kong University Science and Technology, Clear Water Bay, Sai Kung, Hong Kong, and **R. G. Halburd** and **E. F. Lingham**. *Maimquist-type theorems for Painleve equations.*

Abstract: At the beginning of the twentieth century, Painlevé and Gambier analyzed the possible forms of f when the equation $y''(z) = f(z, y(z), y'(z))$, with $f(z, \zeta, \xi)$ rational in ζ and ξ and with z dependent coefficients, has *all* of its solutions to be single-valued around their movable singularities. They found fifty possible classes for f so that the equations possess the required property. Forty four of the f are known to be solvable in terms of known functions, and the remaining six give raise to what is known to be the six Painlevé equations. On the other hand, Malmquist showed in 1931 that if the equation $y'(z) = R(z, y(z))$, where R is rational in y and with polynomial coefficients, admits a meromorphic solution, then the equation must be reduced to a Riccati equation. We extend Malmquist's result that when f in $y''(z) = f(z, y, y')$ is suitably restricted, then we c! an recover some of the six Painlevé equations by *only assuming* the equation to admit a meromorphic solution. The method of approach is based on a combination of Painlevé analysis and Nevanlinna's theory of value distribution of meromorphic functions. (Received February 04, 2009)

32 ► Several complex variables and analytic spaces

1047-32-33 **Malgorzata Aneta Marciniak*** (mammw3@mst.edu), Mathematics and Statistics Department, Rolla Building, 400 W. 12th St., Rolla, 65401. *Holomorphic Extensions in Toric Varieties.*

A combinatorial structure associated with a toric variety enables one to formulate an approach to various analytic problems. During my talk I will present some affirmative and negative results of holomorphic extension problems in smooth toric varieties with dimension 2. (Received December 09, 2008)

1047-32-54 **Adam Coffman*** (CoffmanA@ipfw.edu), Department of Mathematical Sciences, Indiana Univ. - Purdue Univ. Fort Wayne, 2101 E. Coliseum Blvd., Fort Wayne, IN 46805. *CR singularities of real* 4*-manifolds in* $\mathbb{C}^3$.

We consider real 4-submanifolds in complex 3-space at CR singular points, where the tangent space is a complex hyperplane. The extrinsic geometry of a submanifold near such a point is described by quantities depending on the local defining equations but invariant under holomorphic coordinate changes. I will give some concrete examples of compact manifolds embedded with the minimum possible number of non-degenerate CR singularities. (Received January 06, 2009)

1047-32-79 **Andrew Raich*** (araich@uark.edu), Department of Mathematical Sciences, 1 University of Arkansas, SCEN 327, Fayetteville, AR 72701. *Compactness of the Complex Green Operator on CR Manifolds of Hypersurface Type.*

In this talk, I will discuss sufficient conditions for the compactness of the complex Green operator on CR manifolds. In particular, I will focus on the cases when the CR manifold arises as the boundary of a pseudoconvex domain and the generalization of this case to CR manifolds of hypersurface type (i.e., one totally real direction). (Received January 16, 2009)

1047-32-92 **Debraj Chakrabarti*** (dchakrab@nd.edu), 255 Hurley Hall, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556-4618, and **Rasul Shafikov**. *CR functions on subanalytic hypersurfaces.*

We consider a natural notion of CR functions on subanalytic real hypersurfaces in complex manifolds. The holomorphic extension properties of these functions are found to be different than those of CR functions on smooth hypersurfaces. In particular, minimality (i.e. absence of a complex hypersurface inside the real hypersurface) is neither a necessary nor a sufficient condition for holomorphic extension of CR functions. (Received January 20, 2009)

1047-32-166 **Emil J. Straube*** (straube@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843. *Compactness and $\mathcal{L}^2_{loc}$-hypoellipticity for $\overline{\partial}$.* Preliminary report.

I will raise a question concerning the two properties in the title. It is an old result that $\overline{\partial}$ is hypoelliptic in $\mathcal{L}^2_{loc}(\Omega)$ if and only if no compact subset of the boundary of Ω picks up plurisubharmonic hull (Catlin, Diederich-Pflug, Sibony). On the other hand, Catlin had proved earlier that for a smooth pseudoconvex domain in $\mathbb{C}^2$, the latter property is equivalent to the absence of analytic discs from the boundary. Thirdly, also for smooth domains in $\mathbb{C}^2$, Catlin showed that compactness of the $\overline{\partial}$-Neumann operator implies the absence of analytic discs from the boundary. Consequently, in $\mathbb{C}^2$, compactness of the $\overline{\partial}$-Neumann operator implies hypoellipticity of $\overline{\partial}$ in $\mathcal{L}^2_{loc}$. Şahutŏglu and I recently generalized Catlin's results to pseudoconvex domains in $\mathbb{C}^n$ with the property that the Levi form, at each point, has at most one degenerate eigenvalue. Thus the above implication holds in this case as well. However, this implication should not hinge on this special property of the Levi form. (Received January 28, 2009)

1047-32-243 **Loredana Lanzani*** (lanzani@uark.edu), SCEN 301 Mathematical Sciences Department, 1 University of Arkansas, Fayetteville, AR 72701, and **Elias M. Stein**. *Cauchy-Fantappié singular integrals for strongly pseudoconvex domains of class C^2.*

The only known proof of L^2-boundary regularity of the Henkin-Ramirez (Cauchy-Fantappié) integral for a strongly pseudconvex domain, is due to Kerzman and Stein: that proof requires the domain to be of class C^3 and does not extend to lower boundary regularity. In this talk I will present a new proof that works for the C^2 case and discuss some applications. This result is joint with E. M. Stein. (Received January 29, 2009)

1047-32-270 **jae-seong cho*** (cho1@math.purdue.edu), Department of Mathematics, Purdue University, 150 N. University St., West Lafayette, IN 47907. *Sharp Estimates for the $\bar{\partial}$-Neumann Problem on Regular Coordinate Domains.*

We will consider the parameter ϵ in subelliptic estimates on a class of domains known as regular coordinate domains. We will show that the largest value of ϵ is bounded below the inverse of twice the multiplicity of the the associated ideal. This is a joint work with David W. Catlin. (Received January 30, 2009)

1047-32-358 **Han Peters*** (peters@math.sunysb.edu), Institute for Mathematical Sciences, Stony Brook University, Stony Brook, NY 11796. *Attracting Basins for Sequences of Uniformly Attracting Automorphisms.*

Is an attracting basin of a sequence of uniformly attracting automorphisms biholomorphically equivalent to complex Euclidean space?

Joint work with Erik low, Berit Stensones, Liz Vivas and Erlend Wold. (Received February 02, 2009)

1047-32-361 **David W. Catlin*** (catlin@math.purdue.edu), David Catlin, Department of Mathematics, West Lafayette, IN 47907. *Examples of sharp subelliptic estimates for the $\bar{\partial}-$Neumann problem.*

We will discuss examples of sharp subelliptic estimates for the $\bar{\partial}-$Neumann problem. (Received February 02, 2009)

1047-32-363 **David E Barrett*** (barrett@umich.edu), Math Dept. University of Michigan, 530 Church St., Ann Arbor, MI 48104-1043. *Duality between Hardy spaces on dual domains in complex projective space.* Preliminary report.

A smoothly bounded domain D in complex projective space is said to be *strongly $\mathbb{C}$-linearly convex* if the complex hyperplanes tangent to the boundary bD are disjoint from D and have minimal contact with bD. The dual D^* of such a domain is the open set in the dual projective space consisting of all complex hyperplaces disjoint from D; the dual domain D^* will also be smoothly bounded and strongly $\mathbb{C}$-linearly convex.

This talk will set out an invariant duality theory for Hardy spaces on bD and bD^*. Work in progress applying these results to Paley-Weiner theory will also be discussed. (Received February 02, 2009)

1047-32-408 **Michael D Bolt*** (mbolt@calvin.edu), Department of Mathematics and Statistics, 1740 Knollcrest Circle SE, Calvin College, Grand Rapids, MI 49546. *Möbius geometry of hypersurfaces.*

We identify the curvature invariants for a real hypersurface in $\mathbb{C}^n$ under the action of the Möbius group, $SL_{n+1}(\mathbb{C})$. The Levi form captures that part of the second fundamental form that is invariant under biholomorphism. Under Möbius transformations, the skew-hermitian part of the second fundamental form is invariant as well, when restricted to the complex tangent space. The hypersurfaces for which this skew-hermitian part is zero are known to be the hermitian quadrics. Here we characterize the hypersurfaces in $\mathbb{C}^2$ for which (in a sense) the skew-hermitian part is constant. (Received February 02, 2009)

1047-32-450 **Chia-chi Tung*** (chia.tung@mnsu.edu), Department of Math. and Stat., Minnesota State University, Mankato, Mankato, MN 56001. *A note on the weak holomorphicity and analyticity of distributions.* Preliminary report.

In this note, characterizations on a semi-Riemann domain of the weak holomorphicity of Cauchy-Riemann as well as Euler distributions are given. Also, the assertion that weak harmonicity implies the local solid mean-value property is demonstrated without potential theory, thus yielding an alternative proof the extended Weyl's Lemma. (Received February 03, 2009)

1047-32-457 **Roman J. Dwilewicz*** (romand@mst.edu), Department of Mathematics, Missouri University of Science and Technology, Rolla, MO 65409. *Geometry of Tube-like Domains in $\mathbb{C}^2$.* Preliminary report.

In the talk we will consider tube-like domains in $\mathbb{C}^2$, i.e., domains of the form

$$\mathbb{C}^2 \supset U: \ \rho = \rho(x_{i_1}, \ldots, x_{i_k}) < 0, \quad \text{where } (z_1, z_2) = (x_1 + ix_2, x_3 + ix_4) \in \mathbb{C}^2$$

and where $1 \leq i_1 < \ldots < i_k \leq 4$ with $k \leq 3$. This means that ρ depends not on all variables x_1, x_2, x_3, x_4, at least one variable is missing. Some properties of such domains will be presented. This is a preliminary work with Josep M. Burgués (Universitat Autònoma de Barcelona). (Received February 03, 2009)

1047-32-472 **Anna Siano*** (asiano@umich.edu), 530 Church St, 2074 East Hall, Ann Arbor, MI 48109. *On the (non-)extendability of germs of CR functions.*

In 1986, Trépreau found necessary and sufficient conditions for germs at a point p of CR functions on a smooth hypersurface Σ to extend to some side of it. The generalization of this result to the higher-codimensional case is known as "wedge-extendability" (cf. Tumanov, Baouendi-Rothschild). In both cases, local extendability is equivalent to minimality (which, in the codimension-one case, means that Σ does not contain the germ at p of any complex hypersurface). What remains to be done is to determine the side of Σ to which the extension occurs. We will discuss some conditions under which this can be determined, and prove extendability results by means of analytic discs. (Received February 03, 2009)

1047-32-479 **Xianghong Gong*** (gong@math.wisc.edu), Department of Mathematics, University of Wisconsin, Madison, WI 53706, and **Sidney M. Webster** (webster@math.uchicago.edu), Department of Mathematics, University of Chicago, Chicago, IL 60637. *Regularity in the CR embedding problem.* Preliminary report.

We will prove a new regularity result on the local embedding of strongly pseudoconvex CR structures on $\mathbf{R}^{2n-1}$ for $2n - 1 \geq 7$. (Received February 03, 2009)

1047-32-487 **Dror Varolin*** (dror@math.sunysb.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11231. *An L^2 extension problem for affine algebraic varieties.*

We find necessary and sufficient conditions for extending holomorphic functions that are square integrable on the regular part of an affine algebraic hypersurface (i.e., a possibly singular subvariety of $\mathbb{C}^n$ cut out by a single polynomial) with respect to a smooth weight ϕ satisfying $c\sqrt{-1}\partial\bar{\partial}|z|^2 \leq \sqrt{-1}\partial\bar{\partial}\phi \leq C\sqrt{-1}\partial\bar{\partial}|z|^2$ for

some constants $C > c > 0$. We also discuss the situation when the non-negative weight does not dominate a constant multiple of the Euclidean metric, and if time permits we will say something about the non-algebraic case. (Received February 03, 2009)

1047-32-490 **peter ebenfelt***, Dept of Math, UC, San Diego, La Jolla, CA 92093, and **Salah Baouendi**, **Xiaojun Huang** and **Dmitry Zaitsev**. *Rigidity results in CR geometry.* Preliminary report.

We shall report on some results concerning rigidity and super rigidity of CR mappings into hyperquadrics. Rigidity for a given CR manifold may or may not be present, and which is the case depends on relations between the signatures of the manifold and the quadric. (Received February 03, 2009)

33 ► Special functions

1047-33-86 **Jimmy Mc Laughlin*** (jmclaughl@wcupa.edu), Math. Dept., 25 University Avenue, West Chester University, West Chester, PA 19383, and **Peter Zimmer**. *General WP-Bailey Chains.*

Motivated by a recent paper of Liu and Ma, we describe a number of general WP-Bailey chains. We show that many of the existing WP-Bailey chains (or branches of the WP-Bailey tree), including chains found by Andrews, Warnaar and Liu and Ma, arise as special cases of these general WP-Bailey chains.

We exhibit three new branches of the WP-Bailey tree, branches which also follow as special cases of these general WP-Bailey chains.

Finally, we describe a number of new transformation formulae for basic hypergeometric series which follow from these new WP-Bailey chains. (Received January 18, 2009)

1047-33-340 **S. Ole Warnaar*** (o.warnaar@maths.uq.edu.au), Mathematics, The University of Queensland, Brisbane, QLD 4072, Australia. *Branching rules and q-series.* Preliminary report.

In the first part of this talk I will discuss various symmetric functions from the point of view of branching rules. The simplest example of such a rule is the well known definition of the Schur function as a sum over semi-standard Young tableaux.

In the second part of the talk I will apply symmetric functions and their branching rules to the study of q-series on root systems. (Received February 02, 2009)

35 ► Partial differential equations

1047-35-59 **David Hoff*** (hoff@indiana.edu), Department of Mathematics-Rawles Hall, Indiana University, Bloomington, IN 47405, and **Misha Perepelitsa**. *Instantaneous boundary-tangency of singularity curves in compressible fluid flow.*

We show that, for a model system of compressible fluid flow in the upper half space of the plane, curves which intersect the boundary and across which the initial density is discontinuous become tangent to the boundary instantaneously in time. This result is closely related to the instantaneous formation of cusps in two-dimensional incompressible vortex patches. (Received January 07, 2009)

1047-35-68 **John Lewis**, **Kaj Nyström** and **Pietro Poggi-Corradini*** (pietro@math.ksu.edu), Department of Mathematics, Kansas State University, Cardwell Hall, Manhattan, KS 66502. *p-Harmonic measure in simply connected domains.* Preliminary report.

In joint work with John Lewis and Kaj Nyström, we extend to simply-connected domains Makarov-type results about the Hausdorff dimension of p-harmonic measure pioneered by Lewis and Lewis-Bennewitz in the context of quasidisks.

The key to our analysis is a gradient estimate in terms of the distance to the boundary and constants that only depend on p. This is achieved by studying the conformal map from the unit disk to the simply connected domain to construct good quasicurves from an interior point to the boundary. (Received January 12, 2009)

1047-35-113 **Tian Ma**, Department of Mathematics, Sichuan University, Chengdu, Sichuan , Peoples Rep of China, and **Shouhong Wang*** (showang@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405. *El Nino Southern Oscillation as Sporadic Oscillations between Metastable States.*

We present in this talk a new mechanism of the El Nino Southern Oscillation (ENSO), as a self-organizing and self-excitation system, with two highly coupled processes. The first is the oscillation between the two metastable warm (El Nino phase) and cold events (La Nina phase), and the second is the spatiotemporal oscillation of the sea surface temperature (SST) field. The interplay between these two processes gives rises the climate variability associated with the ENSO, leads to both the random and deterministic features of the ENSO, and defines a new natural feedback mechanism, which drives the sporadic oscillation of the ENSO.

The new mechanism is rigorously derived using a dynamic transition theory developed recently by the authors, which has also been successfully applied to a wide range of problems in nonlinear sciences. (Received January 23, 2009)

1047-35-119 **John L Lewis*** (john@ms.uky.edu), Mathematics Department, University of Kentucky, Lexington, KY 40506. *Some remarks on p harmonic measure.*

In this talk we discuss what is known about the dimension of a measure associated with a positive p harmonic function vanishing on a portion of the boundary of a given domain and list related open problems. (Received January 23, 2009)

1047-35-132 **Jean Bourgain**, **Pierre Germain** and **Natasa Pavlovic*** (natasa@math.utexas.edu), Department of Mathematics, University of Texas at Austin, 1 University Station, C1200, Austin, TX 78712, and **Gigliola Staffilani**. *Behavior of solutions to the Navier-Stokes equations in the scaling invariant spaces.*

In this talk we will discuss the Navier-Stokes equations in scaling invariant spaces. In particular, we will briefly describe regularity of so called "mild" solutions to the Navier-Stokes equations evolving from small initial data in a critical space in $\mathbb{R}^n$ (joint work with Pierre Germain and Gigliola Staffilani) and a recent result on ill-posedness of the Navier-Stokes equations in the largest critical space in 3D (joint work with Jean Bourgain). (Received January 24, 2009)

1047-35-136 **Juan J Manfredi*** (manfredi@pitt.edu), 140 Thackeray Hall, 139 University Drive, Pittsbugh, PA 15260, and **Mikko Parviainen** and **Julio D Rossi**. *An Asymptotic Mean Value Characterization for p-harmonic functions.*

We characterize p-harmonic functions in terms of an asymptotic mean value property. A p-harmonic function u is a viscosity solution to $\Delta_p u = \operatorname{div}(|\nabla u|^{p-2}\nabla u) = 0$ with $1 < p \leq \infty$ in a domain Ω if and only if the expansion

$$u(x) = \frac{\alpha}{2}\left\{\max_{B_\varepsilon(x)} u + \min_{B_\varepsilon(x)} u\right\} + \frac{\beta}{|B_\varepsilon(x)|}\int_{B_\varepsilon(x)} u\,dy + o(\varepsilon^2)$$

holds as $\varepsilon \to 0$ for $x \in \Omega$ holds in a weak sense, which we call viscosity sense. Here the coefficients α, β are determined by $\alpha + \beta = 1$ and $\alpha/\beta = (p-2)/(N+2)$. (Received January 25, 2009)

1047-35-152 **Albert Baernstein II*** (al@math.wustl.edu), Math, Washington University, St.Louis, MO 63130, and **A. Yu Solynin**. *Monotonicity and comparison results for conformal invariants.* Preliminary report.

Suppose that Ω is an n-fold symmetric domain in the plane and that u is a function 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 correspomding desymmetrization of f. These results permit us to solve some extremal problems involving Poincaré metrics, harmonic measure and capacities. (Received January 27, 2009)

1047-35-242 **Luca Capogna*** (lcapogna@uark.edu), Department of Mathematics, University of Arkansas, Fayetteville, AR 72701. *Intrinsic regularity of sub-Riemannian minimal surfaces in the first Heisenberg group.*

The talk is focused on recent work joint with C. Citti and M. Manfredini (U. Bologna, Italy). We study the regularity of a class of sub-Riemannian minimal surfaces in the first Heisenberg group, arising as limits of Riemannian minimal surfaces as the metrics collapse. We prove such objects are foliated by legendrian lifts of quadrics. We also prove some regularity across the foliation. (Received January 29, 2009)

1047-35-269 **Mathew A. Johnson*** (mjohns51@illinois.edu) and **Jared C. Bronski** (jared@math.uiuc.edu). *Stability of Periodic Traveling Wave Solutions of the Generalized Korteweg-de Vries Equation.*

In this talk, I will present recent results on the spectral and orbital stability of a four parameter family of periodic traveling wave solutions of the generalized Korteweg-de Vries equation. If time permits, I will explain how similar techniques can be applied to obtain spectral stability results for the generalized Benjamin-Bona-Mahony equation and the generalized Camassa-Holm equation. (Received January 30, 2009)

1047-35-308 **Igor Kukavica** (kukavica@usc.edu), Department of Mathematics, USC, 3620 S. Vermont Avenue, Los Angeles, CA 90089-2532, and **Vlad Vicol*** (vicol@usc.edu), Department of Mathematics, USC, 3620 S. Vermont Avenue, Los Angeles, CA 90089. *The Domain of Analyticity of Solutions to the Three-Dimensional Euler Equations.*

We address the problem of analyticity of solutions to the 3D Euler equations on the periodic domain and in the half space. We characterize the rate of decay of the real-analyticity radius of the solution $u(t)$ in terms of $\exp \int_0^t \|\nabla u(s)\|_{L^\infty} ds$, improving the previously known results. We also prove the persistence of Gevrey–class regularity for the Euler equations in a half space, and obtain an explicit rate of decay of the radius of Gevrey–class regularity.
(Received February 01, 2009)

1047-35-332 **Wilhelm Schlag*** (schlag@math.uchicago.edu), 5734 South University Avenue, University of Chicago, Department of Mathematics, Chicago, IL 60637. *Center-stable manifolds for orbitally unstable evolution equations.*

We will review some recent work on a class of nonlinear wave equations which exhibit both data which lead to blow-up in finite time as well as special families of global 'soliton'-like solutions. These special solutions are orbitally unstable but turn out to be conditionally stable in the sense that there exists a center-stable manifold which contains these solutions. We will review some results in this area and state a number of open problems. (Received February 01, 2009)

1047-35-336 **Andrej Zlatos*** (andrej@math.uchicago.edu), 5734 S University Ave, Chicago, IL 60637. *Traveling fronts in disordered media.*

We study generalized traveling front solutions of reaction-diffusion equations modeling flame propagation in combustible media. Although the case of periodic media has been studied extensively, until very recently little has been known for general disordered media. In this talk we will address questions of existence, uniqueness, and stability of traveling fronts in this framework. (Received February 01, 2009)

1047-35-347 **M. Burak Erdogan*** (berdogan@math.uiuc.edu), **Dirk Hundermark** (dirk@math.uiuc.edu) and **Young-Ran Lee** (younglee@sogang.ac.kr). *Exponential decay of dispersion managed solitons.*

We study the decay and smoothness of the solutions of the dispersion managed nonlinear Schrodinger equation in the case of vanishing average dispersion. We prove that the soliton-like solutions and their Foruier transforms decay exponentially at infinity. The proof uses exponentially weighted multilinear estimates. (Received February 02, 2009)

1047-35-351 **David M Ambrose***, Department of Mathematics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104. *Time-Periodic Interfacial Fluid Flows.*

We introduce a numerical method for computing time-periodic solutions of nonlinear partial differential equations. As an application of this method, we study time-periodic solutions of the Benjamin-Ono equation. We find a large number of such solutions. In particular, we find continua of genuinely time-periodic solutions connecting different traveling waves. This investigation leads us to exact, explicit formulas for these solutions. If time allows, time-periodic solutions for the vortex sheet with surface tension or water waves will be discussed. This is joint work with Jon Wilkening. (Received February 02, 2009)

1047-35-386 **Nicolae Tarfulea*** (tarfulea@calumet.purdue.edu), Purdue University Calumet, 2200 169th Street, Hammond, IN 46323. *Exterior Boundary-Value Problem with Application in General Relativity.*

In this talk, we will address the exterior boundary-value problem $-\Delta u = H(x)f(u)$ in $\Omega := \mathbf{R}^n \setminus \overline{B}(0, r_0)$, $\frac{\partial u}{\partial n} + au = \gamma$ on $\partial\Omega$, and $u(x) \to 0$ as $|x| \to \infty$. When $a > 0$, the Robin boundary condition has a "wrong" sign, and this makes the analyis of the problem interesting and non-trivial. The important model case $f(u) = (u+1)^{-7}$, $a = 1/(2r_0)$, and $\gamma = -1/(2r_0)$, is related to the initial data problem in general relativity. For this model case,

as an example of application of our results, we obtain the existence and uniqueness of the conformal factor corresponding to the Hamiltonian constraint equation in the case of a single black hole in the radial symmetric regime. (Received February 02, 2009)

1047-35-403 **Chi Hin Chan*** (cchan@math.utexas.edu), 1801 South Lakeshore Blvd Apt 275, Austin, TX 78741, and **Magdalena Czubak**. *Regularity of solutions for the critical N-dimensional Burgers' equation.*

We consider the fractional Burgers' equation on $\mathbb{R}^N$ with the critical dissipation term. We follow the parabolic De-Giorgi's method of Caffarelli and Vasseur and show existence of smooth solutions given any initial datum in $L^2(\mathbb{R}^N)$.

The above paragraph is the actual abstract appearing in the joint paper of Chi Hin Chan and Magdalena Czubak. In this talk, we will talk about the way our work originates from the parabolic De-Giorgi's method developed by L. Caffarelli and A. Vasseur in their paper Drift diffusion equations with fractional diffusion and the quasi-geostrophic equation. (Received February 02, 2009)

1047-35-413 **A Cheskidov** and **M S Jolly*** (msjolly@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405, and **E S Van Vleck**. *On a relation between Lyapunov exponents and the radius of analyticity.*

We present a rigorous estimate supporting one side of a relation proposed by Sigeti, [Phys. D, 82:136–153 (1995)] between global Lyapunov exponents and the radius of analyticity for chaotic attractors. A quantity related to the rate of volume distortion is shown to be bounded by an expression inversely proportional to the radius. This rate is numerically computed and compared to the latter expression through rigorous evaluation of the radius. The sharpness of this bound is tested on both the Lorenz and Kuramoto-Sivashinsky equations. (Received February 02, 2009)

1047-35-443 **Nathan E. Glatt-Holtz*** (negh@indiana.edu), Rawles Hall, 831 East 3rd St, Bloomington, IN 47405. *New Well-Posedness Results for the Equations of Stochastic Fluid Dynamics with Multiplicative Noise.*

The addition of white noise driven terms to the fundamental equations of physics and engineering are used to model numerical and empirical uncertainties. In the context of fluid dynamics such forcing terms have also been employed in the theory of turbulence. Although the study of well posedness for the Stochastic Navier-Stokes Equations goes back to the 1970's with the work of Bensoussan and Temam, many basic questions remain unaddressed. In particular the case of nonlinear multiplicative noise remains a challenging problem. In this talk we introduce some recently developed technical machinery, the so called "comparison lemmas" which may be used to circumvent the difficulty of compactness for certain nonlinear systems. In particular our techniques have led to novel local and global existence results concerning pathwise solutions for both the Navier-Stokes and Primitive Equations. This is joint work with M. Ziane. (Received February 03, 2009)

1047-35-469 **Amjad Tuffaha*** (tuffaha@usc.edu), **Igor Kukavica** and **Mohammed Ziane**. *Strong Solutions to a Nonlinear Fluid Structure Interaction System.*

We consider the existence of local in-time strong solutions to a fluid structure interaction model describing the elastic motion of a solid inside a fluid. Mathematically, the model is comprised of a fluid modeled by the Navier Stokes equation interacting with an elastic body equation at the boundary of the solid with stress and velocity matching boundary conditions. (Received February 03, 2009)

1047-35-485 **Qingshan Chen*** (qinchen@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405, and **Ming-Cheng Shiue** and **Roger Temam**. *The zero mode for the Primitive Equations.* Preliminary report.

Considering an expansion of the inviscid Primitve Eqations in the vertical direction, we classically obtain an infinite set of equations which have been studied in different contexts by two of the authors (QC and RT), and by A. Rousseau and J. Tribbia. This lecture is devoted to the (first) zero mode which is different from the others. This mode is of course the most energetic one and thus the most important one. In the linearized case we show that this mode is governed by equations which ressemble the two- dimensional (linearized) Euler equations, but are still different from these equations with several respects. After introducing the necessary concepts, we will discuss the well-posedness of the equations for the zero mode which is not standard . We will then discuss its discretization based on suitable forms of the projection method. And finally we will show results of numerical simulations performed in both the linear and nonlinear cases (with coupling with all the other modes for the nonlinear case). (Received February 03, 2009)

1047-35-492 **Alexey Cheskidov*** (acheskid@math.uic.edu), University of Illinois at Chicago, 322 Science and Engineering Offices, 851 S. Morgan Street, Chicago, IL 60607. *On the maximal enstrophy growth rate for solutions to the 3D Navier-Stokes equations.*

Due to a supercritical nature of the 3D Navier-Stokes equations, the best known estimates on the enstrophy growth rate do not rule out the existence of finite time singularities. Recently Doering and Lu numerically showed that these estimates are sharp. I this talk I will present some analytical results in this direction as well as related regularity criteria in critical spaces. (Received February 04, 2009)

37 ► Dynamical systems and ergodic theory

1047-37-20 **Karl Petersen*** (petersen@math.unc.edu), Department of Mathematics, CB 3250 Phillips Hall, University of North Carolina, Chapel Hill, NC 27599. *Sturmian adic dynamical systems in the Stern-Brocot (Farey) diagram.* Preliminary report.

When drawn as a Bratteli diagram, the Stern-Brocot picture leads not only to interesting C* algebras but also Bratteli-Vershik (adic) dynamical systems. In particular, all irrational circle rotations and thus the Sturmian symbolic dynamical systems which encode them appear via subdiagrams. In general, there are relations among closed invariant sets and ideals in the operator algebra. Some of these observations are joint work with Thierry de la Rue and Elise Janvresse. (Received November 18, 2008)

1047-37-26 **Robert W O'Connell*** (rwoconne@indiana.edu), Rawles Hall, 831 East 3rd St, Bloomington, IN 47405. *Pinching Deformations of Rational Maps.*

Let f be a rational map defined on the Riemann sphere. Then f defines a dynamical system whose chaotic locus is called the Julia set. A pinching deformation, $f_t, t > 0$, is a one-parameter family of deformations of f. It is a way to create a parabolic cycle by forcing an attracting cycle and a repelling cycle to collide. The main result shows that for certain pinching deformations, if $f_t \to g$ uniformly, then the Julia set of f_t converges in the Hausdorff topology to the Julia set of g in the Hausdorff topology. (Received December 03, 2008)

1047-37-110 **Xiangdong Ye*** (yexd@ustc.edu.cn), Dept. of Math., Uni. of Sci. and Tech. of China, Hefei, Anhui 230026, Peoples Rep of China. *The set of sequence entropies for a given space.*

Let X be a compact metric space and $T : X \longrightarrow X$ be continuous. Let $h^*(T)$ be the supremum of sequence entropies of T over all subsequences of $\mathbb{N}$ and $S(X)$ be the set of $h^*(T)$ for all continuous maps T on X. It is known that $S(X) \subset \{\infty, 0, \log 2, \log 3, \ldots\}$. In this talk we will determine $S(X)$ for some spaces and will present some open questions. This is a joint work with F. Tan and R.F. Zhang. (Received January 22, 2009)

1047-37-165 **Mahesh G Nerurkar*** (nmahesh@crab.rutgers.edu), 311 N fifth Street, Department of Mathematics, Camden, NJ 08102. *About positive and zero exponents of $SL(2, R)$ valued cocycles over irrational rotation flows, in the smooth category.*

In the clas of smooth $SL(2, \mathbb{R})$ valued cocycles over kronecker flows, we show that (i) those which have positive exponents are C^r, $(r \in \mathbb{N})$ dense and (ii) those which are either uniformly hyperbolic or with zero exponents are C^r, $(0 < r < 1)$ generic, provided the rotation number of the Kronecker flow satisfies a 'super Liouville' type fast periodic approximation condition. These results are actually valid within much smaller class of cocycles (for example within the the class of Schrödinger cocycles). The proof is base on a result of Kotani and an argument using properties of the rotation number of a cocycle. Result (ii) is a joint work with R. Johnson. (Received January 27, 2009)

1047-37-184 **Jeanette Olli*** (jolli@email.unc.edu), Campus Box 3250, Chapel Hill, NC 27599. *Endomorphisms of Certain Dynamical Systems.* Preliminary report.

When studying dynamical systems, a natural question to ask is what are its endomorphisms. Ethan Coven found that every endomorphism of the Morse substitution system is of the form σ^n or $\delta\sigma^n$, where σ denotes the shift map and δ denotes the dual map. Expanding upon his work, I will discuss the endomorphisms of Sturmian systems, generalized Sturmian systems, and the chair substitution tiling system with the $\mathbb{Z}^2$ action. (Received January 28, 2009)

1047-37-192 **Jeanette Olli*** (jolli@email.unc.edu), Campus Box 3250, Chapel Hill, NC 27599. *Division Point Measures Related to Subdivisions.*

When subdividing a one- or two-dimensional space, a measure on the space can be defined based on the distribution of vertices. The limiting measures for division schemes on the unit interval are well-known. I will discuss

these results as well as the limiting measures related to the distribution of vertices and triangles related to two division schemes based on the division rule for Conway's pinwheel tiling. (Received January 28, 2009)

1047-37-197 **Lev Glebsky** and **Evgeny I Gordon*** (yigordon@eiu.edu), Department of Math&CS, Eastern Illinois University, 600 Lincoln Ave, Charleston, IL 61920, and **C Ward Henson**. *What does Birkhoff's Ergodic Theorem mean for a big finite set?* Preliminary report.

The trivial proof of the ergodic theorem for a finite set X and a permutation $\sigma : X \to X$ shows that for an arbitrary function $f : X \to \mathbb{R}$ the sequence of ergodic means $A_n(f, \sigma)$ stabilizes for $n \gg |X|$. We show that if $|X|$ is very large and $|f(x)| \ll |X|$ for almost all x, then $A_n(f, \sigma)$ stabilizes for significantly long segments of very large numbers n that are, however, $\ll |X|$. This statement has a natural rigorous formulation in the setting of nonstandard analysis, which is, in fact, equivalent to the ergodic theorem for infinite probability spaces. Its standard formulation in terms of sequences of finite probability spaces is complicated. We also discuss some other properties of the sequence $A_n(f, \sigma)$ for a very large finite $|X|$ that can be easily formulated in terms of sequences of finite spaces. (Received January 29, 2009)

1047-37-204 **Valentin Ovsienko** (ovsienko@math.univ-lyon1.fr), CNRS, Institut Camille Jordan, University Lyon 1, 69622 Villeurbanne, France, **Richard Schwartz**, Department of Mathematics, Brown University, Providence, RI 02912, and **Sergei Tabachnikov*** (tabachni@math.psu.edu), Department of Mathematics, Penn State, University Park, PA 16802. *Quasiperiodic motion for the pentagram map.*

The pentagram map is a projectively natural iteration defined on polygons, and also on more general objects called twisted polygons. We find a Poisson structure on the space of twisted polygons and show that the pentagram map relative to this Poisson structure is completely integrable in the sense of Arnold-Liouville. For certain families of twisted polygons, such as universally convex ones, the integrability implies the quasi-periodic motion for the dynamics of the pentagram map. The pentagram map is closely related to the octahedral recurrence and is a discrete version of the well known completely integrable PDE, the Boussinesq equation. (Received January 29, 2009)

1047-37-247 **Kevin M Pilgrim*** (pilgrim@indiana.edu), Dept. Math., Rawles Hall, Indiana University, Bloomington, IN 47405, and **Peter Haissinsky** (phaissin@cmi.univ-mrs.fr), LATP/CMI, Universite de Provence, 39 rue Frederic Joliot-Curie, 13453 Marseille 13, France. *Thurston obstructions and Ahlfors regular conformal dimension.*

For suitably expanding $f : S^2 \to S^2$, we associate a natural quasisymmetry class of Ahlfors regular metrics in which the dynamics is (non-classically) conformal, and we bound from below their Hausdorff dimension in terms of homotopy-theoretic invariants associated to f. (Received January 29, 2009)

1047-37-264 **Marc Chamberland***, Department of Mathematics and Statistics, Grinnell College, Grinnell, IA 50112. *The Mean-Median Map.*

Starting with a non-empty finite set $S_n = \{x_1, \ldots, x_n\} \subset R$, generate the unique number x_{n+1} which satisfies the *mean-median equation*

$$\frac{x_1 + \cdots + x_n + x_{n+1}}{n+1} = median(S_n).$$

As usual, we define the median of the set $S_n = \{x_1, \ldots, x_n\}$, where $x_1 \leq \cdots \leq x_n$, as

$$median(S_n) = \begin{cases} x_{(n+1)/2}, & \text{n odd,} \\ \frac{x_{n/2} + x_{n/2+1}}{2}, & \text{n even.} \end{cases}$$

By applying the mean-median equation repeatedly to a set one generates an infinite sequence $\{x_k\}_{k=1}^{\infty}$.

The dynamics of this map are surprising! Most maps tend to have either relatively simple dynamics or chaotic dynamics. While the mean-median map seems to be asymptotically constant, it seems very hard to predict. (Received January 30, 2009)

1047-37-275 **Vitaly Bergelson*** (vitaly@math.ohio-state.edu), Department of Mathematics, The Ohio State University, Columbus, OH 43210. *Measure preserving actions of WM groups and Hindman's theorem.*

We will report on a recent joint work with H. Furstenberg which links amenable WM groups (that is, groups not admitting non-trivial finitely dimensional representations) with Ramsey theory. (Received January 30, 2009)

1047-37-289 **Paul Balister** and **Randall McCutcheon*** (rmcctchn@memphis.edu), Dept. Math. Sci., U. Memphis, Memphis, TN 38152. *A concentration function estimate and intersective sets from matrices.*

We give several conditions on an infinite integer matrix (d_{ij}) for the set $R = \{\sum_{ij\in\alpha, i>j} d_{ij} : \alpha \subset \mathbf{N}, |\alpha| < \infty\}$ to be a set of measurable recurrence, including $d_{ij} = j^i$ and $0 < d_{nj} = o\big(\sqrt{\frac{n}{\log n}}\big)$. For the latter, a concentration function estimate of independent interest is applied to sums of sequences of 2-valued random variables whose means may tend to ∞ as $\sqrt{\frac{n}{\log n}}$. (Received January 30, 2009)

1047-37-293 **Alex Eskin*** (eskin@math.uchicago.edu), Department of Mathematics, 5734 S. University Ave, Chicago, IL 60637. *The determinant of the Laplacian, Lyapunov exponents and volumes of strata of quadratic differentials.*

This is joint work with M. Kontsevich and A. Zorich (Received January 31, 2009)

1047-37-301 **Ethan Akin*** (ethanakin@earthlink.net), Mathematics Department, The City College, 137 Street and Convent Avenue, New York, NY 10031. *Fractals a la Furstenberg and Gromov.*

Furstenberg introduced a dynamic notion of fractal which we will expond upon and characterize. We will then compare it to what we call a Gromov fractal (with a name like that it has to be good). (Received January 31, 2009)

1047-37-309 **Daniel Meyer*** (dmeyermail@gmail.com), P.O. Box 68, Gustaf Hallstromin katu 2b, FI-00014 University of Helsinki, FI-00014 Helsinki, Finland. *Invariant Peano curves of expanding Thurston maps.*

An Thurston map is a postcritically finite branched covering map $f\colon S^2 \to S^2$. We consider such maps that are expanding in a suitable sense. We show that a suitable iterate $F = f^n$ is semiconjugate to z^d. This means that there is a Peano curve $\gamma\colon S^1 \to S^2$ (onto) such that $F(\gamma(z)) = \gamma(z^d)$, where $d = \deg F$. This generalizes a result by Milnor and corresponds to a result by Cannon-Thurston in the group case. (Received February 01, 2009)

1047-37-342 **Wen Huang*** (wenh@mail.ustc.edu.cn), Department of Math, University of science and Technology of China, Hefei, Anhui 230026, Peoples Rep of China. *A variational principle for subset.*

We prove a variational principle of entropy for any given compact subset. More precisely, for a given dynamical system (X, T), we introduce the measure entropy $\underline{h}_\mu(T)$ and $\overline{h}_\mu(T)$ for any given Borel Probalility measure μ on X. Then for a given non-empty compact subset E of X, we show that the corresponding Bowen entropy $h^B_{\text{top}}(T|E)$ satisfies

$$h^B_{\text{top}}(T|E) = \sup\{\underline{h}_\mu(T) : \mu \text{ is a Borel Probalility measure supported on } E\}.$$

(Received February 02, 2009)

1047-37-345 **Judy Anita Kennedy*** (kennedy9905@gmail.com), Dept. Mathematics, PO Box 10047, Lamar University, Beaumont, TX 77710, and **Barry Peratt**, Dept. Mathematics, Winona State University, Winona, MN. *Simple discrete 3D stirring models.* Preliminary report.

We investigate, both rigorously and numerically, several discrete stirring models. We believe these models mimic actual stirring in tanks. (Received February 02, 2009)

1047-37-360 **Vaibhav Gadre*** (vaibhav@caltech.edu), 3100 N Lake Shore Dr, Apt 1410, Chicago, IL 60657. *Dynamics of Generalized Interval Exchanges.* Preliminary report.

Train tracks with a single vertex are, in a suitable sense, a generalization of interval exchange maps. In this talk, we shall consider recurrent train tracks with a single vertex. We shall call these generalized interval exchanges. These can be studied as a dynamical system by considering Rauzy induction (i.e splitting the track)in this context. This gives a refinement process on the parameter space of such generalized interval exchanges, analogous to the simplicial system studied by Kerckhoff [1] in the context of interval exchange maps. We show that, for generalized interval exchanges, the refinement process has a key dynamical property called *uniform distortion*, again analogous to Kerckhoff's results. An anolog of Keane's conjecture which states that almost every generalized interval exchange is uniquely ergodic is derived as a consequence.

References

[1] Kerckhoff, S.P *Simplicial systems for interval exchange maps and measured foliations* Ergodic Theory and Dynamical Systems (1985),5, 257-271

(Received February 02, 2009)

1047-37-372 **Aimee S. A. Johnson**, **Daniel J Rudolph** and **Ayse A. Sahin*** (asahin@condor.depaul.edu), Department of Mathematical Sciences, DePaul University, 2320 N. Kenmore Ave., Chicago, IL 60614. *Directional recurrence for non-singular actions of $\mathbb{Z}^d$.* Preliminary report.

We introduce the notion of directional recurrence and give some constructions and results indicating the structural complexity of directions of recurrence for non-singular actions of $\mathbb{Z}^d$. (Received February 02, 2009)

1047-37-388 **Ilie Ugarcovici*** (iugarcov@depaul.edu), 2320 N. Kenmore Ave, Chicago, IL 60203. *Generalized Gauss-type interval maps.*

We describe a two-parameter family of continued fractions algorithms and derive some of the ergodic properties of the induced Gauss-type interval maps. Possible generalizations of Bowen-Series boundary maps associated to arbitrary Fuchsian groups will be also described. This is joint work with S. Katok (Penn State). (Received February 02, 2009)

1047-37-409 **O. Michael Melko*** (mike.melko@northern.edu), Department of Mathematics, Northern State University, 1200 South Jay Street, Aberdeen, SD 57401. *Using Mathematica to Visualize Bifurcation and Chaos in the Dynamics of Symplectic Integrators.* Preliminary report.

Symplectic integrators are discrete dynamical systems depending on a time-step parameter h that arise naturally as perturbations of Hamiltonian systems in which the underlying Hamiltonian is separable. By means of the well-known Baker-Campbell-Hausdorff (BCH) series, it can be shown that such integrators are stable approximations to the unperturbed Hamiltonian system for small values of h. However, as h is allowed to grow past the radius of convergence of the BCH series, interesting changes in the dynamics are observed, including bifurcation and chaos. We show how Mathematica may be used to visualize this behavior, focusing on the ideal simple pendulum as a case study. (Received February 02, 2009)

1047-37-416 **Ciprian Demeter*** (demeterc@indiana.edu), Department of Mathematics, Indiana University, 831 East 3rd Street, Bloomington, IN 47405. *On the Pointwise Ergodic Theorem along squares.* Preliminary report.

We reprove Bourgain's Pointwise Ergodic Theorem for polynomial averages, in the case of totally ergodic systems, for bounded functions. The argument presented uses almost no Fourier analysis. (Received February 02, 2009)

1047-37-439 **Nikos Frantzikinakis*** (frantzikinakis@gmail.com), University of Memphis, Department of mathematics, Memphis, TN 38152. *Hardy field configurations on dense subsets of the integers.*

We are going to discuss several new results related to what kind of patterns one can always find within sets of integers with positive density. For example if a(t) is a function of polynomial growth that belongs to some Hardy field, then it turns out that if a(t) is not a polynomial one can always find arithmetic progressions with common difference of the form [a(n)]. This is partly joint work with M. Wierdl. (Received February 03, 2009)

1047-37-440 **Nikos Frantzikinakis*** (frantzikinakis@gmail.com), University of Memphis, Department of mathematics, Memphis, TN 38138. *Multiple ergodic theorems for Hardy field sequences.*

Recently, there has been an outburst of activity in studying multiple ergodic averages along polynomial sequences, one motivation being the potential implications in combinatorics. In this talk, we are going to give a variety of new multiple ergodic theorems involving sequences of integers of polynomial growth, defined by functions that belong to some Hardy field. One interesting feature of these new ergodic theorems is that "typically" one gets a very explicit limit formula, leading to stronger than usual multiple recurrence results, and combinatorial consequences. (Received February 03, 2009)

1047-37-446 **Anatole Katok*** (katok_a@math.psu.edu), Department of Mathematics, The Pennsylvania State University, University Park, PA 16802. *The Weyl chamber flow, sections, and speculations about reduction theory (preliminary report).* Preliminary report.

It is well known that the classical Gauss reduction theory for 2 by 2 integer matrices can be interpreted in terms of properties of the geodesic flow on the modular surface with respect to a particularly chosen section. Moreover various classical "arithmetic" codes correspond to the choice of different sections. It is tempting to try to find a fruitful higher-dimensional analogy for all of those. Dynamical ingredients are present: the Weyl Chamber flow and appropriate sections. The problem is the absence of natural lattice structure on the sections. It is likely that no reasonable lattice structure exists at all. On the other hand, the dynamical properties of the Weyl chamber flow are reasonably well understood and, if anything, they are better that those of geodesic flow. In this talk I will discuss both positive and negative aspects of the problem (Received February 03, 2009)

1047-37-452 **Matthew Foreman***, Math Dept., UC Irvine, Irvine, CA 92617. *Rudolph's Thesis.*
The set of measure preserving transformations of a standard Lebesgue space can be modeled in many different settings. These settings introduce topological and algebraic structure on the collection.

Rudolph conjectured that all of the different settings were equivalent. This conjecture was supported by work of Glasner and King who showed that in two important cases "genericity" was the same for dynamical properties.

In joint work with Rudolph and Weiss, this talk makes Rudolph's thesis precise, discusses some well known models for the measure preserving transformations, introduces some new models and verifies Rudolph's Thesis in the models we know about. (Received February 03, 2009)

1047-37-462 **Vladimir Pestov*** (vpest283@uottawa.ca), Department of Mathematics and Statistics, 585 King Edward Avenue, University of Ottawa, Ottawa, Ontario K1N6N5, Canada. *Some properties of the full groups of measure-preserving equivalence relations.* Preliminary report.
We consider the full groups in the sense of Dye of measure-preserving equivalence relations equipped with the uniform metric (and topology), in connection with the following properties: (i) whirly actions (as defined by Glasner and Benjy Weiss), (ii) approximations with interval exchange transformations and soficity. Some of the work is joint with Thierry Giordano. (Received February 03, 2009)

1047-37-495 **Karl Petersen*** (petersen@math.unc.edu), Department of Mathematics, CB 3250 Phillips Hall, Chapel Hill, NC 27599, and **Alexander Varchenko**. *The Eulerian adic dynamical system.*
We prove that there is a unique fully supported ergodic measure for the Bratteli-Vershik (adic) dynamical system on the Eulerian graph by generalizing a formula for the Eulerian numbers, proving monotonicity of certain sequences of ratios by means of a curious two-dimensional induction argument, and setting up a one-to-one correspondence between large sets of paths beginning from two vertices at the same level of the diagram. (Received February 04, 2009)

41 ► Approximations and expansions

1047-41-38 **Kwang C. Shin*** (kshin@westga.edu), Department of Mathematics, University of West Georgia, Carrollton, GA 30118. *Asymptotic distribution of eigenvalues of non-self-adjoint Schrödinger operators with polynomial potentials.* Preliminary report.
For integers $m \geq 3$, the Schrödinger eigenvalue problem

$$-y'' + (x^m + P(x))y = \lambda y, \quad x \geq 0,$$

under the boundary conditions at $\alpha y(0) + \beta y'(0) = 0$ and $y(+\infty) = 0$ will be studied, where P is a polynomial of degree $\leq m-1$. It is known that the eigenvalues are the zeros of an entire function of order $\frac{1}{2} + \frac{1}{m}$.

In this talk, we present results on direct and inverse spectral problems. In particular, we will talk about asymptotics of the eigenvalues and some effect of the boundary condition at $x = 0$ on the asymptotics. Also, we will mention some inverse spectral results, recovering the polynomial potential from the first few terms of the asymptotics of the eigenvalues. (Received December 09, 2008)

42 ► Fourier analysis

1047-42-13 **Matthew Fickus*** (Matthew.Fickus@afit.edu) and **Melody L. Massar**. *Fast computation of spectral centroids.*
The spectral centroid of a signal is the curve obtained by taking centroids of fixed-time cross sections of its spectrogram. It provides a robust estimate of the dominant frequency of a signal at any given time, and as such, is a useful tool in many applications, such as speech processing. We provide a fast algorithm for the computation of spectral centroids that exploits the fast Fourier transform and properties of Toeplitz matrices. We then apply this theory to a biometric problem, namely, the estimation of a person's heart and breath rates from the Doppler shift induced in a continuous wave radar signal by their body movements. (Received November 01, 2008)

1047-42-34 **Joseph D Lakey*** (jlakey@nmsu.edu), Dept. of Mathematical Sciences, NMSU, Las Cruces, NM 88003-8001. *Time-frequency localization and sampling of multiband signals.* Preliminary report.

The classical "Bell Labs" theory considers spaces of signals that are essentially localized to a bounded interval in time and a bounded interval in frequency. Some communications applications could benefit from an extension of this theory to cases in which the frequency localization support is a finite union of intervals (multiband). Such extensions involve estimates of the decay of eigenvalues of compositions of time and frequency cutoffs and descriptions of the eigenvectors. We will offer some preliminary results relating decay of eigenvalues with the distribution of the frequency support. Numerical approximations of the projections expressed in terms of practical sampling methods and some connections with compressive sampling will also be considered. (Received December 09, 2008)

1047-42-180 **Marlos A.G. Viana*** (viana@uic.edu), 1855 W. Taylor St., Chicago, IL 60612, and **Vasudevan Lakshminarayanan**. *Dihedral Fourier Analysis in Statistical Optics.*

In this talk we will derive the basic spectral analysis for bivariate dihedral Fourier analysis in the context of phase-space optics applications. The data-analytical aspects of those applications will follow from the connection between the Fourier-inverse formula and the canonical decomposition theorem for the regular representation of finite groups and its role in the standard principles of statistical inference. The notion of data indexed by planar dihedral orbits will be introduced with the purpose of demonstrating its efficiency in the characterization of certain elementary optical features, such as those present in refractive profiles. (Received January 30, 2009)

1047-42-199 **Loukas Grafakos*** (loukas@math.missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, and **Christopher Sansing**. *Gabor frames and directional time–frequency analysis.*

We introduce a directionally sensitive time–frequency decomposition and representation of functions. The coefficients of this representation allow us to measure the "amount" of frequency a function (signal, image) contains in a certain time interval, and also in a certain direction. This has been previously achieved using a version of wavelets called ridgelets [E.J. Candes, Harmonic analysis of neural networks, Appl. Comput. Harmon. Anal. 6 (1999) 197–218; E.J. Candes, D.L. Donoho, New tight frames of curvelets and optimal representations of objects with piesewise-C2 singularities, Comm. Pure Appl. Math. 57 (2004) 219–266] but in this work we discuss an approach based on time–frequency or Gabor elements. For such elements, a Parseval formula and a continuous frame-type representation together with boundedness properties of a semi-discrete frame operator are obtained. Spaces of functions tailored to measure quantitative properties of the time–frequency–direction analysis coefficients are introduced and some of their basic properties are discussed. Applications to image processing and medical imaging are presented. (Received January 28, 2009)

1047-42-214 **Tian-Xiao He*** (the@iwu.edu), Dept Math & CS, P. O. Box 2900, Illinois Wesleyan University, Bloomington, IL 61702-2900. *Spline Wavelets, Finite Element Wavelets, and Wavelets with Composite Dilation.* Preliminary report.

We present here some preliminary work for continuing and smoothing off the two-dimensional Haar-type non-separable composite dilation wavelets. A comparison of the wavelets with composite dilation, spline wavelets, and finite element wavelets will be presented. If time permits, the advantages of one-dimensional composite dilation wavelets will also be discussed. (Received January 29, 2009)

1047-42-274 **Qingtang Jiang*** (jiangq@umsl.edu), Dept. of Math and CS, University of Missouri - St. Louis, St. Louis, MO 63121. *Biorthogonal Wavelets with 6-fold Axial Symmetry for Hexagonal Data and Triangle Surface Multiresolution Processing.* Preliminary report.

In this talk we discuss the construction of highly symmetric FIR filter banks and compactly supported biorthogonal wavelets for hexagonal data/image and triangle surface multiresolution processing. Recently hexagonal data processing has attracted attention. Compared with the conventionally used square lattice, the hexagonal lattice has several advantages, including that it has higher symmetry. It is desirable that the filter banks for hexagonal data also have high symmetry which pertinent to the symmetric structure of the hexagonal lattice. While in the field of CAGD, when the filter banks are used for surface multiresolution processing, it is required that the corresponding decomposition and reconstruction algorithms for regular vertices have high symmetry so that these algorithms could be used to process surfaces with extraordinary vertices.

In this talk, we will show that the 6-fold axial symmetry is the desired symmetry which the filter banks and wavelets should possess when they are used for hexagonal data and triangle surface multiresolution processing.

We will also discuss the construction of 6-fold symmetric biorthogonal filter banks and the associated wavelets, with both the dyadic and square-root(3) refinements. (Received January 30, 2009)

1047-42-277 **H.-Q. Bui** and **R. S. Laugesen*** (Laugesen@illinois.edu), Department of Mathematics, University of Illinois, Urbana, IL 61801. *Frequency-scale frames and the solution of the Mexican hat problem.* Preliminary report.

We resolve a twenty year old open problem on L^p completeness of the time-scale (or wavelet) system generated by the Mexican hat function, when $1 < p < \infty$.

Our main result concerns frequency-scale systems generated by modulation and dilation of a single function. The mixed frame operator (analysis followed by synthesis) is shown to be bijective from L^q to itself, for $1 < q < \infty$, and also from $W_*^{1,2}$ to itself, so that the frequency-scale synthesis operator is surjective onto those spaces. Tools include the discrete Calderon condition and a generalization of the Daubechies frame criterion in L^2.

Completeness of the Mexican hat and other time-scale systems in $L^p, 1 < p < \infty$, then follows by Fourier imbedding of the frequency-scale systems. (Received January 30, 2009)

1047-42-319 **David L. Donoho** (donoho@stanford.edu), Department of Statistics, Stanford University, Stanford, CA 94305-4065, and **Gitta Kutyniok*** (kutyniok@uni-osnabrueck.de), Institute of Mathematics, University Osnabrueck, 49069 Osnabrueck, Germany. *Sparsity Equivalence of Anisotropic Decompositions.*

Recently, various types of anisotropic representation systems for 2-dimensional signals were developed which resolve edge- or curve-like features in a sparser way than wavelet systems as isotropic systems are capable of. All these variants such as, e.g., curvelets, 2. generation curvelets, and shearlets offer different advantages and disadvantages. Interestingly, several sparsity-related properties, e.g., optimally sparse decompositions of cartoon-like images, are shared by them precisely.

In this talk, we will show that in fact the aforementioned three systems are 'sparsity equivalent' in the sense of a particular uniform ℓ_p summability of associated coefficient sequences. This result will provide a means to easily transfer sparsity properties of one system to all other systems, thereby leading to several new results concerning sparsity properties of shearlets as well as allowing to reduce sparsity studies to the system easiest to analyze. (Received February 01, 2009)

1047-42-417 **Ciprian Demeter*** (demeterc@indiana.edu), Department of Mathematics, Indiana University, 831 East 3rd Street, Bloomington, IN 47405. *On some maximal multipliers in L^p.*

We extend a result of Bourgain on maximal multipliers on L^2, to all L^p spaces, $1 < p < \infty$. (Received February 02, 2009)

1047-42-426 **S. Zubin Gautam*** (sgautam@math.ucla.edu), UCLA Mathematics Department, Box 951555, Los Angeles, CA 90095-1555. *On curvature and the bilinear multiplier problem.* Preliminary report.

By analogy with C. Fefferman's classical Ball Multiplier Theorem, it is natural to study the impact of curvature on $L^p(\mathbb{R}^d) \times L^q(\mathbb{R}^d) \to L^r(\mathbb{R}^d)$ boundedness properties of bilinear Fourier multiplier operators whose symbols are characteristic functions of domains in $\mathbb{R}^d \times \mathbb{R}^d$. We discuss the nature and extent of this impact, and we establish sufficient sectional curvature conditions on the boundary of a domain to allow the key ideas of Fefferman's argument to yield unboundedness outside the local L^2 setting. In particular, we obtain unboundedness when the symbol is given by a general domain that is strictly convex in some neighborhood; this generalizes existing results of Diestel–Grafakos and Grafakos–Reguera. (Received February 03, 2009)

1047-42-453 **Judith A Packer*** (packer@colorado.edu), Department of Mathematics, Campus Box 395, University of Colorado at Boulder, Boulder, CO 80309. *Notions of equivalence of generalized multiresolution analyses.* Preliminary report.

I discuss some recent work, done in collaboration with L. Baggett, V. Furst, and K. Merrill, that studies in more depth the generalized multiresolution analyses (GMRAs) giving rise to Parseval frames, as first defined by Baggett, Merrill and H. Medina in 1999. Such GMRAs can be described by their multiplicity functions m and matrix-valued filter functions H. In this talk, the emphasis will be on an equivalence relation that can be defined on GMRAs satisfying appropriate properties, in terms of their associated multiplicity functions and filters. (Received February 03, 2009)

1047-42-496 **Xiaochun Li*** (xcli@math.uiuc.edu), Department of Math, University of Illinois at Urbana-Champaign, Urbana, 61801. *Some operators related to multilinear oscillatory integrals.*

We discuss the relation between multilinear oscillatory integrals and some operators such as bilinear Hilbert transform transforms and Calderon-Zygmund type integral operators associated to polynomial phases. (Received February 04, 2009)

43 ► Abstract harmonic analysis

1047-43-295 **Ilya A Krishtal*** (krishtal@math.niu.edu), Department of Mathematical Sciences, Northern Illinois University, Watson Hall 320, DeKalb, IL 60115. *Wiener's Lemma and memory localization.* Preliminary report.

In this semi-expository talk I will describe a unified point of view on how different extensions of the Wiener's Tauberian Lemma are related to different types of memory localization such as off-diagonal decay, frame localization, etc. (Received January 31, 2009)

1047-43-330 **Veronika Furst*** (furst_v@fortlewis.edu), Department of Mathematics, Fort Lewis College, 1000 Rim Drive, Durango, CO 81301. *The trivial intersection property of generalized multiresolution analyses.*

The "problem" of Baggett, Bownik, and Rzeszotnik states that if $\{\psi_k\}$ is a Parseval multiwavelet in $L^2(\mathbb{R}^d)$, i.e., if the functions $\{\psi_{j,n,k}(x)\} \equiv \{2^{j/2}\psi_k(2^j x+n)\}$ form a normalized tight frame for $L^2(\mathbb{R}^d)$, then the collection of sets $V_j = \overline{\text{span}}\{\psi_{l,n,k} : l < j\}$ satisfy all of the properties of a GMRA except possibly the condition $\cap V_j = \{0\}$. In this talk, we will briefly discuss the history of this problem and a recent result that presents two new conditions equivalent to the trivial intersection property. In doing so, we extend a result of Bownik and Rzeszotnik from $L^2(\mathbb{R}^d)$ to an abstract Hilbert space. This is joint work with L.W. Baggett, K.D. Merrill, and J.A. Packer. (Received February 01, 2009)

1047-43-491 **Wojciech Czaja*** (wojtek@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742, and **James H. Tanis**. *Kaczmarz algorithms and frames.* Preliminary report.

In 1937 Stefan Kaczmarz introduced an iterative method for solving linear systems of equations. Recently, Kwapień and Mycielski, and Szwarc and Haller characterized convergent Kaczmarz algorithms in infinite-dimensional Hilbert spaces by means of tight frames of effective sequences. The purpose of this note is to extend some of their results by introducing a more general notion of frames in this cotext. (Received February 04, 2009)

46 ► Functional analysis

1047-46-134 **Kevin Wildrick*** (kevin.wildrick@jyu.fi) and **Ellen Veomett**. *Metric cotype and quasisymmetric embeddings.* Preliminary report.

Type and cotype play a prominent role in the local theory of Banach spaces and the theory of geometric embeddings into Banach spaces. Recent work of Mendel and Naor provides a notion of cotype for metric spaces that coincides with the classical notion when restricted to Banach spaces. They also show that cotype does not decrease under a quasisymmetric embedding of one infinite dimensional Banach space into another. However, little is known about the metric cotype of even very simple non-linear spaces. We discuss whether metric cotype is a quasisymmetric invariant in general, and give results that determine the metric cotype of certain key examples. (Received January 25, 2009)

1047-46-205 **nate brown***, 320 McAllister Buidling, Penn State University, University Park, PA 16802. *Classifying Hilbert Modules.* Preliminary report.

I'll discuss the problem of classifying Hilbert C*-modules. In the finitely generated projective case, K_0 is the most commonly used invariant. For more general countably generated modules, it turns out that a semigroup introduced by Cuntz some 30 years ago is the relevant invariant. (Received January 29, 2009)

1047-46-290 **Eric Ricard*** (eric.ricard@univ-fcomte.fr), 16 route de Gray, 25030 Besançon, France. *Transference of multipliers.*

We try to make precise the links between Schur and Fourier multipliers on L_p spaces. (Received January 31, 2009)

1047-46-346 **Marius Dadarlat*** (mdd@math.purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907, West Lafayette, IN 47906. *On AF embeddability of continuous fields.*

Let A be a separable and exact C*-algebra which is a continuous field of C*-algebras over a connected, locally connected, compact metrizable space. If at least one of the fibers of A is AF embeddable then so is A. As an application we show that if G is a central extension of an amenable and residually finite discrete group by $\mathbb{Z}^n$, then the C*-algebra of G is AF embeddable. (Received February 02, 2009)

1047-46-348 **Hari Bercovici*** (bercovic@indiana.edu), Mathematics Department, Indiana University, Bloomington, IN 47401. *Intersection theory in a finite von Neumann algebra.*

The Grassmannian of a finite algebra consists of all projections of fixed trace. Schubert varieties are analogues of the finite dimensional cycles which generate the homology of Grassmannians. We will describe recent progress in the study of intersections of such Schubert cells. This is joint work with B. Collins, K. Dykema, W.S. Li and D. Timotin. (Received February 02, 2009)

1047-46-355 **Pierre Fima*** (pfima@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green Street, Urbana, IL 61801-2975. *Property T for Discrete Quantum Groups.*

In this talk, we will introduce the notion of property T for discrete quantum groups. From this definition we can prove the basic expected properties: discrete quantum groups with property T are unimodular and finitely generated. Moreover the non-commutative version of the Connes-Jones' Theorem is true: an I.C.C. discrete quantum group has T if and only if its dual von Neumann algebra is a II_1 factor and has property T. We will also discuss property T (and the behavior of Kazhdan's constants) in almost all known examples of discrete quantum groups: the classical ones, the free ones, the q-deformations, the twisting and bicrossed product construction. Finally, if the time permits, we will discuss the notion of residually finite discrete quantum groups. (Received February 02, 2009)

1047-46-377 **Quanhua Xu*** (qxu@univ-fcomte.fr), Laboratoire de Mathematiques, Universite de Franche-Comte, 25030 Besancon, France. *Structures of certain homogeneous Hilbertian operator spaces and applications.*

Let $QS(C \oplus R)$ denote the class of quotients of subspaces of $C \oplus R$. We show that the operator space structure of each homogeneous $F \in QS(C \oplus R)$ is completely determined, under a mild regularity assumption, by its fundamental sequences

$$\Phi_c(n) = \big\| \sum_{k=1}^n e_{k1} \otimes e_k \big\|^2_{C \otimes_{\min} F}, \quad \Phi_r(n) = \big\| \sum_{k=1}^n e_{1k} \otimes e_k \big\|^2_{R \otimes_{\min} F},$$

where (e_k) is an orthonormal basis of F. The underlying result is a canonical representation of F in terms of weighted column and row spaces with weights given by Φ_c and Φ_r. This canonical representation yields an explicit formula for the exactness constant of an n-dimensional subspace F_n of F:

$$ex(F_n) \sim \left[\frac{n}{\Phi_c(n)} \, \Phi_r\big(\frac{\Phi_c(n)}{\Phi_r(n)}\big) + \frac{n}{\Phi_r(n)} \, \Phi_c\big(\frac{\Phi_r(n)}{\Phi_c(n)}\big) \right]^{1/2}.$$

The projection constant of F_n is explicitly expressed in terms of Φ_c and Φ_r too. Orlicz space techniques play a crucial role in our arguments. They also permit to determine the completely 1-summing maps between two homogeneous spaces E and F in $QS(C \oplus R)$. This is a joint work with Marius Junge. (Received February 02, 2009)

1047-46-393 **Timur Oikhberg*** (toikhber@math.uci.edu), Department of Mathematics, University of California - Irvine, Irvine, CA 92617, and **Christian Rosendal**. *An operator space with "few" subspaces (joint work with C.Rosendal).*

Recently, the problem of describing the complexity of the isomorphism relation between subspaces of a separable Banach space has attracted much attention. It has been shown that the relation of isomorphism on the set of subspaces of a separable Banach space X (denoted by $S(X)$) is Borel reducible to the complete analytic relation. The question of whether this relation must be complete analytic whenever X is not isomorphic to a Hilbert space

is open. We present an example of a separable operator space X for which the relation of complete isomorphism on $S(X)$ is complete K_σ, and discuss additional properties of this space. (Received February 02, 2009)

1047-46-410 **Piotr Hajlasz*** (hajlasz@pitt.edu), University of Pittsburgh, Department of Mathematics, 301 Thackeray Hall, Pittsburgh, PA 15260, and **Jan Maly**. *On approximate differentiability of the maximal function.* Preliminary report.

Kinnunen proved that the maximal function is a bounded operator in $W^{1,p}(R^n)$ when $p > 1$. Tanaka showed that the noncentered maximal function in dimension 1 of a function in $W^{1,1}$ belongs locally to $W^{1,1}$ and has integrable derivative. The question whether Tanaka's result holds for the centered maximal function and if it can be generalized to higher dimensions remains open. In the talk we will discuss a weaker result: the a.e. approximate differentiability of Mu, where $u \in W^{1,1}(R^n)$ and also differentiability properties of Mu, where $u \in L^1(R^n)$. (Received February 02, 2009)

1047-46-423 **Tao Mei*** (mei@math.uiuc.edu), 1409 W Green Street, Univ. of Illinois, Dept. of Math., Urbana, IL 61801, and **Javier Parcet** (javier.parcet@uam.es), Instituto de Ciencias Matem aticas, Consejo Superior de Investigaciones Cientýfic, Serrano 121, 28006 Madrid, Spain. *Littlewood-Paley inequalities for operator-valued functions.*

The classical Littlewood-Paley theory states that a function f and the square function corresponding to a "nice" decomposition of f have equivalent Lp norms. We study Littlewood-Paley type inequalities for functions with values in noncommutative L_p spaces for $p = 1, \infty$. By interpolation, the result extends to all $1 < p < \infty$. In the case of Shatten-p class-valued functions, we improved a previous result by Bourgain/Mcconell by giving optimal constants. This is a recent joint work with Javier Parcet. (Received February 03, 2009)

1047-46-458 **Yi-Jun YAO*** (yao@math.psu.edu), Math Department, Penn State University, State College, PA 16802. *Positive Cocycles over Noncommutative 2-Tori.* Preliminary report.

We will discuss the definition of positive cocycles given by Connes and Cuntz twenty years ago and provide (relatively) detailed proofs of certain results. (Received February 03, 2009)

1047-46-459 **Caleb A Eckhardt*** (ceckhard@uiuc.edu), 1409 W. Green St., Urbana, IL 61801. *Perturbations of Finite Rank Maps with applications to Nuclear C*-algebras.*

In this talk we will give a complete answer to the question "Under what conditions can an injective completely positive contraction from $M_n(\mathbb{C})$ into $B(H)$ (the space of bounded operators on a Hilbert space) be perturbed to a complete order embedding?" In particular, we are interested in the cases when the perturbation can be made independent of the dimension of $M_n(\mathbb{C})$. We finish with some applications to $\mathcal{OL}_\infty$ structure of nuclear C^*-algebras. (Received February 03, 2009)

1047-46-480 **Alan D Wiggins*** (alan.d.wiggins@vanderbilt.edu), 1326 Stevenson Center, Department of Mathematics, Vanderbilt University, Nashville, TN 37240, and **Junsheng Fang**, **Roger Smith** and **Stuart White**. *Normalizers of Subalgebras of Finite von Neumann Algebras.*

We present some of our recent work on groupoid normalizers. This is joint work with Junsheng Fang, Roger Smith, and Stuart White. (Received February 03, 2009)

47 ► Operator theory

1047-47-36 **Hasan A Al-Halees*** (hhalees@svsu.edu), Department of Mathematical Sciences, Saginaw Valley State University, 7400 Bay Rd, University Center, MI 48710, and **Richard J Fleming**. *On 2-local isometries on continuous vector-valued function spaces.*

A (not necessarily linear) mapping ¶ from a Banach space X to a Banach space Y is said to be a 2-*local isometry* if for any pair x, y of elements of X, there is a surjective linear isometry $T : X \to Y$ such that $Tx = ¶x$ and $Ty = ¶y$. We show that under certain conditions on locally compact Hausdorff spaces Q, K and a Banach space E, every 2-local isometry on $C_0(Q, E)$ to $C_0(K, E)$ is linear and surjective. We also show that every 2-local isometry on ℓ^p is linear and surjective for $1 \leq p < \infty, p \neq 2$, but this fails for Hilbert space ℓ^2. (Received December 09, 2008)

1047-47-194 **William Arveson*** (arveson@math.berkeley.edu), Department of Mathematics, University of California, Berkeley, CA 94720. *Hyperrigid operator systems.*

A (finite or countably infinite) set G of generators of an abstract C^*-algebra A is called *hyperrigid* if for every faithful representation of A on a Hilbert space $A \subseteq \mathcal{B}(H)$ and every sequence of unital completely positive linear maps $\phi_1, \phi_2, \ldots$ from $\mathcal{B}(H)$ to itself,

$$\lim_{n\to\infty} \|\phi_n(g) - g\| = 0, \forall g \in G \implies \lim_{n\to\infty} \|\phi_n(a) - a\| = 0, \forall a \in A.$$

We show that one can determine whether a given set G of generators is hyperrigid by examining the non-commutative Choquet boundary of the operator space spanned by $G \cup G^*$. We present a variety of concrete applications and discuss open problems and conjectures. (Received January 28, 2009)

1047-47-198 **Yun-Su Kim*** (Yun-Su.Kim@utoledo.edu), Department of Mathematics, Mail Stop 942, The University of Toledo, 2801 W. Bancroft St., Toledo, OH 43606-3390. *Every transcendental operator has a non-trivial invariant subspace.*

In this talk, contraction operators are classified into three classes ; (Case 1) completely non-unitary contractions with a non-trivial algebraic element, (Case 2) completely non-unitary contractions without a non-trivial algebraic element, or (Case 3) contractions which are not completely non-unitary. We know that every operator of (Case 3) has a non-trivial invariant subspace. In this talk, we answer to the invariant subspace problem for the operators of (Case 2). (Received January 28, 2009)

1047-47-258 **Christian Le Merdy*** (clemerdy@univ-fcomte.fr), Laboratoire de Mathematiques, Universite de Franche-Comte, Besancon Cedex, 25030. *Group representations and R-boundedness.*

Let G be an amenable group and let $C^*(G)$ be its associated group C^*-algebra. Let X be a Banach space and let $\pi\colon G \to B(X)$ be a bounded continuous representation. A well-known theorem (Nagy, Dixmier) asserts that if $X = H$ is a Hilbert space, then π is similar to a unitary representation. Equivalently, π naturally extends to a bounded unital homomorphism $C^*(G) \to B(H)$. Our main result is an extension of this result to the Banach space setting. Under some mild conditions on X, it says that if π is R-bounded, then it extends to a bounded unital homomorphism $\widehat{\pi}\colon C^*(G) \to B(X)$. The notion of R-boundedness relies on Rademacher averages in Banach spaces and will be defined during the talk. If times permits, we will explore more relationships between operator algebras, Banach space homomorphisms and R-boundedness. (Received January 30, 2009)

1047-47-311 **Victor Kaftal*** (kaftal@math.uc.edu), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221-0015. *Strong sums of projections.* Preliminary report.

Which positive operators (in a von Neumann algebra) are strong sums of projections? In a recent paper (K,Ng, and Zhang) we found a necessary and sufficient condition for countably generated factors of type I, III, and in certain cases of type II. The technique used is based on a two by two matrix construction with further applications to frame theory and the study of diagonals of positive operator (work in progress with D. Larson.) (Received February 01, 2009)

1047-47-427 **Raúl E Curto*** (rcurto@math.uiowa.edu), Department of Mathematics, University of Iowa, Iowa City, IA 52242. *Cubic Column Relations in Truncated Moment Problems.* Preliminary report.

For a degree $2n$ real d-dimensional multisequence $\beta \equiv \beta^{(2n)} = \{\beta_i\}_{i\in Z_+^d, |i|\le 2n}$ to have a representing measure μ, it is necessary for the associated moment matrix $M(n)$ to be positive semidefinite, and for the algebraic variety associated to β, V_β, to satisfy rank $M(n) \le$ card V_β as well as the following consistency condition: if a polynomial $p(x) \equiv \sum_{|i|\le 2n} a_i x^i$ vanishes on V_β, then $p(\beta) := \sum_{|i|\le 2n} a_i \beta_i = 0$. In previous joint work with L. Fialkow and M. Möller, we proved that for the extremal case (rank $M(n) =$ card V_β), positivity and consistency are sufficient for the existence of a (unique, rank $M(n)$-atomic) representing measure.

In recent joint work with Seonguk Yoo we consider cubic column relations in $M(3)$ of the form (in complex notation) $Z^3 = itZ + u\bar{Z}$, where u and t are real numbers. For (u, t) in the interior of a real cone, we prove that the algebraic variety consists of exactly 7 points, and we then apply the above mentioned solution of the extremal moment problem to obtain a necessary and sufficient condition for the existence of a representing measure. (Received February 03, 2009)

1047-47-465 **Remus Nicoara*** (nicoara@math.utk.edu), University of Tennessee, Math Department, 104 Aconda Court, 1534 Cumberland Avenue, Knoxville, TN 37996. *Continuous Deformations of Commuting Squares.*

We investigate the existence of certain parametric families of commuting squares of finite dimensional *-algebras. We present some applications to subfactor theory and to Hadamard matrices. (Received February 03, 2009)

51 ► Geometry

1047-51-62 **Noah H Rhee*** (RheeN@umkc.edu), 206 Haag Hall, University of Missouri-Kansas City, 5100 Rockhill Road, Kansas City, MO 64110, and **Larry Eifler** (EiflerL@umkc.edu), 206 Haag Hall, University of Missouri-Kansas City, 5100 Rockhill Road, Kansas City, MO 64110. *The n-Dimensional Pythagorean Theorem via the Divergence Theorem.*

The theorem of Pythagoras relating the squares of the lengths of the sides of a right triangle is well known. Its generalization to 3 dimensions is known as de Gua's theorem. The generalization of this result to n-dimension has appeared numerous times in the literature. In this talk we present a proof of n-dimensional Pythagorean theorem using the divergence theorem. (Received January 10, 2009)

1047-51-84 **George Francis*** (gfrancis@uiuc.edu), George Francis, Altgeld Hall, 1409 W Green St, Urbana, IL 61801, and **Tony Robbin** (TonyRobbin@att.net), 1283 South Gilboa Road, Gilboa, NY 12076. *Virtual Installations of Quasicrystalline Structures in 3-space.* Preliminary report.

Nearly three decades ago, DeBruijn proposed two methods for generating quasicrystals as injective projections of 3D sublattices of the 6D unit lattice. Such a packing of space by rhombohedra is the 3D analog of a planar tiling by rhombi, as popularized by Penrose, Conway et al. The packing is quasicrystalline (Steinhardt) if it displays icosahedral symmetry locally, but is aperiodic globally. In this collaboration of an artist and a mathematician, we develop a tool for constructing arbitrarily large virtual quasicrystalline installations in fully immersive virtual environments, such as the Cube and the CAVE. Preliminary work by a succession of REU students have demonstrated the feasibility and difficulty of this project. We report on current progress. [With Matt Gregory and Geoff Ehrman] (Received February 02, 2009)

1047-51-85 **Herbert Edelsbrunner*** (edels@cs.duke.edu), Duke University, and Geomagic, Research Triangle Park, Durham, NC. *Stability of the Fold.* Preliminary report.

Think of the view of the boundary of a solid shape as a projection of a 2-manifold to R^2. Its silhouette is the projection of the critical points. Generalizing the projection to smooth mappings of an n-manifold to R^k, we get the fold (the generalized silhouette) as the image of the points at which the derivative is not surjective. Measuring difference with the erosion distance (the Hausdorff distance between the complements), we prove that the fold is stable. Specifically, we show that the erosion distance between the k-dimensional regions defined by two smooth mappings of the same n-manifold is bounded from above by the maximum Euclidean distance between corresponding image points. [Joint work with Dmitriy Morozov and Amit Patel.] (Received January 17, 2009)

1047-51-91 **Johanna Mangahas*** (mangahas@umich.edu), 1320 W Stadium Blvd Apt 5, Ann Arbor, MI 48103. *Uniform uniform exponential growth of subgroups of the mapping class group.*

Let Mod(S) denote the mapping class group of a compact, orientable surface S. Finitely generated subgroups of Mod(S) which are not virtually abelian have uniform exponential growth with minimal growth rate bounded below by a constant depending only on S. For the proof, one finds in any such subgroup explicit free group generators which are "short" in any word metric. Besides bounding growth, this allows a bound on the return probability of simple random walks. (Received January 19, 2009)

1047-51-105 **Ian Biringer**, University of Chicago, Department of Mathematics, 5734 S. University Ave., Chicago, IL 60637, and **Juan Souto***, Department of Mathematics, University of Michigan, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109-1043. *Rank of the fundamental group of hyperbolic mapping tori.*

We prove that the fundamental group of the mapping torus of a pseudo-Anosov element f in the mapping class group of closed surface has rank 2g+1 provided that f has sufficiently large translation distance in the curve complex. (Received January 22, 2009)

1047-51-107 **D B McReynolds*** (dmcreyn@math.uchicago.edu), 5734 S. University, Chicago, IL 60637. *Controlling covers of arithmetic orbifolds.*

In this talk, I will discuss a generalization of Selberg's Lemma. The main result allows one to gain some control over the geometry of covers of arithmetic orbifolds. The chief application is on the geometry of cusp cross sections of hyperbolic manifolds. (Received January 22, 2009)

1047-51-108 **Dennis M Roseman*** (roseman@math.uiowa.edu), B1J MacLean Hall, Department of Mathematics, University of Iowa, Iowa City, IA 52242-1419. *Geometric Generation of Permutation Sequences.* Preliminary report.

We discuss certain methods of geometrically generating sequences of permutations and families of such sequences based on the geometry of the n-dimensional permutahedron. The basic idea is to discretize generic polygonal paths using the real braid arrangement. Focus of the talk will be on certain polygonal paths which might be described as bouncing a light beam inside a mirrored (high-dimensional) permutahedron. Calculations can be done very fast even for permutations of high order. We also discuss ways of visualizing this process. (Received February 02, 2009)

1047-51-139 **Stewart P Dickson*** (sdickson@uiuc.edu), Illinois Simulator Laboratory, 2100 South Goodwin Avenue (MC-008), Urbana, IL 61801, and **Paul J Steinhardt** (steinh@Princeton.EDU), Center for Theoretical Science, Jadwin 214, Princeton University, Princeton, NJ 08544. *Visualization for the Endless Universe.*

Stewart Dickson created the cover image for Endless Universe by Paul J. Steinhardt and Neil Turok. It was a collaborative process in which Paul and Stewart bounced ideas back and forth. The image visually evokes the lemniscate (Ellipsis) sign for infinity plus a symmetrically repeating surface involution, as in the Klein bottle. If the image were less visually symmetric, it would also be less topologically interesting than it has turned out to be. Stewart then took a crack at re-working the animation that Paul has been using to express the 'colliding branes' aspect of the cyclical cosmological model. (Received February 02, 2009)

1047-51-149 **Ian Biringer*** (biringer@uchicago.edu), 1511 E 54th St, Apt 2, Chicago, IL 60615. *A combinatorial property of isometric Z-actions and geodesic flow.*

The classical 3-gap theorem states that at most 3 distinct distances occur between nearest neighbor points in any segment of an orbit of a rotational Z-action on the circle. We will investigate generalizations of this phenomenon in dimension 2; in particular, we will characterize surfaces whose geodesic flows have a similar property. (Received January 26, 2009)

1047-51-167 **John C. Hart*** (jhc@cs.uiuc.edu), Department of Computer Science, Siebel Center, 201 N. Goodwin, Urbana, IL 61801. *It's Nice To See This Stuff Actually Used For Something.* Preliminary report.

The title quotes John Milnor's comment after I nervously gave an interview talk on Morse theory and its application in computer graphics. In the 1930s Marston Morse invented a method for determining the shape of a manifold from the critical points of a smooth, generic real valued function. A generation later, Raoul Bott, and his students took Morse's methods into the realm of infinite dimensional manifolds, well beyond the practical. Milnor wrote the definitive text accessible to graduate students. Another generation later, the ideas reached computer graphics. With Milnor's quote as encouragement, I'll survey some applications of Morse theory to computer graphics, including isosurface triangulation, surface flattening, quad meshing, illustration and the topology of the space of light in a scene. (Received January 27, 2009)

1047-51-168 **Ulises Cervantes-Pimentel*** (ulises@wolfram.com), 100 Trade Center Drive, Champaign, IL 61802. *Mathematical Modelling and Visualization with Mathematica.* Preliminary report.

The construction of high quality geometric surfaces for mathematical analysis involves techniques from diverse areas, such as computational geometry and precise symbolic and numerical computations. Mathematica provides a computational system where it is possible to combine in a highly effective way the construction of complex geometric shapes driven by multiple symbolic and numerical algorithms such as: boundary representations, adaptive mesh generation, surface simplification, offset curves, mesh overlays, surface-surface intersections, constrained triangulations, algebraic implicit surfaces, arbitrary precision evaluation and automatic streamlines placements. For the visualization of arbitrary functions and data, these features provide a tool for the automatic modeling and visualization of mathematical properties such as piecewise continuous functions, discontinuities, branch cuts, vector fields properties. In this presentation, several examples of this integration will be presented which will show how, from the visualization perspective; Mathematica is an environment for the creation with a minimum

amount of effort of high quality visualizations to be used by experts as well as casual users in areas such as education, art, scientific visualization and exploration. (Received January 27, 2009)

1047-51-172 **Kasra Rafi*** (kasra.rafi@gmail.com), Dept. of Mathematics, 5734 S. University Avenue, Chicago, IL 60637, and **Moon Duchin** and **Christopher Leininger**. *A compactification for the space of singular Euclidean metrics on a surface.*

Let F(S) be the space of singular Euclidean metrics of area one on a surface S. We provide an embedding of F(S) into the space of geodesic currents on S. This is similar to Bonahon's embedding of Teichmuller space into the space of geodesic currents; the length of a closed curve in a given singular flat metric is equal to the intersection number of this curve with the corresponding geodesic current. The closure of the image of this embedding is a compact set. We also give a description of the boundary at infinity. (Joint work with Moon Duchin and Chris Leininger.) (Received January 27, 2009)

1047-51-287 **Thomas F. Banchoff*** (tfb@cs.brown.edu), Department of Mathematics, 151 Thayer St, Providence, RI 2912, and **Michael Schwarz**. *Interactive Geometry Illustrations for Teaching, Research, and Publication.* Preliminary report.

This report highlights collaborative modification of our demonstration software for producing quality illustrations, both static and dynamic. Static examples include illustrations for all the 3-D topics in Marvin Greenberg's book, "Euclidean and Non-Euclidean Geometry" and the multivariable calculus text by Jon Rogawski at UCLA. Examples of dynamic illustrations include multivariable calculus worksheets (with Michael May), applets for differential geometry and physics (with Steve Lovett) and "Interactive Geometry and Critical Points" in the Electronic Journal of Mathematics and Technology. (Received January 30, 2009)

1047-51-288 **Stuart Levy*** (slevy@ncsa.uiuc.edu), 1205 West Clark Street, Urbana, IL 61801, and **William Davis**. *Partiview in the Cube.* Preliminary report.

The interactive data visualization tool used at the Hayden Planetarium Rose Center to explore the Digital Universe, is now available in Syzygy. Static and animated data visualization can now display 2D and 3D polygonal models in the Cube and CAVE virtual environments. Hitherto, Partiview has been chiefly used to visualize large astronomical data sets. We seek mathematical applications of this versatile visualization tool. (Received February 02, 2009)

1047-51-302 **Jing Tao*** (jingtao@math.uic.edu), 3425 W Drummond Place, 2B, Chicago, IL 60647. *Linear bound for the length of a conjugating element in the mapping class group.*

Given two conjugate mapping classes f and g, we produce a conjugating element ω such that $|\omega| \leq K(|f| + |g|)$, where $|\cdot|$ denotes the word metric with respect to a fixed generating set, and K is a constant depending only on the generating set. As a consequence, the conjugacy problem for mapping class groups is exponentially bounded. (Received January 31, 2009)

1047-51-349 **Anna B Lenzhen*** (alenzhen@umich.edu) and **Rafi Kasra**. *Quasi-convexity of balls in Teichmueller space.*

We show that extremal length along a Teichmueller geodesic is a quasi-convex function of time. We conclude that a ball in Teichmueller space is quasi-convex. (Received February 02, 2009)

1047-51-437 **David A Herron*** (david.herron@math.uc.edu), Department of Mathematics, P O Box 210025, Cincinnati, OH 45221. *Uniform Metric Spaces and Pointed Gromov-Hausdorff Distance.*

We establish Väisälä's tangent space characterization for uniformity in the doubling metric space setting. (Received February 03, 2009)

1047-51-438 **David A Herron*** (david.herron@math.uc.edu), Department of Mathematics, P O Box 210025, Cincinnati, OH 45221. *Pointed Gromov-Hausdorff Distance.* Preliminary report.

In this expository talk we recall the Gromov-Hausdorff distance for pointed metric spaces. We explain how convergence with respect to this distance is equivalent to notions appearing in current literature. We present a construction for pointed limits and explain how this provides a straightforward proof of Gromov's compactness theorem in this setting. (Received February 03, 2009)

53 ► Differential geometry

1047-53-37 **Michael Munn*** (mikemunn@gmail.com), 310 W14th St, Apt. 3C, New York, NY 10014.
Volume growth and the topology of manifolds with nonnegative Ricci curvature.

Let M^n be a complete, open Riemannian manifold with $\mathrm{Ric} \geq 0$. In 1994, Grigori Perelman showed that there exists a constant $\delta_n > 0$, depending only on the dimension of the manifold, such that if the volume growth satisfies $\alpha_M := \lim_{r\to\infty} \frac{\mathrm{Vol}(B_p(r))}{\omega_n r^n} \geq 1-\delta_n$, then M^n is contractible. Here we employ the techniques of Perelman to find specific lower bounds for the volume growth, $\alpha(k,n)$, depending only on k and n, which guarantee the individual k-homotopy group of M^n is trivial.

In addition, we extend these results to the setting of metric measure spaces Y which can be realized as the pointed metric measure limit of a sequence $\{(M_i^n, p_i)\}$ of complete, open connected Riemannian manifolds with $\mathrm{Ric}_{M_i} \geq 0$, provided the limit space Y satisfies the same lower bounds on volume growth, i.e. $\alpha_Y > \alpha(k,n)$. (Received December 09, 2008)

1047-53-53 **S. T. Stephen Yau*** (yau@uic.edu), Department of MSCS, UIC, SEO Rm 322, M/C 249, 851 S. Morgan Street, Chicago, IL 60607, **Rong Du** (rdu2@uic.edu), Department of MSCS, UIC, SEO Rm 322, M/C 249, 851 S. Morgan Street, Chicago, IL 60607, and **Yun Gao** (gaoyunmath@uic.edu), Department of MSCS, UIC, SEO Rm 322, M/C 249, 851 S. Morgan Street, Chicago, IL 60607. *EXPLICIT CONSTRUCTION OF MODULI SPACE OF BOUNDED COMPLETE REINHARDT DOMAINS IN C^n AND HILBERT 14th PROBLEMS.*

We shall find a complete set of biholomorphic invariants of complete Reinhardt domains in C^n. This complete set of biholomorphic invariants is used to give explicit construction of moduli space of complete Reinhardt domains in C^n. We shall also discuss the role of the Hilbert 14th problem in the construction of numerical biholomorphic invariants of complete Reinhardt domains in C^n. (Received January 05, 2009)

1047-53-66 **Keith Burns*** (burns@math.northwestern.edu), Department of Mathematics, Northwestern University, Evanston, IL 60208, and **Benjamin Schmidt** (bischmid@uchicago.edu), Department of Mathematics, University of Chicago, Chicago, IL 60637. *Conjugate points and non injectivity of the exponential map.*

It is well known that if $v \in T_pM$ is a vector such that p and $q = \exp_p(v)$ are conjugate along the geodesic tangent to v, then $\exp_p$ is non injective in any neighbourhood of v. This means one can find geodesics starting at p with initial tangent vectors v' and v'' close to v that intersect close to q.

Ben Schmidt and I have sharpened this result by showing that can always choose one of the vectors v' and v'' to be v. (Received January 12, 2009)

1047-53-67 **Igor Belegradek***, School of Mathematics, Georgia Tech, Atlanta, GA 30332-0160, and **Slawomir Kwasik** and **Reinhard Schultz**. *On uniqueness and non-uniqueness of souls.* Preliminary report.

Very little is known about the moduli space of complete non-negatively curved metrics on an open manifold. In the talk I will focus on metrics with souls of codimension one and two. There the geometry is quite rigid, yet the moduli space may be disconnected. In studying these matters one is quickly led to nontrivial problems from higher-dimensional topology, and most of the talk will have strong topological flavor. (Received January 12, 2009)

1047-53-80 **Satyaki Dutta** and **Mohammad Javaheri*** (Mohammad.Javaheri@trincoll.edu), Department of Mathematics, Trinity College, 300 Summit Street, Hartford, CT 06106. *Rigidity of conformally compact manifolds with the round sphere as the conformal infinity.*

We prove that under a lower bound on the Ricci curvature and an asymptotic assumption on the scalar curvature, a complete conformally compact manifold whose conformal boundary is the round sphere has to be the hyperbolic space. It generalizes a previous result of Anderson which deals with the rigidity of AHE manifolds. (Received January 16, 2009)

1047-53-95 **Casey Douglas*** (cjd@rice.edu), Math Department – MS 136, Rice University, 6100 S. Main St., Houston, TX 77005. *Perturbed, Genus One Scherk Surfaces and Their Limits.*

The singly periodic, genus one helicoid is conjectured to be the limit of a one parameter family of doubly periodic minimal surfaces referred to as Perturbed Genus One Scherk Surfaces. Using elementary elliptic function theory, we show that such surfaces exist, solving a two dimensional period problem by perturbing a one dimensional

problem. Using flat structures and Teichmuller-theoretic techniques, we then verify the conjecture. (Received January 20, 2009)

1047-53-120 **Fernando Galaz-Garcia*** (galazg@math.umd.edu). *On nonnegatively curved low-dimensional fixed point homogeneous Riemannian manifolds.*

Let G be a compact Lie group acting isometrically on a compact Riemannian manifold M with nonempty fixed point set M^G. We say that M is *fixed point homogeneous* if G acts transitively on a normal sphere to some component of M^G. Fixed point homogeneous manifolds with positive sectional curvature have been completely classified. We will discuss the structure of fixed point homogeneous Riemannian manifolds with nonnegative curvature and their classification in low dimensions. (Received January 23, 2009)

1047-53-128 **J. Cao** (cao.7@nd.edu), Mathematics department, Notre Dame, IN 46556, and **Jian Ge*** (jge@nd.edu), Mathematics department, Notre Dame, IN 46556. *A new proof to Perelman's collapsing theorem for geometrization of 3-manifolds.* Preliminary report.

We will use an observation of Kasten Grove together with Perelman's convexity lemma to provide a simplified proof of Perelman's collapsing theorem of 3-manifold.

Theorem 1 (Perelman's Collapsing Theorem). Suppose that $\{(M^3_\cdot, g^\alpha_{ij})\}_{\alpha\in\mathbb{Z}}$ is a sequence of compact oriented Riemannian manifolds, closed or with convex incompressible tori boundary, and $\omega^\alpha \to 0$. Assume that

(1) for each point $x \in M^3_\alpha$ there exists a radius $\rho = \rho^\alpha(x), 0 < \rho < 1$, not exceeding the diameter of the manifold, such that the ball $B_{g^\alpha}(x,\rho)$ in the metric g^α_{ij} has volume at most $\omega^\alpha\rho^3$ and sectional curvatures of g^α_{ij} at least $-\rho^{-2}$;

(2) each component of the boundary of M^α has diameter at most ω^α and has a topological trivial collar of length one, where the sectional curvatures are between $(-1/4-\epsilon)$ and $(-1/4+\epsilon)$

Then, for sufficiently large α, M^3_α is diffeomorphic to a graph-manifold. (Received January 24, 2009)

1047-53-150 **Alexander Nabutovsky*** (alex@math.toronto.edu), Department of Mathematics, 40 St. George st., University of Toronto, Toronto, Ontario M5P2X7, Canada. *Effective universal coverings and their applications.* Preliminary report.

I will explain the construction of "effective universal coverings" and outline some of their applications in Riemannian geometry. (Received January 26, 2009)

1047-53-160 **Chia-Yen Tsai*** (ctsai6@uiuc.edu), 1409 W. Green Street, Urbana, IL 61801. *Asymptotics of pseudo-Anosov dilatations.*

In the talk, we will discuss the asymptotic behavior of least pseudo-Anosov dilatations when we vary genus and the number of marked points of a surface. (Received January 27, 2009)

1047-53-164 **Regina Rotman*** (rina@math.toronto.edu), Department of Mathematics, University of Toronto, 40 St. George street, Toronto, Ontario M5S 2E4, Canada. *Short geodesic loops on complete Riemannian manifolds.* Preliminary report.

I will talk about diameter and volume upper bounds for the length of geodesic loops on complete Riemannian manifolds. In particular, I will talk about the following result obtained jointly with A. Nabutovsky: At each point p of a closed Riemannian manifold M of dimension n and diameter d there exist at least k distinct geodesic loops based at p of length $\leq 100nk^2d$. I will also show that on any complete Riemannian manifold of a finite volume there exists a geodesic loop of an arbitrarily small length. (Received January 27, 2009)

1047-53-182 **David Dumas*** (ddumas@math.uic.edu), University of Illinois at Chicago, 851 S. Morgan St., Chicago, IL 60607. *Epstein surfaces, trees, and bubbles.* Preliminary report.

We will discuss a construction of Epstein that starts with a conformal metric on a domain in $\mathbb{C}$ and produces a locally convex surface in 3-dimensional hyperbolic space. By applying this construction to singular Euclidean metrics and analyzing the geometry of the Epstein surface, we obtain new results about the holonomy representations of $\mathbb{CP}^1$ structures on Riemann surfaces.

Specifically, near a finite set of points, the surface has "bubbles" of large area, while everywhere else it approximates a geodesic lamination. This lamination can be used to determine the limit $\mathbb{R}$-tree of a divergent sequence of holonomy representations. (Received January 28, 2009)

1047-53-186 **Bing-Long Chen** and **Xiao-Yong Fu*** (mcsfxy@mail.sysu.edu.cn), Guangzhou, Guangdong 510275, Peoples Rep of China, and **Le Yin** and **Xi-Ping Zhu**. *Yau's Conjecture on holomorphic functions of polynomial growth.*

In order to generalize the classical uniformization theorem to higher dimensions , Yau proposed to study the space of holomorphic functions of polynomial growth on complete noncompact Kahler manifold with nonnegative holomorphic bisectional curvature. In particular, it was asked if the dimension of the space of holomorphic functions of polynomial growth is bounded from above by the dimension of the corresponding space of polynomials on complex Euclidean space, with equality if and only if the manifold is holomorphically isometric to complex Euclidean space. In a joint work with Prof. Xi-Ping Zhu, Bing-Long Chen and Le Yin, we answer the above question affirmatively and give sharp dimension estimates when the manifold is not of maximal volume growth or has positive Ricci curvature somewhere. Our work is inspired by that of Lei Ni. (Received January 28, 2009)

1047-53-200 **Zhongmin Shen*** (zshen@math.iupui.edu), Department of Mathematical Sciences, IUPUI, 402 N Blackford Street, Indianapolis, IN 46202. *Projectively Flat Metrics.*

A metric on a domain in Euclidean space is said to be projectively flat if its geodesics are straight lines. The Beltrami theorem says that a Riemannian metric is locally projectively flat if and only if it is of constant sectional curvature. The notion of sectional curvature can be extended to general regular metrics — Finsler metrics. However, the Beltrami theorem is no longer true for Finsler metrics. There are projectively flat metrics of non-constant flag curvature and there are non-projectively flat metrics of constant flag curvature. In this talk, I will talk about projectively flat metrics of constant flag curvature. (Received January 28, 2009)

1047-53-202 **Ivan C Sterling*** (isterling@smcm.edu), Mathematics and Computer Science Department, St Mary's College of Maryland, St Mary's City, MD 20686-3001. *Visualizing Pseudo-Spherical Cone Points.* Preliminary report.

We study symmetries of pseudospherical surfaces (ps-surfaces) in $\mathbb{R}^3$ via the loop group method developed by Sacharov-Shabot , Terng-Uhlenbeck and Toda. These are surfaces with Gauss curvature $K = -1$. We are particularly interested in examples of ps-surfaces of non-finite type. A rather complete investigation of ps-surfaces of finite-type is Melko-Sterling in 1990. In particular we find the $K = -1$ analogues of CMC-umbilics which has been a long-standing hurdle in the effort to find non-finite type examples of ps-surfaces. Computer visualization played an integral role in the eventual theoretical discovery of these new and promising examples. (Received February 02, 2009)

1047-53-253 **Igor G Nikolaev*** (inik@math.uiuc.edu), University of Illinois at Urbana-Champaign, 273 Altgeld Hall, 1409 West Green Street, Urbana, IL 61801. *Quasilinearization, Euler's inequality and Aleksandrov's curvature.*

This is a joint work with I.D. Berg. We characterize Aleksandrov $\Re_0$ domains (also known as CAT (0) spaces) by introducing a *quasilinearization* for an abstract metric space via the notion of the quadrilateral cosine, cosq, and by employing an analogy between quasilinearization and some characteristic properties of inner product spaces. One of our main results states that a geodesically connected metric space $(\mathcal{M}, \rho)$ is an $\Re_0$ domain if and only if, for every quadruple of points $\{A, B, C, D\} \subset \mathcal{M}$, the following metric analogue of Euler's inequality (also known as Enflo's 2-roundness condition) holds: $AC^2 + BD^2 \leq AB^2 + BC^2 + CD^2 + AD^2$. In particular, our results give a complete solution to the Gromov curvature problem in the context of metric spaces of non-positive curvature. (Received January 29, 2009)

1047-53-271 **Bruce M Solomon*** (solomon@indiana.edu), Math Department, Indiana University, Bloomington, IN 47405. *Compact convex central cross-sections make surfaces quadric.* Preliminary report.

In 1918, Blaschke showed that when the planar cross-sections of a convex surface $S \subset \mathbf{R}^3$ are all centrally symmetric, S must be quadric. His argument, though short, was purely local, and required convexity of S in an essential way. We prove a complementary—and fundamentally global—analogue:

Suppose a complete smooth surface $S \subset \mathbf{R}^3$ has two properties:

- *It cuts some plane transversally along a strictly convex loop.*
- *All strictly convex cuts of this type have central symmetry.*

Then S is either quadric, or S is the cylinder over a centrally symmetric oval.

As an application, we derive the existence of skew-loops—loops having no pair of parallel tangent lines—on all negatively curved tubes except the hyperboloid, which has none. (Received January 30, 2009)

1047-53-279 **Zhou Zhang*** (zhangou@umich.edu), 2145 Medford Road, #20, Ann Arbor, MI 48104. *Scalar Curvature Behavior of Kähler-Ricci Flow.*

In this talk, we discuss general behavior of scalar curvature along Kähler-Ricci flow over a closed manifold. This can be considered as a test for the more geometric picture of the flow metric. (Received January 30, 2009)

1047-53-294 **Peter B Shalen*** (shalen@math.uic.edu), Dept. of Math., Stat. and CS (M/C 249), University of Illinois at Chicago, 851 S. Morgan St., Chicago, IL, IL 60657. *Margulis numbers and trace fields.*

I will describe interactions between the quantitative geometry of a closed, orientable hyperbolic 3-manifold M and its trace field K. Here are some consequences of the general method:

(A) Assume that (1) M is non-Haken and (2) $H_1(M; Z_p)$ is trivial for $p = 2$, 3 and 7. If the trace field of M is quadratic then 0.395 is a Margulis number for M. If the trace field is cubic then 0.3 is a Margulis number for M.

(B) If K is any number field, then for all but finitely many closed, orientable hyperbolic 3-manifolds M which satisfy (1) and (2) and have trace field K, the number 0.183 is a Margulis number for M.

(C) If K is any number field, there is a real number ϵ with $0 < \epsilon \leq 0.3$, having the following property. Let M be any closed hyperbolic 3-manifold which satisfies (1) and (2) and has trace field K. Then about every primitive closed geodesic in M having length $l < \epsilon$ there is an embedded tube having radius $R(l)$, where $R(l)$ is an explicitly defined function such that $\sinh^2 R(l)$ is asymptotic to $(.01869...)/l$. (Received January 31, 2009)

1047-53-296 **Mohammad Ghomi*** (ghomi@math.gatech.edu), School of Mathematics, Georgia Tech, Atlanta, GA 30332, and **Robert E Greene**, Department of Mathematics, UCLA, Los Angeles, CA 90095. *Relative isometric embeddings of Riemannian manifolds.*

We prove the existence of C^1 isometric embeddings, and C^∞ approximate isometric embeddings, of Riemannian manifolds into Euclidean space with prescribed values in a neighborhood of a point. (Received January 31, 2009)

1047-53-299 **Chris Connell*** (connell@indiana.edu), Bloomington, IN , and **Zhenyu Li**. *Leafwise entropy rigidity for foliations.*

We prove an entropy rigidity statement for general foliated maps $f : M \to N$ between compact foliated spaces in the sense of Besson, Courtois and Gallot. In particular, we establish an iso-entropic inequality with respect to a transverse quasi-invariant measure which is optimal when almost every leaf of M is locally symmetric. We give some applications of this as well, and indicate how it relates to the entropy rigidity conjecture for higher rank spaces. This is joint work with Zhenyu Li. (Received January 31, 2009)

1047-53-321 **Oguz C. Durumeric*** (odurumer@math.uiowa.edu), Department of Mathematics, Mac Lean Hall, University of Iowa, Iowa City, IA 52242. *Nonuniform Thickness.*

We investigate nonuniform tubular neighborhoods of submanifolds of the Euclidean space. The motivation comes from determining the ideal/tight shapes of large molecules such as DNA with nonuniform structure. The main tool of our approach is the analysis of weighted distance functions. The (differentiable) normal injectivity radius and the (uniform) thickness formula fail to explain some new phenomena arising from nonconstant weight functions. Different notions of injectivity radii and focal radii are introduced to investigate singular but injective exponential maps. If the submanifold is a union of disjoint closed curves, we obtained quantitative results and some rigidity earlier. In that case, all singularities within almost injectivity radius are of unique type and classified to be horizontal collapses. This suffices to prove a nonuniform thickness formula for curves in all cases, which generalizes the one in the uniform case. In the higher dimensions, the generalized thickness formula still holds on an open and dense subset of the weight functions. For the remaining cases, the thickness formula becomes a series of inequalities. (Received February 01, 2009)

1047-53-327 **Stefan Wenger*** (wenger@math.uic.edu), Department of Mathematics, University of Illinois at Chicago, 851 S Morgan Street, Chicago, IL 60607. *Compactness for manifolds with bounded volume and diameter.*

Gromov's compactness theorem for metric spaces asserts that every uniformly compact sequence of metric spaces has a subsequence which converges in the Gromov-Hausdorff sense to a compact metric space. This theorem has been of great importance in Riemannian and metric geometry, but also other fields. I will show in this talk that if one replaces the Hausdorff distance appearing in Gromov's theorem by the flat distance then every sequence of oriented k-dimensional Riemannian manifolds with a uniform bound on diameter and volume has a subsequence which converges in this new distance to a countably k-rectifiable metric space. In general, such a sequence does not have a subsequence which converges with respect to the Gromov-Hausdorff distance. The

new distance mentioned above was first introduced and studied by Christina Sormani and myself. (Received February 01, 2009)

1047-53-352 **Kanghai Tan*** (tankanghai2000@yahoo.com.cn), Nanjing, Jiangsu 210094, Peoples Rep of China. *Convexity in sub-Riemannian Geometry and Its Applications.*

We studied a notion of convexity in the setting of sub-Riemanian geometry. We will show some interesting applications in several complex variables, in particular in CR geometry. (Received February 02, 2009)

1047-53-357 **Xiaodong Wang*** (xwang@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Boundary effects and rigidity on compact manifolds with nonnegative or positive scalar curvature.*

I will start with the work of Shi and Tam in which they show how the positive mass theorem can be used to study the boundary effect on compact manifolds with nonnegative scalar curvature. I will present some variations and generalizations. Then I will discuss the positive scalar curvature case and joint work with Fengbo Hang on rigidity results assuming positive Ricci curvature. (Received February 02, 2009)

1047-53-405 **Jeremy Wong*** (jwong@math.uga.edu), Department of Mathematics, University of Georgia, 1023 D.W. Brooks, Athens, GA 30602. *Collapsing manifolds-with-boundary.* Preliminary report.

We will discuss the appearance of a lower Alexandrov curvature bound for the limit of a sequence of manifolds-with-boundary, themselves having no lower Alexandrov curvature bound. In the process, we introduce a natural generalization of the notion of submetry between metric spaces. (Received February 02, 2009)

54 ► General topology

1047-54-420 **Lucas Sabalka*** (sabalka@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, SUNY, Binghamton, NY 13902-6000, and **Jerry Kaminker** (kaminker@math.ucdavis.edu), Department of Mathematics, University of California, Davis, Davis, CA 95616. *Generalized expanders.* Preliminary report.

Tessera and Ostrovskii have independently introduced a generalized notion of expander in terms of probability measures on metric spaces. In joint work with Jerry Kaminker, we analyze certain classes of these generalized expanders. In this context we study, among other results, the obstruction to being able to uniformly embed a metric space into a Hadamard manifold. (Received February 02, 2009)

55 ► Algebraic topology

1047-55-3 **Jacob Lurie***, Massachusetts Institute of Technology. *On the classification of topological field theories.*

In 1980's, Atiyah introduced a mathematical definition for the notion of a topological quantum field theory (TQFT). In this lecture, I will review Atiyah's definition and explain the motivation for considering the more elaborate notion of an extended TQFT. I will then explain the Baez-Dolan cobordism hypothesis, which provides a very conceptual classification of extended TQFTs.. (Received May 27, 2008)

1047-55-175 **Matthew Ando*** (mando@uiuc.edu), Department of Mathematics, University of Illinois, 1409 W Green St, Urbana, IL 61801, and **Andrew Blumberg**, **David Gepner** and **Hisham Sati**. *Twisted Umkehr maps.*

Minasian-Moore and Witten proposed that D-brane charges take their values in K-theory. Freed and Witten studied the case that the D-brane charge takes its value in twisted K-theory. We locate this twisted K-theory construction in stable homotopy theory, which enables us to describe the analogue for elliptic cohomology. Motivated by a suggestion of Wang, we explain that a direct analogue of the Freed-Witten argument suggests that M-brane charges may take their values in twisted elliptic cohomology. (Received January 27, 2009)

57 ► Manifolds and cell complexes

1047-57-30 **Joseph Maher*** (maher@math.okstate.edu), 401 Mathematical Sciences, Stillwater, OK 74074. *Asymptotics for pseudo-Anosovs in the Teichmüller lattice.*

Given a point in Teichmüller space, we call the orbit of the point under the mapping class group a Teichmüller lattice. We show that the asymptotic growth rate of the number of pseudo-Anosov lattice points in a ball of radius r is the same as the asymptotic growth rate of the total number of lattice points in the ball of radius r. (Received December 07, 2008)

1047-57-72 **Aaron D Magid*** (magid@umich.edu), 2495 Packard Rd., Apt. X, Ann Arbor, MI 48104. *The Local Topology of Deformation Spaces of Kleinian Surface Groups.*

For any closed surface S, the deformation space $AH(S)$ is the space of all marked hyperbolic 3-manifolds homotopy equivalent to S. After reviewing some of the classical results that describe topology of the interior of $AH(S)$, we will show that for any surface S of genus at least 2, there are points on the boundary where $AH(S)$ is not locally connected. This is a generalization of Ken Bromberg's result that the space of Kleinian punctured torus groups is not locally connected. (Received January 13, 2009)

1047-57-78 **J Scott Carter*** (carter@jaguar1.usouthal.edu), Department of Mathematics and Statistics, Mobile, AL 36688. *An Explicit Eversion of the 2-sphere.*

Several excellent eversions exist in the literature. Many of these are constructed by a clever observation: Outside-In depends on the belt trick; the optiverse depends on perturbing an energy functional; the Froissart-Morin eversion depends on the symmetry at the quadruple point. In this talk, I will illustrate an eversion that I constructed with Sarah Gelsinger, a former graduate student, using only the movie moves of C., Saito, and Reiger. It explicitly involves considerations about the fold set of the projection into the plane, and it is asymmetric at the quadruple point.

Its advantage is that each step is described as a movie of immersed curves while successive steps differ by a unique codimension 1 singularity. The critical set, double point set, fold set, etc are all describe explicitly. It renders itself as one of the more simple eversions in that the fold set is an annulus and at any stage fewer than 4 cusps appear in the projection. (Received February 02, 2009)

1047-57-94 **Christopher Martin Judge*** (cjudeg@indiana.edu), Department of Mathematics, Indiana University, Rawles Hall, Bloomington, IN 47401, and **S. Allen Broughton** (allen.broughton@rose-hulman.edu), Department of Mathematics, Rose-Hulman Institute of Technology, 5500 Wabash Ave., Terre Haute, IN 47803. *Rigid conics and Teichmueller discs.*

A holomorphic quadratic differential q determines a flat metric on the surface with zeros removed. Cylinders and immersions of interiors of ellipses are examples of immersed conics. The set of immersed conics whose frontiers meet at least 5 zeros may be regarded as the vertex set of a graph. Roughly speaking, two conics are adjacent iff they share four zeros. We show that this graph is connected, and we exhibit a precise relationship between the automorphism group of the weighted graph and the affine self-mappings of the surface. This work is a byproduct of our study of certain tessellations of the hyperbolic plane naturally associated to each translation surface by Veech and, later and independently, Bowman. (Received January 20, 2009)

1047-57-185 **Nathan Broaddus*** (broaddus@math.uchicago.edu), Department of Mathematics, 5734 S University Ave, Chicago, IL 60637, and **Benson Farb** and **Andrew Putman**. *Title: The Casson invariant and the word metric on the Torelli group.*

We bound the value of the Casson invariant of any integral homology 3-sphere M by a constant times the distance-squared to the identity, measured in any word metric on the Torelli group $\mathcal{I}$, of the element of $\mathcal{I}$ associated to any Heegaard splitting of M. We construct examples which show this bound is asymptotically sharp. (Received January 28, 2009)

1047-57-291 **Richard Canary*** (canary@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, and **Peter Storm** (canary@umich.edu), Department of Mathematics, University of Pennsylvania, Philadelphia, PA 19104. *Moduli spaces of hyperbolic manifolds.* Preliminary report.

We will discuss the topology of moduli spaces of unmarked hyperbolic 3-manifolds of a fixed homotopy type. This space often fails to be Hausdorff, and sometimes even fails to be T_1.

Our moduli space arises as the quotient of the more often studied space AH(M) of marked hyperbolic 3-manifolds homotopy equivalent to a fixed compact 3-manifold M under the action of the outer automorphism group of the fundamental group of M. (Received January 31, 2009)

1047-57-316 **Marc Culler*** (culler@math.uic.edu), MSCS Department (M/C 249), University of Illinois at Chicago, 851 S. Morgan St., Chicago, IL 60607-7045, and **Peter B. Shalen**. *Four-free groups and hyperbolic geometry.*

We give new information about the geometry of closed, orientable hyperbolic 3-manifolds with 4-free fundamental group. As an application we show that such a manifold has volume greater than 3.44. This is in turn used to show that if M is a closed orientable hyperbolic 3-manifold such that vol$M < 3.44$, then $H_1(M; Z/2Z)$ has dimension at most 7. (Received February 01, 2009)

1047-57-387 **Ben Klaff*** (klaff@math.uic.edu) and **Peter B. Shalen**. *Modular character varieties of knots.*

I'll discuss some of the ways in which the number theory and algebraic geometry of the SL(2)-character variety (over a finite field) of a hyperbolic knot can be used to draw conclusions about the algebraic structure of the knot group and the coverings of the knot. (Received February 02, 2009)

58 ► Global analysis, analysis on manifolds

1047-58-51 **Harold Gerard Donnelly*** (hgd@math.purdue.edu), 150 North University Street, West Lafayette, IN 47907. *Positive curvature and eigenfunctions of the Laplacian.*

Let M be a noncompact Riemannian manifold with a complete metric of nonnegative Ricci curvature. We review recent positive and negative results concerning the existence of square integrable eigenfunctions for the Laplacian of M. (Received January 05, 2009)

1047-58-133 **Christina Sormani*** (sormanic@member.ams.org) and **Stefan Wenger**. *A New Convergence for Riemannian Manifolds.*

We define a new distance between oriented Riemannian manifolds that we call the *intrinsic flat distance* based upon Ambrosio-Kirchheim's theory of integral currents on metric spaces. Limits of sequence of manifolds with a uniform upper bound on their volume and diameter are countably H^m rectifiable metric spaces with an orientation and multiplicity that we call *integral current spaces.*

In general the Gromov-Hausdorff and intrinsic flat limits do not agree. However, we show that they do agree when the sequence of manifolds has nonnegative Ricci curvature and a uniform lower bound on volume and also when the sequence of manifolds has a uniform linear local geometric contractibility function. These results are proven using work of Greene-Petersen, Gromov, Cheeger-Colding and Perelman.

We present an example of three manifolds with positive scalar curvature constructed using Gromov-Lawson connected sums attaching two standard spheres with increasingly many tiny wormholes which converges in the Gromov Hausdorff sense to the standard three sphere but in the intrinsic flat sense to the 0 space due to the cancelling orientation of the two spheres.

This is joint work with S. Wenger. See
http://comet.lehman.cuny.edu/sormani/intrinsicflat.html (Received January 24, 2009)

1047-58-138 **David H Hamilton*** (davidhhamilton@mac.com), 1077 30th St NW Apt 503, Washington, DC 20007. *Explicit Wild Reflections.*

Many years ago Bing proved the existence of a reflection $F : \mathbb{R}^3 \to \mathbb{R}^3$ with fundamental domains which were not simply connected, disproving the Smith Conjecture. Bing asked for a graphic example. Following an idea of Dennis Sullivan we give an example explicit enough to illustrate. We note that if is NOT "bi-hölder" (in the usual definition), contradicting our own conjecture. By our general theory no wild reflection can be quasiconformal. (Received January 25, 2009)

1047-58-305 **Bobo Hua*** (071018011@fudan.edu.cn), No.220, Handan Road, Shanghai, Shanghai 200433, Peoples Rep of China. *Liouville-type Theorem in Alexandrov Spaces.*

In this talk, we will present the proof of Poincaré Inequality for Alexandrov space with non-negative Ricci curvature in the sense of Kuwae and Shioya. Then we get the Liouville theorem for non-negative harmonic function and Hölder regularity by Nash-Moser iteration. (Received February 01, 2009)

60 ► Probability theory and stochastic processes

1047-60-74 **Gregory Budzban*** (gbudzban@math.siu.edu), Department of Mathematics, Southern Illinois University, Carbondale, IL 62901, and **Goran Hognas**. *The Minimal Ideal of the Semigroup of Probability Measures on a Compact Semigroup with applications to Random Measures.*

Given a compact semigroup S, it is well known that the set P(S) of probability measures on S is itself a compact semigroup under convolution. In this presentation, the structure of the minimal ideal of P(S) will be determined. This structure theorem will then be utilized to find conditions for the convergence in distribution of products of independent random variables taking their values in P(S). (Received January 14, 2009)

1047-60-419 **Paul Balister*** (pbalistr@memphis.edu), Department of Math Sciences, University of Memphis, Memphis, TN 38152, and **Béla Bollobás** and **Mark Walters**. *Random transceiver networks.*

Consider randomly scattered radio transceivers in R^d, each of which can transmit signals to all transceivers in a given randomly chosen region about itself. If a signal is retransmitted by every transceiver that receives it, under what circumstances will a signal propagate to a large distance from its starting point? Put more formally, place points $\{x_i\}$ in R^d according to a Poisson process with intensity 1. Then, independently for each x_i, choose a bounded region A_{x_i} from some fixed distribution and let G be the random directed graph with vertex set $\{x_i\}$ and edges $x_i\vec{x}_j$ whenever $x_j \in x_i + A_{x_i}$. We show that for any $\eta > 0$, G will almost surely have an infinite directed path provided the expected number of transceivers that can receive a signal directly from x_i is at least $1 + \eta$, and the regions $x_i + A_{x_i}$ do not overlap too much (in a sense that we shall make precise). (Received February 02, 2009)

62 ► Statistics

1047-62-15 **Amir H Assadi*** (ahassadi@wisc.edu), Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706, **Hesam Torabi Dashti** (dashti@khayam.ut.ac.ir), Department of Computer Science, Tehran University, Tehran, Iran, and **Fatemeh Miri** (ipmars@yahoo.com), Department of Computer Science, Tehran University, Tehran, Iran. *Combinatorial Local-to-Global PCA and an Application to Statistical Analysis of the Human Auditory Evoked Response.* Preliminary report.

Humans are continually subject to diverse stimuli from their environment. The brain must process massive neuronal spike data distributed among local and large-scale neuronal networks, while avoiding waste of resources except for a small fraction of the "relevant stimuli". How is such a complex task performed? This article develops a combinatorial refinement of the senior author's earlier fMRI research to formulate a model for nonlinear feature extraction by the brain in auditory attention. Our model is illustrated using electrophysiology data from human patient brains with normal hearing. The data consists of the evoked response potentials collected by 8x8 intracranial sensor grids. The global features are extracted via combinatorial optimization of the nonlinear features "glued together" from local information, in turn computed by variants of PCA applied to subsets of data from topographically organized sensor channels. The biological prior knowledge is expressed as an information-theoretic heuristic argument for sparse coding, supported by numerous neurophysiology experiments. The outcome is a model for extraction of the dynamic brain patterns carrying significant information during auditory attention. (Received November 02, 2008)

1047-62-21 **Paul Kidwell*** (kidwell@stat.purdue.edu), West Lafayette, IN 47907, **Yi Mao** (ymao@ecn.puedue.edu), West Lafayette, IN 47907, and **Guy Lebanon** (lebanon@cc.gatech.edu), Atlanta, GA 30332. *Non-Parametric Modeling and Survey Design for Censored Preference Data.*

Statistical models on full and partial rankings of n items are often of limited practical use for large n due to computational consideration. We explore the use of non-parametric models for partially ranked data and derive computationally efficient procedures for their use for large n. The derivations are largely possible through combinatorial and algebraic manipulations based on the lattice of partial rankings. A bias-variance analysis and an experimental study demonstrate the applicability of the proposed method. This estimation procedure finds a ready application to survey question design via selection of the best partial ranking form for eliciting subject preferences. By allowing the question form to vary over partial rankings a smoothing is performed which may reduce both MSE and the cognitive burden associated with providing full rankings. A decision

theoretic formulation is then possible in the space of survey cost and optimal estimator form with respect to MSE. (Received November 20, 2008)

1047-62-24 **Helene M Massam*** (massamh@yorku.ca), Department of Mathematics and Statistics, York University, 4700 Keele Street, Toronto, Ontario M3J 1P3. *Alternative parametrizations and reference priors for decomposable discrete graphical models.*

For a given discrete decomposable graphical model, we identify several alternative parametrizations, and construct the corresponding reference priors for suitable groupings of the parameters. Specifically, assuming that the cliques of the graph are arranged in a perfect order, the parameters we consider are conditional probabilities of clique-residuals given separators, as well as generalized log-odds-ratios.

We also consider a parametrization associated to a collection of variables representing a cut for the statistical model. The reference priors we obtain do not depend on the order of the groupings, belong to a conjugate family, and are proper. (Received November 25, 2008)

1047-62-27 **Ahmad Saeid Yasamin*** (syasamin@samsi.info), 19 TW Alexander Drive, Durham, NC 27709. *MAXIMAL INVARIANTS OVER SYMMETRIC CONES.*

In this talk, we consider testing hypotheses for a statistical model, where the observation space and the parameter space are both a symmetric cone. In particular, we derive the joint density of the eigenvalues of the gen- eralized Wishart distribution, and propose a test statistic analog to that of classical multivariate statistics for testing homoscedasticity of covariance pa- rameter. This test extends Bartlett's test, which tests the equality of variances across a normally distributed population, to all types of Wishart distributions: namely, real, complex, quaternion, Lorentz and octonion types. Our main approach to these problems, based on the analysis of symmetric cones and Jordan algebras, is to decompose the probability distribution of the parametric model to the product of the transformed measure, under a maxi- mal invariant statistic, and a quotient measure. We prove that the densities of these two measures, with respect to the restrictions of Lebesgue measures, are indeed functions of the eigenvalues of the Wishart distribution. (Received December 04, 2008)

1047-62-44 **Thomas Klein*** (tpklein@ma.tum.de), Zentrum Mathematik, TU München, Boltzmannstr. 3, D-85748 Garching, Germany. *Kiefer-complete classes of designs for cubic mixture models.*

Mixture experiments are experiments in which the experimental conditions are relative proportions of ingredients. In a second-degree regression model for such experiments, Draper et al. (2000) found the class of weighted centroid designs to be essentially complete with respect to the Kiefer ordering, a preorder based on the idea of measuring the amount of information on the unknown model parameters. Essential completeness means that for any given design there is a weighted centroid design at least as good as the given design, relative to the Kiefer ordering.

One natural question arising from Draper et al. is whether a similar result can be reproduced for cubic models. Understanding symmetry and Loewner comparability of moment matrices is essential. Andersson's (1975) result on invariant symmetric matrices proves valuable in characterizing Loewner comparability of invariant designs. Further, we classify so-called orbit designs in order to derive design improvement lemmas leading to completeness theorems. Our approach extends Draper et al.'s (2000) results from quadratic to cubic models and provides a more systematic method for identifying complete classes of designs.

(Partly joint work with Steen Andersson, Indiana University) (Received December 18, 2008)

1047-62-49 **Seth Sullivant*** (smsulli2@ncsu.edu), Department of Mathematics, North Carolina State University, Box 8205, Raleigh, NC 27695, and **Kelli Talaska**. *Trek separation for Gaussian graphical models.*

Gaussian graphical models are semi-algebraic subsets of the cone of positive definite covariance matrices. Submatrices with low rank correspond to generalizations of conditional independence constraints on collections of random variables. We give a precise graph-theoretic characterization of when submatrices of the covariance matrix have small rank in directed and undirected graphical models. Our new trek separation criterion generalizes the familiar d-separation criterion. Proofs are based on the trek rule, the resulting matrix factorizations, and classical theorems of algebraic combinatorics on the expansions of determinants of path polynomials. (Received January 04, 2009)

1047-62-50 **Akimichi Takemura*** (takemura@stat.t.u-tokyo.ac.jp) and **Hisayuki Hara** (hara@tmi.t.u-tokyo.ac.jp). *Some results on connectivity of fibers with a subset of a Markov basis.*

Markov basis defined by Diaconis and Sturmfels (1998) is very useful for performing conditional tests of discrete exponential family models. Markov basis allows us to construct a connected Markov chain for arbitrary values of the sufficient statistics. However when a data set is given, we are interested in connecting the particular fiber (i.e. the conditional sample space, where the data set belongs) only. Then there is a possiblity that a proper subset of a Markov basis is sufficient for the connectivity of the fiber. In general it is a hard problem to decide whether a particular subset connects the fiber or not. In this talk we present some recent results on connectivity of specific fibers for several important statistical models. (Received January 04, 2009)

1047-62-115 **Steen Andersson*** (standers@indiana.edu), Department of Statistics, Indiana University, 309 N. Park Ave, Bloomington, IN 47405, and **Thomas Klein**. *On Riesz and Wishart Distributions associated with decomposable undirected graphs.*

Classical Wishart distributions on the open convex cones of positive definite matrices and their fundamental features are extended to generalized Riesz and Wishart distributions associated with decomposable undirected graphs using the basic theory of exponential families. The families of these distributions are parameterized by their expectations/natural parameter and multivariate shape parameter and have a non-trivial overlap with the generalized Wishart distributions defined in Andersson and Wojnar (2004a,b). This work also extends the Wishart distributions of type I in Letac and Massam (2007) and, more importantly, presents an alternative point of view.

Andersson, S.A. and Wojnar, G.G. (2004a). Wishart distributions on homogeneous cones. Journal of Theoretical Probability, 17, No. 4, 781-818.

Andersson, S.A. and Wojnar, G.G. (2004b). The Wishart distributions on homogeneous cones. Acta et Commentationes Universitatis Tartuensis de Mathematica, 8, 3-62.

Letac, G. and Massam, H. (2007). Wishart distributions For decomposable graphs. Ann. Statist. 35, 1278-1323. (Received January 23, 2009)

1047-62-178 **Craig M. Browne*** (seeemmbee@aol.com), 172 Paradise Meadow Loop, Edgewood, NM 87015. *A More Accurate Pooled Standard Deviation.* Preliminary report.

The inaccuracy of the existing method for esimating a pooled standard deviation from summary data - counts (Nj), means (Muj), and standard deviations (Sigj) - of the populations (j) being pooled is well known. This paper derives another method to calculate a pooled standard deviation from the summary data (Nj, Muj, & Sigj) which appears to more accurately represent the standard deviation that might be calulated if the raw data were pooled. Because raw data may often be costly to acquire, if not unavailable, this other method, if it is mathematically sound, might benefit medical, biological, pharmaceutical, physical, chemical, materials, demographic, and other researchers. (Received January 28, 2009)

1047-62-188 **Mathias Drton** and **Han Xiao***, Department of Statistics, 5734 S. University Ave, Chicago, IL 60637. *Smoothness of Gaussian conditional independence models.*

Conditional independence in a multivariate normal/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. Following prior work by Lnenicka and Matus (2007), we present exhaustive computations of the singular loci of models involving up to four random variables. (Received January 28, 2009)

1047-62-203 **Sanjay Chaudhuri*** (sanjay@stat.nus.edu.sg), 6 Science Drive 2, Singapore, 117546, Singapore. *Qualitative inequalities for squared partial correlations of a Gaussian random vector.*

We show that if a covariance matrix of a Gaussian random vector satisfies certain conditional independence relationships, suitable squared partial correlations can be ordered qualitatively. Such orderings are invariant over all covariance matrices satisfying the restrictive conditional independencies. These conditional independence relations can be represented by several class of Graphical Markov models. Thus these results and the knowledge of the structure of the underlying graph may be combined to postulate path based rules for comparing the degree of conditional dependence among the variables appearing in the model. We shall also discuss

some algebraic properties of the postulated ordering. Potential applications of these results occur in deriving new information inequalities for Gaussian vectors, model selection, evidence gathering, methodologies for efficient searching and in various models in hydrology, among others. (Received January 29, 2009)

68 ► Computer science

1047-68-8 **Arman Shokrollahi*** (armanshokrollahi@khayam.ut.ac.ir), Ramanujan Institute for Advanced Study in Mat, University of Madras, Chennai 600 005, Tamil Nadu, India, Chennai, India. *Some useful operations and their applications.*

The calculations including arithmetics of the intervals are developing more and more. Hereby, they are integrated in softwares used by medical teams (medicine dosage, blood circulation simulation, . . .) or even in automobiles softwares. As those softwares are often used for calculations in real time, tragic consequences can occur after a mistake, that happened during Ariane 5 first flight in 1995 or during the first flight of the antimissile Patroit in 1991.

The basic operations used in the arithmetic of the intervals are not very interesting on a mathematics point of view.

We would like to build some operations that would be more appropriate to mathematics and to draw a link with other operations. What has to be respected to the fact that the results of the operations on the intervals have to include all the results of the operations applied on any couple of reals contained in the interval.

Our main goal is applying these operations to the problems of linear and non-linear programming. Moreover, building a normed space allows to envisage a direct differential calculation but this one requires the study of infinitely small intervals and associated arithmetics. (Received October 14, 2008)

76 ► Fluid mechanics

1047-76-140 **Susan Friedlander*** (susanfri@usc.edu), Math Dept, 3620 S. Vermont, USC, Los Angeles, CA 90089, and **Natasa Pavlovic** and **Vlad Vicol**. *Nonlinear instability for the critically disipative quasi-geostrophic equation.*

We prove that linear instability implies nonlinear instability in the energy norm for the critically dissipative quasi-geostrophic equation. (Received January 25, 2009)

1047-76-404 **James P Kelliher*** (kelliher@math.ucr.edu), University of California, Riverside, Math Dept, Surge 253, 900 University Ave., Riverside, CA 92507. *Vanishing viscosity and the accumulation of vorticity on the boundary.*

We say that the vanishing viscosity limit holds in the classical sense if the velocity for a solution to the Navier-Stokes equations converges in the energy norm uniformly in time to the velocity for a solution to the Euler equations as the viscosity vanishes. I will show that, for a bounded domain in dimension 2 or higher, the vanishing viscosity limit holds in the classical sense if and only if a vortex sheet forms on the boundary. (Received February 02, 2009)

1047-76-466 **Elaine Cozzi*** (ecozzi@andrew.cmu.edu). *Vanishing viscosity in the plane for nondecaying initial vorticity.*

Assuming that initial vorticity is bounded in the plane and does not necessarily decay at infinity, we show that the unique solutions of the Navier-Stokes equations converge uniformly to the unique solution of the Euler equations as viscosity approaches zero. (Received February 03, 2009)

1047-76-488 **Roman Shvydkoy*** (shvydkoy@math.uic.edu), 851 S Morgan St, MC 249, Department of Math Stat and Comp Sci, Chicago, IL 60607. *C^*-algebra approach to spectral problems arising in hydrodynamics.*

We present a construction based on the Antonevich isomorphism theorem which allows to describe the Fredholm spectrum of the 3D Euler equation in terms of the Sacker-Sell spectrum of a finite dimensional dynamical system. Furthermore we will prove that that the Fredholm spectrum is rotationally invariant and has no circular gaps. As a consequence, it consists of a single annulus. This construction applies to a variety of other equations that appear in ideal fluid mechanics, such as SQG, Euler with Coriolis, etc. This is joint work with Y. Latushkin. (Received February 03, 2009)

81 ► Quantum theory

1047-81-102 **Dmytro Shklyarov*** (shklyarov@math.ksu.edu), Department of Mathematics, Kansas State University, 138 Cardwell Hall, Manhattan, KS 66506-2602. *Representation Theory and Equivariant Topological Field Theories.*

The goal of the talk is to point out a relationship between categorical representations of finite groups and equivariant topological field theories. (Received January 31, 2009)

1047-81-447 **Jared C Bronski*** (jared@math.uiuc.edu), 1409 W Green St, Urbana, IL 61801, and **Zoi Rapti**, 1409 W Green St, Urbana, IL 61801. *Defect Eigenvalues and Diophantine Approximation.*

We consider an eigenvalue problem in one dimension with a potential consisting of a periodic piece together with a compactly supported defect. This defect may introduce an asymptotic phase shift in the periodic potential. We give a Maslov index argument for counting the number of point eigenvalues which are created in gaps in the essential spectrum. We establish upper and lower bounds which differ by at most two, and agree in many cases. As a consequence we prove the following result: the number of eigenvalues in large numbered gaps depends on the solvability of a certain Diophantine approximation problem. If this problem has no solutions then all but a finite number of gaps contain exactly one eigenvalue. If this problem has solutions then there exists a sequence of gaps (related to the solutions of the Diophantine approximation problem) which may contain up to 2 eigenvalues. This has implications for the Korteweg-DeVries equation with initial data which is asymptotically periodic. (Received February 03, 2009)

00 ► General

1048-00-167 **Kyle Thompson*** (kathomp2@ncsu.edu). *On Commuting Involutions of SL(n, k).*
Pairs of commuting involutions of an algebraic group play an important role in the study of such groups as well as in the study of symmetric spaces and their representations. For algebraic groups over algebraically closed fields, pairs of commuting involutions were classified by Helminck, and over the real numbers some results were obtained by Matsuki. In this talk we consider a generalization to arbitrary fields, k, of characteristic not 2, and determine the isomorphy classes of pairs of commuting involutions of the special linear group, SL(n, k). (Received February 05, 2009)

1048-00-192 **Jen-Chieh Hsiao*** (jhsiao@math.purdue.edu), 223 Arnold Dr Apt 03, West Lafayette, IN 47906. *Finiteness of Local Cohomology over D on a toric algebra.* Preliminary report.
Let S be a toric algebra over $\mathbb{C}$, and I be an monomial ideal of S. Denote D to be the ring of $\mathbb{C}$-linear differential operators of S. We show that each local cohomology module $H^i_I(S)$ is of finite length over D, generalizing the classical case of a polynomial algebra S. (Received February 06, 2009)

1048-00-207 **Juilee Thakar*** (juilee.thakar@gmail.com), 104 Davey Lab, #167, University Park, PA 16802, and **Timothy Reluga**. *Modeling of the implications of vaccine on the within-host dynamics of the closely related pathogens.* Preliminary report.
We developed within-host models of respiratory infections caused by two human pathogens, namely Bodetella parapertussis and B. pertussis. B. pertussis is a causative agent of whooping cough, a potentially sever childhood disease. Despite widely available vaccines, B. pertussis is still prevalent in the world and is one of the re-emerging diseases. Further more, current vaccines have low efficacy against the closely-related human pathogen B. parapertussis. A series of models was developed to simulate the in vivo dynamics of immune components and bacterial numbers in single and mixed infections and in the presence and absence of B. pertussis vaccine. The model reproduced bacterial numbers and the qualitative dynamics of immune components remarkably well. The model makes quantitative predictions regarding proliferations rates, binding rates and phagocytosis rates in single and mixed infections in agreement with experimental observations. Our research suggests the reasons why B. parapertussis might have a competitive advantage in vaccinated individuals. (Received February 08, 2009)

05 ► Combinatorics

1048-05-16 **Sergey Kitaev**, **Jeffrey Liese**, **Jeffrey Remmel** and **Bruce Sagan*** (sagan@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Rationality, irrationality, and Wilf oequivalence in generalized factor order.*
Let P be a poset and consider the free monoid P^* of all words over P. If $w, w' \in P^*$ then w' is a factor of w if there are words u, v with $w = uw'v$. Define generalized factor order on P^* by letting $u \leq w$ if there is a factor w' of w having the same length as u such that $u \leq_P w'$, where the comparison of u and w' is done componentwise in P. One obtains ordinary factor order by insisting that $u = w'$.

Given $u \in P^*$, we prove that the language $\{w : w \geq u\}$ is accepted by a finite state automaton. If P is finite then it follows that the generating function $F(u) = \sum_{w \geq u} w$ is rational. This is an analogue of a theorem of Björner and Sagan for generalized subword order.

We also consider the case when P is the positive integers so that P^* is the set of compositions. Then one obtains $F(u; t, x)$ by substituting tx^n each time the integer n appears in $F(u)$. We can show that $F(u; t, x)$ is also rational. Words u, v are said to be Wilf equivalent if $F(u; t, x) = F(v; t, x)$ and we can prove various equivalences combinatorially.

Björner found a formula for the Möbius function of ordinary factor order. Using the Pumping Lemma we show that $M(u) = \sum_{w \geq u} |\mu(u, w)|w$ can be irrational. (Received November 20, 2008)

1048-05-18 **Gabor Pataki*** (gabor@unc.edu), Dept of Statistics and Operations Research, Hanes Hall, UNC Chapel Hill, Chapel Hill, NC 27599, and **Mustafa Tural** (tural@email.unc.edu), Dept of Statistics and Operations Research, Hanes Hall, UNC Chapel Hill, Chapel Hill, NC 27599. *Basis reduction, and the complexity of branch-and-bound.*

Branch-and-bound proposed in the 1960s is a classical method to find an integral point in a polyhedron, and more generally, to solve integer programming problems. On the theoretical side, however, it has been deemed hopelessly inefficient: it can take an exponential number of nodes to prove that a simple polyhedron does not contain a lattice point. As a result, theoretically efficient algorithms, such as Lenstra's and Kannan's algorithms, and the Lovasz-Scarf generalized basis reduction method rely on fairly involved techniques.

In this work we show that branch-and-bound is theoretically efficient, if we apply a simple transformation in advance to the constraint matrix which makes the columns short and near orthogonal. We prove that if the coefficients of the problem are drawn from a sufficiently large interval, then for almost all such instances the number of subproblems that need to be enumerated by branch-and-bound is at most one.

Besides providing an analysis of a classical algorithm, our result also extends a theorem of Furst and Kannan on the solvability of subset sum problems. (Received November 27, 2008)

1048-05-25 **Eran Nevo*** (en87@cornell.edu), Dep. of Math - Cornell University, Malott Hall, Ithaca, NY 14853-4201. *On the g-conjecture.*

In 1970 McMullen conjectured a complete characterization of the possible f-vectors of boundary complexes of simplicial polytopes. These numerical conditions were proved in 1980, necessity by Stanley and sufficiency by Billera and Lee, known as the g-theorem.

The proof of necessity shows that the hard-Lefschetz property (decomposition) holds for an appropriate ring associated with the polytope. A major open problem, known as the g-conjecture, is to extend these numerical and algebraic assertions to the larger family of simplicial sphere, and beyond.

We will indicate recent developments on this conjecture, focusing on the following results:

1. (Joint with Martina Kubitzke.) The (numerical) g-conjecture holds for the barycentric subdivision of homology spheres. This follows from the following algebraic result: An 'almost hard-Lefschetz' property holds for the barycentric subdivision of a shellable complex.

2. (Joint with Eric Babson.) If a homology sphere and one of its face links admit the hard-Lefschetz property, then its stellar subdivision at this face admits the hard-Lefschetz property, and hence satisfies the (numerical) g-conjecture. One ingredient in the proof is showing that the hard-Lefschetz property is preserved under the join operation. (Received December 08, 2008)

1048-05-35 **Satyan L Devadoss*** (satyan.devadoss@williams.edu). *Visibility and deformations of associahedra.* Preliminary report.

The associahedron is a convex polytope whose face poset is based on nonintersecting diagonals of a convex polygon. Given an arbitrary simple polygon P, we construct a polytopal complex analogous to the associahedron based on diagonalizations of P. We describe topological properties of this complex, and provide realizations based on secondary polytopes. Moreover, using the visibility graph, a deformation space of polygons is created which encapsulates substructures of the associahedron. (Received December 19, 2008)

1048-05-38 **Alexander Yong*** (ayong@uiuc.edu), 1409 W. Green Street, Urbana, IL 61801, **Hugh Thomas** (hugh@math.unb.ca), Tilley Hall 418, Fredericton, NB E3B 5A3, Canada, and **Ofer Zeitouni** (zeitouni@math.umn.edu), 127 Vincent Hall, 206 Church Street SE, Minneapolis, MN 55455. *Longest strictly increasing subsequences and the Hecke insertion algorithm.*

We define and study the Plancherel-Hecke probability measure on Young diagrams; the Hecke algorithm of [Buch-Kresch-Shimozono-Tamvakis-Yong '06] is interpreted as a polynomial-time exact sampling algorithm for this measure. Using the results of [Thomas-Yong '07] on jeu de taquin for increasing tableaux, a symmetry property of the Hecke algorithm is proved, in terms of longest strictly increasing/decreasing subsequences of words. This parallels classical theorems of [Schensted '61] and of [Knuth '70], respectively, on the Schensted and Robinson-Schensted-Knuth algorithms. We investigate, and conjecture about, the limit typical shape of the measure, in analogy with work of [Vershik-Kerov '77], [Logan-Shepp '77] and others on the "longest increasing subsequence problem" for permutations. We also include a related extension of [Aldous-Diaconis '99] on patience sorting. (Received January 05, 2009)

1048-05-55 **Isabella Novik*** (novik@math.washington.edu), Department of Mathematics, University of Washington, Box 354350, Seattle, WA 98195-4350, and **Edward B Swartz** (ebs22@cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853-4201. *A variety of recent results concerning f-vectors of manifolds.*

We discuss several recent results on the face numbers of simplicial manifolds. For the class of manifolds with polytopal links these include the proof of (1) Kalai's manifold g-conjecture and (2) Kuhnel's upper bound conjecture on the Betti numbers of manifolds. (Received January 18, 2009)

1048-05-56 **Isabella Novik** and **Edward Swartz*** (ebs@math.cornell.edu), Malott Hall, Dept. of Mathematics, Cornell University, Ithaca, NY 14853. *f-vectors of manifolds with boundary.*

We report on a few recent results on the face numbers of simplicial manifolds with boundary, among them a version of Dehn-Sommerville relations and a new rigidity inequality that strengthens Kalai's 1987 result. This ultimately relates to the study of face numbers of spaces with singularities, and if time permits, we will sketch some of the recent advances on that front. (Received January 18, 2009)

1048-05-61 **Gregg Musiker**, **Ralf Schiffler** and **Lauren Williams*** (lauren@math.harvard.edu), Department of Mathematics, Harvard University, 1 Oxford Street, Cambridge, MA 02138. *Positivity results for cluster algebras.*

We give formulas for cluster variables with principal coefficients for a large class of cluster algebras coming from surfaces. In particular, this proves the positivity conjecture of Fomin and Zelevinsky for cluster algebras of classical types. (Received January 20, 2009)

1048-05-67 **Thomas Lam*** (tfylam@math.harvard.edu), Harvard University, Dept. of Mathematics, Cambridge, MA 02138, and **Pavlo Pylyavskyy**. *Total positivity for loop groups.*

I will discuss a theory of total positivity for the formal loop group $GL_n(\mathbb{C}((t)))$. For the case $n = 1$, the theory reduces to the classical theory of totally positive functions and the Edrei-Thoma theorem. For $n > 1$, new phenomena occur, including a notation of "braid limits" for Coxeter groups. (Received January 21, 2009)

1048-05-81 **Alexander Yong*** (ayong@illinois.edu), 1409 W. Green Street, Urbana, IL 61801, and **Hugh Thomas** (hugh@math.unb.ca). *Equivariant (K-Theory) jeu de taquin for Grassmannians.* Preliminary report.

We introduce the combinatorial notions of *equivariant standard Young tableaux* and *equivariant jeu de taquin*. The latter extends the influential ideas of M. P. Schützenberger from the 1970s. These are applied to construct a new Littlewood-Richardson rule for equivariant cohomology of Grassmannians, complementing earlier rules of [A. Knutson-T. Tao, '01], [V. Kreiman '05] and [A. Molev '07]. Our rule has the feature that it is manifestly positive in the sense of [W. Graham '01]. Moreover, we will explain a conjectural extension to equivariant K-theory that, in addition, manifests the more general positivity of [D. Anderson-S. Griffeth-E. Miller '08]. This provides an alternative rule to a 2004 conjecture of A. Knutson-R. Vakil. (Received January 26, 2009)

1048-05-84 **Hisayuki Hara**, Department of Technology Management for Innov, University of Tokyo, Tokyo, Japan, **Akimichi Takemura**, Graduate School of Information Science and Te, University of Tokyo, Tokyo, Japan, and **Ruriko Yoshida*** (ruriko.yoshida@uky.edu), 805A Patterson Office Tower, University of Kentucky, Lexington, KY 40506. *On connectivity of fibers with positive marginals in multiple logistic regression.*

We study Markov bases for conducting exact tests of a multiple logistic regression, where the levels of covariates are equally spaced. In usual application of multiple logistic regression, the sample size is positive for each combination of levels of the covariates. In this case we do not need a whole Markov basis, which guarantees connectivity of all fibers. We first give an explicit Markov basis for multiple Poisson regression. By the Lawrence lifting of this basis, in the case of bivariate logistic regression, we give a simple subset of the Markov basis which connects all fibers with a positive sample size for each combination of levels of covariates. (Received January 26, 2009)

1048-05-85 **Cristian Lenart*** (lenart@albany.edu), Department of Mathematics, State University of New York at Albany, 1400 Washington Avenue, Albany, NY 12222. *Growth diagrams for the Schubert multiplication.*

We present a partial generalization to Schubert calculus on flag varieties of the classical Littlewood-Richardson rule, in its version based on Schützenberger's jeu de taquin. More precisely, we describe certain structure constants expressing the product of a Schubert and a Schur polynomial. We use a generalization of Fomin's growth diagrams (for chains in Young's lattice of partitions) to chains of permutations in the so-called k-Bruhat order. Our work is based on the recent thesis of Beligan, in which he generalizes the classical plactic

structure on words to chains in certain intervals in k-Bruhat order. Potential applications of our work include the generalization of the S_3-symmetric Littlewood-Richardson rule due to Thomas and Yong, which is based on Fomin's growth diagrams. (Received January 26, 2009)

1048-05-105 **Sylvie Corteel**, **Carla Savage** and **Andrew V Sills*** (ASills@GeorgiaSouthern.edu). *A new look at the partition identities of Goellnitz.* Preliminary report.

H. Göllnitz is famous for his discovery of several partition identities of the Rogers-Ramanujan-Schur type. We shall discuss some new q-series connections and partition identities inspired by his work. (Received January 30, 2009)

1048-05-106 **Richard Ehrenborg*** (jrge@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506, and **Margaret Readdy** (readdy@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *The* **cd***-index of Bruhat and balanced graphs.* Preliminary report.

The **cd**-index is a noncommutative polynomial which compactly encodes the flag vector data of an Eulerian poset. There are two major classes of Eulerian poset: face lattices of convex polytopes (and more generally face posets of regular spherical CW-complexes) and intervals of the strong Bruhat order of Coxeter groups. Billera and Brenti have recently introduced the notion of the complete **cd**-index of a Bruhat interval which encodes more information that than the classical **cd**-index of the interval. Motivated by their work, we extend the notion of Bruhat graphs to balanced labeled graphs and prove the existence of the **cd**-index. (Received January 30, 2009)

1048-05-127 **Matthias Beck*** (beck@math.sfsu.edu), Department of Mathematics, San Francisco State University, San Francisco, CA 94132, and **Alan Stapledon**, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Asymptotics of Ehrhart series of Lattice Polytopes.*

If P is a lattice polytope (i.e., P is the convex hull of finitely many integer points in $\mathbf{R}^d$), Ehrhart's theorem asserts that the integer-point counting function $L_P(m) = \#(mP \cap \mathbf{Z}^d)$ is a polynomial in the integer variable m. Equivalently, the generating function $Ehr_P(t) = \sum_{m \geq 0} L_P(m)t^m$ is a rational function of the form $h(t)/(1-t)^{d+1}$; we call $h(t)$ the Ehrhart h-vector of P. We study the behavior of the Ehrhart series $Ehr_{nP}(t) = \sum_{m \geq 0} L_P(nm)t^m$ as n grows; e.g., we can prove that the Ehrhart h-vector of nP is eventually unimodal, where "eventually" only depends on the dimension of P. Our results are general combinatorial theorems about generating functions and can be applied to other settings, e.g., Veronese subrings of graded rings. (Received February 03, 2009)

1048-05-152 **Nicholas A. Loehr*** (nloehr@vt.edu), 460 McBryde Hall, Blacksburg, VA 24061-0123, and **Jeffrey Remmel**. *Rook-by-Rook Rook Theory.*

Rook theory is a branch of combinatorics in which one counts placements of non-attacking rooks on generalized chessboards. A well-known theorem of Goldman, Joichi, and White provides a simple criterion for deciding when two boards of partition shape are "rook-equivalent." We will describe a bijective proof of this theorem in which non-attacking rook placements on one board are bijectively matched to placements on the other board. Our construction is based on the famed Involution Principle of Garsia and Milne. Another application of the Involution Principle produces bijective proofs of hit-equivalence. (Received February 05, 2009)

1048-05-169 **Ezra Miller*** (ezra@math.duke.edu). *Topological Cohen–Macaulay criteria for monomial ideals.*

Scattered over the past few years have been several occurrences of simplicial complexes whose topological behavior characterize the Cohen-Macaulay property for quotients of polynomial rings by arbitrary (not necessarily squarefree) monomial ideals. The purpose of this survey is to gather the developments and provide direct combinatorial connections between them. (Received February 05, 2009)

1048-05-186 **Ryan K Therkelsen*** (rtherke@ncsu.edu), North Carolina State University, Department of Mathematics, Box 8205, Raleigh, NC 27695-8205. *An introduction to (coloured) constant composition designs.*

A (v, k, r)-design is a collection of k-element subsets (blocks) of a v-element set X, such that every element of X is contained in exactly r blocks. Such objects are often represented by a $(0, 1)$-incidence matrix. We introduce a new notion of design, called "k-coloured constant composition" designs. These designs are a class of multi-set designs satisfying the additional property that the set of all rows, and the set of all columns, of the corresponding incidence matrix are of constant composition. We establish the necessary and sufficient

existence conditions on the parameters of a constant composition 1-design and follow with algebraic and geometric examples. In particular, we show that for certain ring-linear codes, minimum (homogeneous) weight codewords induce constant composition designs. We also show how projective geometries over finite rings can yield constant composition designs. (Received February 06, 2009)

1048-05-187 **Benjamin J Braun*** (braun@ms.uky.edu), Dept of Mathematics, University of Kentucky, Lexington, KY 40506, and **Richard Ehrenborg** (jrge@ms.uky.edu), Dept of Mathematics, University of Kentucky, Lexington, KY 40506. *The Complex of Non-Crossing Diagonals of a Polygon.*

Given a convex polygon P with n vertices, it is well known that there is an associated simplicial complex T(P) with vertices given by diagonals in P and facets given by triangulations of P. A theorem of C. Lee states that T(P) can be realized as the boundary complex of a polytope called the associahedron. We will investigate the topology of T(P) for non-convex polygons using tools from discrete Morse theory. This work is joint with Richard Ehrenborg. (Received February 06, 2009)

1048-05-191 **Mark D Haiman***, Department of Mathematics, 970 Evans Hall, University of California, Berkeley, CA 94720-3840, and **Li-Chung Chen**. *k-Schur functions, graded S_n modules, and the flag variety.* Preliminary report.

I'll give an overview of some conjectures of mine, and some theorems and conjectures of my student Li-Chung Chen, which lead to several (conjecturally equivalent) descriptions for a family of q-symmetric functions which we conjecture to include the k-Schur functions of Lascoux, Lapointe and Morse. One description is representation-theoretic, a second is combinatorial, and the third is an explicit formula which comes from a geometric interpretation. The package of conjectures offers a possible explanation for the various positivity properties that k-Schur functions are expected to satisfy. (Received February 06, 2009)

1048-05-198 **J. Haglund*** (jhaglund@math.upenn.edu), **J. Morse** and **M. Zabrocki**. *Hall Littlewood Polynomials and the Nabla Operator from Macdonald Theory.* Preliminary report.

We introduce a conjectured combinatorial description for the monomial expansion of the nabla operator applied to a Hall-Litlewood polynomial. We show how our conjecture contains both the "shuffle conjecture" of Haglund, Haiman, Loehr, Remmel and Ulyanov for the character of diagonal harmonics and a more recent conjecture of Bergeron, Descouens, and Zabrocki (which involves nabla applied to a certain k-Schur function) as special cases. (Received February 08, 2009)

1048-05-202 **John R. Stembridge***, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109-1043. *Admissible W-Graphs and Commuting Cartan Matrices.* Preliminary report.

A W-graph is a weighted directed graph that encodes certain actions of a Coxeter group W or the associated Iwahori-Hecke algebra $H(W)$. It is admissible if it is bipartite and has nonnegative integer edge weights that satisfy a simple symmetry condition. Of particular interest are the admissible W-graphs and $W \times W$-graphs that encode the one-sided and two-sided actions of the standard generators on the Kazhdan-Lusztig basis of $H(W)$, as well as the strongly connected components of these graphs—the latter are the so-called Kazhdan-Lusztig cells.

In this talk, we will report on further progress toward the classification of admissible W-graphs. In particular, we plan to describe the classification of all admissible $W_1 \times W_2$-cells, where W_1 and W_2 both have rank two. This amounts to classifying pairs of simply-laced Cartan matrices of the same rank that commute and satisfy a simple bipartition condition. It turns out that there are 5 infinite families of such Cartan pairs (up to isomorphism), as well as 8 exceptional pairs whose ranks range from 12 to 32. (Received February 08, 2009)

1048-05-213 **Kevin Woods*** (Kevin.Woods@oberlin.edu), Department of Mathematics, Oberlin College, Oberlin, OH 44074. *Combinatorics and Graphical Models: investigating inference functions.*

Graphical models are important statistical tools in a wide variety of fields, ranging from computational biology to probabilistic artificial intelligence. I will discuss the interrelationship between combinatorics – particularly discrete geometry – and inference functions for these models.

I will concentrate on two results. First an applied result whose proof requires combinatorics: even though it seems there should be extraordinarily many inference functions for a given model, there is a bound that is polynomial in the size of the model, for a fixed number of parameters. Second a pure result discovered while exploring inference functions: the probability that m points randomly chosen in $\mathbb{Z}^d$ can be completed to a basis of $\mathbb{Z}^d$ is $1/(\zeta(d)\zeta(d-1)\cdots\zeta(d-m+1))$, where ζ is the Riemann zeta function.

This is joint work with Sergi Elizalde. (Received February 08, 2009)

1048-05-218 **Matjaz Konvalinka*** (matjaz.konvalinka@vanderbilt.edu), 1326 Stevenson Center, Nashville, TN 37240. *MacMahon master theorem in Hecke algebras.*

MacMahon master theorem gives the coefficients of $1/\det(I - tA)$ for a square matrix A and a variable t, and is classically used to prove binomial identities. Goulden and Jackson proved that Jacobi-Trudi determinants of these coefficients give immanants of the matrix. In this talk, we will see how to formulate and prove similar statements in Hecke algebras of Coxeter groups. Most of this is joint work with Mark Skandera. (Received February 09, 2009)

1048-05-239 **John Shareshian*** (shareshi@math.wustl.edu) and **Michelle Wachs** (wachs@math.miami.edu). *Cyclic sieving and permutation statistics.*

I will discuss several examples of triples (G, X, P) that exhibit the cyclic sieving phenomenon of Reiner, Stanton and White, with G a cyclic subgroup of S_n generated by an n-cycle or an $(n-1)$-cycle, X a union of conjugacy classes in S_n on which G acts by conjugation, and P the generating polynomial for the restriction of some permutation statistic to X. (Received February 09, 2009)

1048-05-251 **Chris R. McDaniel*** (mcdaniel@math.umass.edu), Department of Mathematics, University of Massachusetts Amherst, 710 North Pleasant Street, Amherst, MA 01003. *The Strong Lefschetz Property for Co-invariant Rings of Finite Reflection Groups.*

Let W be a finite reflection group and let R_W denote its co-invariant algebra. If W is a Weyl group one can show that R_W has the strong Lefschetz property by appealing to the hard Lefschetz theorem in algebraic geometry. On the other hand, R_W admits a tensor product decomposition and one can show that if the factors in this decomposition have the strong Lefschetz property then so does R_W. We use this approach to give an "elementary" proof (i.e. a proof that does not appeal to algebraic geometry) that R_W has the strong Lefschetz property for reflection groups of classical type. (Received February 09, 2009)

1048-05-254 **David E Speyer*** (speyer@math.mit.edu), Department of Mathematics, Room 2-332, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, and **Pavlo Pylyavskyy** (pavlo@umich.edu) and **Kyle Petersen** (tkpeters@umich.edu). *Non-crossing and non-nesting bases for the coordinate ring of the Grassmannian.*

The classical subject of standard monomial theory is a way of constructing explicit bases for the coordinate rings of Grassmannians and related spaces. I'll explain a new alternative construction of a "non-crossing basis", due to myself, Pavlo Pylyavsky and Kyle Petersen. This basis is related to LeClerc and Zelvinsky's weakly seperated sets and is well suited for computations with cluster algebras and total positivity. (Received February 09, 2009)

1048-05-261 **Velleda Baldoni**, **Nicole Berline**, **Jesús A. De Loera** and **Matthias Köppe*** (mkoeppe@math.ucdavis.edu), University of California, Davis, Department of Mathematics, One Shields Avenue, Davis, CA 95616, and **Michèle Vergne**. *Efficient exact integration of polynomials over polytopes.*

We study the theoretical and practical efficiency of exact integration procedures for polynomial functions over simplices. Exact (and approximate) integration is a hard problem, as we show by relating it to a hard combinatorial optimization problem.

The methods we study are related to Brion's formulas, Barvinok's exponential sums, polarization of polynomials, and also to the polynomial Waring problem that asks to represent a polynomial as a sum of powers of few linear forms. (Received February 09, 2009)

1048-05-290 **Edward E. Allen**, **Miranda C. Marion** and **Gregory S. Warrington*** (gswarrin@uvm.edu), Dept. of Mathematics and Statistics, University of Vermont, 16 Colchester Ave., Burlington, VT 05401. *Bitableau bases for Garsia–Haiman modules of hollow type.*

Garsia-Haiman modules are quotient rings in variables $X_n = \{x_1, x_2, ..., x_n\}$ and $Y_n = \{y_1, y_2, ..., y_n\}$ that generalize the quotient ring $\mathbb{C}[X_n]/I$, where I is the ideal generated by the elementary symmetric polynomials $e_j(X_n)$ for $1 \leq j \leq n$. A bitableau basis for the Garsia-Haiman modules of hollow type is constructed. (Received February 09, 2009)

1048-05-292 **Gregory S. Warrington*** (gswarrin@uvm.edu), Department of Mathematics and Statistics, University of Vermont, 16 Colchester Ave., Burlington, VT 05405. *Computations of type-A Kazhdan-Lusztig polynomials of maximal degree.* Preliminary report.

A Kazhdan-Lusztig polynomial is associated to every pair of permutations x and w in the symmetric group on n letters. The polynomials of maximal possible degree (i.e., those with $\mu(x, w) \neq 0$) play an important role in the

representation theory of this group. In this talk we discuss some experimental results and conjectures regarding these particular polynomials. (Received February 09, 2009)

1048-05-301 **Francesco Brenti*** (brenti@mat.uniroma2.it), Dipartimento di Matematica, Universita' di Roma "Tor Vergata", Via della Ricerca Scientifica, 1, 00133 Roma, RM, Italy. *The Veronese construction, h-vectors, and unimodality.*

We study the transformation that maps the h-vector of a standard graded algebra to that of its r-th Veronese subalgebra. We give an explicit combinatorial description of this transformation, and show that, if r is sufficiently large, then it maps nonnegative vectors to vectors whose generating polynomial has only real zeros. As consequences of these results we obtain that, if r is sufficiently large, then the numerator polynomial of the Hilbert series of the r-th Veronese subalgebra of a standard graded algebra, and the generating polynomial of the f-vector of the r-th edgewise subdivision of a simplicial complex, have only real zeros and are therefore log-concave and unimodal, and the h-vector of the r-th Veronese subalgebra of a Cohen-Macaulay standard graded algebra is componentwise monotonically increasing with r. This is joint work with V. Welker. (Received February 10, 2009)

1048-05-309 **Christine E Heitsch*** (heitsch@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332-0160. *Meanders and RNA Folding.*

A closed meander of order n is a non-self-intersecting closed curve in the plane which crosses a horizontal line at $2n$ points. Meanders occur in a variety of settings from combinatorial models of polymer folding to the Temperley-Lieb algebra, yet the exact meander enumeration problem remains open. Building on results for plane trees and noncrossing partitions motivated by the biology of RNA folding, we prove that meanders are connected under appropriately defined local move transformations. The resulting meander graphs have some interesting characteristics and suggest new approaches to the enumeration question. As we will explain, meanders also relate to the challenging biomathematical problem of comparing different possible folds for an RNA sequence. (Received February 10, 2009)

1048-05-316 **Zongzhu Lin*** (zlin@math.ksu.edu), Division of Mathematical Sciences (1025 N), National Science Fountation, 4201 Wilson Boulevard, Arlington, VA 22230, and **Yi Fang**. *Quivers with anti-involutions.* Preliminary report.

In the talk I will discuss some Lie theoretic properties of quivers with anti-involutions as well as it application to computing DNS sequences in Biology.

In Lie theory, the representations of quivers with anti-involution is related to computing the adjoint orbits of graded Lie algebras or classical types. In computational biology the Chinese postman type of questions will provide an algorithm to build a minimal DNA sequences that possess all genes or given length. (Received February 10, 2009)

1048-05-323 **Peter Paule*** (ppaule@risc.uni-linz.ac.at), Research Institute for Symbolic Computation, (RISC), Johannes Kepler University Linz, A-4040 Linz, Austria. *Broken Diamonds and Partition Congruences.*

The talk begins with partition explorations made possible by Omega, the computer algebra implementation of MacMahon's Partition Analysis developed jointly with G.E. Andrews and A. Riese. Special focus will be put on directed graphs made up of chains of generalized hexagons. From generating functions of such objects one can build infinite families of modular forms giving rise to partition congruences conjectured by G.E. Andrews and the speaker. Proofs have been delivered by M.D. Hirschhorn and J.A. Sellers, and by S.H. Chan. The talk reports on recent work of S. Radu who with the help of computer algebra was able to discover and to prove additional congruence relations. (Received February 10, 2009)

1048-05-330 **Megan Owen*** (maowen@samsi.info), SAMSI, 19 T. W. Alexander Dr., RTP, NC 27709. *Geometry of Cophylogeny.* Preliminary report.

A cophylogeny is a pair of phylogenetic trees satisfying some given conditions. Cophylogeny theory allows us to study two trees with related structure, such as a gene tree and a species tree, without assuming their independence. In this talk, we introduce several spaces of cophylogenies. We also give some combinatorial results about possible cophylogenies, in the case where one tree of the cophylogeny is a host tree and the other is a parasite tree. (Received February 10, 2009)

1048-05-365 **Anders S Buch*** (asbuch@math.rutgers.edu), **Andrew Kresch** and **Harry Tamvakis**.
Quantum Giambelli formulas for symplectic Grassmannians.

The symplectic Grassmannian X = IG(m,2n) is the set of m-dimensional isotropic subspaces in a symplectic vector space of dimension 2n. In joint work with Kresch and Tamvakis, we have proved a Pieri formula for multiplying with the special Schubert classes that generate the (quantum) cohomology ring of X. I will speak about a Giambelli formula that expresses any quantum Schubert class as a polynomial in the special classes. This formula is new also in the ordinary cohomology of X, and interpolates between the Jacobi-Trudi determinant formula known from Grassmannians of type A, and the Pfaffian formula for Schubert classes on the Lagrangian Grassmannian IG(n,2n). (Received February 10, 2009)

1048-05-370 **John Shareshian** and **Michelle L Wachs*** (wachs@math.miami.edu), Department of Mathematics, University of Miami, Coral Gables, FL 33124. *Rees products of posets and lexicographical shellability.* Preliminary report.

The notion of Rees product of posets was introduced by Björner and Welker in their study of connections between poset topology and commutative algebra, and was further studied by Shareshian and Wachs in connection with permutation enumeration. In this paper we apply lexicographical shellability to some specific examples of Rees products in order to further develop the link with permutation enumeration. (Received February 10, 2009)

08 ► General algebraic systems

1048-08-300 **Tim Ridenour*** (tbr4@math.ucr.edu). *Ideals in parabolic subalgebras of simple Lie algebras.*

An ideal in the positive root system R^+ for a simple Lie algebra over $\mathbb{C}$ is a subset $\Psi \subset R^+$ with the property that if $\alpha \in \Psi$ and $\beta \in R^+$ are such that $\alpha + \beta \in R^+$, then $\alpha + \beta \in \Psi$. An abelian ideal in R^+ is an ideal Ψ with the added condition that if $\alpha, \beta \in \Psi$, then $\alpha + \beta \notin R^+$. A well known result due to D. Peterson is that the number of abelian ideals in the positive roots of a simple Lie algebra of rank n is 2^n. In this talk, I will discuss joint results with Dr. Vyjayanthi Chari and RJ Dolbin from the paper *"Ideals in parabolic subalgebras of simple Lie algebras"* which give an efficient proof for Peterson's theorem while also enumerating all abelian ideals in R^+ for any simple $\mathfrak{g}$. Furthermore, I will demonstrate that these ideas can be extended to ideals in parabolic subalgebras for simple Lie algebras. (Received February 10, 2009)

1048-08-320 **Farrah Jackson Chandler*** (fjchandler@mail.ecsu.edu), 1704 Weeksvill Road, Campus Box 951, Elizabeth City, NC 27909. *Classification of k-involutions of $SP(2n, k)$.*

Symmetric spaces defined over a field k of characteristic not 2 are completely characterized by the k-involution of the corresponding reductive group. A first characterization of the isomorphism classes of k-involutions for reductive algebraic groups defined over a field k of characteristic not 2 was given by Helminck in 2000 using 3 invariants. Two of these 3 invariants are difficult to classify. In this paper we consider the group $SP(n, k)$ and give a different and much more detailed characterization of the isomorphism classes of k-involutions for this group. For this we first show that each involution of $SP(n, k)$ is the restriction of an involution of $SL(n, k)$. Next we determine which involutions of $SL(2n, k)$ remain involutions when restricted to $SP(2n, k)$. To complete the classification for a specific base field it remains to determine in how many $SP(2n, k)$-isomorphy classes one $SP(2n, k)$-isomorphy class of such a k-involution of $SL(2n, k)$ splits. (Received February 10, 2009)

11 ► Number theory

1048-11-2 **Raman Parimala***, Emory University, Department of Mathematics, Atlanta, GA.
Arithmetic of linear algebraic groups over two dimensional geometric fields.

The Hasse principle for number fields states that every principal homogeneous space under a semisimple simply connected linear algebraic group defined over a number field has a rational point provided it has a rational point over every completion at real places of the number field. This is a theorem due to Kneser for classical groups (60's), Harder for all exceptional groups of type other than E_8 (60's) and Chernousov for the case E_8 (in the 80's). The Hasse principle implies that principal homogeneous spaces under a semisimple simply connected linear algebraic group defined over a totally imaginary number field have rational points. Already in the 60's, Serre posed a far-reaching generalisation of this conjecture, now known as Conjecture II: every principal homogeneous space under a semisimple simply connected linear algebraic group defined over a perfect field of cohomological dimension 2 has a rational point. Fields of cohomological dimension 2 includes totally imaginary number fields,

p-adic fields and function fields of surfaces over algebraically closed fields. In this talk, we shall trace progress towards this conjecture over the last two decades. (Received April 10, 2008)

1048-11-80 **Claus Schubert*** (claus.schubert@cortland.edu), PO Box 2000, Cortland, NY 13045. *Field Invariants under Real and Nonreal Extensions.* Preliminary report.

Several invariants of a field F related to quadratic forms exhibit similar patterns under real and nonreal field extensions. We will use a construction by Prestel to explain why examples of invariants that drop from infinite to finite when going up nonreal field extensions lead to similar examples of real extensions. Such invariants include $\widetilde{u}(F)$, $\widehat{u}(F)$, $P(F)$ and $\mathrm{st}_r F$. (Received January 26, 2009)

1048-11-117 **Paul J. Truman*** (pt224@exeter.ac.uk), SECAM, Harrison Building, North Park Road, Exeter, Devon EX4 4QF, England. *Hopf-Galois Module Structure Of Some Tamely Ramified Extensions.* Preliminary report.

The use of nonclassical Hopf-Galois structures in the study of the integral Galois module structure of wildly ramified extensions has proven fruitful. For example, Byott has exhibited finite wildly ramified Galois extensions L/K of p-adic fields for which the ring of algebraic integers $\mathfrak{O}_L$ is not a free module over the associated order in the group algebra $K[G]$, but is a free module over the associated order in some nonclassical Hopf-Galois structure admitted by the extension. On the other hand, if L/K is a tamely ramified extension of local or global fields then little is known about the structure of $\mathfrak{O}_L$ over the associated order in any of the nonclassical structures admitted by the extension. We study this problem for certain classes of tamely ramified extensions. (Received February 02, 2009)

1048-11-142 **Donald Adams**, **Rene Ardila**, **David Hannasch**, **Audra Kosh**, **Hanah McCarthy** and **Vadim Ponomarenko*** (vadim@sciences.sdsu.edu), 5500 Campanile Dr., San Diego, CA 92182-7720, and **Ryan Rosenbaum**. *On Matrix Factorization.*

Natural generalizations are presented of commutative semigroup factorization invariants, for noncommutative semigroups. These are computed for several classes of atomic subsemigroups of $M_n(\mathbb{Z})$. (Received February 04, 2009)

1048-11-195 **Griff Elder*** (elder@unomaha.edu), Dept of Math, University of Nebraska at Omaha, Omaha, NE 68182-0243. *Galois scaffolding for Galois module structure.*

A Galois scaffold, in an extension of local fields, is a generalization of a normal basis that behaves well with respect to valuation and is thus useful for addressing questions in Galois module structure. We will describe a Galois scaffold for arbitrarily large elementary abelian p-extensions in characteristic p and present a result (joint with Nigel Byott) where this Galois scaffold is used to determine necessary and sufficient conditions for the ring of integers to be free over the associated order. (Received February 07, 2009)

1048-11-223 **Max-Albert Knus** and **Jean-Pierre Tignol*** (jean-pierre.tignol@uclouvain.be), Departement de mathematique, Universite catholique de Louvain, chemin du cyclotron, 2, 1348 Louvain-la-Neuve, Belgium. *Quadrics over the field with one element.* Preliminary report.

A notion of Clifford algebra is defined for (commutative) etale algebras with involution, and is related to commutative subalgebras of Clifford algebras. The construction can be translated into geometric terms following Tits's ideas on geometry over the field with one element. (Received February 09, 2009)

1048-11-248 **James E Carter*** (carterj@cofc.edu), Department of Mathematics, College of Charleston, 66 George Street, Charleston, SC 29424-0001, and **Cornelius Greither** and **Henri Johnston**. *On the restricted Hilbert-Speiser and Leopoldt properties.*

Let G be a finite abelian group. A number field K is called a Hilbert-Speiser field of type G if for every tame G-Galois extension L/K, the ring of integers $\mathcal{O}_L$ is free as an $\mathcal{O}_K[G]$-module. If $\mathcal{O}_L$ is free over the associated order $\mathcal{A}_{L/K}$ for every G-Galois extension L/K, then K is called a Leopoldt field of type G. It is well-known (and easy to see) that if K is Leopoldt of type G, then K is Hilbert-Speiser of type G. The converse does not hold in general. However, we show that a modified version does hold for many number fields K (in particular, for $K/\mathbb{Q}$ Galois) when $G = C_p$ has prime order. Finally, we show that even the modified converse is false in general, and we give examples which show that the modified converse can hold while the original does not. (Received February 09, 2009)

1048-11-249 **David B. Leep*** (leep@email.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506-0027. *The u-invariant of a function field over Q_p.* Preliminary report.

Last summer Heath-Brown announced some results on solving systems of quadratic forms over Q_p, where Q_p is the field of p-adic numbers. These results can be applied to obtain some results on the u-invariant of a function field over Q_p. This talk will give some details and background to these u-invariant results. (Received February 09, 2009)

1048-11-282 **George J Schaeffer*** (gschaeff@math.berkeley.edu), University of California at Berkeley, Department of Mathematics, 970 Evans Hall, Berkeley, CA 94720. *Factorization in algebraic orders.* Preliminary report.

After reviewing a few recent results in number theory, we offer some interesting consequences for factorization in algebraic orders. In particular, we answer a question of Coykendall in the affirmative—there exist infinitely many quadratic orders which are half-factorial. (Received February 09, 2009)

1048-11-346 **Adam Topaz*** (adamtopaz@gmail.com), Mathematics Department, University of Pennsylvania, 209 South 33rd Street, Philadelphia, PA 19104. *On the Galois Module Structure of Square Classes of Maximal Elementary Abelian 2-Extensions.*

Let E/F be the maximal elementary abelian 2-extension of a field F of characteristic not 2, with Galois group G, and let $J = E^\times/E^{\times 2}$ be the $\mathbb{F}_2G$-module of square classes of the multiplicative group of E. Denote by J_k the k^{th} element in the socle series for J as an $\mathbb{F}_2G$-module. Adem, Gao, Karagueuzian, andInáč determined necessary and sufficient conditions for the existence of an element in J_2 in terms of the existence of elements in J_1 and a class in $H^3(G, \mathbb{F}_2)$ expressed in terms of cup products and the transgression map on $H^1(E, \mathbb{F}_2)^G$. We produce a similar formula for J_k for any $k \geq 1$. (Received February 10, 2009)

1048-11-363 **Bart de Smit*** (desmit@math.leidenuniv.nl), Mathematisch Instituut, Universiteit Leiden, Postbus 9512, 2300RA Leiden, Netherlands. *On the valuation criterion for normal basis generators.* Preliminary report.

We report on progress with the valuation criterion for normal basis generators, which was first conceived by Nigel Byott and Griff Elder (2007). Suppose L/K is Galois extension of local fields which is totally wildly ramified, and let d be the valuation of the different. If L has positive characteristic then the conjugates of any element in L of valuation $-d-1$ form a basis of L as a vector space over K. However in characteristic zero this is not always the case, and the question is to identify when this holds and when it does not. In the lecture we provide an answer in certain cases, including Kummer extensions. This is joint work with Lara Thomas and Mathieu Florence. (Received February 10, 2009)

1048-11-373 **Dustin Reishus*** (reishus@usc.edu), Department of Computer Science, 941 W. 37th Place, Los Angeles, CA 90089-0781. *Number Theory in Chemical Reaction Networks.* Preliminary report.

The atomic hypothesis, that all substances are composed of a unique set of atoms, is central to chemistry. Similarly, the fundamental theorem of arithmetic, that all natural numbers are composed of a unique set of primes, is central to number theory. The law of mass action describes how substances and the atoms they contain interact through time. We hope to use this law to describe how numbers and the primes that compose them interact through time. In particular, we wish to start with the primes and "watch" through time as they combine via multiplication to generate all of the natural numbers. We will consider thermodynamic properties such as temperature, pressure, energy, and entropy in such systems. (Received February 10, 2009)

12 ► Field theory and polynomials

1048-12-62 **Arne Ledet*** (arne.ledet@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409-1042. Spin_7 *as a differential Galois group.* Preliminary report.

We consider Picard-Vessiot extensions in characteristic 0 with differential Galois group Spin_7, with the objective of giving a 'generic' description of such extensions. (Received January 20, 2009)

1048-12-88 **Erich Kaltofen** (kaltofen@math.ncsu.edu), Dept. Mathematics, North Carolina State University, Raleigh, NC 27695-8205, and **George Yuhasz*** (gyuhasz@math.ncsu.edu), Dept. Mathematics, North Carolina State University, Raleigh, NC 27695-8205. *A Fraction Free Matrix Berlekamp/Massey Algorithm.*

We describe a fraction free version of the Matrix Berlekamp/Massey algorithm. The algorithm computes a minimal matrix generator of linearly generated square matrix sequences over an integral domain. The algorithm performs all operations in the integral domain, so all divisions performed are exact. For scalar sequences, the matrix algorithm specializes to a more efficient algorithm than the algorithm currently in the literature. The proof of integrality of the matrix algorithm gives a new proof of integrality for the scalar specialization. (Received January 30, 2009)

1048-12-129 **Oleg Golubitsky**, **Marina Kondratieva** and **Alexey Ovchinnikov*** (aiovchin@math.uic.edu), University of Illinois at Chicago, Department of Mathematics, Statistics, CS, 851 S Morgan St., SEO 322, Chicago, IL 60607, and **Agnes Szanto**. *On effective differential Nullstellensatz.*

We discuss an upper bound for orders of derivatives in the effective differential Nullstellensatz. If one differentiates a system of algebraic PDEs up to this bound, one can effectively test if the original differential system is consistent applying only algebraic elimination to the differentiated system. Seidenberg originally posed this problem in 1956 but no complete solution was given. Our solution is via analysing differential elimination algorithms estimating lengths of dicksonian sequences. (Received February 03, 2009)

1048-12-174 **Erich L Kaltofen** (kaltofen@math.ncsu.edu), Dept. of Mathematics, NC State University, Raleigh, NC 27695-8205, and **Michael P Nehring*** (mpnehrin@math.ncsu.edu), Dept. of Mathematics, NC State University, Raleigh, NC 27695-8205. *Super-sparse black box rational function interpolation.* Preliminary report.

We present a method for interpolating a super-sparse univariate blackbox rational function with rational coefficients, for example, a ratio of binomials or trinomials with very high degree. We input a blackbox rational function, as well as an upper bound on the number of non-zero terms and an upper bound on the degree. The result is found by interpolating the rational function modulo a small prime p, and then applying Dirichlet's Theorem on Arithmetic Progressions to progressively lift the result to larger primes. Eventually we reach a prime number that is larger than the inputted degree bound and we can recover the original function exactly.

Furthermore, the algorithm is oblivious to whether the numerator and denominator have a common factor. The algorithm will recover the sparse form of the rational function, rather than the reduced form, which could be dense.

The algorithm, as presented, is conjectured to be polylogarithmic in the degree, but exponential in the number of terms. Therefore, it is very effective for rational functions with a small number of non-zero terms, such as the ratio of binomials, but it quickly becomes ineffective for a high number of terms. (Received February 05, 2009)

1048-12-176 **David J Saltman*** (saltman@idaccr.org), 805 Bunn Dr, Princeton, NJ 08540. *Ramification in Bad characteristics.* Preliminary report.

Let C be a curve over a $p-$adic field F and $K = F(C)$. For division algebras of exponent prime to p, it is known that index divides the square of the exponent and division algebras of prime degree are cyclic. Both results avoid the prime p because in that case there is no good theory of ramification of Brauer group elements. However, one can try and avoid this obstacle by defining the ramification group of a discrete valued field K with valuation ring R as the quotient of Brauer groups $\mathrm{Br}(K)/\mathrm{Br}(R)$, and then study the functorial properties of this quotient. One is then lead to the complete case and to consider the paper "A generalization of local class field theory by using K groups I" by Kazuya Kato (J Fac Sci Sec. IA 26, 2 303-376). Here we will discuss the progress we have made on this problem using Kato's work. (Received February 06, 2009)

13 ► Commutative rings and algebras

1048-13-49 **Timothy Kohl*** (tkohl@bu.edu), Boston University, Department of Mathematics and Statistics, 111 Cummington Street, Boston, MA 02215. *Regular Permutation Groups of Order mp.*

For Γ a group of order mp for $p > m$ prime, we study the enumeration of the regular permutation subgroups of $Perm(\Gamma)$ normalized by the left regular representation of Γ. Part of our goal is to determine the number and classes of those regular subgroups, as well as to apply this information to the study of Hopf-Galois structures on separable field extensions L/K with $\Gamma = Gal(L/K)$ since these structures are in one-to-one correspondence

with such regular subgroups. This is a generalization of the author's work on the case where $m = 4$. (Received January 12, 2009)

1048-13-89 **Nicolás Botbol** and **Alicia Dickenstein*** (alidick@dm.uba.ar), Dto. de Matemática FCEN, Universidad de Buenos Aires, Ciudad Universitaria, Pab. I, C1428EGA Buenos Aires, Argentina, and **Marc Dohm**. *Matrix representations for toric parametrizations.*

In this paper we show that a surface in $\mathbb{P}^3$ parametrized over a 2-dimensional toric variety T can be represented by a matrix of linear syzygies if the base points are finite in number and form locally a complete intersection. This constitutes a direct generalization of the corresponding result over $\mathbb{P}^2$ established by Busé, Chardin and Jouanolou. Exploiting the sparse structure of the parametrization, we obtain significantly smaller matrices than in the homogeneous case and the method becomes applicable to parametrizations for which it previously failed. We also treat the case $T = \mathbb{P}^1 \times \mathbb{P}^1$ in detail and give numerous examples. (Received January 27, 2009)

1048-13-93 **Alfred Geroldinger*** (alfred.geroldinger@uni-graz.at), Institute for Mathematics and Scientific, Computing, University Graz, Heinrichstr. 36, 8010 Graz, Austria. *On the arithmetic of Krull monoids with finite Davenport constant.*

Let H be a Krull monoid with class group G, $G_P \subset G$ the set of classes containing prime divisors and $\mathsf{D}(G_P)$ the Davenport constant of G_P (this is, the supremum of the lengths of minimal zero-sum sequences over G_P). We show that the finiteness of the Davenport constant implies the Structure Theorem for Sets of Lengths. More precisely, if $\mathsf{D}(G_P) < \infty$, then there exists a constant M - for which we derive an explicit upper bound in terms of $\mathsf{D}(G_P)$ - such that the set of lengths of every element $a \in H$ is an almost arithmetical multiprogression with bound M.

(joint work with D.J. Grynkiewicz). (Received January 28, 2009)

1048-13-95 **Dan Anderson*** (dan-anderson@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242, and **Jonathan Preisser** (jpreisse@math.uiowa.edu), Department of Matheamtics, The University of Iowa, Iowa City, IA 52242. *Factorization in integral domains without identity.*

We discuss various aspects of factorization in integral domains without an identity. A general theme is how factorization properties between a domain D and D[1] are related. (Received January 28, 2009)

1048-13-100 **Uli Walther*** (walther@math.purdue.edu) and **Mathias Schulze**. *Cohen–Macaulayness and computation of Newton graded toric rings.*

Let $H \subseteq ZZ^d$ be a positive semigroup generated by $A \subseteq H$, and let $KK[H]$ be the associated semigroup ring over a field KK. We investigate heredity of the Cohen–Macaulay property from $KK[H]$ to both its A-Newton graded ring and to its face rings. We show by example that neither one inherits in general the Cohen–Macaulay property. On the positive side we show that for every H there exist generating sets A for which the Newton graduation preserves Cohen–Macaulayness. This gives an elementary proof for an important vanishing result on A-hypergeometric Euler–Koszul homology. As a tool for our investigations we discuss an algorithm to compute algorithmically the Newton filtration on a toric ring. (Received January 30, 2009)

1048-13-119 **George Labahn*** (glabahn@uwaterloo.ca), Cheriton School of Computer Science, University of Waterloo, Waterloo, On N2L 2T6, Canada. *Popov Forms of Matrices of Differential Polynomials.* Preliminary report.

Popov normal forms were introduced by V. Popov for matrices of polynomials in the middle 1960s as an alternative to the better known Hermite normal form. They were found to have better properties for use in the context of linear control theory. In this talk we will discuss Popov normal forms for matrices of differential operators. We show their usefulness in the context of systems of linear differential equations and discuss the various computational challenges in computing the forms for arbitrary matrices of differential operators. (Received February 02, 2009)

1048-13-125 **Wolfgang A Schmid*** (wolfgang.schmid@uni-graz.at), Institute of Mathematics and Sci. Computing, University of Graz, Heinrichstrasse 36, 8010 Graz, Styria, Austria. *Higher order class groups and block monoids of Krull monoids.*

The block monoid associated to a Krull monoid (e.g., a Dedekind domain), i.e., the monoid of zero-sum sequences over the subset (of the class group) of classes containing prime divisors, is a frequently used tool in investigations of the arithmetic of Krull monoids.

First, we present extensions of the notions block monoid and class group of a Krull monoid, focusing on the case that the class group is a torsion group. Then, we discuss shortcomings and potential merits of these notions,

both from a conceptual and technical point of view. Finally, we point out some (new) questions in non-unique factorization theory that are motivated by these notions. (Received February 03, 2009)

1048-13-126 **David E. Dobbs** and **Jay Shapiro*** (jshapiro@gmu.edu), Department of Mathematics, George Mason University, Fairfax, VA 22030-4444. *Universal lying-over rings.*

A (commutative unital) ring R is said to satisfy universal lying-over (ULO) if each injective ring homomorphism $R \to T$ satisfies the lying-over property. If R satisfies ULO, then $R = \mathrm{tq}(R)$, the total quotient ring of R. It is shown that a reduced ring satisfying ULO, also satisfies Property A. Conversely, if a ring $R = \mathrm{tq}(R)$ satisfies Property A and each non-minimal prime ideal of R is an intersection of maximal ideals, then R satisfies ULO. If $0 \leq n \leq \infty$, there exists a reduced (resp., non-reduced) n-dimensional ring satisfying ULO. The $A + B$ construction is used to show that if $2 \leq n < \infty$, there exists an n-dimensional reduced ring R such that $R = \mathrm{tq}(R)$, R satisfies Property A, but R does not satisfy ULO. (Received February 04, 2009)

1048-13-134 **Paul-Jean Cahen*** (paul-jean.cahen@univ-cezanne.fr), Bâtiment poincaré, Av. Escadrille Normandie-Niemen, 13397 Marseille, France, and **David E. Dobbs** and **Thomas G. Lucas**. *Pointwise minimal extensions.* Preliminary report.

A ring extension $R \subsetneq T$ is said to be a *pointwise minimal extension* if for each $t \in T$, either $R = R[t]$ or $R \subsetneq R[t]$ is a minimal extension (that is, there is no proper intermediate ring between R and $R[t]$). As for minimal extensions, if $R \subsetneq T$ is a pointwise minimal extension, we have the following properties: 1) either T is integral over R, or R is integrally closed in T. 2) There exists a maximal ideal M of R, the *crucial maximal ideal*, such that $R_N = T_N := T_{R\setminus N}$ for each maximal ideal $N \neq M$ and $R_M \subsetneq T_M$ is a pointwise minimal extension. 3) If $R \subsetneq T$ is a pointwise minimal integral extension, the crucial maximal ideal is the conductor $M = (R : T)$. (Received February 04, 2009)

1048-13-139 **Thomas G. Lucas***, Department of Mathematics & Statistics, University of North Carolina Charlotte, Charlotte, NC 28223, and **Paul-Jean Cahen** and **David E. Dobbs**. *When is a proper simple extension a minimal extension?*

For a pair of rings $R \subsetneq T$, T is said to be a minimal extension of R if there are no rings properly between R and T. A simple characterization of a minimal extension is that $T = R[t]$ for each $t \in T\setminus R$. Most of the previous work on minimal extensions has concentrated on characterizing when T is a minimal extension of R. We shift the focus from considering when $R \subsetneq T$ is a minimal extension to what properties characterize when a simple extension $R \subsetneq R[u]$ is minimal for a particular element $u \in T\setminus R$ (while perhaps $R \subsetneq R[w]$ is not minimal for some other $w \in T\setminus R$). The talk will focus on characterizing when $R \subsetneq R[u]$ is a closed minimal extension, meaning the extension is minimal and R is integrally closed in $R[u]$ (but not necessarily integrally closed in T). (Received February 04, 2009)

1048-13-145 **David E. Dobbs*** (dobbs@math.utk.edu), Department of Mathematics, 1534 Cumberland Avenue, University of Tennessee, Knoxville, TN 37996-0612, and **Jay Shapiro**, Department of Mathematics, George Mason University, Fairfax, VA 22030-4444. *Patching together a minimal overring.* Preliminary report.

Let R be a (commutative integral) domain and M a maximal ideal of R. Let $T(M)$ be a minimal ring extension of R_M. Our basic question is (*): does there exist a (necessarily minimal) ring extension T of R such that $T_M \cong T(M)$ and $T_N = R_N$ canonically for each prime ideal $N \neq M$ of R? The answer to (*) is affirmative if $T(M)$ is not a domain. Several equivalences are given for an affirmative answer to (*) when $T(M)$ is a domain, such as the existence of $a \in T(M) \setminus R_M$ such that M is the radical of $(R :_R a)$. If R is a Prüfer domain that has property (#), the answer to (*) is affirmative for all such data $\{M, T(M)\}$; the converse is false in general but holds for Prüfer domains each of whose maximal ideals is branched. (Received February 04, 2009)

1048-13-148 **Mireille Boutin*** (mboutin@purdue.edu), 465 Northwestern Avenue, West Lafayette, IN 47907. *An effective solution methods for systems of polynomial equations arising in applications.* Preliminary report.

Most polynomial systems of equation that arise in practice are overdetermined. Moreover, the polynomial coefficients are typically noisy and the presence of outliers is not rare. We propose a solution method for such systems of equations and illustrate its effectiveness in solving some systems of 30-100 equations of degree five in two variables arising in an image processing application. This work is in collaboration with Ji Zhang. (Received February 04, 2009)

1048-13-151 **Marco Fontana*** (fontana@mat.uniroma3.it), Largo S. Leonardo Murialdo, 1, Dipartimento di Matematica, Universita degli Studi Roma Tre, 00146 Rome, Italy, and **Gyu Whan Chang**, Department of Mathematics, University of Incheon, Incheon, 402-749, South Korea. *Star and semistar operations in polynomial extensions.* Preliminary report.

The purpose of this talk is to present some of the results contained in two recent papers, joint with G. W. Chang, concerning the problem of extending, in a canonical way, a star or a semistar operation defined on an integral domain D to the polynomial ring $D[X]$. I will also compare different approaches to this problem considered by several authors with various motivations.

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1048-13-157 **Jean-Luc Chabert*** (jean-luc.chabert@u-picardie.fr), LAMFA/UFR de Sciences, Universite de Picardie, 33 rue Saint Leu, 80039 Amiens, France. *On the polynomial closure.* Preliminary report.

Let D be an integral domain with quotient field K. For every subset E of K, the polynomial closure of E with respect to D is known to be the following subset: $\overline{E} = \{x \in K \mid \forall f \in K[x]\ (f(E) \subseteq D \ \Rightarrow\ f(x) \in D)\}$. In general, and in particular for $D = \mathbf{Z}$, this closure is not a topological closure. Nevertheless, in the local case, the question whether the polynomial closure is a topological closure may be raised. If D is a discrete valuation with finite residue field, then the answer is positive. We study here the case where D is any rank-one valuation domain. In particular, we show that $\overline{E}$ contains all the pseudo-limits of the pseudo-convergent sequences of elements of E (a notion introduced and studied by Ostrowski and Kaplansky). (Received February 05, 2009)

1048-13-172 **Alicia Dickenstein** (alidick@dm.uba.ar), **Laura Felicia Matusevich** (laura@math.tamu.edu) and **Ezra Miller*** (ezra@math.duke.edu). *Combinatorics of binomial primary decomposition.*

An explicit lattice point realization is provided for primary components of an arbitrary binomial ideal in characteristic zero, in terms of congruences on finitely generated commutative monoids. The decomposition is derived from a characteristic-free combinatorial description of certain primary components of binomial ideals in affine semigroup rings, namely those associated to faces of the semigroup.

The relevance to biochemical networks occurs via complex-balancing mass action systems. Each strictly positive initial concentration for a given such system lies in the stoichiometric compatibility class of a unique complex-balancing state, which Horn's Global Attractor Conjecture posits should be a global attractor for the interior of its invariant polyhedron. Approaching this conjecture by definition involves dynamics near the boundary. On the other hand, the space of complex-balancing steady states for a mass action system ("toric dynamical system") is the positive zero set of a certain binomial ideal. Although this ideal can be chosen prime for the purpose of restricting to the interior, the natural ideal produced by the dynamics has components at the boundary. Binomial primary decomposition provides a potential tool for analyzing the boundary components. (Received February 09, 2009)

1048-13-227 **David F Anderson*** (anderson@math.utk.edu), Mathematics Department, University of Tennessee, Knoxville, TN 37996. *How Far is an Element or Ideal from Being Prime.* Preliminary report.

We will discuss several invariants which measure how far an element or ideal in an integral domain is from being prime and how far an atomic integral domain is from being a UFD. For elements, this is joint work with Scott Chapman, and for ideals, it is joint work with Ayman Badawi. (Received February 09, 2009)

1048-13-233 **Terri Moore*** (mooret@seattleu.edu). *Syzygy Sequences and Divisor Sequences for Finitely Generated Krull Monoids.*

Let H be a finitely generated Krull monoid. The irreducible elements of H may satisfy some nontrivial relations. To better understand these relations we define two sequences. The *syzygy sequence* is a sequence of monoids, starting with H, where each subsequent monoid is defined by the relations on the irreducible elements of the previous monoid. The *divisor sequence* is a sequence of natural numbers associated to each element of H where the ith term is the number of irreducible elements dividing the ith power of the element.

We show that the syzygy sequence is periodic of period 2 and use this in the study of the divisor sequences. We show that sequences with certain properties are not the divisor sequence for any irreducible element of a Krull monoid whereas sequences with other properties can always be realized as the divisor sequence of an irreducible element in some Krull monoid. (Received February 09, 2009)

1048-13-238 **Robert G Underwood*** (runderwood@fsu.edu). *Hopf-Galois module structure of graded rings.* Preliminary report.

Let H be an R-Hopf algebra, and let S be a Galois H-extension of R where S is a graded ring. Let $\mathcal{F}$ be a coherent G-sheaf on $X = \operatorname{Proj} S$. We discuss the structure of $\bigoplus_{n\geq 0} \Gamma(X, \mathcal{F}(n))$ as an H-module. (Received February 09, 2009)

1048-13-266 **Bruce M Olberding*** (olberdin@nmsu.edu), Department of Mathematical Sciences, Las Cruces, NM 88011. *Intersections of valuation overrings of two-dimensional Noetherian domains.* Preliminary report.

Viewing integrally closed overrings of two-dimensional Noetherian domains as intersections of valuation overrings, we look at some of the possible ways these rings can be represented by such intersections. For example, we are interested in conditions in which "few" valuation rings are needed to represent the ring, such as when these intersections are irredundant, or when the resulting ring is a Prüfer domain. (Received February 09, 2009)

1048-13-267 **Amanda Hagen Matson*** (Amanda.Matson@gmail.com), 302 South Street Apt 301, Morris, MN 56267. *Existence of Rings of Finite Rank n as well as Further Explorations into the n-generator property.*

For any positive integer n, there is a subring of $\mathbb{Z}[2^{\frac{1}{n}}]$ that is of finite rank n but is not of finite rank $n-1$. The presenter will introduce this subring along with any theorems or lemmata required to support the preceding claim. If time permits, the presenter will look at relations between Noetherian rings and rings of finite rank as well as how field extensions affect the n-generator property. (Received February 09, 2009)

1048-13-269 **K Alan Loper*** (lopera@math.ohio-state.edu), 1179 University Drive, Newark, OH 43055. *Generalized rings of integer-valued polynomials.* Preliminary report.

Let Z be the ring of integers and Q the field of rational numbers. Suppose that T is a ring which contains Z and A is a ring which contains both Q and T. Then if f(X) is a polynomial in Q[X] we can consider the element f(t) where t is an element of T. We then consider the ring of all polynomials in Q[X] which map T to itself. This ring is well-defined even if T has zero-divisors, or is not commutative. Easy, nontrivial examples can be obtained by letting T be the ring of integral quaternions, the ring of n by n integral matrices, or the ring of integers in a finite algebraic extension of Q. We investigate when such rings are Prufer domains. (Received February 09, 2009)

1048-13-270 **Evan Houston*** (eghousto@uncc.edu), Dept. of Mathematics and Statistics, UNC Charlotte, Charlotte, NC 28223, and **Abdeslam Mimouni** (amimouni@kfupm.edu.sa), Department of Mathematics and Statistics, King Fahd University of Petroleum and Mineral, Dhahran, 31261, Saudi Arabia. *Counting the Number of Star Operations on an Integral Domain.* Preliminary report.

For a domain R, denote by $|S(R)|$ the number of star operations on R. It is well known that if R is a valuation domain, then $|S(R)| \leq 2$, with equality holding if and only if the maximal ideal of R is not principal. We attempt to compute the number of star operations in a few other cases. For example, we show that if R is a pseudo-valuation domain such that R has residue field k and its associated valuation overring has residue field K, then $|S(R)| = 2$ if and only if $[K : k] = 3$. (Received February 09, 2009)

1048-13-283 **Lance Bryant*** (lbryant@math.purdue.edu), 175 Villefranche Dr, West Lafayette, IN 47906. *The Gorenstein property of associated graded rings of ideal filtrations in one-dimensional analytically irreducible Noetherian local domains.*

Let (R, m) be a one-dimensional analytically irreducible Noetherian local domain, $\bar{R}$ its integral closure in the quotient field K, and $v : K \to \mathbb{Z}$ the corresponding valuation. Assume R and $\bar{R}$ have the same residue field. For an ideal filtration $F = \{F_i\}_{i\geq 0}$, I will discuss some necessary and sufficient conditions for the associated graded ring $gr_F(R) = \bigoplus_{i\geq 0} F_i/F_{i+1}$ to be Gorenstein that involve the value-semigroup $v(R)$ of R. These conditions include an analogue of a recent result of Barucci and Fröberg concerning the Cohen-Macaulay property of $gr_m(R)$, an analogue of a classic result of Kunz relating the Gorenstein property of R to the symmetric property of $v(R)$, and a numerical criterion. (Received February 09, 2009)

1048-13-284 **Roger A Wiegand** (rwiegand@math.unl.edu), Department of Mathematics, University of Nebraska Lincoln, Lincoln, NE 68588-0130, and **Sylvia M Wiegand*** (swiegand@math.unl.edu), Department of Mathematics, University of Nebraska Lincoln, Lincoln, NE 68588-0130. *Prime ideals in two-dimensional domains.* Preliminary report.

This will be a survey talk about the spectra of two-dimensional domains, particularly for the spectra of two-dimensional Noetherian domains. We give some examples and remarks. (Received February 09, 2009)

1048-13-299 **Florian Kainrath*** (florian.kainrath@uni-graz.at), Institut f. Mathematik und Wiss. Rechnen, Karl-Franzens Universitaet Graz, Heinrichstrasse 36, 8010 Graz, Austria. *On the arithmetic of certains noetherian domains.*

Let R be a noetherian domain whose integral closure $\bar{R}$ is a finitely generated R-module. Additionaly, assume that the class groups of R and $\bar{R}$ are finite and that the R-module $\bar{R}/R$ has no embedded components. I study the following arithmetical properties of R: local tameness, the catenary degree, tameness and the elasticity.

For that I use the concept of weakly C-monoids introduced recently by A. Geroldinger a W. Hassler. (Received February 10, 2009)

1048-13-303 **Michael Freeze*** (freezem@uncw.edu), Department of Mathematics and Statistics, 601 South College Road, Wilmington, NC 28403, and **Alfred Geroldinger**. *Unions of Sets of Lengths.*

Let H be an atomic monoid. For $k \in \mathbb{N}$ let $\mathcal{V}_k(H)$ denote the set of all $m \in \mathbb{N}$ such that there exist atoms $u_1, \ldots, u_k, v_1, \ldots, v_m \in H$ with $u_1 \cdots u_k = v_1 \cdots v_m$. We consider conditions on H for which $\mathcal{V}_k(H)$ is eventually an arithmetical progression. (Received February 10, 2009)

1048-13-360 **Jason Greene Boynton*** (jason.boynton@ndsu.edu), North Dakota State University, Department of Mathematics, 300 Minard Hall, Fargo, ND 58105. *A generalization of* $\mathrm{Int}(E, D)$ *when E is finite.*

In this talk, we will survey some fairly recent results concerning the ring of integer-valued polynomials determined by a finite subset. One may view this ring as a pullback allowing some slight generalizations. Many of these results carry over from $\mathrm{Int}(E, D)$ to the more general setting, however some do not. We will consider the (strong) n-generator property for ideals as well as atomicity in $\mathrm{Int}(E, D)$ and the more general setting of the pullback. It is worth noting that the results presented for $\mathrm{Int}(E, D)$ are due to Bill Smith (et al.). (Received February 10, 2009)

1048-13-362 **Nathan Kaplan*** (nkaplan@math.harvard.edu), Department of Mathematics, Harvard University, One Oxford Street, Cambridge, MA 02138. *Counting Numerical Semigroups.*

Let S be a primitive numerical semigroup. We call the set of nonnegative integers not belonging to S the gaps of S and note that this set determines S. The size of this set is called the genus of S and the largest element of this set is the Frobenius number of S. In this talk we will discuss various approaches to counting numerical semigroups.

Let n_g denote the number of numerical semigroups of genus g. For $g \geq 1$ this sequence begins,

$$1, 2, 4, 7, 12, 23, 39, 67, 118, 204, 343, 592, 1001, 1693, 2857, \ldots$$

Let n_F be the number of numerical semigroups with Frobenius number F. For $F \geq 1$ this sequence begins,

$$1, 1, 2, 2, 5, 4, 11, 10, 21, 22, 51, 40, 106, 103, 200, \ldots$$

We will discuss some results and conjectures relevant to these sequences and to related problems. (Received February 10, 2009)

14 ► Algebraic geometry

1048-14-42 **Hoon Hong*** (hong@math.ncsu.edu), Department of Mathematics, Campus Box 8205, North Carolina State University, Raleigh, NC 27695. *Root Bound for Pham Systems.* Preliminary report.

Root bound plays an important role in isolating and approximating the roots of polynomial equations, analyzing their computational complexity, etc. In this talk, we briefly review root bounds for one univariate polynomial and multivariate polynomial system. Then, we describe a root bound for Pham systems, which are certain "nice" multivariate polynomial systems. We show that the root bound is much tighter than the one for arbitrary multivariate polynomial system. We hope that the tighter bound would be useful for obtaining faster algorithms for isolating/approximating the roots of Pham system. (Received January 10, 2009)

1048-14-53 **Luis D Garcia-Puente*** (lgarcia@shsu.edu), Department of Mathematics and Statistics, Sam Houston State University, Huntsville, TX 77341-2206, and **Gheorghe Craciun** (craciun@math.wisc.edu) and **Frank Sottile** (sottile@math.tamu.edu). *Injectivity of toric patches.*

In this talk, we will present an application of algebraic geometry to geometric modeling. We apply methods from toric geometry to investigate the self-intersection, or injectivity of a toric patch (a generalization of the classical Bézier patches). We give a simple and easy-to verify condition on a set of control points which implies that the resulting patch has no self-intersection, for any choice of weights. This uses Craciun and Feinberg's injectivity theorem from the theory of chemical reaction networks. (Received January 16, 2009)

1048-14-74 **Jose Antonio Vargas*** (javargas1@excite.com), Constitucion 204, centro, 68000 Oaxaca, Oaxaca, Mexico. *The infancy of trilinear algebra.*

Let V be a vector space of dimension $n+1$ over the complex field. The group $G = PGL_{n+1}$ acts on $\mathbb{P}(V \otimes V \otimes V)$, identified with the projective space of matrices of linear forms on the variables $x_0, ..., x_n$, naturally: By conjugation followed ba a linear change of variables. We call this the triple action.

We call "trilinear algebra" the study of this action. This subject is in its infancy; and we propose as an underlying ground the study of a discrete dynamical system associated to any given matrix of linear forms, in order to obtain invariants and canonical forms for the original matrix.

Our dynamical systems are originated by the iteration of quadratic rational maps of projective space $\mathbb{P}^n$. The group G also acts by conjugation on the projective space of these maps. These actions are related by a surjective concomitant map.

We identify the discrete and continuous components of the problem for some orbits of the triple action. We obtain some canonical forms for these cases. The discrete invariants are given by geometric configurations involving toric varieties. The main continuous invariants are interpreted as speeds of convergence along different directions. (Received February 03, 2009)

1048-14-103 **Sandra Di Rocco**, **David Eklund**, **Christopher Peterson*** (peterson@math.colostate.edu) and **Andrew J Sommese**. *Intersection Theory and Homotopy for Computation of Invariants.*

Intersection theory relates the equivalence of a smooth variety in an intersection product to the degrees of the Chern classes of the variety. Liaison Theory and Homotopy theory is used in conjunction with Intersection theory to compute the degrees of Chern classes and other invariants of smooth varieties. (Received January 30, 2009)

1048-14-115 **Frank Sottile** (sottile@math.tamu.edu), Texas A&M University, Department of Mathematics, College Station, TX 77843-3368, **Ravi Vakil** (vakil@math.stanford.edu), Stanford University, Department of Mathematics, Stanford, CA 94305-2125, and **Jan Verschelde*** (jan@math.uic.edu), University of Illinois at Chicago, Dept. of Math., Stat., and CS, 851 S. Morgan St. (m/c 249), Chicago, IL 60607-7045. *Littlewood-Richardson Homotopies for Schubert Problems.* Preliminary report.

Given a sequence of nested linear spaces (called flags) and prescribed dimensions for each flag, a Schubert problem asks for all planes that meet the given flags at the prescribed dimensions. A geometric Littlewood-Richardson rule developed by Ravi Vakil leads to homotopy algorithms to solve a Schubert problem. Littlewood-Richardson homotopies are the families of polynomial systems constructed by these homotopy algorithms. Symbolically, homotopy algorithms degenerate a moving flag, using polynomial equations to keep conditions imposed by other flags fixed. At the degenerate configuration of the flag, a linear system provides a start solution for a path to track by numerical continuation methods. The specialization of a flag follows a combinatorial checker game.

For sufficiently generic Schubert problems, the number of paths to track is optimal. The Littlewood-Richardson homotopies are implemented using the path trackers of the software package PHCpack. (Received February 02, 2009)

1048-14-123 **Renzo Cavalieri*** (crenzo@umich.edu), Weber building, Oval drive, Fort Collins, CO 80524. *Wall crossing formulas for double Hurwitz numbers.*

We discuss a graph theoretic way of computing double Hurwitz numbers that sheds light on the piecewise polynomial structure shown by Goulden-Jackson-Vakil, re-proves the genus 0 wall crossing formula of Shadrin-Shapiro-Vainshtein and proposes a general genus wall crossing formula.

This is joint work with Paul Johnson and Hannah Markwig. (Received February 03, 2009)

1048-14-165 **Christine Berkesch*** (cberkesc@math.purdue.edu), Department of Mathematics, Purdue University, 150 North University Street, West Lafayette, IN 47907. *The rank of a hypergeometric system.*

The holonomic rank of the A-hypergeometric system $H_A(\beta)$ is at least the simplicial volume of $A \subset \mathbb{Z}^d$, with equality for generic parameters $\beta \in \mathbb{C}^d$. The exceptional parameters are given by a subspace arrangement $\mathcal{E}_A$ in $\mathbb{C}^d$. We introduce another arrangement whose combinatorics determine the rank of $H_A(\beta)$ for any β and use it to induce a stratification of $\mathcal{E}_A$ that refines the one given by the holonomic rank of $H_A(\beta)$. (Received February 05, 2009)

1048-14-168 **David E Anderson*** (dandersn@umich.edu) and **Alan Stapledon** (astapldn@umich.edu). *Arc spaces and equivariant cohomology.*

Let X be a smooth variety with an action of an algebraic group G. The arc space of X carries a natural action by the arc space of G; we show how the orbits in the arc space determine classes in the equivariant cohomology of X. When X is a smooth toric variety, the classes of certain orbits form a $\mathbb{Z}$-linear basis for the equivariant cohomology of X. Our approach applies more generally to the situation where X has a dense free G-orbit. (Received February 05, 2009)

1048-14-171 **Edward L Richmond*** (erichmo2@uoregon.edu). *A multiplicative formula for structure constants in the cohomology of flag varities.*

Let G be a complex semi-simple Lie group and let $P \subseteq Q$ be a pair of parabolic subgroups of G. Consider the flag varieties $G/P, G/Q$ and Q/P. We show that certain structure constants in $H^*(G/P)$ with respect to the Schubert basis can be written as a product of structure constants coming from $H^*(G/Q)$ and $H^*(Q/P)$ in a very natural way. We also give a generalization of this product formula in the branching Schubert calculus setting. (Received February 05, 2009)

1048-14-173 **David E. Anderson**, **Stephen Griffeth** (griffeth@umn.edu) and **Ezra Miller*** (ezra@math.duke.edu). *Positivity and Kleiman transversality in equivariant K-theory of homogeneous spaces.*

We prove the conjectures of Graham–Kumar and Griffeth–Ram concerning the alternation of signs in the structure constants for torus-equivariant K-theory of generalized flag varieties G/P. These results are immediate consequences of an equivariant homological Kleiman transversality principle for the Borel mixing spaces of homogeneous spaces, and their subvarieties, under a natural group action with finitely many orbits. The computation of the coefficients in the expansion of the equivariant K-class of a subvariety in terms of Schubert classes is reduced to an Euler characteristic using the homological transversality theorem for non-transitive group actions due to S. Sierra. A vanishing theorem, when the subvariety has rational singularities, shows that the Euler characteristic is a sum of at most one term—the top one—with a well-defined sign. The vanishing is proved by suitably modifying a geometric argument due to M. Brion in ordinary K-theory that brings Kawamata–Viehweg vanishing to bear. (Received February 05, 2009)

1048-14-175 **Edward L Richmond*** (erichmo2@uoregon.edu). *Decomposing structure constants for the Belkale-Kumar product in the cohomology of flag varieties.*

Let G be a complex semi-simple Lie group and let $P \subseteq Q$ be a pair of parabolic subgroups of G. Consider the flag varieties $G/P, G/Q$ and Q/P. We look at the cohomology ring $(H^*(G/P), \odot_0)$ equipped with the Belkale-Kumar product structure $\odot_0$. We give a formula for the structure constants with respect to the Schubert basis in $(H^*(G/P), \odot_0)$ in terms of the structure constants in $(H^*(G/Q), \odot_0)$ and $(H^*(Q/P), \odot_0)$. We also give an application of this formula in the representation theory of G. (Received February 05, 2009)

1048-14-196 **Allen Knutson** and **Thomas Lam***, Harvard University, Dept. of Mathematics, Cambridge, MA 02138, and **David Speyer**. *The cohomology class of positroid varieties, and quantum cohomology.*

Positroid varieties are subvarieties of the Grassmannian, obtained by intersecting cyclically rotated Schubert varieties, and first studied by Postnikov. We will describe an indexing of positroid varieties by certain affine permutations. We prove that the cohomology class of a positroid variety is equal to the affine Stanley symmetric function labeled by the same affine permutation. We show that certain subvarieties of the Grassmannian occurring in the study of quantum cohomology are in fact positroid varieties, and that their cohomology classes are Postnikov's toric Schur functions. (Received February 07, 2009)

1048-14-197 **Marc Moreno Maza*** (moreno@csail.mit.edu), Cambrideg, MA, and **Xin Li** (xli96@csd.uwo.ca) and **Wei Pan** (wpan9@gmail.com). *Computations modulo Regular Chains.*

The computation of triangular decompositions of polynomial systems are based on two fundamental operations: polynomial GCDs modulo regular chains and regularity test modulo saturated ideals.

In this talk, we propose new algorithms for these operations, together with a theoretical study and an implementation report. Given two polynomials p and t and a regular chain T we exhibit conditions for a subresultant of p and t to be a GCD of them w.r.t. T. We deduce asymptotically fast and modular algorithms for the operations under study.

We obtain significant improvements with respect to previous work on the subject. First, we do not assume that saturated ideals are radical and we do not reduce to such cases either. Secondly our algorithms do not suffer from any notion of bad specialization, in other words, all our specializations are good. Finally, our implementation report illustrates the high efficiency of the proposed algorithms: we obtain speed-up factors of several orders of magnitude w.r.t. packages with similar specifications in Maple and Magma. (Received February 07, 2009)

1048-14-217 **Patrick Gerald Brosnan*** (brosnan@math.ubc.ca), 1984 Mathematics Road, Vanocuver, BC V6T 0A2, Canada. *Essential dimension and abelian varieties.* Preliminary report.

In a joint paper with R. Sreekantan, I used a number theoretical result coupled with a result of M. Florence to show that abelian varieties over number fields have infinite essential dimension. In this talk, I will prove that abelian varieties have infinite essential dimension over a much more general class of fields including all p-adic fields. The proof uses the results of Karpenko and Merkurjev on essential dimension of p-groups. (Received February 09, 2009)

1048-14-262 **David E Speyer*** (speyer@math.mit.edu), Department of Mathematics, Room 2-332, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02138, and **Allen Knutson** (allenk@math.cornell.edu) and **Thomas Lam** (tfylam@math.harvard.edu). *The positroid stratification of the Grassmannian.* Preliminary report.

George Lusztig and Alex Postnikov have studied those points on the Grassmannian all of whose Plücker coordinates are nonnegative, and found that they can be grouped into strata indexed by combinatorial objects called positroids. We follow these positroids into the rest of the Grassmannian and find that their Zariski closures form a elegant stratification which refines the classical stratification into Schubert cells. In this talk, we will describe the combinatorics of this stratification and give defining equations and Gröbner degenerations of these varieties. (Received February 09, 2009)

1048-14-298 **Zach Teitler*** (zteitler@tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843. *Experimentation at the Frontiers of Reality in Schubert Calculus.* Preliminary report.

When a Schubert problem is given by real reference flags, all, some, or none of the solutions may be real. A conjecture of B. and M. Shapiro asserts that all the solutions will be real if the reference flags osculate a real rational normal curve. This is known for Schubert problems on Grassmanians by work of Mukhin-Tarasov-Varchenko. A variant of the conjecture asserts the reality of the solutions when the reference flags are secant to disjoint intervals on the curve. This is known on the Grassmanians $G(n-2,n)$ by work of Eremenko, Gabrielov, M. Shapiro, and Vainshtein. Massive computational experimentation provides overwhelming support for the secant conjecture more generally and hints at intriguing new phenomena, including reality of solutions even when the disjointness hypothesis is relaxed. I will describe the conjecture and the ongoing computation. (Received February 10, 2009)

1048-14-324 **Benjamin F Jones*** (bjones@math.uga.edu). *Computing Singular Chern Classes and Related Invariants for Schubert Varieties in a Grassmannian.*

We describe how various types of singular Chern classes and related invariants may be computed in the case of Schubert varieties in a Grassmannian. The main tool is Zelevinsky's small resolution of singularities construction. In particular, we describe the computation of Chern-Schwartz-MacPherson classes, Chern-Mather classes, and the local Euler obstruction. (Received February 10, 2009)

1048-14-352 **Julianna Tymoczko***, Mathematics Department, 14 MacLean Hall, University of Iowa, Iowa City, IA 52245. *Pieri rules.*

We discuss Pieri rules in several families of varieties related to flag varieties and Grassmannians. (Received February 10, 2009)

1048-14-356 **Julianna Tymoczko***, Mathematics Department, 14 MacLean Hall, University of Iowa, Iowa City, IA 52245. *Intersecting some special subvarieties of the flag variety.* Preliminary report.

Subvarieties of the flag variety like Springer varieties and their generalizations, Hessenberg varieties, arise naturally in representation theory. We describe natural combinatorial characterizations of the geometry in some special cases, and how it relates to representation theory. (Received February 10, 2009)

1048-14-377 **Radu Laza***, 2074 East Hall, Dept. of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Counting the hyperplane sections with fixed moduli.* Preliminary report.

I will speak on counting the hyperplane sections with fixed moduli. (Received February 10, 2009)

1048-14-380 **Alex Bene*** (bene@usc.edu). *Intersections of Combinatorial Cycles in the Moduli Space of Curves.*

The use of combinatorics has been ubiquitous in the study of the tautological ring of the moduli space of stable curves. In one perspective, the moduli space of smooth curves has a description as a moduli space of metric fatgraphs, and certain classes of the tautological ring have nice combinatorial descriptions in terms of these graphs. In this talk, I will discuss a computation which derives a relation between tautological classes by analyzing and enumerating chain-level intersections of some of these combinatorial classes. If time permits, I will also comment on an alternate approach to the same problem by Bertin and Romagny using Hurwitz spaces and discuss its implications for the fatgraph approach. (Received February 11, 2009)

15 ► Linear and multilinear algebra; matrix theory

1048-15-60 **J William Helton***, Math Dept, UC San Diego, La Jolla, CA 92093, and **Igor Klep**, Math Dept, Univ of Ljubljana, Jadranska 19, Ljublja, Slovenia. *Signed matrices and chemical reaction networks.* Preliminary report.

A signed matrix is actually a class of matrices consisting of matrices whose ij-th entry has the same sign. The talk gives some extensions of the classical theory of signed matrices. Chemical reaction networks CRN have dynamics dx/dt =f(x) with the Jacobian of f often having a sign pattern. Our results will be applied to CRN. (Received January 20, 2009)

1048-15-156 **Ian Anderson*** (ian.anderson@usu.edu), Dept. of Math. and Stat., Utah State Univ., Logan, UT 84322, and **Evelyne Hubert** (Evelyne.Hubert@sophia.inria.fr), Sophia, France. *Lie's Theorem and its Applications.*

A fundamental theorem of Lie asserts that for any representation of a solvable Lie algebra, there is a basis in which the representation is given by upper triangular matrices. We shall present a new, computationally effective proof of this theorem. Applications to the symbolic solution of systems of first order ODE shall be discussed. (Received February 05, 2009)

1048-15-274 **Moody T. Chu*** (chu@math.ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695-8205. *Orthogonal Polynomials, Moments, Measure Deformation, Dynamical Systems, and SVD Algorithm.*

Iterates generated from discrete dynamical systems such as the QR algorithm and the SVD algorithm are time-1 samples of solutions to the Toda lattice and the Lotka-Volterra equation, respectively. In this talk we present some recent discoveries that connect diverse topics such as soliton theory, integrable systems, continuous fractions, τ functions, orthogonal polynomials, Sylvester identity, moments, and Hankel determinants together. Of particular interest are the three facts that

(1) Each of the Toda lattice and the Lotka-Volterra equation governs the evolution of a certain class of orthogonal polynomials whose orthogonality is determined by a specific time-dependent measure.

(2) Since the measure deformation is explicitly known, moments can be calculated which, when properly assembled, lead to the conclusion abstractly, but literally, that the iterates of the QR algorithm and the SVD algorithm can be expressed in closed-form!

(3) Hankel determinantal solutions are too complicated to be useful. However, a "smart" integrability-preserving discretization of the Lotka-Volterra equation can yield a new SVD algorithm.

(Received February 09, 2009)

1048-15-347 **Christopher Dometrius*** (chris.dometrius@lr.edu), PO Box 7216, Lenoir-Rhyne University, Hickory, NC 28603, and **Aloysius Helminck** and **Ling Wu**. *Bilinear Forms on $V = k^n$ and Involutions of SL(n,k) and SO(n,k,β).* Preliminary report.

Reductive symmetric spaces are defined as the homogeneous spaces G/H with G a reductive group and H the fixed point group of an involution. To classify these spaces one has to classify the involutions. We show first that there is a natural correspondence between outer involutions and non-degenerate symmetric or skew-symmetric bilinear forms. This enables one to classify isomorphism classes of these involutions using congruence properties of bilinear forms.

We use this to give a detailed characterization for the classes of involutions of $SL(n,k)$ and classify them for a number of fields, including algebraically closed fields, real numbers, p-adic numbers, and finite fields. Next we give a characterization for the classes of involutions of $SO(n,k,\beta)$ where β is any non-degenerate symmetric bilinear form. Finally, we classify the involutions of $SO(n,k,\beta)$ in the case of the standard bilinear form for the same fields listed above. (Received February 10, 2009)

16 ► Associative rings and algebras

1048-16-17 **Vladislav Kharchenko*** (vlad@servidor.unam.mx), Papagayo #4, Col. Lago de Guadalupe, 54760 Cuautitlan, Mexico. *Right coideal subalgebras for quantum groups of type B_n.* Preliminary report.

We give a complete classification of right coideal subalgebras which contain all group-like elements for the quantum group $U_q^+(\mathfrak{so}_{2n+1})$ provided that q is not a root of 1. If q has a finite multiplicative order $t > 4$, this classification remains valid for homogeneous right coideal subalgebras of the small Lusztig quantum group $u_q^+(\mathfrak{so}_{2n+1})$. As a consequence, we determine that the total number of right coideal subalgebras which contain the coradical equals $(2n)!!$, the order of the Weyl group defined by the root system of type B_n. (Received November 27, 2008)

1048-16-19 **Thomas Tradler*** (ttradler@citytech.cuny.edu), New York City College of Technology, Department of Mathematics N-711, 300 Jay Street, Brooklyn, NY 11201. *Explicit higher Hochschild complexes.*

We will describe the higher Hochschild complexes of an associative algebra A, which are induced for any given simplicial pointed set. In particular, spheres and tori will be examined in detail, and generalizations of Chen's iterated integral map will be discussed in this context. (Received December 02, 2008)

1048-16-52 **Martin Lorenz*** (lorenz@temple.edu), Department of Mathematics, Temple University, 1805 N. Broad St., Philadelphia, PA 19122. *Algebraic group actions on noncommutative spectra.*

Let G be an affine algebraic group that acts rationally by algebra automorphisms on an arbitrary associative algebra R. We study the induced G-action on the spectrum of all prime ideals of R, viewed as a topological space with the Jacobson-Zariski topology. The main themes are local closedness of G-orbits and the so-called G-stratification of the prime spectrum. Our principal results are based on, and generalize, prior work of Moeglin & Rentschler and Vonessen. (Received January 14, 2009)

1048-16-76 **Leonid Krop*** (lkrop@condor.depaul.edu), Department of Mathematical Sciences, DePaul University, Chicago, IL 60614. *Central quotients of Drinfel'd quantum doubles.*

For every Hopf algebra H and a ground field k the subgroup C of central grouplike elements gives rise to an exact sequence

$k \to kC \to H \to H_c \to k$ in the category of Hopf algebras where $H_c = H/I$ with $I = (kC)^+H$. We call H_c the central quotient of H. Let R be a finite-dimensional pre-Nichols algebra in the category ${}^G_G\mathcal{YD}$ of Yetter-Drinfel'd

modules over an abelian group G. Set $H = R\#kG$ and put D for the Drinfel'd double of H. We give a necessary and sufficient conditions for splitting of D into the tensor product of kC and its central quotient. We specialize to R of Cartan type and give a criterion for splitting of D in terms of the datum for R. We further treat the case of Lusztig's small quantum groups. (Received January 28, 2009)

1048-16-90 **Michael J Hilgemann*** (hilgem1@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011, and **Siu-Hung Ng**. *Hopf algebras of dimension $2p^2$.*

Let H be a non-semisimple Hopf algebra whose dimension is a product of three primes over an algebraically closed field of characteristic zero. The question of whether there exists such a Hopf algebra H with neither H nor H^* pointed is still open. Fukuda has shown that every non-semisimple Hopf algebra of dimension 18 is either pointed or isomorphic to the dual of a pointed Hopf algebra. In this talk, we will discuss a recent result that completes the classification of Hopf algebras of dimension $2p^2$, for p an odd prime. In particular, we will use irreducible representations and their projective covers to show that if H has dimension $2p^2$ then H or H^* is pointed. This is joint work with Siu-Hung Ng. (Received February 10, 2009)

1048-16-98 **Joost Vercruysse*** (jvercruy@vub.ac.be), Department of Mathematics, Faculty of Engineering, Pleinlaan 2, Brussel, Belgium. *Hopf-Galois theory and the quasi-co-Frobenius property.*

A ring extension $\iota : B \to A$ is called an H-Galois extension for a Hopf algebra H, if there is a coaction of H on A, such that $B \subset A^{coH}$, the H-coinvariants of A, and the cannonical map $A \otimes_B A \to A \otimes H$, is bijective. More general, a B-A bimodule Σ is said to be a C-Galois comodule for an A-coring C, if Σ is a right C-comodule, $B \subset \mathrm{End}^C(\Sigma)$ and the canonical map $can : \mathrm{Hom}_A(\Sigma, A) \otimes_B \Sigma \to C$ is bijective.

We study the situation $\Sigma = C$, in a framework where B is a ring with local units. This allows us to characterize quasi-co-Frobenius corings as faithfully flat Galois comodules or as (locally) projective generators in their category of comodules. Our theory can be specialized to coalgebras and Hopfalgebras, in which case we obtain some new results and new proofs for well-known results. (Received January 29, 2009)

1048-16-130 **S. Forcey*** (sforcey@tnstate.edu), **A. Lauve** and **F. Sottile**. *Polytopes, positrons, and antipodes.* Preliminary report.

The process of renormalization lets us use path integrals to calculate the precise strengths of many forces of nature, despite the suspicious subtraction of infinities. Connes and Kreimer found a way to mathematically model the process using the antipode of a graded Hopf algebra of Feynman diagrams. Their algebra turns out to be fundamental in mathematics as well as physics, as part of a larger family of algebras based on combinatorial structure. I'll show a new pictorial way of looking at that family and its inner relations. The advantage of our viewpoint is that it allows factorizations of the map from the Malvenuto-Reutanauer Hopf algebra to the Loday-Ronco Hopf algebra of binary trees.

Our factorizations proceed through new algebras based on convex polytopes such as the multiplihedra and graph-associahedra. Reading has defined translational and insertional lattice congruences which give subalgebras and sub-coalgebras of the Malvenuto-Reutanauer Hopf algebra. We'll talk about how this relates to the cellular projections of polytopes between our new sequences.

If time permits we can go on to discuss multicolored versions and new Hopf modules over the algebras already introduced. (Received February 03, 2009)

1048-16-141 **Jinkui Wan**, VA , and **Weiqiang Wang***, Department of Mathematics, University of Virginia, Charlottesville, VA 22904. *Modular representations of wreath Hecke algebras and crystals.*

We introduce a generalization of degenerate affine Hecke algebra, called wreath Hecke algebra, associated to an arbitrary finite group G. The simple modules of the wreath Hecke algebra and of its associated cyclotomic algebras are classified over an algebraically closed field of any characteristic p. The modular branching rules for these algebras are obtained, and when p does not divide the order of G, they are further identified with crystal graphs of integrable modules for quantum affine algebras. (Received February 04, 2009)

1048-16-143 **Ta Khongsap** and **Weiqiang Wang*** (ww9c@virginia.edu). *Spin Hecke algebras.*

We construct systematically degenerate Hecke algebras of finite, affine and double affine type, associated to the spin Weyl groups (including spin symmetric groups of Schur). (Received February 04, 2009)

1048-16-178 **Darrell E. Haile*** (haile@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405, and **Jean-Pierre Tignol** (jean-pierre.tignol@uclovain.be), Departement de mathematiques, Universite catholique de Louvain, chemin du cyclotron, 2, Louvain-la-Neuve, Belgium. *On the Okubo product and a theorem of Rost.* Preliminary report.

Let F be a field containing a primitive third root of unity. If A is a central simple F–algebra of degree 3, the subspace A_0 of elements of trace 0 is an 8 dimensional space which is hyperbolic with respect to the trace form. This space admits a product, the Okubo product, useful for understanding the geometric properties of A_0. We give a derivation of this product and then use it to give a geometric proof of a theorem of Rost on the chain length of a degree 3 algebra. (Received February 06, 2009)

1048-16-179 **Alina N. Duca*** (anduca@ncsu.edu), North Carolina State University, Department of Mathematics, Box 8205, Raleigh, NC 27695-8205. *Injective modules over a principal left and right ideal domain.*

Over a noetherian ring R every injective module is a direct sum of indecomposable injective modules. Such objects have been classified as either "tame" or "wild". The tame ones are uniquely determined by the prime ideals of the ring and are now relatively well understood. Much less is known about wild injectives, and so far there are no known descriptions of wild injectives over noetherian rings. In particular, the modern methods of ring and module theory from the second half of the century, which drove massive advances in the field, have not proved effective in analyzing wild injectives.

In this talk, we will discuss the injective modules over a principal left and right ideal domain, which is a noetherian ring. Motivated by a classic treatment of O.Ore (1930's), I take advantage of the factorization theory in R and investigate the internal structure of an indecomposable injective. More specifically, it is described as a "layered" structure in two ways: first as the union of its socle series, and secondly, as the union of its elementary socle series, a concept from model theory introduced by Herzog in 1993 as the elementary analogue of the socle series of a module. (Received February 06, 2009)

1048-16-201 **Minxian Zhu*** (minxian@math.rutgers.edu), 110 Frelinghuysen Rd., Department of Mathematics, Piscataway, NJ 08854. *Regular representations of quantum groups at roots of unity.*

I will discuss how the quantum function algebra decomposes as a bimodule of the big quantum group at roots of unity. I will explain how it is related to the structure of a family of vertex algebras associated to algebraic groups in rational levels. (Received February 08, 2009)

1048-16-244 **Michael Natapov*** (mnatapov@indiana.edu), Department of Mathematics, Rawles Hall 116, 831 East 3rd St, Bloomington, IN 47405, and **Darrell Haile** (haile@indiana.edu), Department of Mathematics, Rawles Hall 116, 831 East 3rd St, Bloomington, IN 47405. *On graded polynomial identities of matrices.* Preliminary report.

Let $A = M_n(F)$ be a full $n \times n$ matrix algebra over an algebraically closed field F. Given a group G, there are two basic ways to define a $G-$grading on A, elementary and fine. A G–grading on A is fine if and only if the support of the grading $H = \{g \in G \mid A_g \neq 0\}$ is a subgroup of G and A is isomorphic to the twisted group algebra F^cH for an appropriate two-cocycle $c \in Z^2(H, F^\times)$. We refer to such group H as a group of central type. Given a fine grading on A supported by a group of central type H, let $F\langle x_{i,g} |\ g \in H, i = 1, 2, \ldots\rangle$ be an associative H–graded free algebra, and T_H be the T–ideal of H–graded polynomial identities of A. Unlike the classical (non-graded) case the relatively free algebra $F\langle x_{i,g}\rangle/T_H$ may or may not be a domain. It is a domain exactly when H is on a precise list of families of nilpotent groups, called Λ. We describe generating set for T_H where H is any group of central type, and the minimal generating sets for groups on the list Λ. (Received February 09, 2009)

1048-16-279 **Paul M Terwilliger*** (terwilli@math.wisc.edu), Math Department, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706. *Tridiagonal pairs of q-Racah type.*

This talk concerns the tridiagonal pairs of linear transformations. These pairs come in a number of types depending on the form of the eigenvalues. The most general type is called q-Racah. We classify up to isomorphism the tridiagonal pairs of q-Racah type. Our proof uses the representation theory of the quantum affine algebra $U_q(\widehat{\mathfrak{sl}}_2)$. This is joint work with Tatsuro Ito. (Received February 09, 2009)

1048-16-286 **Kelly McKinnie***, Department of Mathematics - MS 136, Rice University, 6100 S. Main St., Houston, TX 77098, and **Eric Brussel** and **Eduardo Tengan**. *Indecomposable division algebras in the Brauer group of $\mathbb{Q}_p(t)$.* Preliminary report.

A division algebra over a field is decomposable if it is isomorphic to the tensor product of two subalgebras of positive degree. In this talk I will discuss the existence of indecomposable division algebras over various fields, including new examples over $\mathbb{Q}_p(t)$ with exponent strictly less than index. (Received February 09, 2009)

1048-16-313 **Stefaan Caenepeel*** (scaenepe@vub.ac.be), Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium, and **Andrei Marcus** (marcus@math.ubbcluj.ro), Babeş-Bolyai University, Str. Mihail Kogălniceanu 1, 400084 Cluj-Napoca, Romania. *Morita equivalences between Hopf-Galois extensions. Applications.*

Let A and B be two Hopf algebra extensions, and suppose that $A^{\mathrm{co}H}$ and $B^{\mathrm{co}H}$ are connected by a strict Morita context. We investigate when this Morita context can be lifted to a Morita context between A and B. To this end, we present a Structure Theorem for Hopf bimodules: the category of A-B-Hopf bimodules is equivalent to the category of modules over the cotensor product of A and B^{op}. We present applications to the Miyashita-Ulbrich actions and to Hopf subalgebras. As another application, we present a Hopf algebra version of an exact sequence due to Beattie and del Rio, connecting the graded Picard group of a strongly graded ring, and the stable part of the Picard group of its part of degree zero. (Received February 10, 2009)

1048-16-337 **David Harbater**, **Julia Hartmann** and **Daniel Krashen*** (dkrashen@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30602. *Patching subfields of division algebras.*

In 1968, Schacher asked the question of when a given group G could be the Galois group of a maximal subfield in an F-central division algebra for a given field F. Such a group G is called admissible over F. The characterization of such admissible groups is still unknown for global fields, even in the case $F = \mathbb{Q}$. In this talk I will present a complete characterization of admissible groups over the function field of a curve over a complete discretely valued field with algebraically closed residue field of characteristic 0 (and give partial results in the positive characteristic situation). I will also relate the question of admissibility to rationality problems for function fields. (Received February 10, 2009)

1048-16-348 **Stefan Forcey**, Tennessee State University, **Aaron Lauve*** (lauve@math.tamu.edu), Texas A&M University, and **Frank Sottile**, Texas A&M University. *Hopf structures on binary trees (variations on a theme).*

We discuss several algebraic structures that can be placed on the vertices of the multiplihedra $\{\mathcal{M}_n\}$, a family of polytopes defined by Stasheff in the study of higher categories and homotopy theory. The vertices may be indexed by certain "bi-leveled" binary trees, intermediate between ordered trees and ordinary (planar binary) trees. The structures we find stem from the relationship between these three types of trees.

The ordered trees (i.e., permutations) and ordinary trees index the vertices of two additional families of polytopes more familiar to combinatorists: the permutahedra $\{\mathcal{P}_n\}$ and the associahedra $\{\mathcal{A}_n\}$. They also arrange themselves into Hopf algebras (after work of Malvenuto–Reutenauer and Loday–Ronco, respectively). In this talk, we give $\mathcal{M}$ the structure of $\mathcal{P}$-module and $\mathcal{A}$-Hopf module algebra in a manner respecting the cellular maps $\mathcal{P}_n \to \mathcal{M}_n \to \mathcal{A}_n$. We also give a basis of coinvariants for a second $\mathcal{A}$-Hopf module structure on $\mathcal{M}$. (Received February 10, 2009)

1048-16-374 **William Chin*** (wchin@condor.depaul.edu), DePaul University, Dept. of Mathematical Sciences, Chicago, IL 60610, and **Daniel Simson** (simson@mat.uni.torun.pl), Faculty of Mathematics and Computer Science, Nicolaus Copernicas University, Torun, Poland. *Coxeter transformation and inverses of Cartan matrices for coalgebras.*

Let C be a coalgebra and consider the Grothendieck groups of left and right socle-finite injective comodules. We study the Coxeter transformation and its dual for certain classes of coalgebras and relate them to the Auslander-Reiten translate and the end terms of almost split sequences. (Received February 10, 2009)

17 ► Nonassociative rings and algebras

1048-17-14 **Mikael Vejdemo-Johansson*** (mik@math.stanford.edu), Stanford University, Dept. of Mathematics, Bldg 380, Stanford, CA 94305-2125. *Finite time computation of A-infinity algebra structures on Ext algebras.* Preliminary report.

For a k-algebra R, the Ext algebra $\mathrm{Ext}^*_R(k,k)$ carries rich information about the ring and its module category. The algebra $\mathrm{Ext}^*_R(k,k)$ is a finitely presented k-algebra for most nice enough rings. Computation of this ring is done by constructing a projective resolution P of k and either constructing the complex $\mathrm{Hom}(P_n,k)$ or equivalently constructing the complex $\mathrm{Hom}(P,P)$. By diligent choice of computational route, the computation can be framed as essentially computing the homology of the differential graded algebra $\mathrm{Hom}(P,P)$.

Being the homology of a dg-algebra, $\mathrm{Ext}^*_R(k,k)$ has an induced A-infinity structure. This structure, has been shown by Keller and by Lu-Palmieri-Wu-Zhang, can be used to reconstruct R from $\mathrm{Ext}^{\leq 2}_R(k,k)$.

It turns out that for good k-algebras R, the computation of a complete A-infinity algebra structure, specifying explicitly all the structure maps, can be performed with a finite amount of explicit computation. Furthermore, there is an easy sufficient but not necessary test to recognize that an A-infinity structure is complete. In this talk, I will describe these properties and give examples of computations that are feasible using these techniques. (Received November 12, 2008)

1048-17-46 **Sankaran Viswanath*** (svis@math.iisc.ernet.in), Department of Mathematics, Indian Institute of Science, Bangalore, 560012, India. *On Constant term identities of Cherednik-Macdonald-Mehta type for $\widehat{sl_2}\mathbb{C}$.*

We consider Hall-Littlewood polynomials associated to the simplest affine Lie algebra $\widehat{sl_2}\mathbb{C}$. Work of Macdonald and Fishel-Grojnowski-Teleman deal with levels 0 and 1, and allow us to explicitly compute the t-analogs of string functions in these cases.

We describe how to compute principal specializations of the Hall-Littlewood polynomials for certain other highest weights, of levels 2 and 4. These in turn allow us to give closed form expressions for the corresponding t-string functions, and further to derive higher-level analogs of Cherednik's constant term identities of Macdonald and Macdonald-Mehta type. (Received January 12, 2009)

1048-17-47 **Xin Tang*** (xtang@uncfsu.edu), Dept of Math & Computer Science, Fayetteville State University, 1200 Murchison Road, Fayetteville, NC 28301. *Mad subalgebras and finite-dimensional Lie subalgebras of an enveloping algebra.*

In this talk, we present a determination of all maximal ad-nilpotent (mad) associative subalgebras and finite-dimesional Lie subalgebras of the enveloping algebra of the two-dimensional nonabelian Lie algebra. (Received January 12, 2009)

1048-17-54 **Eric Sommers*** (esommers@math.umass.edu), Department of Mathematics and Statistics, LGRT, UMass, Amherst, MA 01002. *A duality map for nilpotent orbits.*

For a simple Lie algebra g and its Langlands dual g', we define a certain set of nilpotent orbits in g x g'. Motivated by work of Achar, we discuss a duality map on this set, which extends the duality map of Lusztig-Spaltenstein. (Received January 16, 2009)

1048-17-99 **Louis A. Levy*** (louis_levy@ncsu.edu), Department of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695. *Multipliers for the Lower Central Series of Strictly Upper Triangular Matrices.*

Lie algebra multipliers and their properties is a recent area of study. A multiplier is the Lie algebra analogue of the Schur multiplier from group theory. By definition a multiplier is central, so we only need to find its dimension in order to characterize it. In this talk we will investigate how to find the dimensions of the multipliers for the lower central series of strictly upper triangular matrices. The closed form result is a set of six polynomial answers in two variables: the size of the matrix and the position in the series. (Received January 29, 2009)

1048-17-121 **Mark L MacDonald*** (mlm@math.ubc.ca), Department of Mathematics, University of British Columbia, Room 121, 1984 Mathematics Road, Vancouver, BC V6T 1Z2, Canada. *Essential dimension of Jordan algebras.* Preliminary report.

One can use knowledge of the structure theory of Jordan algebras to count the number of parameters needed to define an arbitrary reduced simple Jordan algebra of a given degree. This number is called the essential dimension.

More specifically, all reduced simple Jordan algebras of degree $n \geq 3$ are made by combining a quadratic form of dimension n and a composition algebra. This follows from Jacobson's Coordinatization theorem. We

will use this to find the essential dimension of the associated automorphism groups, such as PSp_{2n} and $\mathrm{Spin}(m)$ for $m = 7, 8, 9$. (Received February 02, 2009)

1048-17-132 **Laurie Zack*** (lzack@highpoint.edu), 833 Montlieu Ave, High Point, NC 27262.
Realizations of the Complex Nilpotent Lie Algebras with Small Second Derived Quotient.
The fourteen complex nilpotent Lie algebras with a small second derived quotient are realized here using 7x7 matrices. (Received February 03, 2009)

1048-17-137 **Antun Milas*** (antun.milas@gmail.com), 1400 Washington Avenue, Albany, 12222.
W-algebras, quantum groups and logarithmic conformal field theory.
I will discuss certain W-(super)algebras and their representations in connection with quantum groups and logarithmic conformal field theory. (Joint work with D. Adamović) (Received February 04, 2009)

1048-17-162 **Ben L Cox*** (coxbl@cofc.edu), Department of Mathematics, 66 George St, Charleston, SC 29424, **Andre G. Bueno**, Sao Paulo, Brazil, and **Vyacheslav Futorny**, Sao Paulo, Brazil. *On Free Field Type Realizations for $\widehat{\mathfrak{sl}_n}$.* Preliminary report.
We give a geometric interpretation of several free field type realizations for the affine Lie algebra $\widehat{\mathfrak{sl}_n}$. (Received February 05, 2009)

1048-17-163 **Brian D. Boe**, **Jonathan R. Kujawa** and **Daniel K. Nakano*** (nakano@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30605. *Complexity and varieties for modules over Lie superalgebras.*
Let $\mathfrak{g} = \mathfrak{g}_{\bar{0}} \oplus \mathfrak{g}_{\bar{1}}$ be a classical Lie superalgebra and $\mathcal{F}$ be the category of finite-dimensional $\mathfrak{g}$-modules which are semisimple over $\mathfrak{g}_{\bar{0}}$. In this talk the speaker will explore the homological properties of the category $\mathcal{F}$. In particular it will be shown that $\mathcal{F}$ is Frobenius in the sense that all projective modules are injective. Moreover, all modules in $\mathcal{F}$ admit a projective resolution with polyonomial rate of growth. Later the speaker will show that when $\mathfrak{g}$ is a Type I Lie superalgebra with a (strong) duality that the condition of tilting and projective are equivalent through the use of support varieties in conjunction with the associated varieties defined by Duflo and Serganova. (Received February 05, 2009)

1048-17-177 **Michael R Penkava*** (penkavmr@uwec.edu), Department of Mathematics, University of Wisconsin-Eau Claire, 105 Garfield Avenue, Eau Claire, WI 54702. *Constructing Moduli Spaces of Infinity Algebras.*
In a series of papers, the speaker and Alice Fialowski have been studying the structure of moduli spaces of infinity algebras, using miniversal deformations to determine how the moduli space is glued together. For moduli spaces of complex finite dimensional associative and (super) Lie algebras, the moduli spaces they have constructed have a unique stratification into projective orbifolds, which are connected by jump deformations. In this talk I will discuss some of the methods we have been using to construct these moduli spaces, and some conjectures about their structure. I will also discuss the moduli spaces of Real Lie algebras, which have a decomposition into strata which are given by orbifolds modelled on spheres, rather than projective spaces. (Received February 06, 2009)

1048-17-199 **Dijana Jakelić*** (jakelicd@uncw.edu), Department of Mathematics and Statistics, University of North Carolina, Wilmington, 601 S. College, Wilmington, NC 28401-5970, and **Adriano Moura**. *Representations of hyper loop algebras.*
Hyper loop algebras are certain Hopf algebras associated to affine Kac-Moody algebras. We will focus on finite-dimensional representations of hyper loop algebras over arbitrary fields. The main results concern the classification of the irreducible representations, their tensor products, the construction of the Weyl modules, and base change. Several of the results are related to the study of irreducible representations of polynomial algebras and Galois theory. Time permitting, we may also address multiplicity problems for the underlying tensor category. (Received February 08, 2009)

1048-17-206 **Lindsey R. Bosko*** (lrbosko@gmail.com), 1707 Crest Rd, Apt 6, Raleigh, NC 27606.
Multipliers of Lie Algebras of Maximal Class. Preliminary report.
For a nilpotent Lie algebra, L, of dimension n with multiplier $M(L)$ define $t(L) = \frac{1}{2}n(n-1) - \dim M(L)$. The classification of all such Lie algebras for which $t(L) \leq 8$ is known, but by requiring L to be of maximal class, we can characterize L for cases in which $t(L) > 8$. In this talk we discuss how this classification led to a proposition which bounds $t(L)$. In addition, the group theory analogue of this proposition has been proven for maximal class p-groups. (Received February 08, 2009)

1048-17-208 **Shun-Jen Cheng*** (chengsj@math.sinica.edu.tw), Institute of Mathematics, Academia Sinica, 128 Academia Road, Taipei, 11529, Taiwan. *Representations of Lie algebras and Lie superalgebras.*

We establish a connection between the representation theory of Lie algebras and that of Lie superalgebras of type A. (Received February 08, 2009)

1048-17-226 **William J Cook*** (cookwj@appstate.edu), Appalachian State University, Mathematical Sciences – Walker Hall, 121 Bodenheimer Dr., Boone, NC 28608. *On contragradient modules for a vertex operator algebra associated with an affine Lie algebra.* Preliminary report.

Modules for vertex operator algebras (VOAs) associated with affine Lie algebras are some of the most familiar examples of VOA modules. Given such a module, we will explicitly determine what its contragradient module is (up to equivalence).

With this information in hand, we will discuss the interaction of this contragradient action and the action of certain operators of Haisheng Li on the equivalence classes of irreducible modules.

Along with Yi-Zhi Huang, the author guided Sjuvon Chung and Christopher Sadowski's study of these actions during Rutgers University's REU program this past summer. (Received February 09, 2009)

1048-17-246 **Alex J Feingold*** (alex@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, Vestal Parkway East, Binghamton, NY 13902-6000. *Hyperbolic Weyl groups and related Coxeter groups.* Preliminary report.

In recent work of Alex Feingold, Axel Kleinschmidt and Hermann Nicolai ("Hyperbolic Weyl groups and the four normed division algebras"), the Weyl groups of many hyperbolic Kac-Moody algebras of ranks 3, 4, 6 and 10 were explicitly realized as certain 2x2 matrices with entries from the four normed division algebras, R, C, H and O, respectively, acting on spaces of 2x2 Hermitian matrices. In the rank 3 case associated with R, the Weyl group is the hyperbolic triangle group $T(2,3,\infty)$ isomorphic to PGL(2,Z), an index two extension of the modular group. That case, and the corresponding hyperbolic Kac-Moody algebra, were extensively studied in 1983 by A. Feingold and I. Frenkel, who also knew that two rank 4 cases had Weyl group containing PSL(2,Z[i]) with index four. This talk will present some extensions of the work of Feingold, Kleinschmidt and Nicolai, including a realization of other hyperbolic triangle groups such as T(3,4,5), and possible use of other algebras in place of the four normed division algebras. (Received February 09, 2009)

1048-17-256 **Maarten Bergvelt*** (bergv@uiuc.edu). *Non Associativity for Quantum Vertex Algebras.* Preliminary report.

Quantum vertex algebras, in contrast with the usual vertex algebras, are in general non associative.

Haisheng Li introduced vertex operators for vertex operators, giving a vertex algebra structure on the space of vertex operators. We show that, maybe surprisingly, the quantum vertex operators of qauntum vertex operators ARE associative.. (Received February 09, 2009)

1048-17-259 **Elizabeth Jurisich*** (jurisiche@cofc.edu), 66 George Street, Mathematics Dept RSS, Charleston, SC 29424. *Borcherds (GKM) algebras and finite order automorphisms.* Preliminary report.

We consider some special cases of Borcherds type algebras, finite order automorphisms and the corresponding fixed subalgebras. (Received February 09, 2009)

1048-17-291 **Michael K Lau*** (mlau@uwindsor.ca), University of Windsor, Dept. of Math and Stats, 401 Sunset Ave., Windsor, Ontario N9B 3P4, Canada. *Representations of Multiloop Algebras.*

Multiloop algebras and their extensions have recently appeared in a variety of algebraic, geometric, and physical contexts, including extended affine Lie algebras, toroidal symmetries, and twisted current algebras. They are multivariable generalizations of the loop algebras appearing in affine Kac-Moody theory.

An untwisted multiloop algebra is simply a Lie algebra of polynomial maps from an N-torus to a finite-dimensional simple Lie algebra L. Twisted multiloop algebras are fixed point subalgebras determined by any family of N commuting finite-order automorphisms of L. In this talk, we describe the finite-dimensional simple modules of all (twisted and untwisted) multiloop algebras. These modules can be classified up to isomorphism by equivariant maps on N-tori. (Received February 09, 2009)

1048-17-302 **Brian D. Boe*** (brian@math.uga.edu), Mathematics Department, University of Georgia, Athens, GA 30602, **Daniel K. Nakano** (nakano@math.uga.edu), Mathematics Department, University of Georgia, Athens, GA 30602, and **Emilie Wiesner** (ewiesner@ithaca.edu), Mathematics Department, Ithaca College, Ithaca, NY 14850.
Ext^1-quivers for the Witt Algebra $W(1,1)$.

Let $\mathfrak{g}$ be the finite dimensional Witt algebra $W(1,1)$ over an algebraically closed field of characteristic $p \geq 5$. It is well known that all simple $W(1,1)$-modules are finite dimensional. Each simple module admits a character $\chi \in \mathfrak{g}^*$. Given $\chi \in \mathfrak{g}^*$ one can form the (finite dimensional) reduced enveloping algebra $u(\mathfrak{g}, \chi)$. The simple modules for $u(\mathfrak{g}, \chi)$ are precisely those simple $W(1,1)$-modules admitting the character χ. In this talk I will show how to compute Ext^1 between pairs of simple modules for $u(\mathfrak{g}, \chi)$. (Received February 10, 2009)

1048-17-321 **Dimitar V Grantcharov*** (grandim@uta.edu), Department of Mathematics, UT Arlington, Arlington, TX 76019, and **Ivan Dimitrov**. *Weight Modules of Affine Lie Algebras.* Preliminary report.

The problem of classifying irreducible weight modules with finite dimensional weight spaces over affine Lie algebras has been studied actively for the last 20 years. Remarkable results include the classification of integrable modules by V. Chari, the study of parabolically induced modules by V. Futorny, and the study of weight modules with bounded weight multiplicities by D. Britten and F. Lemire. There are two important classes of irreducible weight modules with finite dimensional weight spaces: the parabolically induced modules and the loop modules. Several authors made conjectures that would imply that these exhaust all irreducible weight modules with finite dimensional weight spaces. In a joint work with I. Dimitrov we confirm that these conjectures are correct and as a result obtain the classification. In this talk we will present the main ideas and results from our joint work. (Received February 10, 2009)

1048-17-322 **Audrey Malagon*** (audrey.malagon@emory.edu), 400 Dowman Dr., Atlanta, GA 30322.
A New Approach to Killing Forms.

One approach to the problem of classifying Lie Algebras is to find invariants. One such invariant is the Killing form. In this talk I will give a formula for computing the Killing form of an isotropic Lie algebra defined over an arbitrary field of characteristic zero, based on the Killing form of a subalgebra containing its anisotropic kernel. I will then explicitly compute the Killing form for several Lie algebras of exceptional type and give a general formula for the Killing form of all inner type Lie algebras of type E6, including the anisotropic ones. (Received February 10, 2009)

1048-17-325 **Markus Hunziker** and **W. Andrew Pruett*** (drew_pruett@baylor.edu), Baylor University, Department of Mathematics, One Bear Place #97328, Waco, TX 76798.
Generalized Young Diagrams for Hermitian Symmetric Spaces.

Using a generalization of Young diagrams, we give a unified description of the BGG resolutions of unitary highest weight modules. Our generalized Young diagrams can also be used to compute Kazhdan-Lusztig polynomials for the Hermitian symmetric spaces. (Received February 10, 2009)

1048-17-327 **Fred W. Helenius*** (fheleni@emory.edu). *Freudenthal Triple Systems by Root System Methods.*

A *Freudenthal triple system* (FTS) is a vector space endowed with a quartic form and a bilinear form such that a triple product defined from these forms satisfies a specific identity. The original example is the 56-dimensional representation of E_7; here, the group stabilizing both forms is precisely E_7. M. Rost observed that an 8-dimensional vector space with quartic form occurring in a paper of M. Bhargava was, with a suitable bilinear form, a FTS; he asked what the stabilizer of the forms was in this case. We answer his question by showing that both his example and the 56-dimensional representation of E_7 are instances of a general construction that reveals a FTS within any Lie algebra of type B, D, E or F, with natural definitions for the quartic and bilinear forms. (Received February 10, 2009)

1048-17-336 **Robert Lee Wilson*** (rwilson@math.rutgers.edu), Rutgers University, Department of Mathematics, Piscataway, NJ 08854-8019. *Multisum identities related to $A_1^{(1)}$.* Preliminary report.

Let $k, k_0, k_1 \geq 0$ be integers with $k_0 \leq k-1$ and $k_0 + k_1 = 2k-1$. Then the principally specialized character of the vacuum space for the standard $A_1^{(1)}$-module with highest weight $\Lambda = k_0\Lambda_0 + k_1\Lambda_1$ may be expressed (by a result of Gordon) as as an infinite sum $\sum_{m\geq 0} |A(k,k_0,m)|q^m$ where $A(k,k_0,m)$ is the set of partitions $(a_1, ..., a_s)$ of m satisfying $a_1 \geq a_2 \geq ... \geq a_s, a_i - a_{i+k-1} \geq 2 \ \ \forall\ i, 1 \leq i \leq s-k+1$, and $a_{s-k_0} > 1$. It may

also be expressed (by a result of Andrews) as a multisum. We relate these two expressions using the operators $X^{(i)}$ introduced by Meurman and Primc on the standard $A_1^{(1)}$-module V_Λ. (Received February 10, 2009)

18 ► Category theory; homological algebra

1048-18-59 **Rafael Diaz*** (ragadiaz@gmail.com). *N-differential graded algebras: examples and applications.*

Introduced by Meyer in the 40's and revived by Kapranov in the 90's the theory of N-complexes is gradually attaining its due place in homological algebra. A fundamental task is to find out the analogue for the notion of differential graded algebras in the context of N-complexes. Kerner proposed the notion of q-differential graded algebras, which are associative graded algebras provided with a degree 1 linear map d such that $d^N = 0$ and the q-deformed Leibnitz rule holds. Another option is that of N-differential graded algebras (N-dga) which are graded associative algebras provided with a degree 1 linear map such that $d^N = 0$ and the usual Leibnitz rule holds. We show that there are plenty of examples of N-dga arising naturally in algebra differential geometry, and topology. We also show that there are interesting theoretical results concerning N-dga, for example there is an equation called the (N, M) Maurer-Cartan equation which controls deformations of a N-dga into a M-dga. The theory of N-dga may lead to the discovery of new forms of infinitesimal symmetries, for example we discuss and provide examples of Lie 3-algebroids. Finally, we report on a homotopical generalization of the notion of N-dga. (Received January 19, 2009)

1048-18-87 **Alissa S. Crans*** (acrans@lmu.edu), Loyola Marymount University, Department of Mathematics, One LMU Drive, Suite 2700, Los Angeles, CA 90045. *L-infinity algebras and Lie 2-algebras.*

A 'Lie 2-algebra' is a categorified version of a Lie algebra where the Jacobi identity holds up to a natural isomorphism called the 'Jacobiator', which in turn must satisfy a certain law of its own. This law is closely related to the Zamolodchikov Tetrahedron Equation, which is the higher-dimensional analogue of the Yang-Baxter Equation, or third Reidemeister move. The tetrahedron equation plays a role in the theory of knotted surfaces in 4-space which is closely analogous to that played by the third Reidemeister move in the theory of ordinary knots in 3-space. We show that just as any Lie algebra gives a solution of the Yang-Baxter equation, any Lie 2-algebra gives a solution of the Zamolodchikov tetrahedron equation. In addition, construct a 2-category of Lie 2-algebras and show that it is 2-equivalent to the 2-category of '2-term L-infinity algebras'. Finally, we classify Lie 2-algebras in terms of third cohomology classes in Lie algebra cohomology. This classification allows us to construct for any finite-dimensional Lie algebra $\mathfrak{g}$ a 1-parameter family of Lie 2-algebras, $\mathfrak{g}_k$. (Received January 27, 2009)

1048-18-164 **Tom Lada*** (lada@math.ncsu.edu), Mathematics Department, Box 8205, North Carolina State University, Raleigh, NC 27695. *Finite Dimensional L_∞ Algebras.* Preliminary report.

We will discuss several finite dimensional examples of L_∞ algebras. In particular, of such example will be shown to be a non-trivial example of an open-closed homotopy algebra. (Received February 05, 2009)

20 ► Group theory and generalizations

1048-20-128 **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. *Vanishing ranges for the cohomology of finite groups of Lie type.* Preliminary report.

Let G be a simple algebraic group over a field k of prime characteristic p which is split over the prime field $\mathbb{F}_p$, and $\mathrm{Fr} : G \to G$ denote the Frobenius map. The fixed points of the rth iterate of the Frobenius map, denoted $G(\mathbb{F}_{p^r})$, is a finite Chevalley group. A long standing elusive open problem is to determine the cohomology ring $\mathrm{H}^\bullet(G(\mathbb{F}_{p^r}), k)$. In general one does not even know in which degree the first non-trivial cohomology class occurs. In this talk we investigate two problems:

1. Determining Vanishing Ranges: Finding $D > 0$ such that the cohomology group $\mathrm{H}^i(G(\mathbb{F}_{p^r}), k) = 0$ for $0 \leq i \leq D$.

2. Locating the First Non-Trivial Cohomology Class: In many instances we will find a D such that $\mathrm{H}^i(G(\mathbb{F}_{p^r}), k) = 0$ for $0 < i \leq D$ and $\mathrm{H}^{D+1}(G(\mathbb{F}_{p^r}), k) \neq 0$. (Received February 03, 2009)

1048-20-146 **C. Ryan Vinroot*** (vinroot@math.wm.edu), Mathematics Department, College of William and Mary, P. O. Box 8795, Williamsburg, VA 23187. *Shintani lifting, finite subfield symmetric spaces, and real-valued characters.* Preliminary report.

Let G be a connected reductive algebraic group with connected center defined over a finite field $\mathbb{F}_q$ with Frobenius map F, and so defined over $\mathbb{F}_{q^2}$ with Frobenius map F^2. Let χ be an irreducible real-valued uniform character of G^{F^2}. We show that if χ is the Shintani lift of a character of G^F, then χ must be the character of a representation defined over the real numbers. The proof of this statement follows from results on subfield symmetric spaces over finite fields due to Kawanaka and others. We also obtain results concerning the behavior of real-valued irreducible Deligne-Lusztig characters under Shintani lifting of arbitrary degree. (Received February 04, 2009)

1048-20-150 **Ting Xue*** (txue@math.mit.edu), Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA 02139. *Nilpotent orbits in characteristic 2 and Springer correspondence.*

Let G be an adjoint algebraic group of type B, C or D defined over an algebraically closed field $\mathbf{k}$ of characteristic 2 and $\mathfrak{g}$ be the Lie algebra of G. Let $\mathfrak{g}^*$ be the dual vector space of $\mathfrak{g}$. We construct Springer correspondences for the nilpotent varieties in $\mathfrak{g}$ and $\mathfrak{g}^*$. The correspondence in $\mathfrak{g}$ (resp. $\mathfrak{g}^*$) is a bijective map from the set of isomorphism classes of irreducible representations of the Weyl group of G to the set of all pairs $(\mathrm{c}, \mathcal{F})$, where c is a nilpotent G-orbit in $\mathfrak{g}$ (resp. $\mathfrak{g}^*$) and $\mathcal{F}$ is an irreducible G-equivariant local system on c (up to isomorphism). In particular, we classify the nilpotent G-orbits in $\mathfrak{g}^*$ over $\mathbf{k}$ and the nilpotent G-orbits in $\mathfrak{g}$ and $\mathfrak{g}^*$ over finite fields of characteristic 2. (Received February 04, 2009)

1048-20-189 **Christopher P Bendel*** (bendelc@uwstout.edu), Math, Stats, and Comp Sci Dept, 237 Harvey Hall, University of Wisconsin-Stout, Menomonie, WI 54751. *Cohomology of Frobenius kernels and vanishing of line bundle cohomology.* Preliminary report.

Let G be a simple algebraic group over an algebraically closed field k of prime characteristic p. If p is greater than Coxeter number of G, then the cohomology of the first Frobenius kernel of G can be identified with the coordinate algebra of the nullcone of Lie(G). For small primes, the cohomology algebra has not been determined in general. This talk will briefly discuss recent work with D. Nakano, B. Parshall, and C. Pillen in which identifications were made for some small primes. Two geometric conditions were identified, which, if known to be true, would allow one to identify the cohomology ring in almost all cases. One condition involves the normality of certain varieties and the second involves the vanishing of line bundle cohomology of symmetric powers of the dual of a nilpotent subalgebra of Lie(G). We will discuss the latter condition, a recent algorithm (and computer program) developed by A. Christophersen (in her Aarhus University Ph.D. Thesis) for a group of type E_6 to potentially verify the condition in special cases, and modifications of the original program to arbitrary types made by an undergraduate student J. Mankovecky. (Received February 06, 2009)

1048-20-193 **George J McNinch*** (mcninchg@member.ams.org), Department of Math, Tufts University, 503 Boston Ave, Medford, MA 02155. *Rational nilpotent orbits for a reductive group over a local field.* Preliminary report.

Let G be a semisimple group defined over a local field F, and suppose that the residual characteristic is very good for G. The talk will discuss the relationship between the G(F)-orbits on nilpotent elements in Lie(G)(F) with the nilpotent orbits of the special fibers of parahoric subgroup schemes attached to G. This relationship was first described by DeBacker when the residual characteristic p is sufficiently large; the talk will discuss how to relax the conditions on p. (Received February 07, 2009)

1048-20-203 **Chuck Hague*** (chuck.hague@tufts.edu), Tufts University Department of Mathematics, Bromfield-Pearson Building, 503 Boston Ave., Medford, MA 02155. *Cohomology of Cotangent Bundles of Flag Varieties and the BK-Filtration.*

Let G be a complex algebraic group and let P be a parabolic subgroup of G. Let $T^*(G/P)$ denote the cotangent bundle of the flag variety G/P. In this talk I will describe results connecting cohomology of bundles on $T^*(G/P)$ to purely combinatorial objects such as filtrations on G-modules and generalizations of Lusztig's q-analog of weight multiplicity. (Received February 08, 2009)

1048-20-245 **Jennifer R Daniel*** (jennifer.daniel@lamar.edu), Lamar University, Department of Mathematics, Campus Box 10047, Beaumont, TX 77710, and **Daniel J Gagliardi** (gagliardid@canton.edu), 328 Faculty Office Building, 37 Cornell Drive, Canton, NY 13617. *Algorithms for computing characters of real reductive symmetric spaces.*

Gagliardi and Helminck gave a complete set of algorithms to compute the characters of Riemannian symmetric spaces. In this work we extend these results to general real reductive symmetric spaces. The fine structure of

these symmetric spaces can be obtained from a complex reductive Lie group with a pair of commuting involutions, σ and θ. The actions of σ and θ are represented graphically by a (σ, θ)- diagram. Implicit in each diagram is four root systems $\Phi(\mathfrak{a})$, $\Phi(\mathfrak{a}_1)$, $\Phi(\mathfrak{a}_2)$, and $\Phi(\mathfrak{t})$. The weight lattices associated with these root systems are denoted by $\Lambda_{\mathfrak{t}}$, $\Lambda_{\mathfrak{a}}$, $\Lambda_{\mathfrak{a}_1}$, and $\Lambda_{\mathfrak{a}_2}$, respectively. The natural projection maps π, π_1, and π_2 extend linearly to the associated weight lattices. Gagliardi and Helminck showed that $\pi_1(\Lambda_{\mathfrak{t}}) = \Lambda_{\mathfrak{a}_1}$ and $\pi_2(\Lambda_{\mathfrak{t}}) = \Lambda_{\mathfrak{a}_2}$. In this work, we extend these results to show that $\pi(\Lambda_{\mathfrak{t}}) = \pi_2|_{\mathfrak{a}_1}(\pi_1(\Lambda_{\mathfrak{t}})) = \pi_1|_{\mathfrak{a}_2}(\pi_2(\Lambda_{\mathfrak{t}})) = \Lambda_{\mathfrak{a}}$. (Received February 09, 2009)

1048-20-289 **Brian Parshall*** (bjp8w@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22903. *Reduced standard and costandard modules.* Preliminary report.

Let G be a simple, simply connected algebraic group defined over a field k of characterstic $p > h$ (the Coxeter number). Given a dominant weight λ, the reduced standard (resp., costandard) module $\Delta^{\mathrm{red}}(\lambda)$ (resp., $\nabla_{\mathrm{red}}(\lambda)$ are defined by a process of reduction mod p from the quantum enveloping algebra at a pth root of unity. When the Lusztig character formula holds, these modules have remarkable homological properties. This talk (which is joint work with Leonard Scott) reports on progress to establish that Weyl modules have reduced standard filtrations. Some applications are indicated. (Received February 09, 2009)

1048-20-332 **Stacy L. Beun*** (slb96@cabrini.edu), Cabrini College, 610 King of Prussia Rd, Radnor, PA 19087. *Classifying conjugacy classes of maximal (θ, k)-split tori in $SL(n, k)$.* Preliminary report.

Classifying the orbits of a minimal parabolic k-subgroup acting on a symmetric k-variety is essential to the study of symmetric k-varieties and their representations. For general fields, Helminck and Wang gave several general characterizations of these orbits; however, field-specific classifications are still needed for each class of symmetric k-variety. In order to classify these orbits, we need to first classify the H_k-conjugacy classes of maximal (θ, k)-split tori, where θ is the defining involution of the symmetric k-variety and H_k is the fixed point group of θ. In this work, we classify the H_k-conjugacy classes of maximal (θ, k)-split tori for various involutions of $\mathrm{SL}(n, k)$ and for a number of bases fields, including finite fields and the p-adic numbers. (Received February 10, 2009)

1048-20-339 **Esther Beneish***, Department of Mathematics, Mount Pleasant, MI 48859. *Lattice invariants over cyclic groups and Noether settings.*

Let F be a field of characteristic zero containing primitive m^{th} roots of 1 for all natural numbers m. Let ω_m be a primtive m^{th} root of 1 for some positive integer m, and let p be a prime such that m divides $p-1$. Let a be an integer which is a primitive m^{th} root of 1 mod p, and let $I_{p,m}$ be the ideal in $Z[\omega_m]$ generated by p and $\omega_m - a$. Let G be a cyclic group of order n with the following property. For each class C in the class group of ZG, which contains a maximal ideal, there exists a maximal ideal U in C with ZG/U of exponent p, such that n divides $p-1$, and such that for all m dividing n, $I_{p,m}$ is principal. This condition is satisfied by all finite cyclic groups for which the class group of ZG is zero. We show that for any ZG-lattice M, $F(M)^G$, the fixed subfield of $F(M)$, is stably rational over F. As a direct consequence of this, we obtain the following result. For any finite G-module T, $F(G')^{G'}$, the fixed subfield of the Noether setting of the group $G' = T \rtimes G$, is stably rational over F. (Received February 10, 2009)

22 ► Topological groups, Lie groups

1048-22-51 **Shrawan Kumar*** (kumar@math.unc.edu), Department of Mathematics, UNC at Chapel Hill, Chapel Hill, NC 27599-3250. *A conjectural presentation of fusion algebras.* Preliminary report.

This is a joint work with Arzu Boysal. Let G be a compact connected and simply-connected Lie group and let R(G) be its representation ring. For any positive integer k, let R(G;k) denote the fusion ring of G at level k. Then, R(G;k) is a quotient of R(G). Let I(G;k) be the kernel. Generalizing some results of Gepner, we give a conjectural presentation of this ideal for classical groups as well as for the exceptional group G2. (Received January 13, 2009)

1048-22-63 **Konstanze Rietsch** and **Lauren Williams***, Department of Mathematics, Harvard University, 1 Oxford Street, Cambridge, MA 02138. *Discrete Morse theory for totally nonnegative flag varieties.*

In a seminal 1994 paper, Lusztig extended the theory of total positivity by introducing the totally non-negative part $(G/P)_{\geq 0}$ of an arbitrary (generalized, partial) flag variety G/P. He referred to this space as a "remarkable polyhedral subspace," and conjectured a decomposition into cells, which was subsequently proven by the first

author. In this article we use discrete Morse theory to show that the cell decomposition of $(G/P)_{\geq 0}$ is polyhedral in the following sense: closures of cells are collapsible and hence contractible. This answers a question posed by Lusztig in 1996, and generalizes a later result of Lusztig's, that $(G/P)_{\geq 0}$ – the closure of the top-dimensional cell – is contractible. Furthermore, we show that the boundary of each cell – hence in particular the boundary of $(G/P)_{\geq 0}$ – is homotopy equivalent to a sphere. (Received January 20, 2009)

1048-22-66 **Alfred Gérard Noël*** (alfred.noel@umb.edu) and **Steven Glenn Jackson**. *Invariant Theory of the Enveloping Algebra.* Preliminary report.

A theorem of Harish-Chandra says that an irreducible $(\mathfrak{g}, K)$-module is determined up to infinitesimal equivalence by the action of the centralizer of K in the enveloping algebra of $\mathfrak{g}$, $U_{\mathfrak{g}}^K$, on any K-primary component.

This work explains how to exploit the Kostant-Rallis theorem in order to accelerate a computationally intensive algorithm of Kostant which computes a set of generators for $U_{\mathfrak{g}}^K$.

We illustrate our approach by computing generators for several unsolved cases such as $SL(3,\mathbb{R})$, $SL(4,\mathbb{R})$, $Sp(4,\mathbb{R})$ and the split real form of G_2. (Received January 20, 2009)

1048-22-70 **Jeffrey Adams**, **Marc van Leeuwen**, **Peter Trapa** and **David A. Vogan*** (dav@math.mit.edu), Room 2-243, MIT, 77 Massachusetts Ave, Cambridge, MA 02139. *Kazhdan-Lusztig polynomials for signatures.* Preliminary report.

Suppose G is a real reductive Lie group. One of the classical problems in representation theory is to describe completely the set $\widehat{G}_u$ of irreducible unitary representations of G. There are still complete answers only for some special cases.

We will discuss work in progress aimed at creating and implementing an algorithm to solve this problem: a computer program that, for any particular G, can calculate $\widehat{G}_u$. The work is based on ideas of Wai Ling Yee, who solved an analogous problem for highest weight representations of reductive Lie algebras. As with Yee's work, the main tool is a generalization of Kazhdan-Lusztig polynomials, designed to carry information about signatures of invariant Hermitian forms (in the same way that classical Kazhdan-Lusztig polynomials carry information about characters of representations). (Received January 22, 2009)

1048-22-102 **Robert Milson*** (rmilson@dal.ca), DEPT. OF MATHEMATICS and STATISTICS, Dalhousie University, Halifax, NS B3L 4B6, Canada. *On projective equivalence of univariate polynomial subspaces.*

We pose and solve the equivalence problem for subspaces of P_n, the $n+1$ dimensional vector space of univariate polynomials of degree less than or equal to n. The group of interest is PSL_2 acting by projective transformations on the grassmannian variety $G_k P_n$ of k-dimensional subspaces. We establish the equivariance of the Wronski map and use this map to reduce the subspace equivalence problem to the equivalence problem for binary forms. (Received January 30, 2009)

1048-22-107 **Ryad A Ghanam*** (ghanam@pitt.edu), 150 Finoli Dr, Department of Mathematics, University of Pittsburgh at Greensburg, Greensburg, PA 15601. *Representations of Low Dimensional Lie Algebras and Applications.*

In this talk I will report on the progress of the problem of finding linear representations for low-dimensional real Lie algebras. For each Lie algebra of dimension less than or equal to 6, I will give a matrix Lie group whose Lie algebra is the given algebra in the list. I will also report on the progress of finding representations for the 7-dimensional real nilpotent Lie algebras. As an application, I will show how to use these representations to solve the inverse problem of Lagrangian mechanics for the canonical connection on Lie groups. (Received January 31, 2009)

1048-22-209 **John M. Absher*** (jmabsher@ncsu.edu), John M. Absher, E.S. King Village, Apt. Q-222, 3930 Jackson St., Raleigh, NC 27607, and **A. Helminck** (loek@ncsu.edu), NC. *Classification of isomorphism classes of involutions of SO(2n,k).* Preliminary report.

Symmetric k-varieties are defined as the homogeneous spaces G/H, where H is the fixed point group of an involution θ of a reductive algebraic group G defined over a field k of characteristic not 2. The classification of these symmetric k-varieties reduces to a classification of the isomorphism classes of involutions of G. In this talk we discuss the classification of these isomorphism classes of involutions in the case of the group $G = \mathrm{SO}(2n,k)$. Naturally this classification depends on the field k and we will present a detailed classification for k algebraically closed, the real numbers, the p-adic numbers or a finite field. (Received February 08, 2009)

1048-22-212 **Aloysius G Helminck*** (loek@math.ncsu.edu), Department of Mathematics, Campus Box 8205, North Carolina State University, Raleigh, NC 27695. *Computing in Symmetric Spaces.*

In the last few decades much of the structure of Lie groups, Lie algebras, and their representations has been implemented in several excellent computer algebra packages. The structure of reductive symmetric spaces and more generally symmetric k-varieties in the case of arbitrary base fields rests on that of the underlying Lie group. Until a few years ago very few algorithms existed for computations in these symmetric spaces, mostly due to the fact that their structure is more complicated then that of the underlying group. For example instead of just 1 root system the study of symmetric k-varieties involves 5 root systems.

In this talk we will give an introduction to symmetric k-varieties, discuss briefly the similarities between the structure of the real symmetric spaces and these symmetric k-varieties and explain for which aspects of the structure there exists algorithms. One aspect of this structure will be discussed in more detail, namely, the orbits of minimal parabolic k-subgroups acting on the symmetric k-variety. These are of fundamental importance in the study of these symmetric k-varieties. For $k = \mathbb{R}$ a characterization of these orbits was given by Matsuki, for $k = \bar{k}$ by Springer and for arbitrary fields by Helminck and Wang. (Received February 08, 2009)

1048-22-237 **Milen T Yakimov*** (yakimov@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Poisson structures on flag varieties.*

The geometry of Poisson structures originating from Lie theory found numerous applications in representation theory, ring theory, and dynamical systems.

In this talk we will describe in detail the geometry of a class of Poisson structures on complex flag varieties and their relations to Schubert cells and Deodhar partitions, cluster algebras, and total positivity. For hermitian symmetric spaces of compact type, these Poisson structures further elucidate works of Wolf, Richardson, Röhrhle, and Steiberg on the orbit structure of certain Levi factors. For Grassmannians they can be used to give a short proof of the recent cyclicity theorem of by Knutson, Lam and Speyer for the Lusztig stratification. (Received February 09, 2009)

1048-22-268 **William Graham*** (wag@math.uga.edu) and **Roger Zierau** (zierau@math.okstate.edu). *Smooth components of Springer fibers.*

We study components of Springer fibers for $GL(n)$ associated to closed $GL(p) \times GL(q)$-orbits on the flag variety. Building on work of Barchini and Zierau, we show that these components have the structure of iterated fiber bundles, and hence are smooth; moreover, the components are invariant under the maximal torus of $GL(n)$. This allows us to obtain some multiplicity formulas related to associated cycles for discrete series representations. (Received February 09, 2009)

1048-22-272 **G. F. Helminck*** (g.f.helminck@uva.nl), Korteweg de Vries Institute for Mathematics, University of Amsterdam, Plantage Muidergracht 24, 1018TV Amsterdam, Netherlands, and **A. G. Helminck**. *New results for p-adic symmetric spaces and their representations.*

Symmetric spaces are defined as the homogeneous spaces G_k/H_k with G a reductive algebraic group defined over a field k, $H = G^\sigma$ the fixed point group of an k-involution σ and G_k and $H_k = G^\sigma(k)$ denote the sets of k-rational points of G and H. These symmetric spaces occur in many problems in representation theory, geometry, singularity theory, the study of automorphic forms, etc. Best known are the symmetric spaces over the real numbers (also called *reductive symmetric spaces*). Over the last few decades many people have studied the structure and representations associated with these real reductive symmetric spaces, leading to a Plancherel formula in the mid 90's. More recently a number of people have started to study representations associated with symmetric spaces over finite fields and p-adic symmetric spaces. The latter is the natural next case to study now that the Plancherel formula for the real symmetric spaces has been completed. In this talk we present some recent results about these p-adic symmetric spaces and their representations. (Received February 09, 2009)

1048-22-278 **Molly Fenn*** (mafenn2@ncsu.edu), 255 Harrelson Hall, Box 8205, Raleigh, NC 27695. *Generating equivalence classes of B-stable ideals.*

Given a complex semisimple algebraic group G and a fixed Borel subgroup B, we consider the set of B-stable ideals in the nilradical of the Lie algebra of B. Each ideal corresponds to a nilpotent orbit in the Lie algebra of G in a natural way, and also to a subgroup of the component group associated to that orbit. This leads us to define two equivalence relations on the set of ideals. We will look at a series of simple 'moves', ways to move from one ideal to a smaller ideal, which may generate the equivalence classes. (Received February 09, 2009)

1048-22-328 **Jeffrey Adams*** (jda@math.umd.edu), Mathematics Department, University of Maryland, College Park, MD 20742, and **Peter Trapa**, **Marc van Leeuwen** and **David Vogan**. *Computing Hermitian Representations of Real Groups.* Preliminary report.

Abstract: Suppose G is a real reductive Lie group. One of the classical problems in representation theory is to describe completely the set $\widehat{G}_u$ of irreducible unitary representations of G. There are still complete answers only for some special cases. This is one of the primary goals of the Atlas of Lie Groups and Representations project, and its accompanying software.

The first step is to compute the Hermitian representations: those representations which admit an invariant Hermitian form (it is unitary if this form is positive definite). This is known by work of Knapp and Zuckerman. I will describe how this manifests itself in the Atlas software.

This is the first of a series of two talks; the other is by David Vogan. (Received February 10, 2009)

26 ► Real functions

1048-26-133 **Douglas David Marks*** (ddmarks@ncsu.edu), 7832 Silverthread ln, Raleigh, NC 27617. *Deciding Feasibility of Polynomial Inequalities by Numerical Filtering.* Preliminary report.

Deciding the feasibility (existence of solution) of system of polynomial inequalities is a fundamental problem in computational real algebraic geometry. Furthermore, it has many applications in science and engineering. Thus, there has been extensive research on the problem. However, many important and challenging application problems are still practically out of reach for the existing algorithms in spite of tremendous progress made in their efficiency during last 60 years.

In this talk, we will describe an efficient numerical "filter" that can decide the feasibility for "most" cases. We need to call the existing symbolic algorithms only when the filter fails (which is rare). (Received February 03, 2009)

32 ► Several complex variables and analytic spaces

1048-32-8 **Maher M.H. Marzuq*** (mmarzuq@moc.edu), 634 Henderson Street, Mount Olive, NC 28365. *On Class of Spaces of Holomorphic and Pluriharmonic Functions on Bounded Symmetric Domains in $C^n (n > 1)$.*

Let D be a bounded symmetric domain in with Bergman-Silov boundary b. The spaces of holomorphic functions with norm are considered. Estimations for the Fourier coefficients of a function are obtained generalizing a result on the unit disc of Gvaradze (1977). The corresponding spaces of pluriharmonic functions are introduced and it is shown that is self-conjugate generalizing a result of Mitchell (1981) who studied on bounded symmetric domains. (Received October 12, 2008)

34 ► Ordinary differential equations

1048-34-13 **Saeed Otarod*** (sotarod@yahoo.com), Physics Department, Yasouj University, 7591874831 Yasouj, Yasouj, Iran, and **Mohamad Reeza Khodakarim Ardekani** (khodakarim@yahoo.com), Physics Department, Yasouj University, 7591874831 Yasouj, Yasouj, Iran. *More On The Exact Solutions Of The Second Order Linear Homogeneous Differential Equations.*

Exact solution of an infinite number of different complicated second order linear homogeneous differential equations will be given. This will add much to our knowledge about these types of differential equations and the physics behind them. As a result their related nonhomogeneous differential equations in many cases will be found accordingly. (Received October 26, 2008)

1048-34-50 **Murat Arcak*** (arcak@eecs.berkeley.edu), 569 Cory Hall, University of California, Berkeley, CA 94720, and **Eduardo Sontag** (sontag@math.rutgers.edu), Rutgers, the State University of New Jersey, Hill Center, Piscataway, NJ 08854. *Passivity-Based Stability Analysis and Applications to Biochemical Reaction Networks.*

The passivity concept - an abstraction of energy conservation and dissipation in physical systems - has been instrumental in feedback control theory and led to breakthroughs in nonlinear and adaptive control design. In this talk we discuss the use of passivity as a stability test for classes of biochemical reaction networks. The main result determines global asymptotic stability of the network from the diagonal stability of a dissipativity

matrix which incorporates information about the passivity properties of the subsystems, the interconnection structure of the network, and the signs of the feedback terms. This stability test encompasses the well-known "secant criterion" for cyclic networks and extends it to general interconnection structures represented by graphs. The results are illustrated on MAPK cascade models and on branched interconnection structures motivated by metabolic networks. (Received January 13, 2009)

1048-34-91 **Elizabeth L Mansfield*** (e.l.mansfield@kent.ac.uk), IMSAS, University of Kent, Canterbury, CT2 7NF, England. *Moving frames and Noether's Theorem.* Preliminary report.

The reformulation of the concept of moving frames by Fels and Olver allows it to apply to many classes of equivalence problems that do not necessarily arise in differential geometry. Suppose that a Lie group G acts smoothly on some smooth space M. A moving frame is defined to be an equivariant map $\rho : M \to G$. The equivariance, together with a straightforward use of multivariable calculus, allows for a plethora of results concerning the symbolic manipulation of invariants to be obtained.

Recently the author obtained a method that yields the Euler Lagrange equations of a Lagrangian which is invariant under a Lie group action, directly in terms of the invariants, but using only the symbolic invariant calculus. This complements work by Kogan and Olver who used a trivariational complex to solve the same problem.

As a by product of the speaker's method, the conservation laws yielded by Noether's Theorem can be written down in terms of a particular matrix representation of the frame and a vector of invariants.

The result presented is joint work with Tania Gonçalves (University of Kent, UK). Recent results due to Hubert on obtaining generating sets of syzygies of differential invariants will play a role in turning template calculations into theorems. (Received January 28, 2009)

1048-34-92 **Harry Gingold*** (gingold@math.wvu.edu), West Virginia University, Department of Mathematics, Morgantown, WV 26505. *THE PARABOLIC COMPACTIFICATION AND APPLICATIONS TO DYNAMICAL SYSTEMS.*

The properties of a compactification that maps the n dimensional Euclidean space onto a "parabolic bowl" are studied. Unlike the stereographic projection this compactification distinguishes among the different directions "at infinity". This compactification represents the n dimensional Euclidean space in terms of rational functions. A new invariant set for solutions of dynamical systems emerges.

A partial list of the applications of the parabolic compactification include the following. The rational approximation of unbounded functions. The approximation of unbounded periodic functions by quotients of trigonometric polynomials. The identification of critical points at infinity of polynomial dynamical systems. The representation of solutions of polynomial dynamical systems and their rate of blow up. The global nature of solutions to the Lorenz equations away from the attractor set. (Received January 28, 2009)

1048-34-147 **Ian Price*** (imp5@pitt.edu), 301 Thackeray, Pittsburgh, PA 15260, **David Swigon** (swigon@pitt.edu), 301 Thackeray, Pittsburgh, PA 15260, **G Bard Ermentrout** (bard@math.pitt.edu), 301 Thackeray, Pittsburgh, PA 15260, and **Gilles Clermont** (cler@pitt.edu), 3350 Terrace St, Pittsburgh, PA 15261. *MATHEMATICAL MODEL OF THE MAMMALIAN IMMUNE RESPONSE TO INFLUENZA A.*

Influenza A virus triggers innate before adaptive immunity; but, an exaggerated response harms tissue and does not further viral elimination. This project models the immune response, and identify methods of preventing lung failure and improving recovery. The model introduces a dynamic innate immunity with relevant biology, expanding upon existing models of adaptive immune response to Influenza A virus. The inflammatory process begins with macrophage mediated production of cytokines and chemotaxis of immune cells. Viral immune responses such as interferon I and NK cells are introduced. Interferon II, CTLs and antibodies are produced to complete virus removal. The project employs an ODE–based model to study the dynamics of regulation between virus, immune and respiratory cells, and signaling macromolecules. The system allows for stable health and death, with initial viral load leading to each. For some choices of key parameters unstable health and a stable chronic state with viral clearance can be attained. The model gives us a metric relating initial infection, strength of various immune responses, and total lung damage. Decoding the pathways of immunity allows us to measure their effect on damage and recovery, and motivates experimental studies. (Received February 04, 2009)

1048-34-219 **Manoj Gopalkrishnan*** (manoj.gopalkrishnan@gmail.com). *On the Mathematics of the Law of Mass Action.*

In 1864, Waage and Guldberg formulated chemistry's "Law of Mass Action." Since that time, chemists, chemical engineers, physicists and mathematicians have amassed a great deal of knowledge on the topic. In our view, sufficient understanding has been acquired to warrant a formal mathematical consolidation. A major goal of this consolidation is to solidify the mathematical foundations of mass action chemistry: to provide precise definitions, elucidate what can now be proved, and indicate what is only conjectured. In addition, we believe that the law of mass action is of intrinsic mathematical interest and should be made available in a form that might allow it to transcend its application to chemistry alone. We are led to a dynamical theory of sets of binomials over the complex numbers. This is joint work with Len Adleman, Ming-Deh Huang, Dustin Reishus and Pablo Moisset. (Received February 09, 2009)

1048-34-221 **Raouf Dridi*** (dridi.raouf@gmail.com). *Cartan's equivalence method and singularity analysis.*

I will address the link between Cartan's equivalence method and singularity analysis. The work is at its early stage and there is nothing more behind, and nothing less, than the improvement of current (symbolic and numerical) ODE solvers. (Received February 09, 2009)

1048-34-247 **Pavel Winternitz*** (wintern@crm.umontreal.ca), Centre de recherches mathematiques, Unversite de Montreal, C.P.6128-CV, Montreal, Quebec H3C 3J7, Canada. *Lie point symmetries and numerical solutions of differential equations.*

Lie point symmetries and numerical solutions of differential equations

A method of discretizing ordinary and partial differential equations while preserving their continuous symmetries is presented. By construction the obtained difference equations have the same symmetries as the original difference ones and this dictates many properties of their solution set. On specific examples we show how this type of discretization improves the accuracy of solutions and improves the behaviour of solutions close to singularities. (Received February 09, 2009)

1048-34-253 **Anthony M Bloch***, Dept. of Mathematics, 530 Church Street, Ann Arbor, MI 48109. *Nonholonomic Mechanics and Quantization.*

In this work I consider various representations of the dynamics of nonholonomic systems. I will show in particular how one can represent the constraints as limiting friction and in turn how one can represent this friction by an external field. This provides a method of quantizing certain nonholonomic systems. I will also discuss other methods of quantization. (Received February 09, 2009)

1048-34-275 **Patrick De Leenheer*** (deleenhe@math.ufl.edu), **David Angeli** and **Eduardo Sontag**. *Graph-theoretic characterizations of monotonicity of chemical networks in reaction coordinates.*

This paper derives new results for certain classes of chemical reaction networks, linking structural to dynamical properties. In particular, it investigates their monotonicity and convergence without making assumptions on the form of the kinetics (e.g., mass-action) of the dynamical equations involved, and relying only on stoichiometric constraints. The key idea is to finding an alternative representation under which the resulting system is monotone. As a simple example, the paper shows that a phosphorylation/dephosphorylation process, which is involved in many signaling cascades, has a global stability property. We also provide a global stability result for a more complicated example that describes a regulatory pathway of a prevalent signal transduction module, the MAPK cascade. (Received February 09, 2009)

1048-34-342 **Pablo Moisset de Espanes*** (pmoisset@ing.uchile.cl), Blanco Encalada N 2120, 5 piso, Santiago, Chile. *On the nature of polynomial conservation laws in reversible reaction networks.* Preliminary report.

Dynamical systems arising from the modeling of chemical reactions have been studied for over a century. In 1864 Waage and Guldberg introduced the now well known law of mass action. Later on, Horn, Jackson, Feinberg and others generalized the idea to reaction networks. In this talk, we will characterize polynomial conservation laws in reversible networks. We can show that all linear conservations laws are independent of reaction rates, i.e. they depend only on the "stoichiometry" of the network. We can also show that if the network has the property of "detailed balance", all polynomial conservation laws belong to the ideal generated by the linear laws. (Received February 10, 2009)

1048-34-357 **Stanca Ciupe*** (stanca.ciupe@duke.edu), 2424 Erwin Rd, Hock Plaza, Durham, NC 27705, and **Louise M Markert**, **Blythe Devlin** and **Thomas Kepler**. *Mathematical Models of T-cell Development.*

The immune response to infectious agents involves the presence and maintenance of a large number of T cells with highly variable antigen receptors and functional diversity. We develop a stochastic population-dynamic model that studies the mechanisms responsible for the establishment of T cell receptor diversity. We fit the model to human data from immunocompromised DiGeorge anomaly patients undergoing thymus transplantation. The dynamics we see in the evolution of T cells gives valuable information about the characteristics of the healthy immune system. (Received February 10, 2009)

1048-34-371 **Bo Yang*** (byang@kennesaw.edu), 1000 Chastain Road, #1204, Kennesaw, GA 30144. *Positive Solutions for Boundary Value Problems of the Beam Equation.*

We consider several boundary value problems for the fourth order beam equation, which arise from the study of elasticity. Upper and lower estimates for positive solutions to the problems are obtained. Sufficient conditions for the existence and nonexistence of positive solutions are also obtained. (Received February 10, 2009)

35 ► Partial differential equations

1048-35-4 **Jonathan C. Mattingly***, Department of Mathematics, Duke University, Durham, NC. *Stochastically forced fluid equations: Transfer between scales and ergodicity.*

Consider the 2 dimensional Navier-stokes equation on a periodic domain which describes the time evolution of a incompressible fluid. If left in isolation, energy will leave the system and solution will decay to zero. Hence to obtain a non trivial longtime statistics, we need to inject energy into the system. We choose to do this by adding a random forcing to the system. We wish that this perturbation disturb the structure of the solution "as little as possible". Since we are interested in how the nonlinearity organizes the energy, we will inject the randomness at a certain spatial scale and study how it moves to other scales. This will involve understanding the algebra which describes how the nonlinearity propagates randomness.

From a probabilistic point of view, such stochastic partial differential equations (SPDEs) give rise to very interesting class of Markov processes in infinite dimensions. The generators of such SPDE are very degenerate. Understanding their longtime behavior will require understanding hypoelliptic operators in infinite diminutions. We will need a generalisation of Hormander's sum of squares theorem for SPDEs and a version of Harris' ergodic theorem adapted to the infinite dimensional setting. I will start from the beginning and empathize what is typically true in such infinite dimensional settings, highlighting the principle complications in the ergodic theory of SPDEs. Similar ideas can be applied to stochastic delay equations. (Received April 16, 2008)

1048-35-68 **Kris Jenssen*** (hkj1@psu.edu), Dept. Math, Penn State University, University Park, State College, PA 16801, and **Irina Kogan** (iakogan@math.ncsu.edu), Dept. Math., North Carolina State University, Raleigh, NC 27695. *Geometry of Hyperbolic Conservation Laws.*

We consider the problem of constructing systems of hyperbolic conservation laws in one space dimension with prescribed geometry in state space: the eigenvectors of the Jacobian of the flux are given. This is formulated as a system of algebraic-differential equations which are analyzed with techniques from exterior differential systems (Cartan-Kahler theory).

It turns out that already the case with three equations is fairly complex. The role of richness (i.e. pairwise involution of the given eigenvector fields) is analyzed. As an application we characterize conservative systems with the same eigencurves as compressible gas dynamics.

This is joint work with Irina Kogan (North Carolina State University) (Received January 22, 2009)

1048-35-75 **Martin Juras*** (martinj@qu.edu.qu), Department of Mathematics and Physics, College of Arts and Sciences, Qatar University, P. O. Box 2713, Doha, Qatar. *A fresh look at Darboux integrability for hyperbolic second-order differential equation in the plane.*

A classical result of E. Goursat states that a linear equation

$$u_{xy} + a(x,y)u_x + b(x,y)u_y + c(x,y)u = 0$$

is integrable by the method of Darboux (the general solution can be written explicitly as a function of the coefficients) if and only if the two sequences of the classical Laplace invariants is finite. Anderson and Kamran (1997) generalized Laplace invariants to nonlinear equations and proved that if a hyperbolic second-order equation in the plane

$$F(x,y,u,u_x,u_y,u_{xx},u_{xy},u_{yy}) = 0$$

is Darboux integrable, then the two sequences of it's *generalized Laplace invariants* are finite. Conversely, Juráš and Anderson (1997), proved that the finiteness of the sequences of generalized Laplace invariants for $F = 0$ insures that this equation is integrable by the Darboux method. The proofs of the central results in this last paper are rather lengthy and on several instances the authors avoid exhibiting the tedious computational arguments, which makes the paper difficult to follow.

In this paper, we present a much shorter and more elegant proof of the result above. The reader will see that the original proof can be significantly shortened and "cleaned up" by examining certain relative invariant forms associated with the equation. (Received January 25, 2009)

1048-35-101 **Luigi C Berselli*** (berselli@dma.unipi.it), Dipartimento di Matematica Applicata "U.Dini", Universita' di Pisa, Via F. Buonarroti 1/c, I-56127, ITALY, PISA, Italy. *Analysis of an anisotropic scale similarity LES model.*

We propose and give some mathematical analysis for a Large Eddy Simulation model which involves regularization only in the horizontal variables. The method we consider, which fits into the class of *scale similarity models*, is similar to the "Simplified Bardina model" introduced by Layton and Lewandowski (2006). We are able prove that our new model has good mathematical properties (existence and uniqueness in appropriate Sobolev space). The mathematical foundation is one of the first steps for the validation, even if numerical experiments on realistic problems will be the necessary further step. (Received January 30, 2009)

1048-35-118 **Nicoleta Virginia Bila*** (nbila@uncfsu.edu), 1200 Murchison Road, Fayetteville, NC 28301. *Special classes of symmetry reductions for PDEs involving arbitrary functions.* Preliminary report.

Specific classes of symmetry reductions for partial differential equations involving arbitrary functions that depend only on the independent variables are discussed. These symmetry reductions can be especially associated with parameter identification problems described by partial differential equations. The relationship between the determining equations of the generalized equivalence transformations and the determining equations of the extended classical symmetries is analyzed. As a consequence, any symbolic manipulation program designed to find the classical Lie symmetries can also be used to determine the generalized equivalence transformations. (Received February 02, 2009)

1048-35-136 **Thomas P Witelski*** (witelski@math.duke.edu), Dept of Math, Duke University, Box 90320, Durham, NC 27708-0320. *On computing solutions of thin film equations.*

Thin film equations are a class of fourth-order nonlinear partial differential equations motivated by the Reynolds lubrication equation for the evolution of free-surface flows of thin layers of viscous fluids spreading on solid surfaces. There are many issues that make computing solutions of such parabolic PDEs difficult, including the lack of a maximum principle, degeneracy of the mobility coefficient and associated questions about regularity and uniqueness of compactly-supported weak solutions. We discuss regularizations of thin film equations for computing (i) non-negative finite-time blow-up and (ii) spreading solutions with sign-changes on the half-line. (Received February 04, 2009)

1048-35-166 **Francesco Strazzullo*** (francesco.strazzullo@aggiemail.usu.edu), Department of Mathematics & Statistics, Utah State University, 3900 Old Main Hill, Logan, UT 84322-3900. *Symmetry classification of General rank-3 Pfaffian systems in 5-dimension.*

In his famous *five-variables* paper, Cartan provided normal forms for general rank-3 Pfaffian systems on a 5-manifold, whose symmetry algebras have dimension ≥ 6. I will present new normal forms for those Pfaffian systems whose symmetry algebra is 3-dimensional and acting freely. Applications to the integration of involutive systems of PDE in the plane and to the study of Darboux integrability will be described. (Received February 05, 2009)

1048-35-182 **Antoine Mellet** and **James Nolen*** (nolen@math.duke.edu), Mathematics Department, Duke University, Box 90320, Durham, NC 27708, and **Jean-Michel Roquejoffre** and **Lenya Ryzhik**. *Stability and Fluctuations of Generalized Traveling Waves in Random Media.*

Some nonlinear reaction-diffusion equations (PDEs) admit stable traveling wave solutions. Even for a heterogeneous medium there may be generalized traveling waves that are stable attractors. If the environment is random, then under suitable assumptions on the statistical behavior of the environment, the moving interface behaves asymptotically like a Brownian Motion with positive drift. (Received February 06, 2009)

1048-35-188 **Truyen Nguyen*** (tnguyen@uakron.edu), University of Akron, 302 Buchtel Common, Akron, OH 44325, and **Adrian Tudorascu** (tudorasc@math.wisc.edu), University of Wisconsin-Madison, 480 Lincoln Drive, Madison, WI 53706. *Pressureless Euler/Euler-Poisson systems via adhesion dynamics.*

We study the pressureless Euler/Euler-Poisson system arising in adhesion particle dynamics. The sticky particles model at the discrete level is employed to obtain global solutions for these systems of equations in spatial dimension one. We consider the case of finite, nonnegative initial Borel measures with finite second-order moment, along with continuous initial velocities of at most quadratic growth and finite energy. We prove the time regularity of the solution and obtain that the velocity satisfies the Oleinik entropy condition, which leads to a result on uniqueness for the pressureless Euler system. (Received February 06, 2009)

1048-35-235 **Wenyuan Wu*** (wenyuanwu@math.msu.edu), Mathematics Department, Wells Hall, MIchigan State University, East Lansing, MI 48823, and **Greg J Reid** (reid@uwo.ca), Department of Applied Mathematics, Middlesex College, University of Western Ontario, London, Ontario N6A 5B7. *On the algorithmic geometric prolongation of systems of partial differential equations.* Preliminary report.

In the formal geometric theory of PDEs, prolongation-projection (differential-elimination) procedures determine integrability conditions. Fundamental results were initially conjectured by Cartan, proved by Kuranishi under certain generic conditions, and recently refined by Malgrange. However while geometers may implicitly invoke geometric descriptions, it still remains to replace their methods by algorithmic prolongation procedures, which are effective for systems of differential polynomials with multiplicities. The methods of Rosenfeld-Kolchin-Ritt, extended to effective (and implemented) algorithms by Boulier et al, are applicable to exact input over computable fields, and not amenable to approximate computation.

In this talk, an effcient approach is presented to compute the geometric prolongation of PDE at a point. Such a geometric approach can be adapted to numerical computation by using the Singular Value Decomposition (SVD) - a fundamental technique of numerical linear algebra. Both symbolic and numerical examples are given and further applications for partial differential equations will be also discussed in this talk.

Keywords: Geometric Prolongation, Tangent Space, Local Ring, Multi-plicity, Jet Space, Geometric Theory of PDE, Algorithms (Received February 09, 2009)

1048-35-294 **Zora Thomova*** (thomovz@sunyit.edu), Department of Mathematics, SUNY Institute of Technology, P.O. Box 3050, Utica, NY 13504-3050. *Separation of Variables and Integrability in 4-dimensional Space - An Example.*

We will present a general form of a scalar and vector potentials allowing a separation of variables of four dimensional Schrodinger equation in a specific nonorthogonal coordinate system. The coordinate system we will use is the one with the maximal number of ignorable variables allowing a separation of variables in free Schrodinger equation constructed from maximal Abelian subgroups of the Euclidean group E(4). (Received February 09, 2009)

1048-35-315 **Taufiquar R Khan*** (khan@clemson.edu), O-201 Martin Hall Box 340975, Clemson University, Clemson, SC 29672, and **Peter Maass** and **Bonnie McAdoo**. *Maximizing Distinguishibility Using Optimal Source In Optical Tomography.* Preliminary report.

In this talk, we will discuss a mini-max optimal source design problem in optical tomography. We propose an algorithm for computing the optimal source by maximizing a distinguish-ability criteria for a given set of optical parameters. Finding the optimal source involves computing the maximum eigenvalue and the corresponding eigenfunction of a linear operator A that maps $L^2(\partial\Omega)$ or $H^{-1/2}(\partial\Omega)$ to $L^2(\Omega)$ or $H^1(\Omega)$. Therefore the optimal source depends on the choice of the pairs of the function spaces used. We devise algorithms for the optimal source for four different choices of these function space pairs. We compare the solutions corresponding to these pairs in terms of the distinguish-ability criteria using simulation studies. (Received February 10, 2009)

1048-35-343 **Konstantin Khanin*** (khanin@math.toronto.edu), Department of mathematics, University of Toronto, 40 St George Street, Toronto, ontario M6S 4L3, Canada. *On dynamics on the shock manifolds.*

Solutions to the Hamilton-Jacobi equations are associated to trajectories of Lagrangian particles. It is well known that only action-minimizing trajectories are essential. Other particles are merging with the shocks, and their dynamics traditionally is not considered after the merge.

We shall discuss two different approaches to the construction of such dynamics on the shock manifolds. the first is related to viscosity regularization, another one is based on introduction of the small random noise. It turns out that in a general case these two methods correspond to different dynamical behavior. We shall also

discuss the relation between the dynamics on the shocks and the problem of optimal transportation. (Received February 10, 2009)

1048-35-364 **Stephen Anco*** (sanco@brocku.ca), Department of Mathematics, Brock University, St. Catharines, Ontario L2S3A1, Canada. *Klein geometry, group invariant soliton equations, and bi-Hamiltonian geometric curve flows.*

The sine-Gordon (SG) equation, modified Korteweg-de Vries (mKdV) equation, and nonlinear Schrodinger (NLS) equation each have a remarkable geometric origin connected with the classical frame structure equations for curve flows in S^2, R^2, and R^3, respectively. In this talk I will describe a broad generalization of these results to the setting of curve flows in Klein geometry, which gives a geometrical derivation of group-invariant (multicomponent) generalizations of mKdV, NLS, and SG soliton equations along with their bi-Hamiltonian structure, symmetries, and conservation laws. As one example, new scalar/vector quaternion soliton equations will be presented. (Received February 10, 2009)

37 ► Dynamical systems and ergodic theory

1048-37-120 **Yun Kang*** (yun.kang@asu.edu), **Dieter Armbruster** and **Yang Kuang**. *Dynamics of plant-herbivore models with monotone plant growth rate.*

The impact of monotone plant growth models in general plant-herbivore models on the dynamics of the plant-herbivore interaction is studied. It is shown that all monotone growth models generate a unique interior equilibrium. We investi- gate the uniform persistence of monotone growth models with a single nonzero equilibrium of the plant population. Such models lead to noise sensitive burst- ing which is identified as a dynamical mechanism for almost periodic outbreaks of the herbivore infestation. Montone and non-monotone plant growth models are contrasted with respect to bistability and crises of chaotic attractors. (Received February 02, 2009)

1048-37-140 **J Robert Buchanan*** (Robert.Buchanan@millersville.edu), Department of Mathematics, Millersville University, P.O. Box 1002, Millersville, PA 17551-0302. *A Stochastic Model of a Pioneer/Climax Interaction.* Preliminary report.

The interactions and population dynamics of pioneer and climax species sharing the same ecosystem are well studied from a deterministic, ordinary differential equations perspective. In this presentation a stochastic model of the pioneer/climax interaction will be described. The challenges of establishing the existence of solutions to the stochastic differential equation will be discussed. As the numbers of individuals in the populations grow large, the stochastic model has as its limit the deterministic model (the fluid approximation), allowing the long-term dynamics of the large-population stochastic model to be understood from the deterministic model while the small-population stochastic model may exhibit behaviors differing from the deterministic model. (Received February 04, 2009)

1048-37-271 **David Swigon*** (swigon@pitt.edu), University of Pittsburgh, Department of Mathematics, 511 Thackeray Hall, Pittsburgh, PA 15260. *Dynamical equivalence of chemical reaction networks.* Preliminary report.

The dynamics of a network of interacting chemical species is frequently studied using a system of nonlinear ODEs with rate functions given by the principle of mass-action kinetics. Classical theorems of Horn, Jackson and Feinberg, and several new results of Craciun and Feinberg relate the existence, uniqueness and stability of equilibria of the reaction network to its topological properties. It will be shown that by considering smooth dynamical equivalence of dynamical systems and their relation to the reaction networks, one can find transformations that alter the reaction network topology without changing its dynamical properties. Such transformations can be used to enlarge the class of reaction networks to which the theorems can be applied. (Received February 09, 2009)

39 ► Difference and functional equations

1048-39-71 **Willy A Hereman*** (whereman@mines.edu), Dept. of Mathematical and Computer Sciences, Colorado School of Mines, Goden, CO 80401-1887. *Symbolic Computation of Lax Pairs of Two-Dimensional Nonlinear Partial Difference Equations.*

A partial difference equation (P-Delta-E) is a fully discretized version of a partial differential equation. The talk focuses on 2-dimensional nonlinear P-Delta-Es which are completely integrable, i.e., they admit a Lax representation.

Based on work by Nijhoff, Bobenko and Suris, a method to compute Lax pairs will be presented. The method is largely algorithmic and can be implemented in the syntax of computer algebra systems, such as Mathematica and Maple.

A Mathematica program will be presented that automatically computes Lax pairs for a variety of 2-dimensional P-Delta-Es, including lattice versions of the potential Korteweg-de Vries (KdV) equations, the modified KdV and sine-Gordon equations, as well as lattices derived by Adler, Bobenko, and Suris. (Received January 23, 2009)

45 ► Integral equations

1048-45-159 **Bo Zhang*** (bzhang@uncfsu.edu), Department of Math and Computer Science, Fayetteville State University, Fayetteville, NC 28304. *Boundedness and Global Attractivity of Solutions for a System of Nonlinear Integral Equations.*

It is well-known that Liapunov's direct method has been used very effectively for differential equations. The method has not, however, been used with much success on integral equations until recently. The reason for this lies in the fact that it is very difficult to relate the derivative of a scalar function to the unknown non-differentiable solution of an integral equation. In this paper, we construct a Liapunov functional for a system of nonlinear integral equations. From that Liapunov functional we are able to deduce conditions for boundedness and global attractivity of solutions. As in the case for differential equations, once the Liapunov function is constructed, we can take full advantage of its simplicity in qualitative analysis. (Received February 05, 2009)

49 ► Calculus of variations and optimal control; optimization

1048-49-184 **Dong Wang*** (dwang@uncfsu.edu), 1200 Murchison Road, Fayetteville, NC 28301. *Optimization of Delay-Differential Inclusions in Infinite Dimensions.*

This talk concerns the study of dynamic optimization problems governed by delay-differential inclusions with finitely many equality and inequality endpoints constraints and multivalued initial conditions. We employ the method of distrete approximations and advanced tools of generalized differentiation in infinite-dimensional spaces to derive necessary optimality conditions in the extended Euler-Lagrange form. (Received February 06, 2009)

1048-49-264 **Gábor Pataki** (gabor@unc.edu), Dept. of Statistics and Operations Research, CB #3260, Hanes Hall, UNC Chapel Hill, Chapel Hill, NC 27599, and **Mustafa Kemal Tural*** (tural@email.unc.edu), Dept. of Statistics and Operations Research, CB #3260, Hanes Hall, UNC Chapel Hill, Chapel Hill, NC 27599. *On sublattice determinants in reduced bases.*

A basis reduction algorithm computes a reduced basis of a lattice consisting of "short" and "nearly orthogonal" vectors. The polynomial time LLL basis reduction algorithm was introduced in 1982 by Lenstra, Lenstra and Lovász; and has since been used in numerous applications in computational mathematics and computer science starting with factoring polynomials with rational coefficients and solving the integer linear programming problem in polynomial time in fixed dimensions.

As shown by Lenstra, Lenstra, and Lovász, in an LLL-reduced basis of a lattice L, the norm of the first vector is bounded by a function of the norm of a nonzero shortest vector of L, and also by a function of the determinant of L. We prove several inequalities on the determinants of sublattices in LLL-reduced bases generalizing these fundamental inequalities, and show that LLL-reduction finds not only a short vector, but also sublattices with small determinants.

We also prove new inequalities on the product of the norms of the first few basis vectors. (Received February 09, 2009)

51 ► Geometry

1048-51-7 **Ana Maria Breda*** (ambreda@ua.pt), Departamento de Matematica, Universidade de Aveiro, Campus de Santiago, Aveiro, Portugal, and **Patrica Ribeiro** (pribeiro@est.ips.pt), Campus do IPS, Estefanilha, Setubal, Portugal. *Spherical dihedral f-triangulations.*

The theory of isometric foldings (maps of Riemannian manifolds sending piecewise geodesics to piecewise geodesics of the same length) was initiated by S. Robertson in 1977. An isometric folding is a continuous locally isometry which is not necessarily differentiable. The points where it fails to be differentiable is said to be singular. Robertson has shown that the singularity set of isometric foldings on surfaces are embedded graphs (f-tilings) of even valency satisfying the angle relation, that is, at each vertex, the alternate angle sums are both equal to pi. Here we present the algebraic and combinatorial structure of a class of dihedral f-triangulations of the Riemannian sphere (Received October 03, 2008)

1048-51-33 **James S. Cook*** (jcook4@liberty.edu), 1971 University Blvd., Department of Mathematics, Lynchburg, VA 24502, and **Ronald O. Fulp**. *On Sections and Curvature for Super Yang-Mills Theory.* Preliminary report.

In physics, Super Yang-Mill's Theory is expressed in terms of local coordinate dependent expressions on superspace. We show how the classical constructions of Lichernowicz extend to the G^∞ super context. When the curvature is restricted to leaves of a certain foliation it is shown to be trivial. However, the curvature is nontrivial in other directions. The Bianchi identities have solutions which are used to construct the Lagrangian. Our goal is to show how the theory on the base superspace can be seen as a pull-back of a theory on a super bundle space. These results are derived over an infinite dimensional Banach manifold which possess a G^∞ supermanifold structure. (Received December 19, 2008)

1048-51-149 **Dan Rutherford*** (rutherd@math.duke.edu). *Normal rulings of Legendrian knots.*

A normal ruling of a Legendrian knot in standard contact R^3 is a certain way of decomposing the knot's front diagram into pairs of paths. Normal rulings were introduced independently by Chekanov-Pushkar and Fuchs in quite different contexts. In this talk, I will survey some results (of many authors) in Legendrian knot theory related to normal rulings. Time permitting, I will talk about relationships with the Legendrian contact homology DGA, Bennequin type inequalities, and generating families. (Received February 04, 2009)

1048-51-257 **J. Elisenda Grigsby*** (egrigsby@math.columbia.edu), 2990 Broadway, MC 4406, New York, NY 10027, and **Stephan Wehrli**. *A connection between Khovanov- and Heegaard Floer-type homology theories.*

The relationship between Khovanov- and Heegaard Floer-type homology invariants is intriguing and still poorly-understood. In this talk, I will describe a connection between a version of Khovanov homology for tangles in certain product sutured manifolds and the Heegaard Floer homology of the sutured double-branched covers. As a corollary, we can conclude that Khovanov's categorification of the reduced, n-colored Jones polynomial detects the unknot whenever n $>$ 1. (Received February 09, 2009)

52 ► Convex and discrete geometry

1048-52-240 **Serkan Hosten*** (serkan@math.sfsu.edu), 1600 Holloway Avenue, San Francisco, CA 94132. *Phylogenetic Tree Spaces and Phylogenetic Reconstruction Algorithms.* Preliminary report.

In this work we explore the interaction of the (tropical) geometry of various phylogenetic tree spaces with the popular phylogenetic reconstruction algorithms such as neighbor net algorithm. (Received February 09, 2009)

1048-52-242 **Carlos M Nicolas*** (cmnicola@uncg.edu), Department of Mathematics and Statistics, Room 116, Petty Building, 317 College Ave., Greensboro, NC 27455. *Defining k-triangulations for points in general position in the d-dimensional space.*

A k-triangulation of the n-gon is a maximal set of diagonals of the n-gon such that no $k+1$ mutually cross. We review recent results on k-triangulations of the n-gon, including a characterization which does not use the concept of crossings. We show how this characterization can be rephrased in terms of k-splitters and use this approach to define k-triangulations for sets of points in general position in the d-dimensional space. This definition agrees with the usual triangulations of points for $k = 1$. We consider the problem of constructing k-triangulations for

arbitrary sets of points in d dimensions and the connections with results on k-splitters. (Received February 09, 2009)

53 ► Differential geometry

1048-53-5 **Abraham D Smith*** (adsmith@math.duke.edu), Mathematics Department, Duke University, Box 90320, Durham, NC 27708-0320. *Integrability of 2nd order PDE and the geometry of $GL(2,\mathbb{R})$-structures.*

A $GL(2,R)$ structure on a manifold of dimension $n+1$ corresponds to a distribution of rational normal cones over the manifold. Such a structure is k-integrable if there exist submanifolds of dimension k whose tangent spaces are spanned by vectors in the cones.

This structure was first studied by Bryant ($n=3, k=2$) in the search for exotic holonomies. Recent work by Ferapontov, et al., showed that the integrability of second-order PDE on $u: R^3 \to R$ by means of hydrodynamic reductions implies 3-integrability of a natural $GL(2)$-structure over M^5. ($n=4, k=3$). Ferapontov, et al., also showed that there is an open orbit of such PDE.

Using the techniques of Cartan, we study the equivalence and k-integrability of $GL(2)$-structures for arbitrary n and k. For $n=4, k=3$, we discover a complete classification of local integrable structures into 54 orbits, by the action of $GL(2)$ on binary octic polynomials. This allows explicit construction of all second-order PDE which are integral by hydrodynamic reductions.

Also, the interesting geometry is essentially restricted to this case, as increasing n or k forces the the $GL(2)$-structure to be flat.

This work is from my PhD thesis, completed March 2009, directed by Robert Bryant at Duke. (Received January 31, 2009)

1048-53-82 **Gloria Mari Beffa*** (maribeff@math.wisc.edu), Mathematics Department, Van Vleck Hall, University of Wisconsin, Madison, WI 53706. *On the preservation of invariants of arc-length type by geometric Hamiltonian curve flows.*

In this talk we will comment on curve differential invariants of arc-length type and on the preservation of these invariants under geometric Hamiltonian evolutions. We will describe how Hamiltonian evolutions of curves on homogeneous parabolic manifolds G/H with G semisimple often do not need to preserve an invariant of arc-length type, while in classical geometries of the form $G \ltimes R^n/G$, with G semisimple, preservation is almost always the case. We discuss the Riemannian sphere $SO(n+1)/SO(n)$ as a case connected to both these situations. (Received January 26, 2009)

1048-53-104 **Carlos J Almada*** (almada_carlos@colstate.edu), Department of Mathematics, Columbus State University, 4225 University Ave, Columbus, GA 31907. *The Hessian of a Harmonic Reduction.*

In this work, following ideas of Eells-Lemaire, we define the notion of Hessian of a section $\sigma \in \Gamma(M, P/H)$. We obtain an explicit formula for the Hessian and in the case that σ is a harmonic reduction, we show the Hessian is symmetric. The notion of stability for harmonic reductions is also introduced. (Received January 30, 2009)

1048-53-109 **Dennis The*** (dthe@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843-3368. *Maximally symmetric hyperbolic equations of generic type.*

The classification of (in general nonlinear) scalar second order PDE in the plane into elliptic, parabolic, hyperbolic classes is well-known to be invariant under contact transformations. There is a finer contact-invariant sub-classification of hyperbolic equations into Monge-Ampere, Goursat, and generic types. While the Monge-Ampere class has been well-studied from a geometric perspective, the latter two classes have not. An intriguing property about the generic class is that any such equation admits at most a nine-dimensional contact symmetry group. Moreover, there is a one-parameter family of such maximally symmetric equations which I will describe in this talk. I will also illustrate a curious connection relating these maximally symmetric models to equations admitting G2 symmetry mentioned in Cartan's famous five-variables paper. (Received February 01, 2009)

1048-53-153 **Ian Anderson*** (ian.anderson@usu.edu), Dept. of Math. and Stat., Utah State University, Logan, UT 84322, and **Mark Fels**. *Bäcklund Transformations via Symmetry Reduction.* Preliminary report.

We shall present some new group theoretic methods for constructing Bäcklund transformations based upon the notion of symmetry reduction for exterior differential systems. We then use the Vessiot group associated

to a Darboux integrable system to construct various Bäcklund transformations for such systems. (Received February 05, 2009)

1048-53-229 **Niky Kamran*** (nkamran@math.mcgill.ca), Department of Mathematics and Statistics, McGill University, 805 Sherbrooke Street West, Montreal, Quebec H3A 2K6, Canada. *Green's function for the Hodge Laplacian on some classes of Riemannian and Lorentzian symmetric spaces.*

We compute the Green's function for the Hodge Laplacian on the symmetric spaces $M \times \Sigma$, where M is a simply connected n-dimensional Riemannian or Lorentzian manifold of constant curvature and Σ is a simply connected Riemannian surface of constant curvature. Our approach is based on a generalization to the case of differential forms of the method of spherical means and on the use of Riesz distributions on manifolds. The radial part of the Green's function is governed by a fourth order analogue of the Heun equation. This is joint work with Alberto Enciso (Universidad Complutense and ETH). (Received February 09, 2009)

1048-53-280 **Jeanne Clelland***, Dept. of Mathematics, 395 UCB, University of Colorado, Boulder, CO 80309-0395, and **Christopher Moseley** and **George Wilkens**. *Geometry of control-affine systems in low dimensions.*

We introduce the notion of a *point-affine distribution*: a rank s affine distribution on an n-manifold X, together with a distinguished vector field contained in the distribution. This geometric structure is motivated by the consideration of control-affine systems

$$\dot{x} = a_0(x) + A(x)u,$$

where $x \in \mathbb{R}^n$, $u \in \mathbb{R}^s$, $A(x) \in \mathbb{R}^{n \times s}$, and $a_0(x) \in \mathbb{R}^n$. This system gives rise to the affine distribution

$$\mathcal{F}_x = a_0(x) + \text{image}(A(x)),$$

with distinguished vector field $a_0(x)$.

It is well-known that generic distributions on manifolds of dimension ≤ 4 have no local invariants with respect to diffeomorphisms of the underlying manifold. The first local invariants appear for rank 2 distributions on 5-manifolds; these were described in Cartan's famous "five variables" paper. However, invariants appear in lower dimensions for affine distributions; e.g., Elkin found local invariants for rank 1 affine distributions on 3-manifolds. Here we use Cartan's method of equivalence to compute local invariants for point-affine distributions in low dimensions. Local invariants appear even in the smallest non-trivial case: that of rank 1 point-affine distributions on 2-manifolds. (Received February 09, 2009)

1048-53-310 **Roman Smirnov*** (smirnov@mathstat.dal.ca), Department of Mathematics and Statistics, Dalhousie University, Halifax, NS B3H 3J5, Canada. *Hamilton-Jacobi theory in Minkowski space via Cartan geometry.*

A complete solution to the problem of orthogonal separation of variables of the Hamilton-Jacobi equation in three-dimensional Minkowski space is obtained. The solution is based on the underlying ideas of Cartan geometry and ultimately developed into a general new algorithm that can be employed in the study of Hamiltonian systems defined by natural Hamiltonians within the framework of Hamilton-Jacobi theory. To demonstrate its effectiveness, we investigate, from this viewpoint, the Morosi-Tondo integrable system derived as a stationary reduction of the seventh-order Korteweg-de Vries flow to show explicitly that the system in question is an orthogonally separable Hamiltonian system. The latter result is a new characterization of the Morosi-Tondo system. This is joint work with Joshua Horwood and Raymond McLenaghan (Received February 10, 2009)

1048-53-372 **Marianty Ionel*** (mionel@utnet.utoledo.edu) and **Thomas Ivey**. *Austere Submanifolds of Dimension 4.*

An austere submanifold in $\mathbb{R}^n$ has the property that its second fundamental form in any normal direction has eigenvalues occurring in oppositely signed pairs. This notion was first introduced by Harvey and Lawson in 1982 through their result that showed that the conormal bundle of a submanifold M in $\mathbb{R}^n$ is a special Lagrangian submanifold in the cotangent bundle of $\mathbb{R}^n$ if and only if M is an austere submanifold. The austere submanifolds of dimension 3 in Euclidean space were classified by R. Bryant. In this talk I will present some new results towards a classification of austere submanifolds of dimension 4 in Euclidean space. This is joint work with Thomas Ivey. (Received February 10, 2009)

55 ► Algebraic topology

1048-55-20 **Alastair Ethan Hamilton*** (hamilton@math.uconn.edu), Mathematics Department, University of Connecticut, 196 Auditorium Road, Storrs, CT 06269. *Noncommutative Geometry and A-infinity structures.*

In this talk I will describe how an important type of A-infinity structure, called a cyclic A-infinity structure, can be described as a Maurer-Cartan element in a certain Lie algebra introduced by Kontsevich. This Lie algebra is a noncommutative analogue of the Poisson algebra of Hamiltonian vector fields on a symplectic manifold. I will use this formulation to explain how a cyclic A-infinity algebra produces a class in the moduli space of curves. (Received December 04, 2008)

1048-55-26 **John E Harper*** (john.edward.harper@gmail.com), EPFL SB IGAT GR-HE, BCH 5115 (Batiment BCH), 1015 Lausanne, Switzerland. *Bar constructions and Quillen homology of modules over operads.*

In Haynes Miller's proof of the Sullivan conjecture on maps from classifying spaces, Quillen's derived functor notion of homology (in the case of commutative algebras) is a critical ingredient. This suggests that homology for the larger class of algebraic structures parametrized by an operad will also provide interesting and useful invariants. Working in the two contexts of symmetric spectra and unbounded chain complexes, we establish a homotopy theory for studying Quillen homology of modules and algebras over operads, and we show that this homology can be calculated using simplicial bar constructions. A key part of the argument is proving that the forgetful functor commutes with certain homotopy colimits. A larger goal is to determine the extra structure that appears on the derived homology and the extent to which the original object can be recovered from its homology when this extra structure is taken into account. This talk is an introduction to these results with an emphasis on several of the motivating ideas. (Received December 09, 2008)

1048-55-27 **Michael P Allocca*** (mpallocc@ncsu.edu), Department of Mathemaics, North Carolina State University, Raleigh, NC 27695. *A Finite Dimensional A_∞ algebra Example.*

A_∞ algebras have been objects of current research. However, concrete examples of such structures have remained elusive. We construct a finite dimensional example of an A_∞ structure over a simple graded vector space that has been of interest in the study of L_∞ algebras, and briefly discuss the task of proving that this simple structure satisfies the A_∞ relations. (Received December 10, 2008)

1048-55-28 **Samson Saneblidze** and **Ronald Umble*** (ron.umble@millersville.edu), Department of Mathematics, Millersville University, Millersville, PA 17551. *The homology of a DG bialgebra is an A_∞-bialgebra.*

Theorem *Consider a DG bialgebra (A, d, μ, Δ) over a field, its homology $(H = H(A), 0, \mu_*, \Delta_*)$, and a map $f : H \to A$ that sends each class to one of its representatives. Then there is*

(1) *an A_∞-bialgebra structure $\{\omega^{j,i} : H^{\otimes i} \to H^{\otimes j}\}_{i,j\geq 1}$ on H such that $\omega^{1,2} = \mu_*$ and $\omega^{2,1} = \Delta_*$ and*

(2) *an A_∞-bialgebra morphism $f : (H, 0, \omega_H) \Longrightarrow (A, d, \mu, \Delta)$ extending $\mathfrak{f}$.*

The chain map $\mathfrak{f}$ extends canonically to f. This extension is controlled by a new family of polyhedra that properly contains the multiplihedra. Indeed, the universal relative matrad structure on the cellular chains of these new polytopes induces the higher order operations $\omega^{j,i}$, $i + j > 3$. (Received December 14, 2008)

1048-55-32 **Eduardo Hoefel*** (hoefel@ufpr.br), Departamento de Matemática - UFPR, C.P. 019081, Curitiba, PR 81531-990, Brazil. *OCHA: examples and related structures.*

This talk is a survey of our work on Kajiura-Stasheff's OCHA. Using its geometrical description in terms of the Axelrod-Singer compactification of certain configuration spaces, we will provide examples of OCHA structures on the singular chain complexes of certains pairs of topological spaces. On the other hand, one of the important related structures is that of Leibniz Pairs (or $\mathfrak{g}$-algebras). Using the algebraic description of OCHAs in terms of coderivations, we will give an application to the study of deformations of Leibniz Pairs. (Received December 16, 2008)

1048-55-39 **Hisham Sati*** (hisham.sati@yale.edu), Yale University, Mathematics Department, PO Box 208283, New Haven, CT 06520-8283. *Fivebrane structures in string theory and M-theory.*

We consider geometric and topological aspects of the 'dual formulations' of string theory and M-theory. The dual version of the Green-Schwarz anomaly cancelation condition can be read as a higher analog of String structure,

which we call Fivebrane structure. This involves lifts to higher connected covers of the structure groups. We characterize the topological obstructions to the existence of Fivebrane structures and describe some aspects of their geometry. We also describe twists of such structures which can be thought of as generalizations of the twist of Spin^c-structures. This is joint work with Urs Schreiber and Jim Stasheff. (Received January 08, 2009)

1048-55-69 **Mahmoud Zeinalian*** (mzein@mpim-bonn.mpg.de), **John Terilla** (jterilla@qc.cuny.edu) and **Thomas Tradler** (ttradler@citytech.cuny.edu).
Homotopy triviality of the circle action and the Hochschild complex. Preliminary report.

I will discuss operadic meaning and some consequences of the homotopy triviality of the circle action given by Connes B operator on the Hochschild complex. This is joint work with John Terilla and Thomas Tradler. (Received January 22, 2009)

1048-55-200 **R Marangell*** (roble81@unc.edu), The University of North Carolina, Department of Mathematics, CB #3250, Phillips Hall, Chapel Hill, NC 27599, and **R Rimanyi**. *The General Quadruple Point Formula and Applications of Thom Polynomials to Problems in Enumerative Geometry.*

The idea of applying multisingularity formulas to problems in enumerative geometry is well established. In this talk I will apply Thom polynomials to find the number of 4-secant linear spaces to smooth projective varieties. I will also discuss how characteristic classes and Thom polynomials can be used to find the number of incident singularities for a wide range of problems coming from enumerative geometry. (Received February 10, 2009)

57 ► Manifolds and cell complexes

1048-57-1 **Nathan Dunfield***, University of Illinois, Department of Mathematics, Urbana-Champaign, IL. *Surfaces in finite covers of 3-manifolds: The virtual Haken conjecture.*

As with many areas of topology and geometry, a starting point in the study of 3-manifolds is to try to understand codimension one objects in them, namely embedded surfaces. A particularly useful class of surfaces are the "incompressible" ones which are topologically essential; a 3-manifold containing such a surface is called a Haken manifold. There are many 3-manifolds which are not Haken, but if we ask about immersed, rather than embedded, surfaces the situation becomes much more mysterious. A closely related question is this: Suppose M is a 3-manifold with infinite fundamental group, does M have a finite cover which is Haken? The Virtual Haken Conjecture posits that the answer to this question is yes.

This talk will survey some recent results in this area, focusing on my work with (variously) William Thurston, Dylan Thurston, and Frank Calegari. From the point of view of Thurston's Geometrization Conjecture, this is really a question about hyperbolic 3-manifolds, that is, lattices in PSL(2, C). This opens the door to a rich array of tools that might seem quite surprising in light of the purely topological description of the problem above. Indeed, some unlikely- sounding terms that I will probably mention in my talk are "the Classification of Finite Simple Groups" and "the Langlands Conjecture", as well as such topological oddities as "random 3- manifolds"! (Received April 10, 2008)

1048-57-23 **Noah Kieserman*** (nmkieser@colby.edu), Mayflower Hill 5830, Waterville, ME 04901. *The Liouville phenomenon in the deformation of coisotropics.*

The deformation of coisotropic submanifolds provides an excellent venue for understanding the geometric meaning of P_∞-structures and higher derived brackets. I will demonstrate an example of fine structure detected by this machinery in the moduli space of coisotropics. (Received December 04, 2008)

1048-57-34 **Satyan L Devadoss*** (satyan.devadoss@williams.edu) and **Stefan Forcey**. *Graph Multiplihedra.*

Given a graph G, we construct a convex polytope whose face poset is based on marked subgraphs of G. This polytope yields a natural generalization of the multiphihedron, classically known to capture associativity information between spaces. We show features of this polytope appear in works related to quilted disks, bordered Riemann surfaces, operadic structures, and higher category theory. Indeed, certain examples of graph multiplihedra are related to Minkowski sums of simplices and cubes and others to the permutohedron. (Received December 19, 2008)

1048-57-41 **Robert Lipshitz*** (lipshitz@math.columbia.edu), 2990 Broadway, New York, NY 10025, and **Peter Ozsvath** and **Dylan Thurston**. *Putting bordered Floer homology in its place.*

Bordered Floer homology is an extension of the Heegaard Floer invariant HF-hat to 3-manifolds with parametrized boundary. It enjoys good properties with respect to gluing, and can be computed in many cases. In this talk we will discuss how similar structures occurring in related fields (including Khovanov homology, contact homology and Floer theory) led to bordered Floer homology. This is joint work with Peter Ozsvath and Dylan Thurston. (Received January 09, 2009)

1048-57-78 **John B Etnyre*** (etnyre@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Open books and cabling.*

Giroux's correspondence between open books and contact structures has become instrumental in studying contact structure on 3-manifolds. In this talk I will discuss joint work with Ken Baker and Jeremy Van Horn-Morris concerning the effect on the contact structure when one cables the binding components of an open book decompositions. As corollaries of this result I will exhibit interesting monoids in the mapping class group of surfaces and discuss positive monodromies and Stein fillings of contact structures. (Received January 25, 2009)

1048-57-86 **Matthew E Hedden*** (mhedden@math.mit.edu), 77 Massachusetts Avenue, Math Department, Building 2, Room 230, Cambridge, MA 02139. *Knot theory and algebraic curves in subcritical Stein domains.* Preliminary report.

Generalizing the work of Rudolph and Boileau-Orevkov, I'll characterize those knots in the connected sum of $S^1 \times S^2$ which arise as the boundary of a properly embedded algebraic curve in the Stein filling of this manifold. The characterization is given by quasipositivity in the braid group of a punctured sphere.

Time almost certainly not permitting, I will discuss how this is connected to knot Floer homology. (Received January 26, 2009)

1048-57-108 **Adam Lowrance*** (lowrance@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *The Khovanov width of twisted links and closed 3-braids.*

We show that if a link diagram meets certain conditions, then a crossing can be replaced by a rational tangle without changing the homological width of the Khovanov homology for that link. As an application to this construction, we compute the Khovanov width for all closed 3-braids and the Turaev genus for many closed 3-braids. (Received January 31, 2009)

1048-57-110 **Lenhard Ng***, Mathematics Department, Duke University, Box 90320, Durham, NC 27708. *Knot contact homology and string topology.*

I will discuss the current state of affairs regarding knot contact homology, a knot invariant defined through contact-geometric techniques. In particular, I would like to present a partial topological interpretation of knot contact homology in the language of string topology (in joint work with Kai Cieliebak, Tobias Ekholm, and Janko Latschev). (Received February 01, 2009)

1048-57-113 **John A Baldwin*** (baldwinj@math.princeton.edu), John Baldwin, Department of Mathematics, Fine Hall, Washington Road, Princeton, NJ 08544-1000. *Capping off open books and the Ozsváth-Szabó contact invariant.*

If (S, ϕ) is an open book with disconnected binding then we can form a new open book (S', ϕ') by capping off one of the boundary components of S with a disk. We define a U-equivariant map on Heegaard Floer homology which sends $c^+(S', \phi')$ to $c^+(S, \phi)$, and we discuss various applications. (Received February 01, 2009)

1048-57-114 **Hugh N Howards***, Math Dept, Winston-Salem, NC 27109, and **Jennifer Schultens**. *Thin Position of knots and 3-manifolds.*

We prove that for 2-bridge knots and 3-bridge knots in thin position the double branched cover inherits a manifold decomposition in thin position. We also argue that one should not expect this sort of correspondence to hold in general. (Received February 01, 2009)

1048-57-190 **THANG LE*** (letu@math.gatech.edu), 686 Cherry Street, School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *L^2-torsion, Mahler measure, and homology growth.* Preliminary report.

Using L^2-torsion of 3-manifolds we proved old and new results about the growth rate of the order of the torsion of the first homology group of finite coverings of a knot (or link) complement. (Received February 06, 2009)

1048-57-215 **Keiko Kawamuro** and **Elena Pavelescu*** (Elena.Pavelescu@rice.edu), Rice University, Department of Mathematics - MS 136, 6100 S Main Street, Houston, TX 77005. *The self-linking number for braids in $L(k,1)$.* Preliminary report.

We construct an immersed surface for a braid in an annulus open book decomposition, which is a generalization of the so called Bennequin surface for a braid in $\mathbb{R}^3$. By resolving the singularities of the immersed surface, we obtain an embedded Seifert surface for the braid. We find a self-linking number formula associated to the surface and prove that it is a generalization of the Bennequin's self-linking formula for a braid in $\mathbb{R}^3$. We also prove that our self-linking formula is invariant (changes by 2) under a positive (negative) braid stabilization which preserves (changes) the transverse knot class. (Received February 08, 2009)

1048-57-224 **Nathan Dunfield** and **Helen Wong***, 8600 College Station, Brunswick, ME 04011. *Quantum invariants of random Heegaard splittings.*

The quantum invariants are known to give (sometimes sharp) lower bounds to the Heegaard genus of a 3-manifold. In order to study the broader effectiveness of such an approach, we consider the distribution of the complex-valued quantum invariants for a random Heegaard splitting, i.e. one associated to the result of a random walk in the mapping class group. (Received February 09, 2009)

1048-57-225 **David Shea Vela-Vick*** (dvick@math.upenn.edu), Department of Mathematics, 209 South 33rd Street, Philadelphia, PA 19104. *Transverse Invariants and Bindings of Open Books.*

Let $B \subset (Y,\xi)$ be a transverse knot which is the binding of some open book, (B,π), for the ambient contact manifold (Y,ξ). In this talk, we show that the transverse invariant $\mathcal{T}(B) \in \widehat{\mathrm{HFK}}(-Y,K)$, defined by Lisca, Ozsváth, Stipsicz and Szabó (LOSS), is nonvanishing for such transverse knots. We will also discuss a vanishing theorem for the invariants defined by LOSS. As a corollary, we will see that if (B,π) is an open book with connected binding, then the complement of B has no Giroux torsion. (Received February 09, 2009)

1048-57-307 **Lev Rozansky*** (rozansky@math.unc.edu), Department of Mathematics, CB #3250, Phillips Hall, Chapel Hill, NC 275999, and **Mikhail Khovanov**. *A categorification of the $SU(2)$ Reshetikhin-Turaev invariant of links in $S^2 \times S^1$.*

The $SU(2)$ Reshetikhin-Turaev invariant of a link in $S^2 \times S^1$ has a stable polynomial limit at large level r. We categorify this polynomial by using the Hochschild homology of the H_n algebra. We relate the resulting homology of a tangle closed in $S^2 \times S^1$ to Khovanov's $SU(2)$ homology of a link constructed by inserting a tangle into a torus link with high twist. (Received February 10, 2009)

58 ► Global analysis, analysis on manifolds

1048-58-24 **M. V. Movshev*** (mmovshev@math.sunysb.edu), Mathematics Department, Stony Brook University, Stony Brook, NY 11794-3651. *Non Self-Dual Pure Yang-Mills Theory On the Twistor Space.*

For almost forty years the twistor space has been an indispensable tool in the theory of self-dual connections. Are the twistors useful for the full Yang-Mills theory? The answer on this question is in the affirmative. I will explain how one can reformulate the pure Yang-Mills theory on the twistor space using the language of L-infinity algebras. (Received December 07, 2008)

1048-58-57 **Peter J Olver*** (olver@math.umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *Moving frames, variational problems, and geometric flows.*

I will discuss applications of the equivariant method of moving frames to the analysis of invariant variational problem and the evolution of differential invariants under invariant geometric flows. (Received January 18, 2009)

1048-58-161 **Juha Pohjanpelto*** (juha@math.oregonstate.edu), Department of Mathematics, Oregon State University, Corvallis, OR 97331. *Pseudogroups, Moving Frames, and Invariant Variational Principles.*

Continuous pseudogroups appear as the infinite dimensional counterparts of local Lie groups of transformations in various physical and geometrical contexts, including gauge theories, Hamiltonian mechanics and symplectic and Poisson geometries, conformal field theory, symmetry groups of differential equations, such as the Navier-Stokes and Kadomtsev-Petviashvili equations, image recognition, and geometric numerical integration.

In this talk I will describe some applications of my joint work with Peter Olver on the moving frames method to the cohomologies of the variational bicomplex invariant under a pseudogroup action and of its edge complex, the so-called Euler-Lagrange complex. Moving frames can be used to produce complete sets of differential invariants and invariant coframes on jet bundles and to analyze the algebraic structure of the invariant quantities, thus providing a basic tool for the study of invariant bicomplexes. In particular, the moving frames method allows one, at least in principle, to reduce the computation of their local cohomologies to an algebraic problem. I will illustrate the new methods in the case of the symmetry-pseudogroup of the Kadomtsev-Petviashvili equation. (Received February 05, 2009)

1048-58-211 **Rustam Sadykov*** (rstsdk@gmail.com). *Enumerating singularities of smooth maps.*
According to the Whitney theorem, each smooth generic map $\mathbb{R}P^2 \to \mathbb{R}^2$ of a projective plane has an odd number of cusps. I will talk about how to count singularities of smooth maps of manifolds of higher dimension. (Received February 08, 2009)

60 ► Probability theory and stochastic processes

1048-60-160 **Zenghu Li** and **Jie Xiong***, Department of Mathematics, University of Tennessee, Knoxville, TN 37996-1300, and **Mei Zhang**. *Ergodic theory for a superprocess over a stochastic flow.*
We study the longtime limiting behavior of the occupation time of the superprocess over a stochastic flow introduced by Skoulakis and Adler (2001). The ergodic theorems for dimensions $d = 2$ and $d \geq 3$ are established. The proofs depend heavily on a characterization of the conditional log-Laplace equation of the occupation time process. (Received February 05, 2009)

1048-60-183 **Amarjit Budhiraja*** (amarjit@unc.edu), Department of Statistics and OR, University of North Carolina, Chapel Hill, NC 27516, and **Rami Atar**, Department of Electrical Engineering, Technion, Haifa, Israel. *Elliott-Kalton Stochastic Differential Games Associated with the Infinity Laplacian.*
In a recent work, Peres, Schramm, Sheffield, Wilson [PSSW] have considered a two player, zero sum, discrete time stochastic game, called Tug of War. In this game two competing players are allowed to drive the state dynamics in a bounded domain with step sizes bounded by c. The game ends at the first time instant when the boundary is reached with a payoff given in terms of a terminal cost function and a suitably scaled running cost. Player 1 seeks to maximize the expected payoff while Player 2 aims to minimize it. It is shown in [PSSW] that if the running cost is bounded away from zero then the game has a value u(c) and as c approaches 0, u(c) converges uniformly to the "continuum value" u which is the unique viscosity solution of an inhomogeneous infinite Laplace equation with a Dirichlet boundary data. In this work we consider a continuous time two player zero sum stochastic differential game that is motivated by the Tug of War game. We show that, under certain conditions, the game has a value in the usual Elliott-Kalton sense which is characterized as the unique viscosity solution of the equation in [PSSW]. Thus the result provides a game theoretic interpretation for the "continuum value" in the [PSSW] analysis. (Received February 06, 2009)

1048-60-230 **P. Sundar*** (sundar@math.lsu.edu), Department of Mathematics, Lockett Hall, Louisiana State University, Baton Rouge, LA 70803. *Stochastic Navier-Stokes equations driven by fractional Brownian motions.*
The two-dimensional stochastic Navier-Stokes equation with a fractional Brownian noise term is considered. The existence and uniqueness of solutions of the stochastic equation is proved. Fractional Brownian motions (fBms) are not semimartingales. Hence, suitable space-time stochastic integrals with respect to fBms are constructed in this study. Further properties of the solution will be discussed. (Received February 09, 2009)

1048-60-263 **Garegin A Papoian*** (gpapoian@unc.edu), Department of Chemistry, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3290, and **Pavel Zhuravlev** (zhur@unc.edu), Campus Box # 3290, The University of North Ca, Chapel Hill, NC 27599-3290. *Stochastic Dynamics of Cell Signaling and Cell Motility.*
Capping proteins are among the most important regulatory proteins involved in controlling complicated stochastic dynamics of filopodia, which are dynamic finger-like protrusions used by eukaryotic motile cells to probe their environment and help guide cell's motility. They attach to the barbed end of a filament and prevent polymerization, leading to effective filament retraction due to retrograde flow. When we have simulated filopodial growth in presence of capping proteins, qualitatively new dynamics emerged. We discovered that molecular noise due

to capping protein binding and unbinding leads to macroscopic filopodial length fluctuations, compared with minuscule fluctuations in the actin only system. Thus, our work shows for the first time that molecular noise of signaling proteins may induce growth-retraction cycles in filopodia. When capped, some filaments eventually retract all the way down to filopodial base and disappear. This process endows filopodium with a finite lifetime. We have also developed an accurate mean field model which provides qualitative explanations of our numerical simulation results. Our results are broadly consistent with experiments, in terms of predicting filopodial growth retraction cycles and also the average filopodial lifetimes. (Received February 09, 2009)

1048-60-314 **David F Anderson*** (anderson@math.wisc.edu), 617 Van Vleck Hall, 480 Lincoln Drive, Madison, WI 53562. *The deficiency zero theorem for stochastically modeled systems.*

The dynamics of chemical reaction networks can be modeled either deterministically or stochastically. The deficiency zero theorem for deterministically modeled systems gives conditions under which a unique equilibrium value with strictly positive components exists within each stoichiometric compatibility class (invariant manifold). The conditions of the theorem actually imply the stronger result that there exist concentrations for which the network is "complex balanced." That observation in turn implies that the standard stochastic model for the reaction network has a product form stationary distribution. (Received February 10, 2009)

1048-60-326 **Ilie Grigorescu** (igrigore@math.miami.edu), Department of Mathematics, University of Miami, Coral Gables, FL 33124, and **Min Kang*** (kang@math.ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695. *Limit Theorems for Branching Diffusive Particles with Catalyst on the Boundary.*

We consider evolution of a large system of branching particles following diffusions on a bounded domain D in $\mathbf{R}^n$ where the branching mechanism is triggered by catalyst (hard obstacle) on the boundary ∂D of the domain. When a particle in the domain reaches the boundary ∂D, it is killed and one of the remaining particles in D is chosen under a probability law and splits into two independent particles then they continue with diffusion. The limiting behavior of the empirical distribution and a tagged particle under scaling will be discussed. Further discussions on propagation of chaos (limiting behavior of the joint law of any finite sub-system under scaling), a connection to Doeblin theorem, large deviation of the system and the law of the survival particles will follow, if time permits. (Received February 10, 2009)

1048-60-333 **Stanislav Molchanov***, Univeristy of North Carolina - Charlotte, Dept of Mathematics and Statistics, Fretwell 376, 9201 University City Blvd., Charlotte, NC 28223. *Reaction – diffusion equations with the evolution of the particles.*

We will discuss the dynamics of the population of the particles governed by the KPP equation, but with the additional parameter (call it a mass). The model can describe the real biological situations , for example, plankton in an ocean. We will present several results: the propagation of the "wave front" for the particles or masses, the distribution of the masses of the "typical" particles, the joint distribution for the number of the particles and their mass, the intermittency effects etc. (Received February 10, 2009)

1048-60-334 **leonid koralov*** (koralov@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742, and **Dmitry Dolgopyat**. *Averaging of Hamiltonian Flows with an Ergodic Component.*

We consider a process which consists of the fast motion along the stream lines of an incompressible vector field perturbed by white noise. We showed that for almost all rotation numbers of the unperturbed flow, the perturbed flow converges to an 'effective', averaged Markov process. This is a generalization of the classical results of Freidlin and Wentzell who considered the case when all the flow lines of the unperturbed flow are closed curves. (Received February 10, 2009)

1048-60-341 **Scott McKinley***, Mathematics Department, Duke University, Box 90320, Durham, NC 27708-0320, and **M. Gregory Forest** and **Lingxing Yao**. *Diffusion in Soft Matter.*

With the advent of sophisticated microscopic tracking techniques, researchers can now conclusively demonstrate that the use of simple Brownian motion as a universal model for diffusion in soft matter is no longer adequate. Long-term memory effects in physical systems are inconsistent with the basic assumptions of Brownian motion and yield qualitatively different behavior. We shall look at one model of such anomalous diffusion – the Generalized Langevin Equation (GLE) – and study it in its singular zero-mass limit. (Received February 10, 2009)

1048-60-344 **Scott McKinley***, Mathematics Department, Duke University, Box 90320, Durham, NC 27708-0320, and **M. Gregory Forest** and **Lingxing Yao**. *Transient Anomalous Diffusion in Soft Matter: An Exactly Solvable Model.*

Stochastic models for diffusion of Brownian particles in soft matter (viscoelastic media) play a central role in polymer dynamics and rheology, microrheology, and medical science. A sufficiently robust class of stochastic processes is required to capture the range of observed anomalous diffusive behavior, in particular transient power law scaling of the mean-squared displacement (MSD) of tracked particles. We consider the Generalized Langevin Equation characterized by a Prony series approximation to the relaxation kernel, and study in particular this system in its zero mass limit. Such a study reveals a robust class of models which exhibit transient anomalous diffusion with a scaling law exactly expressible in terms of a parameter characterizing the relaxation spectrum of the GLE. (Received February 10, 2009)

1048-60-354 **Jason Swanson***, University of Central Florida, Dept of Mathematics,4000 Central Florida Blvd, P.O. Box 161364, Orlando, FL 32816-1364. *Fluctuations of the empirical quantiles of independent Brownian motions.*

We consider n independent, identically distributed one-dimensional Brownian motions, $B_j(t)$, where $B_j(0)$ has a rapidly decreasing, smooth density function f. The empirical quantiles, or pointwise order statistics, are denoted by $B_{j:n}(t)$, and we are interested in a sequence of quantiles $Q_n(t) = B_{j(n):n}(t)$, where $j(n)/n \to \alpha \in (0,1)$. This sequence converges in probability in $C[0,\infty)$ to $q(t)$, the α-quantile of the law of $B_j(t)$. Our main result establishes the convergence in law in $C[0,\infty)$ of the fluctuation processes $F_n = n^{1/2}(Q_n - q)$. The limit process F is a centered Gaussian process and we derive an explicit formula for its covariance function. We also show that F has many of the same local properties as $B^{1/4}$, the fractional Brownian motion with Hurst parameter $H = 1/4$. For example, it is a quartic variation process, it has Hölder continuous paths with any exponent $\gamma < 1/4$, and (at least locally) it has increments whose correlation is negative and of the same order of magnitude as those of $B^{1/4}$. (Received February 10, 2009)

1048-60-361 **Yuri Bakhtin*** (bakhtin@math.gatech.edu), School of Mathematics, Atlanta, GA 30332. *SPDE limit for random trees.* Preliminary report.

We study the infinite random tree serving as the infinite volume limit for plane rooted trees under Gibbs distributions. We show that under a properly chosen rescaling this tree converges in a special topology to a solution of an SPDE that can be viewed as a random continuum tree. The SPDE defines infinite-dimensional stochastic dynamics on monotone transformations with interesting properties that will be discussed in the talk. (Received February 10, 2009)

1048-60-376 **H. Christian Gromoll*** (gromoll@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22903. *Fluid and diffusion limits for shortest remaining processing time queues.*

In an SRPT queue, a server gives preemptive priority to the job with the shortest remaining processing time, that is, the job that can be completed first. There has been recent renewed interest in the SRPT policy due to its relevance to scheduling in web servers. This talk will discuss fluid and diffusion limit theorems for this model, under quite general distributional assumptions. These results illustrate the essential behaviors of the model, and give a way to compute some important performance measures. Key tools are provided by measure-valued processes, used to keep detailed track of the system state. (Received February 10, 2009)

1048-60-379 **Tai Melcher*** (melcher@virginia.edu), University of Virginia, Department of Mathematics, Charlottesville, VA 22903. *Heat kernel analysis for semi-infinite Lie groups.*

I'll talk about heat kernel measure on a class of infinite dimensional Lie groups based on an abstract Wiener space. Heat kernel measure here will be defined as the law of a Brownian motion, constructed as the solution to a stochastic differential equation. We'll discuss results for the heat kernel measure, including a Cameron-Martin type quasi-invariance theorem and a logarithmic Sobolev inequality, as well as some potential applications. (Received February 10, 2009)

62 ► Statistics

1048-62-358 **Cliburn C Chan*** (cliburn.chan@duke.edu), 11078 Hock Plaza, Durham, NC 27710. *A model-based approach to multi-parameter flow cytometry analysis.*

The ability to monitor complex immune responses quantitatively is increasingly recognized as essential for the development of vaccines, and also in the diagnosis and prognosis of several diseases, including cancer, HIV and

both stem cell and solid organ transplantation. One of the most versatile technologies used in immune monitoring is flow cytometry, which can be used to simultaneously track phenotype and effector responses of individual cells in a population. However, robust and accurate quantification of flow data can be difficult, and manual gating for exploring multi-parameter data is extremely inefficient. This talk will describe the development of statistical mixture models and software for the automated analysis of multi-parameter flow cytometry, a nd illustrate applications to several translational and clinical research data sets. (Received February 10, 2009)

65 ► Numerical analysis

1048-65-36 **John Paul Roop*** (jproop@ncat.edu), Greensboro, NC 27411, and **Traian Iliescu**, Blacksburg, VA 24061. *Two-level finite element approximation of Navier-Stokes equations with nonlinear subgridscale artificial viscosity.*

In this talk, we review the concept of a two-level finite element method and discuss theoretical and numerical results from the application of a two-level method to Navier-Stokes equations with nonlinear subgridscale artificial viscosity. In the two-level finite element method, the solution to a fully nonlinear coarse mesh problem is utilized in a single step linear fine mesh problem. It is important to note that the two-level finite element method is not the same as multigrid. Two-level finite element methods for Navier-Stokes equations are well studied. However, we examine mathematical complications which arise from the inclusion of subgridscale artificial viscosity into the modeling equations. A corresponding variational problem is formulated in the appropriate Sobolev spaces; stability, error convergence, and scaling estimates are proven; and numerical results are given which illustrate the utility of two-level algorithms in reducing the computational cost of the numerical simulation of turbulent flows. (Received December 23, 2008)

1048-65-116 **Jeb Collins*** (jbcolli2@unity.ncsu.edu), Box 8205, Department of Mathematics, North Carolina State University, Raleigh, NC 27695, and **Pierre Gremaud** (gremaud@unity.ncsu.edu), Department of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695. *Numerical simulation of laser drilling.*

Laser drilling is used in many industries due its advantages over conventional drilling techniques. Advantages include low heat release, consistency and accuracy. The process is quite involved and includes absorption and reflection of the beam, creation of plasma and melt ejection. The goal of this work is to show that for some regimes, simple and fast computational models can very accurately predict depth penetration, the fore most important aspect of the process. To this end, we will describe a quasi one-dimensional model and compare its prediction to experimental results. (Received February 02, 2009)

1048-65-144 **Jingfang Huang*** (huang@amath.unc.edu), CB # 3250, Phillips Hall, Department of Mathematics, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3250, and **Benzhuo Lu**, **Xiaolin Cheng** and **J. Andrew McCammon**. *An adaptive fast multipole algorithm for electrostatic interactions in biomolecular systems.*

Poisson-Boltzmann (PB) electrostatics is a well established model in biophysics, however its application to the study of large scale biosystem dynamics such as the protein-protein encounter is still limited by the efficiency and memory constraints of existing numerical techniques. In this talk, we present an efficient and accurate scheme which incorporates recently developed novel numerical techniques to further enhance the present computational ability. In particular, a boundary integral equation approach is applied to discretize the linearized Poisson-Boltzmann (LPB) equation; the resulting integral formulas are well conditioned and are extended to systems with arbitrary number of biomolecules; the solution process is accelerated by the Krylov subspace methods and an adaptive new version of fast multipole method (FMM); and in addition to the full electrostatic interaction energy, the forces and torques can be computed in a post-processing procedure. The Adaptive Fast Multipole Poisson-Boltzmann (AFMPB) solver will be released under open source license agreement. (Received February 04, 2009)

1048-65-154 **Anita T Layton*** (alayton@math.duke.edu), Department of Mathematics, Duke University, Box 90320, Durham, NC 27705. *A Velocity Decomposition Approach for Moving Interfaces in Viscous Fluids.*

We present a second-order accurate method for computing the coupled motion of a viscous fluid and an elastic material interface with zero thickness. The fluid flow is described by the Navier-Stokes equations, with a singular force due to the stretching of the moving interface. We decompose the velocity into a "Stokes" part and a "regular" part. The first part is determined by the Stokes equations and the singular interfacial force.

The Stokes solution is obtained using the immersed interface method, which gives second-order accurate values by incorporating known jumps for the solution and its derivatives into a finite difference method. The regular part of the velocity is given by the Navier-Stokes equations with a body force resulting from the Stokes part. The regular velocity is obtained using a time-stepping method that combines the semi-Lagrangian method with the backward difference formula. Because the body force is continuous, jump conditions are not necessary. For problems with stiff boundary forces, the decomposition approach can be combined with fractional time-stepping, using a smaller time step to advance the interface quickly by Stokes flow, with the velocity computed using boundary integrals. (Received February 05, 2009)

1048-65-155 **Anita T Layton*** (alayton@math.duke.edu), Department of Mathematics, Duke University, Box 90320, Durham, NC 27705. *Selectively Accelerated Semi-implicit Spectral Deferred Correction Methods.*

Spectral deferred correction (SDC) methods have been show to offer a flexible strategy for constructing numerical methods with very high order of accuracy for ordinary differential equations. Order reduction for SDC methods has been shown to coincide with a reduction in the rate at which the iterative solutions generated by SDC methods converge to the solution of the standard spectral collocation formulation. Hence the use of Krylov subspace based methods which accelerate the convergence of SDC methods also effectively eliminates order reduction. However, for very large systems of ODEs (such as those arising from the discretization of PDEs), the computational and storage costs of Krylov acceleration could be prohibitive. In this paper, we investigate the effectiveness of applying Krylov based accleration techniques only to the stiffest part of systems of ODEs which can be decomposed into terms of various stiffness. For many relevant examples, this can dramatically reduce the cost and storage requirement of applying accleration, while maintaining the advantage of improving convergence of the iterates or equivalently avoiding order reduction. Numerical examples demonstrate the effectiveness of this acceleration technique for problems with two and three distinctive time scales. (Received February 05, 2009)

1048-65-158 **Michael L Minion*** (minion@email.unc.edu), Dept. of Mathematics, CB 3250 Phillips Hall, University of North Carolina, Chapel Hill, NC 27599. *The parareal algorithm and spectral deferred corrections.*

The efficient parallelization of numerical methods for ordinary or partial differential equations in the temporal direction is an intriguing possibility that has of yet not been fully realized despite decades of investigation. For partial differential equations, virtually all large scale computations now employ parallelization across space, and there are freely available computational tools and libraries to aid in the development of spatially parallelized codes. Conversely, parallelization in the temporal direction is rarely even considered. I will discuss a relatively recent parallel strategy called the parareal algorithm that has generated a renewed wave of interest in time parallelization. I will show how the iterative structure of the parareal algorithm can be interpreted as a particular form of deferred corrections and then present a modified parareal strategy based on spectral deferred corrections that can significantly reduce the computational cost of the method. Finally I will make some observations as to why parallel in time methods may be attractive in the future. (Received February 05, 2009)

1048-65-181 **Jingfang Huang*** (huang@amath.unc.edu), CB # 3250, Phillips Hall, Department of Mathematics, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3250, and **Quandong Feng**. *Krylov Deferred Correction Accelerated High Order Symplectic Methods.*

In this talk, an efficient numerical procedure is presented to implement the Gaussian Runge-Kutta (GRK) methods. The GRK technique first discretizes each marching step of the initial value problem using collocation formulations based on Gaussian quadrature which preserves the geometric structures of Hamiltonian systems. Existing analysis shows that the GRK discretization with s nodes is of order 2s, A-stable, B-stable, symplectic and symmetric, and hence "optimal" for solving initial value problems of general ordinary differential equations. However, as the unknowns at different collocation points are coupled in the discretized system, direct solution of the resulting algebraic equations is in general inefficient. Instead, we use the Krylov deferred correction (KDC) method in which the spectral deferred correction (SDC) scheme is applied as a preconditioner to decouple the original system, and the resulting preconditioned nonlinear system is solved efficiently using Newton-Krylov schemes such as Newton-GMRES method. The KDC accelerated GRK methods have been applied to several Hamiltonian systems and preliminary numerical results are presented to show the accuracy, stability, and efficiency features of these methods. (Received February 06, 2009)

1048-65-210 **Jeffrey M. Connors** (jmc116@pitt.edu) and **Alexander E. Labovsky*** (ayl@math.missouri.edu). *Semi-implicit spectral deferred correction decoupling methods for a parabolic two domain problem.* Preliminary report.

A numerical approach to estimating solutions to coupled systems of equations is partitioned time stepping methods, an alternative to monolithic solution methods, recently studied in the context of fluid-fluid and fluid-structure interaction problems. Few analytical results of stability and convergence are available, and typically such methods have been limited to first order accuracy in terms of discretization parameters. Many proposed higher-order schemes are unstable, or their stability is yet to be proven analytically. We consider two heat equations in $\Omega_1, \Omega_2 \subset \mathbb{R}^2$ adjoined by an interface $I = \Omega_1 \cap \Omega_2 \subset \mathbb{R}$ - as a simplified model for the fluid-fluid or fluid-structure interactions. We present the family of semi-implicit spectral deferred correction (SISDC) methods for the partial differential equations. We prove stability and the desired second-order accuracy of the two-step SISDC method (one simpler method from this family), and we also perform computational tests which verify the second-order time accuracy of the two-step method. (Received February 08, 2009)

1048-65-214 **Jian-Guo Liu*** (jliu@math.umd.edu), Dept of Physics, Duke University, Durham, NC 27708. *A simple proof of Cucker-Smale flocking dynamics and the mean field limit.*

Flocking, a universal phenomenon, has found applications in many areas ranging from herding to the emergence of common languages in primitive societies. Flocking refers to autonomous agents reaching a consensus based on limited environmental information and simple rules with or without a hierarchical leadership. Last year, Felipe Cucker and Steve Smale postulated a model for flocking of birds and showed convergence to consensus (the same velocity) exponentially.

In this talk, I will show a simple proof of the flocking behavior for the Cucker-Smale system based on a construction of Lyapunov function. A simple phase plane analysis provides a unified condition on the initial states in which the convergence to consensus will occur. For large agent systems and their mean field limit, we give a uniform bound on the velocity field. This enable us to show the stability in Wasserstein-1 distance

(Kantorovich-Rubinstein distance), hence the convergence of large agent systems to the unique measure valued solution of a Vlasov type equation (mean field limit). (Received February 08, 2009)

1048-65-220 **Thomas Hagstrom*** (thagstrom@smu.edu), Department of Mathematics, PO Box 750156, Dallas, TX 75275-0156. *Local Time Stepping for Spectral Element Methods.*

Spectral element methods, as implemented, for example, in a discontinuous Galerkin framework, can provide accurate solutions of wave propagation problems in complex geometry using a small number of degrees-of-freedom per wavelength. However, the associated time-stepping problem is artificially stiff due to the need to differentiate polynomials throughout their domain of definition. Directly, the norm of the derivative matrix scales like P^2/H where P is the polynomial degree and H is a measure of the element size. Locally refined elements, associated with larger values of P or smaller values of H and required to resolve local features, then lead to further time step restrictions. We discuss various strategies for circumventing these issues including:

: Integral evolution formulas;

: Deferred correction of flux contributions from neighboring cells;

: Dual grid filters, including novel Hermite-based discretizations which circumvent the quadratic P-dependence of the discrete differentiation operator.

(Received February 09, 2009)

1048-65-228 **Elizabeth L Bouzarth*** (bouzarth@math.duke.edu), Duke University, Department of Mathematics, Box #90320, Durham, NC 27708. *A multi-explicit spectral deferred correction method applied to regularized Stokeslets.*

Regularized Stokeslets provide a way to calculate fluid velocities in the Stokes regime due to regularized point-forces. In this discussion, the method of regularized Stokeslets is used to model immersed rigid or elastic objects by connecting such forces with springs, potentially introducing stiffness into the underlying system of ODEs. In certain scenarios, the fluid velocity can be decomposed to isolate stiffness into one portion of the velocity, leaving the remainder non-stiff. The multi-explicit spectral deferred correction (MESDC) method utilizes such a decomposition and integrates the stiff velocity component with a small time step while treating the non-stiff component with a larger time step. This eliminates unnecessary expensive calculations while still treating the system explicitly in a stable, efficient manner. (Received February 09, 2009)

1048-65-231 **Sorin M. Mitran*** (mitran@unc.edu), Department of Mathematics, CB 3250, Chapel Hill, NC 27599. *A fresh look at dispersion-preserving, compact schemes using the Z-transform.* Preliminary report.

A number of physical phenomena require accurate modeling in both spectral and real space. Dispersion relation preserving and spectral schemes have reached a high degree of development for such applications. Both are based upon Fourier expansions of the field variables of interest. Ideally suited for periodic boundary conditions, the modifications required to deal with general domains are often cumbersome. The Fourier transform itself is the restriction to the unit circle of the Z-transform. An investigation of how compact, dispersion relation preserving schemes can be derived from the Z-transform is presented along with applications to wave propagation and turbulence modeling. (Received February 09, 2009)

1048-65-252 **Alexander Labovsky*** (ayl@math.missouri.edu) and **Catalin Trenchea** (trenchea@pitt.edu). *Approximate Deconvolution Models for MagnetoHydroDynamic Turbulence.* Preliminary report.

Magnetically conducting fluids arise in important applications including climate change forecasting, plasma confinement, controlled thermonuclear fusion, liquid-metal cooling of nuclear reactors, electromagnetic casting of metals, MHD sea water propulsion. In many of these, turbulent MHD (MagnetoHydroDynamic) flows are typical. The difficulties of accurately modeling and simulating turbulent flows are magnified many times over in the MHD case. They are evinced by the more complex dynamics of the flow due to the coupling of Navier-Stokes and Maxwell equations via the Lorentz force and Ohm's law. We consider the family of approximate deconvolution models (ADM) for the simulation of the large eddies in turbulent viscous, incompressible, electrically conducting flows. We prove existence and uniqueness of solutions, we prove that the solutions to the ADM-MHD equations converge to the solution of the MHD equations in a weak sense as the averaging radii converge to zero, and we derive a bound on the modeling error. We prove that the energy and helicity of the models are conserved, and the models preserve the Alfven waves. We provide the results of the computational tests, that verify the accuracy and physical fidelity of the models. (Received February 09, 2009)

1048-65-273 **Shaozhong Deng*** (shaodeng@uncc.edu), Department of Mathematics and Statistics, UNC at Charlotte, Charlotte, NC 28223. *Efficient methods of images for hybrid explicit/implicit solvent simulations.*

Electrostatic interactions are well-known to provide crucial contributions to the structure, dynamics and function of bio-macromolecules; as such, they remain as major objects of computational biology. In this talk, we will discuss our past results as well as recent efforts in the development of multiple-image-based reaction-field methods for calculating electrostatic interaction in hybrid explicit/implicit bio-molecular dynamics simulations. Some preliminary results of molecular dynamics simulation of liquid water by using the multiple image methods are also to be presented. (Received February 09, 2009)

1048-65-276 **Sun young Bu*** (agatha@email.unc.edu), **Jingfang Huang** and **Michael Minion**. *Semi-implicit Preconditioning Techniques for Krylov Deferred Correction Methods.*

In the recently developed Krylov deferred correction (KDC) methods for differential equation initial value problems, a Picard-type collocation formulation is preconditioned using low order time integration schemes coupled with the spectral deferred correction (SDC) ideas, and the resulting system is solved efficiently using the Newton-Krylov methods. Existing analyses show that the new KDC methods are of arbitrary order and A-stable. In this paper, we further improve the efficiency of the KDC methods by introducing the semi-implicit preconditioning scheme (SI-KDC), in which the stiff component is solved by implicit schemes and the nonstiff parts by explicit methods. Compared with the fully implicit KDC (FI-KDC) methods, preliminary analyses show that the convergence of Newton-Krylov iterations in the SI-KDC methods is similar to that in FI-KDC, while for systems with a nonlinear non-stiff component and a linear stiff part, the SI-KDC can greatly reduce the computational cost in each spectral deferred correction iteration for the same accuracy requirement. The analyses are validated by preliminary numerical results. (Received February 09, 2009)

1048-65-297 **Wenjun Ying*** (wjying@mtu.edu), Michigan Technological University, Department of Mathematical Sciences, 1400 Townsend Drive, 206 Fisher Hall, Houghton, MI 49931. *Kernel-free Boundary Integral Method for Elliptic Boundary Value Problems.*

It is well-known that an elliptic boundary value problem (BVP) can be equivalently reformulated as a boundary integral equation (BIE). The solution of the elliptic BVP is obtained by solving the corresponding BIE via an operator discretization approach, which gives the method the name of boundary integral method. The applicability of the boundary integral method is based on the assumption that the kernels of the integral operators

are analytically known. However, the kernels of the integral operators are generally very difficult to find except in the simplest cases where the elliptic operator has isotropic and constant coefficients and the BVP is posed in a free space or a simple domain with idealized boundary conditions. This talk will introduce the kernel free boundary integral (KFBI) method for general elliptic BVPs. The KFBI method avoids the need to know the analytical expressions for the kernels of the integral operators. Instead, the boundary and volume integrals involved are approximated by structured grid-based numerical solutions, which are obtained with the standard finite difference or finite element method. Some preliminary results of an adaptive version of the KFBI method for constant coefficients problems will be presented. (Received February 09, 2009)

1048-65-304 **Padmanabhan Seshaiyer*** (pseshaiy@gmu.edu), 4400, University Drive, MS 3F2, Department of Mathematical Sciences, George Mason University, Fairfax, VA 22030.
Advances in computational methods for soft-tissue biomechanics. Preliminary report.

In the last decade, there has been a lot of development in understanding the biomechanics of an intracranial saccular aneurysm, the rupture of which is the most common cause of nontraumatic subarachnoid hemorrhage (bleeding onto the surface of the brain). Modeling the mechanical behavior of such soft-tissues in their service configuration is often challenging because of their complicated geometry, material heterogeneity, nonlinear behavior under finite strains and the associated fluid-structure interaction problem. Efficient solutions to such complex coupled biological processes are still a challenging problem in computational sciences. Direct numerical simulation of the associated non-linear equations, governing even the most simplified model depends on the convergence of iterative solvers which in turn rely heavily on the properties of the coupled system. In this talk we will review analytical, computational and experimental approaches for quantifying the multiaxial mechanical properties of hyperelastic membranes interacting with fluid dynamics. Some numerical findings on the dynamic stability and the influence of contact constraints on these lesions will also be presented. (Received February 10, 2009)

1048-65-308 **Andrew Christlieb*** (christlieb@math.msu.edu), **Benjamin Ong** and **Jing-Mei Qiu**.
Integral Deferred Correction.

In this talk we will discuss a class of defect correction methods we have been developing, which are motivated by Spectral Deferred Correction (Dutt, Greengard and Rokhlin, BIT-2000), SDC. The relation between SDC and our approach is that the correction step is reformulated so that the integral of the residual appears in the correction equation, rather than the derivative of the residual. Because it is the integral of the residual appears in the correction loop, we have dubbed the method Integral Deferred Correction (IDC). One difference between SDC and IDC is that, in IDC, we are able to use high order single step methods in the correction loop. We have formally established that, under key assumptions, if an r^{th} order single step method is used in the correction loop of IDC, the order of IDC increases by r with each correction loop, for both explicit and implicit IDC, up to a maximum order M. Further, it has been observed that when a high order method is used in the correction step of explicit IDC, dramatically improved regains of absolute stability are observed. We have applied this class of methods to a range of stiff and non stiff test problems and we are currently working on applying this adaptive approach to fully Lagrangian plasma simulations. (Received February 10, 2009)

1048-65-311 **Jun Jia*** (jiaj@ornl.gov), Oak Ridge National Laboratory, MS-6367, Oak Ridge, TN 37923. *Stable and Spectrally Accurate Schemes for Navier-Stokes Equations.*

In this talk, we present an accurate, efficient and stable numerical method for the incompressible Navier-Stokes equations (NSE) with no-slip and open boundary conditions. The method is based on (1) an equivalent pressure Poisson equation formulation of NSE with proper pressure boundary conditions, which facilitates the design of high-order and stable numerical methods, and (2) the Krylov deferred correction (KDC) accelerated method of line transpose (MoL^T), which is very stable, efficient and of arbitrary order in time. Numerical tests with known exact solutions in 3D show that the new method is spectrally accurate in time. 2D computational results of a flow past a cylinder and a flow in a bifurcated tube are also reported. (Received February 10, 2009)

1048-65-317 **Alina Chertock*** (chertock@math.ncsu.edu), North Carolina State University, Department of Mathematics, Campus Box 8205/ HA 243, Raleigh, NC 27695, **Charles Doering** (doering@umich.edu), Univeristy of Michigan, Department of Mathematics, 328 WH East Hal, Ann Arbor, MI 48109, **Eugene Kashdan** (ekashdan@post.tau.ac.il), Tel Aviv University, Department of Applied Mathematics, 69978 Tel Aviv, Israel, **Alexander Kurganov** (kurganov@math.tulane.edu), Tulane University, Mathematics Department, 6823 Saint Charles Ave, New Orleans, LA 70118, and **Guergana Petrova** (gpetrova@math.tamu.edu), Texas A&M University, Department of Mathematics, College Station, TX 77843. *Fast Explicit Operator Splitting Method for Convection-Dominated Problems.*

Convection-diffusion equations model a variety of physical phenomena. Computing solutions of these equations is an important and challenging problem, especially in the convection-dominated case, in which viscous layers are so thin that one is forced to use underresolved methods that may be unstable. If an insufficient amount of physical diffusion is compensated by an excessive numerical viscosity, the underresolved method is typically stable, but the quality of the resolution may be severely affected. At the same time, the use of dispersive schemes may cause spurious oscillations that may, in turn, trigger numerical instabilities.

I will present a special operator splitting technique that may help to overcome these difficulties by numerically preserving a delicate balance between the convection and diffusion terms, which is absolutely necessary when an underresolved method is used. The performance of the splitting-based methods will be illustrated on a number of numerical examples including the polymer system arising in modeling of the flooding processes in enhanced oil recovery, systems modeling the propagation of passive pollutant in shallow water and in a random stirring flow field, and the incompressible Navier-Stokes equations. (Received February 10, 2009)

1048-65-318 **Alexander Kurganov*** (kurganov@math.tulane.edu), Mathematics Department, Tulane University, 6823 St. Charles Ave., New Orleans, LA 70118. *Non-Oscillatory Central Schemes for Traffic Flow Models with Arrhenius Look-Ahead Dynamics.*

We first develop nonoscillatory central schemes for a traffic flow model with Arrhenius look-ahead dynamics, proposed in [A. Sopasakis and M.A. Katsoulakis, SIAM J. Appl. Math., 66 (2006), pp. 921-944]. This model takes into account interactions of every vehicle with other vehicles ahead ("look-ahead" rule) and can be written as a 1-D scalar conservation law with a global flux, for which no Riemann problem solver is available. The proposed schemes are extensions of the nonoscillatory central schemes that belong to a class of Riemann-problem-solver-free Godunov-type projection-evolution methods, which are especially attractive for the studied traffic flow model. The designed schemes are used to numerically investigate both dispersive and smoothing effects of the global flux.

We also modify the model by Sopasakis and Katsoulakis by introducing a more realistic, linear interaction potential that takes into account the fact that a car's speed is affected more by nearby vehicles than distant (but still visible) ones. The central schemes are extended to the modified model. Our numerical studies clearly suggest that in the case of a good visibility, the new model yields solutions that seem to better correspond to reality. (Received February 10, 2009)

1048-65-359 **Matthew Bowen*** (mmbowen@math.duke.edu). *Spectral Deferred Correction and Alternans.*

In many experiments and simulations, the observation has been made that, under rapid period pacing, cardiac cells undergo a period-doubling bifurcation in which the duration of action potentials alternates between a long value and a short value. While in a single cardiac cell this bifurcation is understood, even in a one dimensional cable of cardiac cells, its exact nature is still unclear. A model introduced by Mitchell and Schaeffer exhibits this so called alternan behavior. Like most models of action potentials, this model has both "fast" and "slow" timescales, resulting in a relatively stiff numerical problem. In 2 or 3 spatial dimesions, this makes mesh refinement inefficient. In this talk, I will discuss the results of applying a spectral deferred correction method to the reaction-diffusion system suggested by the model. In particular, I will focus on what the results say about the nature of these alternans and compare the efficiency of the method with the schemes currently used to solve the problem. (Received February 10, 2009)

1048-65-375 **kazufumi ito*** (kio@math.ncsu.edu), Dept.of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695. *High order finite difference schemes for wave equation in heterogeneous media.*

A fourth order full time-space discretization that extends naturally the Yee's scheme is discussed. It is a compact, well-structured, explicit time and space finite difference scheme and provides an efficient and high

resolution method for wave propagation problems. A second order interface treatment is developed. (Received February 10, 2009)

1048-65-382 **Wei Cai*** (wcai@uncc.edu), Department of Mathematics, University of North Carolina at Charlotte, 9201 University City Boulevard, Charlotte, NC 28223. *Adaptive Cell-average Spectral Element Methods for transient Wigner Equations in quantum transport.*

In this talk, we will introduce a new numerical method for solving time dependent Wigner equations with application to quantum transport. This method takes advantage of equivalent representations for the Wigner distribution function in the k-space between cell-averages (local electron density) and point values in the Chebyshev polynomial spaces. Coupled with conventional collocation method in the x-space, the resulting conservative algorithm provides a highly accurate method for the Wigner equations, and adaptivity in both x and k spaces are achieved within the spectral element framework to address the high dimensional Wigner distributions. Numerical results of quantum transport in resonant tunneling diode are included. (Received February 11, 2009)

68 ► Computer science

1048-68-43 **Felix A Ulmer*** (felix.ulmer@univ-rennes1.fr), IRMAR, Université de Rennes 1, Campus de Beaulieu, 35042 Rennes, France. *Coding with skew polynomial rings.*

In this approach, we generalize the notion of cyclic code and construct codes via ideals in finite quotients of non commutative polynomial rings, so called skew polynomial rings of automorphism type. Since there is no unique factorization in skew polynomial rings, there are much more ideals and therefore much more codes than in the commutative case.

We propose a method to construct block codes of prescribed rank and a method to construct block codes of prescribed distance (joint work with L. Chaussade and P. Loidreau). Also, using Groebner bases, we computed all Euclidean and Hermitian self-dual linear codes over $\mathbb{F}_4$ of this type of length less than 40, including a [36, 18, 11] Euclidean self-dual code which improves the previously best known self-dual linear codes over $\mathbb{F}_4$ (joint work with D. Boucher) (Received January 11, 2009)

1048-68-368 **David Soloveichik*** (dsolov@caltech.edu), Caltech MC 136-93, 1200 E California Blvd, Pasadena, CA 91125. *Robust Stochastic Chemical Reaction Networks and Bounded Tau-Leaping.*

The behavior of some stochastic chemical reaction networks is largely unaffected by slight inaccuracies in reaction rates. We formalize the robustness of state probabilities to reaction rate deviations, and describe a formal connection between robustness and efficiency of simulation. Without robustness guarantees, stochastic simulation seems to require computational time proportional to the total number of reaction events. Even if the concentration (molecular count per volume) stays bounded, the number of reaction events can be linear in the duration of simulated time and total molecular count. We show that the behavior of robust systems can be predicted such that the computational work scales linearly with the duration of simulated time and concentration, and only polylogarithmically in the total molecular count. Thus our asymptotic analysis captures the dramatic speedup when molecular counts are large, and shows that for bounded concentrations the computation time is essentially invariant with molecular count. Finally, by noticing that even robust stochastic chemical reaction networks are capable of embedding complex computational problems, we argue that the linear dependence on simulated time and concentration is likely optimal. (Received February 10, 2009)

70 ► Mechanics of particles and systems

1048-70-234 **Sorin M. Mitran*** (mitran@unc.edu), Department of Mathematics, CB 3250, Chapel Hill, NC 27599. *Continuum-microscopic computation of biological material mechanical properties.* Preliminary report.

Mechanical properties of biological materials exhibit large variability - one of the fundamental reasons underlying this behavior is associated with changes in the microscopic structure. A computational framework for coping with changing microscopic configurations is presented based upon coupling of a classical continuum model (e.g. membranes, beams) with a microscopic model of the system. The key question of how to identify statistics of the microscopic model is addressed and a method based upon systematic sampling and identification of the associated probability distribution functions is presented. The computational framework is applied to the modeling of the cytoskeleton and microtubules. (Received February 09, 2009)

1048-70-285 **Anthony M Bloch**, **Jerrold E Marsden** and **Dmitry V Zenkov*** (dvzenkov@ncsu.edu). *Quasivelocities and Symmetries in Nonholonomic Dynamics.*

Quasivelocities are the components of a mechanical system's velocity relative to a set of vector fields that are not associated with configuration coordinates. Nonholonomic systems are mechanical systems subject to velocity constraints. This talk concentrates on the utilization of quasivelocities in the formulation of nonholonomic systems with symmetry. In particular, the use of quasivelocities in understanding unusual momentum conservation laws and qualitative analysis of nonholonomic dynamics is discussed. (Received February 09, 2009)

1048-70-287 **David A Long*** (dalong@ncsu.edu), **Anthony M Bloch**, **Jerrold E Marsden** and **Dmitry V Zenkov**. *Relaxed Matching for Stabilization of Lagrangian Systems.*

The method of controlled Lagrangians is a technique for stabilizing relative equilibria of mechanical systems with symmetry. The key idea of the method is to modify the kinetic and potential energies of the original system and to view the new terms in the equations of motion introduced by this modification as the control inputs. In this talk we discuss a modification to this technique that gives greater flexibility to the theory, making it applicable to a broader class of systems. This "relaxed matching" technique is demonstrated with the problem of the pendulum on a rotor arm. (Received February 09, 2009)

1048-70-288 **Cameron Lynch** and **Dmitry V Zenkov*** (dvzenkov@ncsu.edu). *Stability of Relative Equilibria of Discrete Nonholonomic Systems.*

Nonholonomic systems are mechanical systems subject to velocity constraints, such as rolling and/or sliding contacts. Nonholonomic integrators are discrete-time analogues of nonholonomic mechanical systems. Conditions for partial asymptotic stability of relative equilibria of nonholonomic integrators with symmetry are established. For integrators obtained by discretization of continuous-time dynamics, stability conditions are compared to those of the associated continuous-time systems. (Received February 09, 2009)

1048-70-295 **Scott David Kelly*** (scott@kellyfish.net), 9201 University City Boulevard, Charlotte, NC 28223-0001. *Momentum-Conserving Models for Aquatic Locomotion through Discrete Vortex Shedding.*

The shedding of vorticity from solid surfaces is central to the locomotion of a variety of marine animals and aquatic vehicles. Hydrodynamic models which account for the viscous physics underpinning vortex shedding are frequently too complex to be studied analytically or to be used for model-based control design. We describe an approach to introducing thrust-producing vortex shedding to Hamiltonian models for the locomotion of deformable bodies in inviscid fluids. (Received February 09, 2009)

74 ► Mechanics of deformable solids

1048-74-73 **Silas Alben*** (alben@math.gatech.edu), 686 Cherry St. NW, Atlanta, GA 30332. *The structure of fish fins.*

Fish fins have evolved over millions of years in a convergent fashion, leading to a highly-intricate fin-ray structure that is found in half of all fish species. This fin ray structure gives the fin flexibility plus one degree of freedom for shape control. I will present a linear elasticity model of the fin ray, based on experiments performed in the Lauder Lab in Harvard's Biology department. I will then describe numerical simulations of a fully-coupled fin-fluid model, based on a new method for computing the dynamics of a flexible bodies and vortex sheets in 2D flows. The simulations are applied to the mode of fish swimming based on tail fin oscillations. (Received January 23, 2009)

76 ► Fluid mechanics

1048-76-15 **Pengtao Yue*** (ptyue@math.vt.edu), 460 McBryde, Virginia Tech, Blacksburg, VA 24061-0123. *Cahn-Hilliard model for moving contact lines.*

Continuum hydrodynamics with no-slip boundary conditions leads to a stress singularity at the moving contact line. This singularity can be either regularized by the diffusion in the Cahn-Hilliard diffuse-interface model or removed by the slip conditions in sharp-interface models. This talk discusses the basic questions underlying the Cahn-Hilliard model. Through dimensional analysis and numerical computations, we demonstrate that the Cahn-Hilliard model approaches a sharp-interface limit when the interfacial thickness is reduced below a threshold while other parameters are appropriately chosen. In this limit, the contact line has a diffusion length that is related to the slip length in sharp-interface models, and the relaxation of wall energy determines the

deviation of the dynamic contact angle from the static one. From these results, we develop practical guidelines for attaining the sharp-interface limit in numerical simulations and for quantitatively reproducing experimental data on the apparent contact angle. Finally, with hints from the Cahn-Hilliard model, we show a practical way to implement the slip conditions such that the sharp-interface models can generate mesh-independent results and even fit the experimental data. (Received November 14, 2008)

1048-76-40 **Zhenlu Cui*** (zcui@uncfsu.edu), Department of Math and Computer Science, Fayettevill state University, 1200 Murchison Rd, Fayetteville, NC 28301. *Hydrodynamics and Rheology of Active Particle Suspensions.* Preliminary report.

Active materials are a challenging class of systems driven out of equilibrium by an internal or an external energy source. Examples are self-propelled particles in bacterial colonies, or the membrane and the cytoskeleton of eukaryotic cells, etc. In this talk, I will present a hydrodynamic theory of flowing active particle suspensions and discuss the flow and rheological behaviors of these materials. In sharp contrast to their passive counterparts, the flow is either permeative or oscillatory under weak external forcing. The rheological behaviors are altered due to the activity induced by the system. (Received January 09, 2009)

1048-76-48 **Leo G Rebholz*** (rebholz@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634, and **Myron M Sussman**. *The NS-alpha-deconvolution turbulence model.* Preliminary report.

We study a high-order accurate generalization of the NS-alpha turbulence model, called the NS-alpha-deconvolution model. We show that by combining the alpha filter with van Cittert approximate deconvolution, the resulting model can retain the many attractive properties of NS-alpha while also achieving higher formal accuracy. We prove the new model admits unique weak solutions, conserves energy, helicity, and 2d enstrophy, is frame invariant, and can be solved with many less degrees of freedom than the NSE. We also study its limiting behavior, and present a numerical scheme and experiments that illustrate the advantages of the new model. (Received January 12, 2009)

1048-76-77 **Richard J Braun*** (braun@math.udel.edu), Dept of Mathematical Sciences, University of Delaware, Newark, DE 19716. *Models of the Human Tear Film During the Blink Cycle.*

Lubrication models for the tear film are discussed in one and two spatial dimensions. In 1D, results for the blink cycle are presented. Notions of a full blink and periodic solutions are linked. In 2D, we present results for tear film dynamics on eye-shaped domains. Our understanding of the tear film drainage system is modified by the role of the meniscus in driving flow on the 2D domain. This work is in collaboration with K.L. Maki and P. Ucciferro (U of Delaware), W.D. Henshaw (LLNL) and P.E. King-Smith (Ohio State U). (Received January 25, 2009)

1048-76-138 **William Layton*** (wjl@pitt.edu), math dept/Univ of Pittsburgh, 301 Thackery hall, pittsburgh, PA 15260. *Uncoupling Atmosphere-Ocean Models.*

This talk will present 2 algorithms for uncoupling at each time step Atmosphere-Ocean models. The methods are unconditionally stable and, most importantly, require only black box solves of the Atmosphere and the Ocean sub problems. The development will be for a simplified case of two fluids coupled across an interface with commonly used Atmosphere-Ocean coupling conditions. This model captures some of the essential difficulties of Atmosphere-Ocean coupling. The two base methods are first order accurate. The talk will also show how to get fully uncoupled, unconditionally stable, higher order methods using the base methods and deferred correction. The research presented in this talk is based on joint work with Jeff Connors (Pitt, http://www.pitt.edu/ jmc116/), Jason Howell (CMU, http://www.math.cmu.edu/ howell4/) and Alex Labovschii (U. Missouri, http://www.math.missouri.edu/ ayl). (Received February 04, 2009)

1048-76-170 **Mow Ebrahimi**, **Michael Holst**, **Evelyn M. Lunasin*** (elunasin@math.ucsd.edu) and **Edriss S. Titi**. *The 2D Navier-Stokes-Voight and 2D damped Navier-Stokes equations for image inpainting.*

In 2001, Bertalmio, et. al. have built an analogy between the image intensity function for the inpainting problem and the stream function in 2D incompressible fluid. The solution to the inpainting problem is obtained by solving the steady state solution of the 2D NSE vorticity transport equation, and simultaneously solving the Poisson problem between the vorticity and the stream function, in the region to be inpainted. From this analogy one can investigate the quality and efficiency of a sub-grid scale turbulence model in the context of image inpainting. For small regularization parameter $\alpha > 0$, our numerical results show that the 2D Navier-Stokes-Voight equation gives a solution to the inpainting problem which is comparable with NSE (both in using subjective and objective

measures) but requires reduced computational resources. A similar result holds true for the 2D damped NSE for a small damping coefficient. (Received February 05, 2009)

1048-76-180 **Clement Kleinstreuer*** (ck@eos.ncsu.edu), NC State University, Dept. of Mechanical & Aerospace Engineering, Raleigh, NC 27695-7910, and **Jie Li**. *Nanofluid Flow in Bio-MEMS.*

Nanofluids are dilute suspensions of nano-size solids in liquids with particle volume fractions of 0.1 to 6%. Examples of such quasi-homogeneous mixtures include metal (or metal-oxide) nanospheres, carbon nanotubes and nanodrugs in water (or aqueous solutions), oil, ethanol glycol, etc. As originally shown at ANL (see Choi, 2009), Cu-water nanofluids in vessels generated effective thermal conductivity coefficients, k-eff, up to 25% higher than the base fluid. Nevertheless, the accuracy of k-effective measurements for nanofluids and a comprehensive theory are still controversial (see Choi, 2009; Kleinstreuer & Li, 2008; Koo et al., 2008; among many others). A key dynamic component of a bio-MEMS is "nanofluid flow in microchannels". In the special case of nanomedicine application, the nanoparticles are drugs and the tasks include controlled drug delivery in miniaturized, implantable devices. Hence, in this ongoing research project, we advance the underlying theory for nanofluid properties, especially k-eff, and analyze computationally nanoparticle mixing in a heated microchannel to achieve pre-determined, near-uniform nanodrug exit concentrations and minimal microchannel lengths at lowest possible pumping power (Li & Kleinstreuer, 2008). (Received February 06, 2009)

1048-76-205 **Hans Johnston*** (johnston@math.umass.edu), Dept. of Math and Stat., 16th floor LGRT, University of Massachusetts, Amherst, MA 01003, and **C.R. Doering**, **C. Wang** and **J.-G. Liu**. *A Comparison of Turbulent Thermal Convection Between Conditions of Constant Temperature and Constant Flux.*

We report the results of high resolution direct numerical simulations of two-dimensional Rayleigh-Bénard convection for Rayleigh numbers up to $Ra = 10^{10}$ in order to study the influence of temperature boundary conditions on turbulent heat transport. Specifically, we considered the extreme cases of fixed heat flux (where the top and bottom boundaries are poor thermal conductors) and fixed temperature (perfectly conducting boundaries). Both cases display identical heat transport at high Rayleigh numbers fitting a power law $Nu \approx 0.138 \times Ra^{.285}$ with a scaling exponent indistinguishable from $2/7 = 0.2857\ldots$ above $Ra = 10^7$. The overall flow dynamics for both scenarios, in particular the time averaged temperature profiles, are also indistinguishable at the highest Rayleigh numbers. The findings are compared and contrasted with results of recent three-dimensional simulations. (Received February 08, 2009)

1048-76-250 **Sorin M. Mitran*** (mitran@unc.edu), Department of Mathematics, CB 3250, Chapel Hill, NC 27599. *Adaptive mesh refinement for turbulent flow computations.* Preliminary report.

Fully developed turbulence is characterized by the presence of a large range of flow scales. Hence it would seem futile to employ adaptive mesh refinement (AMR) on the argument that a fine mesh would be needed everywhere. However, the prevalence of coherent structures in many turbulent flows offers opportunities for an AMR approach. The goal would be to capture the large scale structure and cut off additional refinement when some simple model (e.g. eddy viscosity) can be confidently applied. In many ways this is reminiscent of large eddy simulation, but the creation of additional grid levels brings about some new aspects with regard to how prolongation and restriction operators are defined. Standard linear interpolation of coarse grids to subgrids constitutes an artificial excitation of fine scales which vitiates the overall model. Similarly, cell average coarsening leads to spurious excitation at coarse-fine boundaries. Finally, the usual AMR refinement criteria do not apply and have to be reformulated as ascertaining the validity of a subgrid stress model. An AMR approach which addresses these issues is presented along with results for channel flow. (Received February 09, 2009)

1048-76-296 **Christel Hohenegger*** (choheneg@cims.nyu.edu), Courant Institute of Mathematical Sciences, New York University, 251 Mercer Street, New York, NY 10012-1185, and **Michael J Shelley**. *On the Stability of Active Suspensions.*

Large-scale swirling motions have been observed in bacterial baths which are suspensions of many swimming bacteria. From a recent model of an "active suspension" we investigate the instabilities of such systems from a state of near isotropy and uniformity. We consider the two distinct swimming motions of Pushers (swimming using the tail) or Pullers (swimming using the head). We show that, while the long wave instability depends on the swimming mechanism, the short wave instability, which is important for well-posedness, does not. (Received February 09, 2009)

1048-76-305 **Jie Yu*** (jie_yu@ncsu.edu), 311 Mann Hall, Campus Box 7908, Raleigh, NC 27695-7908. *Bragg resonance, shore reflection and longshore sandbars.*

Multiple sand bars, nearly parallel to the shoreline and with approximately regular spacing, have been observed on some beaches. It remains unanswered how these longshore sand bars are formed, and what controls their spacing. On the other hand, it has long been recognized that a series of such bars on the seabed can have a cooperative effect on the incident water waves, called 'Bragg resonance' or 'Bragg reflection'. In this talk, we will discuss some recent work on Bragg resonance of water waves, with particular emphasis on the presence of some degree of shoreline reflection. A quantitative theory of longshore sand bar formation will also be discussed, which utilizes an asymptotic theory of Bragg resonance, wave-induced mass transport in the bottom boundary layer and sediment transport dynamics. An exact theory has been developed to examine the effects of Bragg resonance on the normal modes of a rectangular tank, and to compare with the asymptotic theory. (Received February 10, 2009)

1048-76-329 **Roberto Camassa*** (camassa@amath.unc.edu), Phillips Hall CB3250, Department of Mathematics, University of North Carolina, Chapel hill, NC 27599, **Terry Jo Leiterman**, Department of Mathematics, St. Norbert College, 100 Grant Street, DePere, WI 54115, and **Richard M McLaughlin**, Phillips Hall CB3250, Department of Mathematics, Chapel hill, NC 27599. *Spinning rods, microfluidics, and propulsion by cilia in biological systems.*

An important component in understanding and modeling how human lungs function lies in the hydrodynamics of the mucus fluid layers that coat lung airways. In healthy subjects, the beating of cilia is thought to be the primary mechanism for moving mucus. With the aim of establishing a quantitative benchmark of how cilia motion propels the surrounding fluid, we study the idealized situation of a single rod spinning in a fluid obeying the Stokes approximation, the appropriate limit for a Newtonian fluid with typical dimensions and time scales of cilia dynamics. New approximate – for cylindrical rods pinned to a flat plane boundary, and exact – for ellipsoidal rods freely spinning around their center – solutions for the fluid motion will be presented and compared with the experimental data collected with spinning magnetic nano-rods in water. In order to assess the influence of Brownian perturbations in this micro-scale experiment, data from an experimental set-up scaled by dynamical similarity to macroscopic (table-top) dimensions will also be presented and compared to the theoretical predictions. (Received February 10, 2009)

81 ► Quantum theory

1048-81-30 **Jason Holt*** (jholt@mailbox.sc.edu), PO Box 889, Lancaster, SC 29721. *Generalizations of the Simon-Spencer Theorem for 1-D Schödinger Operators.*

Let $H = -d^2/dx^2 + V$ be the 1-D Schrödinger operator on the half axis with an unbounded potential V and Dirichlet boundary condition at the origin. We present joint work with A. Gordon and S. Molchanov which gives sufficient conditions on the potential V for the absence of the absolutely continuous spectrum. These conditions assume only that $V \geq 0$ and involve only local L^1 norms of V, thereby generalizing the fundamental result of Simon and Spencer. We also present an example showing that these local L^1 conditions, together with the condition of essential self-adjointness of H, cannot guarantee the absence of absolutely continuous spectrum. (Received December 15, 2008)

1048-81-44 **Anton Zeitlin*** (anton.zeitlin@yale.edu), 10 Hillhouse Avenue, 442 Dunham Lab, Yale University, Department of Mathematics, New Haven, CT 06511. *Field Equations from Homotopy Algebras of CFT.*

We show that homotopy structures of Conformal Field Theory (CFT), discovered in the pure chiral case by Lian and Zuckerman, for a certain type of CFTs, being generalized to the non-chiral case, lead to nonlinear differential-geometric equations and their symmetries, which arise as the certain "classical" limits of the corresponding Maurer-Cartan structures. According to such an approach, we derive Yang-Mills equations, Einstein equations with matter fields, and (generalized) Kodaira-Spencer theory. We also give the conjectures about a possible algebraic approach to the study of beta-functions in String Theory sigma-models. (Received January 11, 2009)

1048-81-65 **Anton Zeitlin*** (anton.zeitlin@yale.edu), 10 Hillhouse Avenue, Yale University, 442 Dunham Lab, Department of Mathematics, New Haven, CT 06511, and **Igor Frenkel** (igor.frenkel@yale.edu). *Title: Braided Vertex Algebras, Semi-infinite Cohomology and Quantum Group.*

We construct the quantum group $SL_q(2)$ via semi-infinite cohomology of the Virasoro algebra, acting in the tensor product of two braided vertex operator algebras (VOA), such that the total central charge is equal to 26. The associative structure on cohomology, which reproduces the multiplication in quantum group, is given by the Lian-Zuckerman associative product. We explicitly construct four cohomology classes corresponding to the four generators of $SL_q(2)$ and check their relations. (Received January 20, 2009)

1048-81-216 **Iana I Anguelova*** (anguelov@math.sunysb.edu), Iana Anguelova, Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *Vertex algebras: generalized, twisted and quantum–a comparison.* Preliminary report.

The bicharacter presentation of a vertex algebra provides an excellent tool for studying its properties. I will provide a bicharacter description of some typical examples of generalized, twisted and quantum vertex operators. Based on that one can compare the different properties such as location and type of singularities, associativity, etc., and eventually formulate an axiomatic system encompassing the variety of the examples. (Received February 08, 2009)

1048-81-260 **Gaywalee Kerman Yamskulna*** (gyamsku@ilstu.edu), Department of Mathematics, Illinois State University, Normal, IL 61790-4520. *Rationality of the vertex algebra V_L^+ when L is a non-degenerate even lattice of arbitrary rank.*

In this talk, I will first discuss about one of the main conjectures in the theory of vertex algebras. Next, I will review the construction of the vertex algebras V_L^+ which are one of the most important classes of vertex algebras. They were originally introduced in the Frenkel-Lepowsky-Meurman construction of the moonshine module vertex algebra. Finally, I will discuss about the representation theory of the vertex algebra V_L^+ when L is a non-degenerate even lattice of arbitrary rank. (Received February 09, 2009)

86 ► Geophysics

1048-86-72 **Tian Ma**, Department of Mathematics, Sichuan University, Chengdu, Sichuan , Peoples Rep of China, and **Shouhong Wang*** (showang@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405. *El Nino Southern Oscillation as Sporadic Oscillations between Metastable States.*

We present in this talk a new mechanism of the El Nino Southern Oscillation (ENSO), as a self-organizing and self-excitation system, with two highly coupled processes. The first is the oscillation between the two metastable warm (El Nino phase) and cold events (La Nina phase), and the second is the spatiotemporal oscillation of the sea surface temperature (SST) field. The interplay between these two processes gives rises the climate variability associated with the ENSO, leads to both the random and deterministic features of the ENSO, and defines a new natural feedback mechanism, which drives the sporadic oscillation of the ENSO.

The new mechanism is rigorously derived using a dynamic transition theory developed recently by the authors, which has also been successfully applied to a wide range of problems in nonlinear sciences. (Received January 23, 2009)

1048-86-124 **Traian Iliescu*** (iliescu@vt.edu), Department of Mathematics, Virginia Tech, 456 McBryde Hall, Blacksburg, VA 24061. *Numerical Simulation of Oceanic Gravity Currents.*

This talk presents some of the main mathematical and computational challenges encountered in the numerical simulation of ocean flows. These challenges and some possible solutions will be presented in the context of oceanic gravity currents.

Oceanic gravity currents are cold (dense) water masses which are released into the large-scale ocean circulation from high-latitude and marginal seas. The entrainment of ambient waters into oceanic gravity currents is recognized as being a prominent oceanic process with significant impact on the ocean general circulation and climate.

The numerical simulation of oceanic gravity currents at realistic parameters represents a grand challenge. Recent developments in this area, including new mathematical models and computational methodologies for stratified flows will be presented. (Received February 03, 2009)

91 ► Game theory, economics, social and behavioral sciences

1048-91-6 **Dejun Xie*** (dxie@math.udel.edu), Department of Mathematics, University of Delaware, Newark, DE 19716. *A PDE Approximation Approach to the Valuation of American Put Option.*

Consider the American put option where the holder has the choice to sell a stock at a preset price K at any time when the contract is effect. Several integral representations of the option value are provided, then a PDE approximation method is applied to find an exact near expiry approximation of the optimal early exercise boundary from the holder's point of view. Our formula is compared with both an existing result and the true numerical solution. (Received September 24, 2008)

92 ► Biology and other natural sciences

1048-92-3 **Reinhard C. Laubenbacher***, Virginia Bioinformatics Institute. *Algebraic models in systems biology.*

The technological revolution in molecular biology has provided data that allow the study of large-scale molecular networks through mathematical models. Algebraic models, such as Boolean networks, cellular automata, and more general types of models, are being used increasingly for this purpose. They have the advantage of being intuitive and accessible to a broad range of researchers in the life sciences. At the same time, they lead to many interesting and deep mathematical problems in algebra, combinatorics, dynamical systems theory, and stochastic processes. This talk will introduce algebraic models and their application to biological networks. It will also describe mathematical results and open problems related to them. (Received April 10, 2008)

1048-92-10 **Michael S. Waterman***, University of Southern California, Los Angeles, CA. *Reading DNA sequences: Twenty-first century technology with eighteenth century mathematics.*

With the discovery of the double helix in 1953, it became clear that determining DNA sequence was an important goal. The Sanger method was invented in 1975 and by 2001 refinements of that method allowed sequencing of the human genome. Today an exciting new generation of sequencing methods is rapidly increasing the speed of DNA sequencing. This lecture will consider the mathematical and computational challenges of sequencing DNA. (Received October 15, 2008)

1048-92-21 **Wyatt A. Mangum** (wmangum@umw.edu), 1301 College Ave, Fredericksburg, VA 22401, and **Suzanne Sumner*** (ssumner@umw.edu), 1301 College Avenue, Fredericksburg, VA 22401. *Worker Bee Aggression Towards a Foreign Queen: Comparing Deterministic and Stochastic Models with Empirical Data.*

When introducing a foreign queen into a colony, worker bees often display hostility known as balling. Ideally, the number of balling bees exponentially decays to zero before the queen's release; if not, she may be killed. Prior experimental work indicates that attendant bees increase balling duration and are associated with other erratic balling patterns. An initial deterministic model displays chaotic dynamics that mimic some of the aggression behaviors, but not other behaviors called reversions. Random disturbances could be the cause of reversions and the prior deterministic model is modified to include a stochastic term. Both mathematical models give the number of ballers on the introduction cage as a function of time. The results of the deterministic model and several runs of the stochastic model are compared to experimental data. The inclusion of the stochastic term simulates reversions and noisy fluctuations, as observed in the experimental data. This stochastic model is a first step at understanding the importance of the random initiation and cessation of balling among individual bees. Understanding how to minimize these uncertainties can make queen introduction more reliable with fewer queen losses. (Received December 04, 2008)

1048-92-22 **Wyatt A. Mangum*** (wmangum@umw.edu), 1301 College Ave, Fredericksburg, VA 22401. *A Nonlinear Difference Equation Model of the Population Biology and Resistance Evolution of the Mite Varroa destructor, a Parasite of Honey Bees.*

Miticide-resistant varroa mites constitute a grave threat to honey bee populations in North America, Europe, and other temperate climates. Extensive observational studies on the population biology and population genetics of resistant varroa mites revealed unexpected dynamics and motivated the following model. The complete model is composed of a system of nonlinear difference equations that originate from population biology and population genetics. The population biology model, a logistic model greatly modified for the mite's life cycle, is coupled

with a population genetics model, a haploid-diploid selection model with density-dependent inbreeding based on additional life history parameters of the mite. Together these equations calculate the number of mites in a colony and the frequency of the miticide-resistant ones, a frequency that depends on the selection regime (the chemical treatments). When the population biology model exhibits cyclic behavior, a cycle of the same period temporarily emerges in the frequency of the susceptible varroa mites in the genetics model. Under several regimes the model exhibits chaotic dynamics and apparently period-doubling reversals. Several modeling scenarios will be discussed. (Received December 04, 2008)

1048-92-29 **David Chan*** (dmchan@vcu.edu), Department of Mathematics, Virginia Commonwealth University, 1001 West Main Street, Richmond, VA 23229, and **H. Sedaghat**, **M.A. Wood**, **J.W. Cain**, **C.K. Cheng** and **C.M. Baumgarten**. *Complex temporal patterns of spontaneous initiation and termination of reentry in a loop of cardiac tissue.*

A two-component model is developed consisting of a discrete loop of cardiac cells that circulates action potentials as well as a pacing mechanism. Physiological properties of cells such as restitutions of refractoriness and of conduction velocity are given via experimentally measured functions. The dynamics of circulating pulses and the pacer's action are regulated by two threshold relations. Patterns of spontaneous initiations and terminations of reentry (SITR) generated by this system are studied through numerical simulations and analytical observations. These patterns can be regular or irregular; causes of irregularities are identified as the threshold bistability (T-bistability) of reentrant circulation and in some cases, also phase-resetting interactions with the pacer. (Received December 15, 2008)

1048-92-45 **G Craciun**, **J W Helton** and **R J Williams***, Dept of Mathematics, UCSD, 9500 Gilman Drive, La Jolla, CA 92093-0112. *Homotopy Methods for Counting Reaction Network Equilibria.*

Dynamical system models of complex biochemical reaction networks are usually high-dimensional, nonlinear, and contain many unknown parameters. In some cases the reaction network structure dictates that positive equilibria must be unique for all values of the parameters in the model. In other cases multiple equilibria exist if and only if special relationships between these parameters are satisfied. We describe methods based on homotopy invariance of degree which allow us to determine the number of equilibria for complex biochemical reaction networks and how this number depends on parameters in the model. (Received January 11, 2009)

1048-92-58 **Eduardo D Sontag*** (sontag@math.rutgers.edu), Dept. of Mathematics, New Brunswick, NJ 08903. *Remarks on Interconnections, Modularity, and Dynamics in Systems Biology.*

For systems made up of interconnected components, it would be desirable to be able to deduce global behaviors through a bottom-up analysis, based on partial knowledge of the input/output behaviors of the individual components. This is particularly important in the field of systems biology, where neither internal descriptions nor complete input/output behaviors are usually available. From a systems and control theory perspective, many new theoretical problems and exciting directions for research arise.

Two sources of difficulty in any modular approach are (a) impedance or "dynamic retroactivity" effects due to resource sharing, (b) feedback loops that expose modes of behavior that were "hidden" when individual subsystems had been studied in isolation, and (c) the lack of sufficient input variation. This talk, which is based on research done in collaboration with David Angeli, Murat Arcak, Domitilla Del Vecchio, and others, discusses mathematical concepts and theoretical results that address some of these issues, including the use of monotone systems theory or passive systems theory to deal with the "hidden behavior" problem and the lack of richness in input classes, and the introduction of a modeling framework to represent dynamic retroactivity effects. (Received January 19, 2009)

1048-92-64 **Toby L Shearman*** (tshearman@vt.edu), 325 New Kent Road, Blacksburg, VA 24060, and **Pablo Diaz**, **Michael Gillespie**, **Justin Krueger**, **Jose Perez**, **Alex Radebaugh**, **Garret Vo** and **Christine Wheatley**. *A mathematical model of the immune system's role in obesity-related chronic inflammation.*

Obesity is quickly becoming a pandemic. The low-grade chronic inflammation associated with obesity leads to health risks such as cancer, heart disease, and type 2 diabetes mellitus. To better understand the progression of obesity-related chronic inflammation, mice were fed either a high fat or low fat diet over 140 days. At days 0, 35, 70, and 140, the percentages of macrophage subsets, CD4+ T cells, and regulatory-T cells infiltrating the intra-abdominal white adipose tissue (WAT) were examined. Monocyte chemoattractant protein-1 (MCP-1) mRNA expression in WAT was also quantified. Additionally, glucose-normalizing ability was examined by administering peritoneal glucose tolerance tests. A system of ordinary differential equations models this system. The model

consists of 8 differential equations, has 25 parameters, and has 1 forcing function. Tools used to characterize the model include parameter estimation, sensitivity analysis, and stability analysis. Based on the data provided, the system describes the growth of adipocyte size and chronic inflammation over 105 days beginning at day 35, which is approximately when the adipose cells become hypertrophic. The model shows that without intervention, chronic inflammation escalates and the related health problems persist. (Received January 20, 2009)

1048-92-83 **Cammey Cole Manning*** (ManningC@meredith.edu), Mathematics and Computer Science Department, 3800 Hillsborough Street, Raleigh, NC 27607. *Using Toxicokinetic Data to Develop Model Predictions for 4-Methylimidazole Chronic Exposure.* Preliminary report.

4-methylimidazole (4MI) is a light, yellow crystalline solid that has been under investigation by the National Toxicology Program. Exposure results from the use of 4MI as a starting material in the manufacture of various products including pharmaceuticals, dyes and pigments, and rubber; it is also a by-product in various food products including caramel and soy sauce. A physiologically based pharmacokinetic model representing the uptake, distribution, and metabolism of 4MI in rats and mice was developed to describe the processes involved in 4MI toxicokinetics. Model development was based on single-dose toxicokinetic data for male and female mice and rats. Most of the model parameters were obtained from estimates in the literature. However, the model had six parameters that did not have literature estimates. These parameters were estimated by least squares techniques. The model was fit to short timespan (less than 30 hours) intravenous injection and gavage toxicokinetic data. The fit model was used to make predictions of plasma concentrations of 4MI in feed dose study using a time scale of months. (Received January 26, 2009)

1048-92-94 **Meagan C Herald*** (heraldmc@vmi.edu), Mathematics and Computer Science Department, Virginia Military Institute, Lexington, VA 24450-0304. *A General Model of Inflammation.*

Dysfunctions in the immune system, due to genetics, disease or environmental factors, can lead to bacterial colonization and chronic inflammation. In chronic obstructive pulmonary disease (COPD), respiratory infections can initiate chronic inflammation of the airway. We propose a system of nonlinear ordinary differential equations to describe interactions between macrophages, both inflammatory and anti-inflammatory cytokines, and bacteria. Small changes in parameters governing inflammatory cytokine production and macrophage sensitivity to these cytokines result in dramatically different model behaviors. When the immune system is functioning properly, a non-aggressive pathogen will not provide a sufficient trigger to initiate chronic inflammation, however, in disease positive feedback of the inflammatory cytokine can induce chronic inflammation even after a bacterial infection has been resolved. In addition, if the macrophage population is more sensitive to inflammatory cytokines small perturbations initiated by bacteria will also lead to chronic inflammation. We have found nonaggressive bacteria are able to initiate chronic inflammation and propose why anti-inflammatory cytokine therapy may not be effective in resolving this inflammation. (Received January 28, 2009)

1048-92-97 **Grzegorz A Rempala***, Medical College of Georgia, 1469 Laney Walker Blvd, (Pavilion I) AE-1005, Augusta, GA 30912. *Algebraic Statistical Model for Inferring Biochemical Reactions Network.*

Algebraic statistical model is a set of polynomial equations mapping the set of parameters into a probability simplex. The idea is useful for finding MLEs via direct inspection of all zeros of the score equations and has been applied for instance to certain comparative genomics problems as well as to developing extensions of the Fisher exact test in contingency tables. The talk shall present yet another application of algebraic statistical models which is related to statistical inference for biochemical reactions and possibly also useful in discovering genetic networks. (Received January 28, 2009)

1048-92-111 **Leona A Harris*** (harrisl@tcnj.edu), Department of Mathematics and Statistics, The College of New Jersey, 2000 Pennington Road, Ewing, NJ 08628, and **Hugh A Barton** (habarton@alum.mit.edu), Pharmacokinetics, Dynamics, and Metabolism, Pfizer Global Research and Development, Groton, CT 06340. *A Physiologically-Based Pharmacokinetic Model of a Perfluorinated Chemical Using Time-Dependent and Concentration-Dependent Changes in the Pharmacokinetic Parameters.*

Physiologically-based pharmacokinetic (PBPK) models describe the disposition of chemicals in the body following some external exposure to the body. These models are used to predict tissue and blood levels of a chemical over time and provide a framework for dose-response analyses needed to help assess the risk a chemical has on human health and the environment. The PBPK model presented here describes the fate of a perfluorinated chemical, perfluorooctane sulfonate (PFOS), in adult rats following intravenous, oral, and chronic dietary exposures. While

this chemical has a variety of consumer and industrial applications, it has been shown to cause toxicity in adult and developing laboratory animals. This model was developed to characterize existing time-course data for PFOS and to better understand its pharmacokinetics in the body. Inconsistencies among single-dose and repeated-dose exposure scenarios were observed during the modeling process. This led to the use of time-dependent and concentration-dependent changes in the pharmacokinetic parameters in order to obtain reasonable predictions of the time-course data. We investigate the effects of changes in the model parameters on various model outputs. (Received February 01, 2009)

1048-92-112 **Brynja Raquel Kohler*** (Brynja.Kohler@usu.edu), Department of Mathematics and Statistics, 3900 Old Main Hill, Logan, UT 84321. *Incorporating Continuous, Antigen-Dependent T-Cell Differentiation in Viral Infection Dynamics.*

We report on the derivation and analysis of a model for tracking the distribution of T cell populations as a function of antigen experience gained through interactions with dendritic cells in lymph nodes during the activation phase of an immune response. This model is motivated by the heterogeneity of specific T cell lineages which have been observed from early stages in an immune response with different characteristics including the capacity to become short lived effector cells or memory cells. Linear reaction-hyperbolic systems of partial differential equations in one space dimension arise in the model formulation. We also incorporate this model in a viral dynamics simulation and discuss the fit with experimental systems such as Murine Lymphocytic Choriomeningitis Virus. (Received February 01, 2009)

1048-92-122 **Casian A Pantea*** (pantea@math.wisc.edu), 480 Lincoln Dr., Madison, WI 53706, and **James B Rawlings** and **Gheorghe Craciun**. *Solvability of QSSA in chemical kinetics.*

We show that the 100-year-old approach of classic QSSA model reduction cannot be achieved in many relevant kinetics problems. By using Galois theory, we prove that the algebraic equations cannot be solved even for simple examples involving five reactions and five species (three intermediates), with nothing more complex than bimolecular mass action kinetics. In addition, we present a realistic chemical example that cannot be reduced with the classical approach. We also show that two simple alternatives to solving the QSSA equations, including Horiuti-Temkin theory, do not achieve the requirements of model reduction. We propose a reparametrization of the QSSA system that reduces the number of parameters and, for many cases, makes the system identifiable. (Received February 03, 2009)

1048-92-131 **Jeremy Gunawardena*** (jeremy@hms.harvard.edu), Department of Systems Biology, Harvard Medical School, 200 Longwood Avenue, Boston, MA 02139. *Algebraic geometric approaches to biological complexity.*

Biomolecular systems often give rise to polynomial dynamical systems and have to be studied by simulation. This requires specification of parameter values, which are often unknown. Furthermore, mechanisms like post-translational modification (PTM) lead to combinatorial explosion, since a protein with n sites may occupy 2^n states. Simulation makes it hard to discern biological principles amidst these details. The steady states of a polynomial dynamical system form an algebraic variety but this has not previously been exploited. Here we show that for certain kinds of PTM systems, algebraic geometric methods provide two important advantages. First, they reduce the complexity of finding steady states from integrating an exponentially large number of differential equations to solving a small number of algebraic equations. Second, they allow parameters to be treated as symbols, rather than as numbers. These results enable the first estimate of the information storage capacity of PTM systems. Underlying these results is the surprising finding that the steady state variety is rational and that its geometry can be biologically significant. If these methods can be extended to a broader class of systems, they would provide powerful tools for analysing biological complexity. (Received February 03, 2009)

1048-92-135 **Alicia Dickenstein*** (alidick@dm.uba.ar), Dto. de Matemática, FCEN, Universidad de B. A, Ciudad Universitaria - Pab. I, C1428EGA Buenos Aires, Argentina, and **Mercedes Pérez Millán**. *How far is complex balancing from detailed balancing?* Preliminary report.

We show that a reversible Horn–Jackson generalized mass action kinetics system satisfying Wegscheider's condition is detailed balanced if and only if it is complex balanced. In other words, under *formal* balancing conditions for the cycles (of the underlying undirected graph) of the reaction graph, both notions coincide. We formulate this property in terms of the algebraic equations defining the corresponding varieties in rate constant space. (Received February 04, 2009)

1048-92-185 **Sarah Anne Hews*** (sarah.hews@asu.edu), Mathematical and Statistical Sciences, Arizona State University, Tempe, AZ 85281. *Capturing the Dynamics of Hepatitis B.*

Chronic hepatitis B (HBV) infection is a major cause of human suffering, and a number of mathematical models have examined within-host dynamics of the disease. An effective HBV mathematical model should exhibit four states: a disease free state, an acute infection state, a chronic infection state, and an acute liver failure state. Most previous models are based on assumptions that contradict experimental data, provide problematic basic infection numbers, and only yield a disease free and a chronic infection steady state. Specifically, these models assume that there is a constant influx of healthy hepatocytes and that infection takes place via mass action . This talk will present a model that includes a logistic growth term for hepatocytes and a standard incidence function for infection transmission. These simple changes produce a model that has a disease free state, a chronic infection state with hepatocyte oscillations, and an acute liver failure state. Parameter regimes for these states and techniques used to evaluate the non-differentiable liver failure state will be explored. Finally, preliminary models that also include an acute infection state will be presented. (Received February 06, 2009)

1048-92-204 **Katia Koelle*** (katia.koelle@duke.edu), Duke Biology, Box 90338, Durham, NC 27708, and **Meredith Kamradt**. *A simple mathematical model to understand influenza's complex evolutionary dynamics.*

Seasonal influenza epidemics in humans are caused almost exclusively by three viral variants: influenza A (H3N2), influenza A (H1N1), and influenza B. Despite sharing a common route of aerosol transmission, these variants differ significantly from one another in both ecological and evolutionary dynamics. In this session, we will present a mathematical model to explain these dynamical differences. Applying the model first to H3N2, we show that a combination of punctuated and gradual antigenic evolution is required to capture H3N2's ecological dynamics and the evolutionary dynamics of its hemagglutinin protein. After taking into consideration the differences between influenza A and B's mutation rates, we then show that differences in the basic reproductive number alone are sufficient to account for these variants' distinct ecological and phylogenetic patterns. (Received February 08, 2009)

1048-92-222 **Abdessamad Tridane*** (tridane@asu.edu), Arizona State University, Applied Mathematics Program, Mesa, AZ 85212. *Kinetic of influenza A virus in the human respiratory tract and the interferon response.* Preliminary report.

The aim of this work is to investigate, via a series of coupled PDE and ODE models, the dynamics of the viral infection of influenza A virus (IAV) and the degree of protection to the epithelial cells by the innate interferon response. Since the goal is to quantify certain features of IAV infection such as the length of the eclipse phase, specific virus replication rate and specific cell death rate due to infection, our models were fit to an existing data from an experimental H1N1 influenza infection. These simulations indicate that neglecting the delay between the cell infection and the release of new interferon gives similar results with respect to overall interferon dynamics compared with delayed differential equations model. (Received February 09, 2009)

1048-92-232 **Nicholas S Luke*** (luke.nicholas@epa.gov), 109 T.W. Alexander Drive, Mail Drop B143-01, RTP, NC 27711, and **Michael J DeVito**, **Imran Shah** and **Hisham A El-Masri**. *Development of a Quantitative Model for Nuclear Receptor-Mediated Induction of Xenobiotic Metabolizing Enzymes.*

The pregnane X receptor plays an integral role in the regulation of hepatic metabolism. It has been shown to regulate CYP3A4, which is the most abundant cytochrome P450 in the human liver. With its large and flexible ligand-binding domain, PXR can be activated by an enormous range of relatively small, hydrophobic, exogenous compounds. Upon activation, PXR partners with the retinoid X receptor (RXR) to form a heterodimer. The newly formed heterodimer binds to an appropriate DNA response element, causing increased transcription. This leads to an induction in the level of CYP3A4. These mechanistic steps are included into a biologically-based mathematical model. The quantitative model predicts fold level inductions of CYP3A4 mRNA and protein in response to PXR activation. Model parameter values have been taken from literature when appropriate. Unknown parameter values are estimated by optimizing the model results to published in vivo and in vitro data sets. A sensitivity analysis is performed to evaluate the model structure and identify future data needs which would be critical to revising the model. (Received February 09, 2009)

1048-92-236 **Mette S Olufsen*** (msolufse@ncsu.edu), Campus Box 8205, Raleigh, NC 27695. *Modeling blood flow and pressure-area dynamics in arteries.*

The mechanics of the arterial wall is complex, due to its material structure and load conditions, which influences hemodynamic properties as well as the growth and remodeling of the arterial network. In this study we discuss the

use of arterial wall properties in fluid dynamics modeling and show how elastic and viscoelastic wall properties can be assessed using mathematical modeling. A 1D fluid dynamics model predicting flow, vessel area and pressure will be used as an example to show the importance of arterial wall modeling. To analyze wall properties we use a Kelvin and a generalized viscoelastic model, which relates blood pressure to vessel area. The fluid dynamics model was validated against in-vivo measurements of blood flow, while the vessel wall model was validated using in-vitro measurements of vessel diameter and arterial blood pressure. For the arterial wall models, material properties, represented by the model parameters, were predicted by solving an inverse problem minimizing the residual between the data and the model. Results showed that the smaller arteries, the inclusion of viscoelastic behavior is important to capture pressure-area dynamics, while for the larger arteries nonlinear elastic responses should be modeled to accurately predict pressure area dynamics. (Received February 09, 2009)

1048-92-243 **Gilles Gnacadja*** (gnacadja@amgen.com), Research and Development Information Systems, Amgen, Inc., One Amgen Center Drive, MS 34-2-A, Thousand Oaks, CA 91320-1799. *Complete Networks of Reversible Binding Reactions.*

A binding reaction is a chemical reaction that transforms two or more reactants into a single product. Networks of reversible binding reactions describe many pathogenic and therapeutic mechanisms that are studied in pharmacology. Determining the equilibrium state is a recurrent issue in that context. Toward an effort to do so systematically, we propose the class of complete networks of reversible binding reactions and characterize their equilibrium states. Completeness consists of structural and kinetic requirements that are applicable in the motivating context. The structural requirement is that there is a notion of composition that is intrinsic to the network and defines species, and that reactions preserve composition. The kinetic requirement is that the law of mass action applies, and that certain coherence equations constrain rate constants along reaction pathways with same outcome. In a complete network, the nonnegative stoichiometric compatibility classes are convex polytopes defined by equations that express the conservation of composition. Within each class, there exists a unique equilibrium state; it is detailed-balanced and characterized by a positive polynomial system with rather interesting features, and is globally attracting. A simple formula gives the deficiency. (Received February 09, 2009)

1048-92-255 **Mansoor A Haider*** (m_haider@ncsu.edu), Dept. of Mathematics. Box 8205, N.C. State University, Raleigh, NC 27695-8205, and **Eunjung Kim** and **Farshid Guilak**. *Continuum mixture models of cell-matrix mechanics in articular cartilage.*

Articular cartilage is the primary load-bearing soft tissue in diarthrodial joints such as the knee, shoulder and hip. Cartilage extracellular matrix (ECM) can be idealized as a biphasic continuum mixture of interstitial water and a solid ECM comprised of collagen fibers and proteoglycan macromolecules. The ECM is maintained by a sparse population of cells (chondrocytes) that are encapsulated by a thin, stiff layer called the pericellular matrix. Mechanical variables in the vicinity of the chondrocytes strongly influence cell metabolic activity and, in turn, the progression of matrix degradation due to osteoarthritis. We present multiscale computational models for characterization of cellular and pericellular biomechanics in cartilage. Models include finite element simulations of dynamic cell-matrix interactions under cyclic loading, and an inverse boundary element method for in situ characterization of cellular and pericellular mechanical properties in tissue explants. (Received February 09, 2009)

1048-92-258 **Laura A Miller*** (lam9@email.unc.edu), CB 3250 Phillips Hall, Department of Mathematics, Chapel Hill, NC 27599. *An electromechanical model of myocardial contraction in the embryonic heart tube.*

Recent work on the fluid dynamics of the embryonic heart has been motivated by studies that suggest that fluid forces are necessary for heart morphogenesis. These intracardiac flows depend upon the electrophysiology and muscle mechanics of the developing heart. Contraction kinematics and electrocardiograms recorded when the embryonic heart tube first forms suggest that the blood is pumped by peristaltic contractions of the heart; however, recent work based on particle image velocimetry suggests that the heart uses a valveless suction pump mechanism, whereby active pumping occurs only in a localized region of the heart and waves of contraction are passive.

Although work that has attempted to integrate the electrophysiology of the heart with pumping kinematics and fluid dynamics is limited, recent improvements in numerical methods and scientific computing are starting to make such studies possible. In this project, an electromechanical model of the embryonic heart based on the Fitz-Hugh Nagumo equations will be presented. The local electropotential along the heart tube will then be used to trigger muscle contractions and drive the flow in immersed boundary simulations of the heart tube. (Received February 09, 2009)

1048-92-277 **Patrick De Leenheer*** (deleenhe@math.ufl.edu). *Multi-strain within-host virus dynamics.*

We consider a standard within-host multi-strain virus model and allow mutations between different strains. In the absence of mutations, the fittest strain drives the remaining strains to extinction. Treating the mutation rate as a perturbation parameter, we show that the corresponding steady state persists, perhaps with small concentrations of some or all other strains, depending on the connectivity of the graph describing all possible mutations. Using a particular global perturbation result, we show that the perturbed steady state remains globally asymptotically stable. (Received February 09, 2009)

1048-92-281 **Karen A. Yokley*** (kyokley@elon.edu), Department of Mathematics, Elon University, 2320 Campus Box, Elon, NC 27244, and **Marina V. Evans** and **Jane E. Simmons**. *Establishing metabolic changes in the rat during exposures of carbon tetrachoride and trichloroethylene through the use of physiologically based (PBPK) modeling.* Preliminary report.

Toxicological interactions of chemicals can affect metabolism, and changes in metabolism can be evaluated through mathematical modeling. Trichloroethylene (TCE) and carbon tetrachloride (CCl_4) are common contaminants in water and at superfund sites. A gas uptake system was used to collect metabolic data using F344 rats at various initial concentrations of TCE and CCl_4. This particular binary mixture pair is an example of metabolic synergy as opposed to the more common inhibition expected during exposure to multiple chemicals. A previously developed physiologically based pharmacokinetic (PBPK) model of CCl_4 was used to simulate chamber concentrations for the aforementioned mixtures. In order to fit chamber concentration data for CCl_4 when administered with TCE, the parameter of the maximum rate of metabolism (V_{max}) was increased. An increase of 2.8 times the V_{max} value from the original model of CCl_4 produced reasonable predictions for mixture data with higher concentrations of TCE, and an increase of 1.4 times the original V_{max} worked well at predicting CCl_4 chamber concentration for mixtures with 100 ppm TCE. The increase in V_{max} suggests that metabolism of CCl_4 is amplified by the presence of TCE and this amplification is dose-dependent. (Received February 09, 2009)

1048-92-293 **R. Drew Pasteur*** (rpasteur@wooster.edu) and **James F. Selgrade**. *Dynamics of a Human Menstrual Cycle Model with Multiple Inhibins.* Preliminary report.

In clinical studies of adult women, a variety of qualitatively different reproductive hormone profiles have been observed. We consider the dynamics of a two-inhibin model for hormonal control of the human menstrual cycle, in this regard. Based on single-parameter bifurcations and exogenous hormone treatment, predicted possible cycles could have either high or low amplitudes, or even alternate-month profiles. We relate these differences to ovulation and fertility. (Received February 09, 2009)

1048-92-306 **Abdul-Aziz Yakubu*** (ayakubu@howard.edu), Department of Mathematics, Washington, DC 20059, **Bassidy Dembele** (dem_77@hotmail.com), Department of Mathematics and Computer Scienc, Grambling, LA 71245, and **Avner Friedman** (afriedman@mbi.ohio-state.edu), Mathematical Bioscience Institute (MBI), Columbus, OH 43210. *Mathematical Model For Optimal Use of Sulfadoxine-Pyrimethamine As A Temporary Malaria Vaccine.*

In this talk, we will introduce a deterministic malaria model for determining the drug administration protocol that leads to the smallest first malaria episodes during the wet season in Mali. To explore the effects of administering the malaria drug on different days in the wet season while minimizing the potential harmful effects of drug overdose, we define 40 drug administration protocols. Our results fit the clinical studies of Coulibaly et al. at a site in Mali. In addition, we provide protocols that lead to smaller number of first malaria episodes during the wet season than the protocol of Coulibaly et al. (Received February 10, 2009)

1048-92-319 **Maya Mincheva*** (mincheva@math.niu.edu), Department of Mathematical Sciences, Northern Illinois University, DeKalb, IL 60115. *Oscillations in Biochemical Reaction Networks.*

Understanding the dynamics of interactions in complex biochemical networks is an important problem in modern cellular biology. Mathematical models of biochemical reaction networks give rise to large nonlinear dynamical systems with many unknown kinetic parameters, making the models challenging for computational analysis. However, some important properties, such as the ability of a biochemical network to oscillate can be determined by the network structure. The structure of a bipartite graph associated with a biochemical reaction network can be used to predict oscillations without knowing the kinetic parameters. We will discuss the connection between

the bipartite graph of a reaction network and the graph associated with the corresponding dynamical system model. (Received February 10, 2009)

1048-92-335 **David M Bortz*** (dmbortz@colorado.edu), Applied Mathematics, University of Colorado, Box 526, Boulder, CO 80309-0526, **Erin Byrne**, Applied Mathematics, University of Colorado, Box 526, Boulder, CO 80309-0526, and **John Younger**, Emergency Medicine, University of Michigan, Ann Arbor, MI 48019. *Fragmentation and Aggregation of Bacterial Emboli.*

Klebsiella pneumoniae is one of the most common causes of intravascular catheter infections, potentially leading to life-threatening bacteremia. These bloodstream infections dramatically increase the mortality of illnesses and often serve as an engine for sepsis. Our current model for the dynamics of the size-structured population of aggregates in a hydrodynamic system is based on the Smoluchowski coagulation equations.

In this talk, I will discuss the progress of several investigation into properties of our model equations. In particular, I will focus on a) accurate characterization of the fractal properties for the aggregates, b) a differential geometry approach to fragmentation modeling, and (time permitting) c) self-similar solutions to the equations. (Received February 10, 2009)

1048-92-345 **Alun L. Lloyd*** (alun_lloyd@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695. *Stochasticity and Heterogeneity in Models for Vector-Borne Diseases.*

Demographic stochasticity and heterogeneity in transmission can have important impacts on the dynamics of infectious diseases. Simulation of stochastic models can be highly time consuming, so analytic insights are of great value. We discuss the use of branching process theory and moment equations to assess the impact of demographic stochasticity on the transmission of vector-borne diseases in both well-mixed and heterogeneous settings. (Received February 10, 2009)

1048-92-350 **Anne Catlla*** (catllaaj@wofford.edu), 429 North Church Street, Spartanburg, SC 29303, and **Stanca Ciupe**, **Jonathan Forde** and **David Schaeffer**. *Stability analysis of a model of host-pathogen interaction during hepatitis B infection.* Preliminary report.

Hepatitis B is a virus that infects liver cells (hepatocytes) and leads to either acute (short-term) or chronic (long-term) liver disease. In previous work a model describing the interactions between infected hepatocytes, uninfected hepatocytes, recovering hepatocytes that are immune to reinfection, immune system cells, and virus was developed and analyzed numerically. We simplify this model via a quasi-steady state approximation so that it may be studied analytically. The simplified system has steady states corresponding to the healthy state where all hepatocytes are uninfected, to chronic infection where some hepatocytes are infected, and to liver death (the trivial state). We derive conditions that guarantee local and global stability of the healthy state. We show numeric results supporting our stability findings and discuss the biological implications of these findings. (Received February 10, 2009)

1048-92-355 **Jonathan Forde*** (forde@hws.edu), 4178 Scandling Center, Hobart and William Smith Colleges, Geneva, NY 14456, and **Bailey Meeker**. *A Model of Varicella-Zoster Virus Reactivation.*

Varicella-Zoster Virus (VZV) is a alpha-herpes virus which causes varicella (chickenpox) as a result of primary infection, remains latent in the host for life after the initial inflammation, and can cause zoster (shingles) as a result of reactivation in later life. This reactivation is generally thought to occur as a result of diminished immune control in aging patients. It is known that exposure to individuals infected with VZV (such as children with chickenpox) boosts the immune response, decreasing the likelihood of reactivation. The development of a VZV vaccine has raised questions about the advisability of universal vaccination, as it increases the number of cases of zoster likely to occur. In this paper, we present a differential equations model of the virus-host interaction over the course of infection, up to reactivation. At the population level, we also present a model with the random effect of immune boosting and mortality. (Received February 10, 2009)

1048-92-367 **Damir B. Khismatullin*** (damir@tulane.edu), Department of Biomedical Engineering, Tulane University, 500 Lindy Boggs Center, New Orleans, LA 70118. *Application of the viscoelastic Volume-of-Fluid algorithm to biological systems.*

Biological systems are characterized by a significant level of heterogeneity and, on the macro-scale, behave as viscoelastic materials. To study the mechanical behavior of biological systems, we have developed a novel parallel algorithm for fully three-dimensional numerical simulation of multiphase viscoelastic flow. The algorithm consists of the second order Volume-of-Fluid method for tracking fluid-fluid interfaces, the projection method

for solving the Navier-Stokes equations, and the semi-implicit factorized scheme for the constitutive equation for the stress tensor (Giesekus, Oldroyd-B, or Upper-Convected Maxwell fluid). We will talk about the application of the algorithm to the problems in microvascular hemodynamics, such as leukocyte-endothelial cell adhesion and blood flow in channels with complex geometry. We will show that the code we developed can accurately predict leukocyte rolling on vascular endothelium and blood flow in sprouting vessels. Proposals for extending the algorithm to other biological problems will also be discussed. (Received February 10, 2009)

1048-92-381 **Xue-Zhi Li**, **Ji-Xuan Liu** and **Maia Martcheva*** (maia@math.ufl.edu), Department of Mathematics, 358 Little Hall, P.O. Box 118105, University of Florida, Gainesville, FL 32611. *An age-structured two-strain epidemic model with super-infection.* Preliminary report.

Well known mechanisms of pathogen coexistence include super-infection, coinfection, cross-immunity, and others. Recently, host age structure has been identified as a possible coexistence mechanism. Host heterogeneity in age allows different pathogen strains to infect different age classes leading to coexistence. Understanding the role of host age-structure in maintaining pathogen genetic diversity is of paramount importance. This necessitates the development and analysis of two-strain age-structured models. We extend the one-strain age-structured SIS model, considered by Busenberg, Iannelli and Thieme, to a two-strain age-structured model with super-infection. We obtain explicit expressions of the basic reproduction numbers of both strains. We show that the infection-free steady state is globally asymptotically stable if the reproduction number is below one. With appropriate conditions on the invasion reproduction numbers, we establish the existence, and the local stability of the boundary, strain one and strain two exclusive equilibria. We show that if both invasion reproduction numbers are above one, there exists a coexistence equilibrium. (Received February 11, 2009)

1048-92-383 **Martin Feinberg*** (feinberg@chbmeng.ohio-state.edu), Ohio State University, Columbus, OH. *Chemical Reaction Network Theory: The Strange Relationship of Chemistry, Biochemistry and Mathematics*

Mathematicians, chemists, and biochemists have prejudices about how polynomial differential equations generated by chemical reaction networks should behave. In some cases these prejudices are useful guides to behavior, but in other cases they are very misleading. In this talk, I will try to discuss mathematical foundations for some of these prejudices and also indicate where they go wrong. Much of what I say will be based on joint work with Gheorghe Craciun. (Received February 16, 2009)

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1048-93-265 **Dong Eui Chang*** (dechang@uwaterloo.ca), 200 University Ave. W., Waterloo, ON N2L 3G1, Canada. *Energy Shaping for Stabilization of Mechanical Systems.*

I will present the energy shaping method for stabilization of mechanical systems. The basic idea in this method is that a given controlled mechanical system is transformed via feedback to another controlled mechanical system with positive definite energy and a dissipative external force such that a dissipative feedback force will stabilize the closed loop system by decreasing the energy as Lyapunov function. This method will be presented with various easily verifiable criteria and examples. (Received February 09, 2009)

1048-93-312 **Carsten Conradi*** (conradi@mpi-magdeburg.mpg.de), Max-Planck-Institute Magdeburg, Sandtorstr. 1, 39106 Magdeburg, Germany. *Multistationarity in subnetworks of biochemical reaction networks.* Preliminary report.

The standard model of biochemical reaction networks with mass action kinetics is a set of first order ODEs. The right hand side of this vector ODE is given by the product of the stoichiometric matrix N and a vector of reaction rates. If the matrix N does not have full row rank, the state is confined by a system of affine equations. Multistationarity is then equivalent to a positive answer to the following question: is there a vector of rate constants such that two different positive steady state solutions exist that satisfy the same algebraic constraints? To answer this question we previously proposed a decomposition of the overall network in subnetworks based on generators of the pointed polyhedral cone defined by the intersection of the kernel of N with the nonnegative orthant. Under some mild constraints each subnetwork can be analysed by the deficiency one algorithm (thus multistationarity can be established by linear inequality systems).

Here we show that multistationarity for the subnetworks can always be established by analysis of linear inequality systems (regardless, whether or not the deficiency one algorithm can be applied). An algorithm to obtain parameterizations of all pairs of steady states is also presented. (Received February 10, 2009)

1048-93-331 **Nina Mahmoudian*** (ninam@vt.edu), Virginia Tech, Aerospace & Ocean Engineering, 215 Randolph Hall (MC 0203), Blacksburg, VA 24061, and **Craig Woolsey** (cwoolsey@vt.edu), Virginia Tech, Aerospace & Ocean Engineering, 215 Randolph Hall (MC 0203), Blacksburg, VA 24061. *Feedforward/Feedback Tracking of a First Order Approximate Equilibrium Manifold.*

Inspired by the problem of motion control for an underwater glider, we develop and analyze stability of a feedback/feedforward controller for a simple dynamical system that exhibits a saddle-node bifurcation. In analogy with the underwater glider problem, the stable manifold of the dynamical system is approximated in the neighborhood of a particular equilibrium, to first order in the bifurcation parameter, using regular perturbation theory. The control objective is to track a slowly varying desired state which corresponds, at any instant, to an equilibrium state of the system, i.e., a point on the (true) stable manifold. To meet this objective, a feedforward term commands a value of the perturbation parameter that corresponds, to first order in the perturbation parameter, to the desired equilibrium state. A proportional-integral feedback term then compensates for the error due to the approximation. Stability of the closed-loop system is examined using slowly varying systems theory. (Received February 10, 2009)

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