Second Joint Meeting of AMS, DMV, and ÖMG

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Plenary Talks

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Deligne's Integrality Theorem in Unequal Characteristic and Rational Points over Finite Fields

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We will review recent results on congruences for the number of rational points over a finite field, based on Deligne's philosophical link with the Hodge type over the complex numbers.

The Ricci Flow

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We shall discuss the Ricci Flow on three-dimensional manifolds and applications.

Solving Algebraic Equations, up to Homotopy

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The theory of topological modular forms is a hybrid of algebraic topology and the theory of elliptic curves. It offers a rich and surprising relationship between modular forms and the homotopy groups of spheres. This talk will consist of an introduction to this area and to the recent work of Jacob Lurie, who describes the whole structure in the context of "algebraic geometry up to homotopy."

Exact and Asymptotic Enumeration of Vicious Walkers with a Wall Interaction

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The vicious walker model was introduced by Michael Fisher in Statistical Mechanics in the early 1984s. Many variations of this model have been studied since then. In the particular variation that I shall be interested in there, is an interaction of the walkers with a fixed wall. It was originally proposed by Owczarek, Essam and Brak who found partial results for it. I show how to completely solve the problem of determining the asymptotic behaviour of the corresponding partition function (and of another interesting parameter). In the course of doing that, we shall meet some of my dear friends: determinants, a tableau bijection, and hypergeometric series.

Imaging and Inverse Problems of Partial Differential Equations

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The "mother" of imaging methods is computerized tomography (CT). From a mathematical point of view CT is just an application of Radon's 1907 inversion formula for the Radon transform. So, the mathematics of imaging is usually considered as part of integral geometry in the Gelfand-Helgason sense, i.e. reconstructing functions from integrals over manifolds of lower dimension.

Recently imaging has got a different slant. Virtually all imaging problems can be formulated as inverse problems of PDE's, i. e. estimating coefficients of PDE's from boundary measurements of the solution. In CT the relevant differential equation is the transport equation, in optical imaging the diffusion equation, in acoustic imaging the wave equation. Integral geometry comes in only because integral operators are often approximate solution operators to these equations.

In the talk we will describe the progresses and unifications that have been achieved recently by this broader view of imaging.

Dynamics of Bose-Einstein Condensates

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Gross and Pitaevskii proposed to model the dynamics of the Bose-Einstein condensate by a nonlinear Schrödinger equation, the Gross-Pitaevskii equation. This equation plays a key role in the theory and experiments of the Bose-Einstein condensation. The fundamental mathematical question is to derive this equation from the first principle physics law, the many-body Schrödinger equation. In the time-independent setting, this problem was solved by Lieb-Seiringer-Yngvason. In this lecture, we shall review the recent progress concerning the dynamical aspects of this problem and the analytic methods developed for quantum dynamics of many-body systems.

Affine Algebraic Geometry
(S. Abhyankar, H. Flenner, I. Makar-Limanov)

Contents

The Newton fan associated with an ideal

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Let I be an ideal of the ring of formal power series $\mathbf{K}[[x_1, ..., x_n]]$, $\mathbf{K}$ is a field. If $n = 2$ and $I = (f)$ is a principal ideal, then we can associate with f its Newton polygon. This notion is very useful in the study of the singularity of f. In this talk, we shall show how to generalise this notion to an arbitrary ideal. We shall also give some applications.

Affine Geometry and Engel-like identities for Finite Solvable Groups

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A subject of the communication is the Affine Geometry aspect of a joint work of T. Bandman, G.-M. Greuel, F. Grunewald, B. Kunyavskii , G. Pfister, and Eu. Plotkin. We characterize solvable groups in the class of finite groups by identities in two variables.

We define a sequence: $u_1(x, y) := x^{-2}y^{-1}x$, and inductively $u_{n+1}(x, y) := [\, x\, u_n(x, y)\, x^{-1},\, y\, u_n(x, y)\, y^{-1}\,]$. Our main result is

Theorem 1. *A finite group G is solvable if and only if for some n the identity $u_n(x, y) = 1$ holds in G.*

Although the Theorem is a purely group-theoretic result, its proof involves surprisingly diverse methods of algebraic topology, algebraic geometry, arithmetic geometry, group theory, and computer algebra.

The "only if" part of the Theorem is trivial. The non-trivial direction of the Theorem follows immediately from the following

Theorem 2. *Let G be a finite non-abelian simple group. Then there are elements x, y of G such that $u_1(x, y) \neq 1$ and $u_1(x, y) = u_2(x, y)$.*

Using Thompson's list of the minimal simple non-solvable groups we only need to prove Theorem 2 for the groups G in the following list.

(1) G=$\mathbf{PSL}(3, \mathbb{F}_3)$,

(2) G=$\mathbf{PSL}(2, \mathbb{F}_q)$ where $q > 3$ ($q = p^n$, p a prime),

(3) G =$\mathbf{Sz}(2^n)$, $n > 2$ and odd.

Here $\mathbb{F}_q$ stands for the finite field with q elements and $\mathbf{Sz}(2^n)$ $(n > 2)$ denote the Suzuki groups.

For small groups from this list it is a computer task to verify Theorem 2. There are for example altogether 44928 suitable pairs x, y in the group $\mathbf{PSL}(3, \mathbb{F}_3)$.

The general idea of our proof can be roughly described as follows. For a group G in the above list, using a matrix representation over $\mathbb{F}_q$ we interpret solutions of the equation $u_1(x,y) = u_2(x,y)$ as $\mathbb{F}_q$-rational points of an affine variety V_G.

In case (2) this variety does not depend on n. We investigate geometry and topology of this variety in order to use Hasse–Weil type estimates for the number of rational points on a variety defined over a finite field, which guarantee the existence of such points for big q.

In case (3) variety V_G for Suzuki group G depends on n. We manage to find a closed affine absolutely irreducible affine subset V of $\mathbb{A}^8$ together with the endomorphism α of $\mathbb{A}^8$ such that

(1) V is invariant under α,

(2) α^2 is the Frobenius map.

(3) the elements of the group $G = \mathbf{Sz}(2^n)$ are precisely the points of V which are fixed for α^n. In order to use the Lefschetz trace formula and to show that such points exist, we had to analyze this affine set, i.e. to find its singular locus, to estimate betti numbers and to understand what happens at infinity.

Associated graded rings of one-dimensional analytically irreducible rings

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Let (R,m) be a one-dimensional analytically irreducible and residually rational ring, e.g. the local ring of an irreducible curve singularity. Since the integral closure of R is a DVR V, if v is the valuation on V, we can consider $S = v(R) = \{v(r);\ 0 \neq r \in R\}$, which is a numerical semigroup. If e is the multiplicity of R, we call a subset $\{f_0, \dots, f_{e-1}\}$ of R an *Apery basis* of R if, for each i, $0 \leq i \leq e-1$, $\{v(f_0), \dots, v(f_{e-1})\}$ is the *Apery set* of S with respect to e, i.e. the set of the smallest elements in S in the e congruence classes mod e.

If $\{f'_0, \dots, f'_{e-1}\}$ is an Apery basis of R', the first neighborhood ring of R, i.e. the overring $\cup_{n\geq 0}(m^n : m^n)$, for each i, $0 \leq i \leq e-1$, we define the integers a_i and b_i in the following way:

a_i by $v(f'_i) = v(f_i) - a_i e$

b_i as the largest integer j such that $f_i \in m^j$.

We prove the following criterion:

The associated graded ring $\mathrm{gr}(R) = \oplus_{n\geq 0} m^n/m^{n+1}$ is Cohen Macaulay if and only if $a_i = b_i$, for each i.

Some applications of the criterion will also be given.

v-quasi-ordinary and quasi-ordinary power series

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Let K be a field of characteristic 0. In this talk, we will associate to v-quasi-ordinary power series, decorated trees, that we call Newton trees. In the case of curves, these trees are an algebraic version of the splice diagrams introduced by Eisenbud and Neumann. We will give some applications of these trees such as the computation of the discriminant of a quasi-ordinary power series.

New developments concerning the Jacobian Conjecture

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In this talk I will discuss several new results concerning the Jacobian Conjecture: the solution of the homogeneous case in dimension three, partial results for the inhomogeneous case in dimension three, the solution of the dependence problem, the symmetric Jacobian Conjecture and graphs related to the Jacobian Conjecture.

Counterexamples to the fourteenth problem of Hilbert in low dimensions

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In this talk I will give some new counterexamples to the fourteenth problem of Hilbert in low dimensions. Moreover, I will explain a method to construct such counterexamples systematically. I also discuss the problem of finite generation of the kernel of a derivation of a polynomial ring.

On the classification of rational cuspidal curves

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We will discuss some aspects of the problem of classification of rational cuspidal projective plane curves, some open problems related and new results (obtained jointly with Fernandez de Bobadilla, Melle Hernandez and Nemethi) and ideas coming from the theory of normal surface singularities via superisolated singularities.

Embeddings of a family of Danielewski hypersurfaces

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This talk describes recent work in collaboration with P.-M. Poloni on embeddings of surfaces in complex three-dimensional space. We consider polynomials P_r in $\mathbb{C}[x, y, z]$ of the form $P_r = x^2y - z^2 + xr(z)$ where $r(z)$ is a polynomial of one variable. We classify these polynomials up to equivalence. Two polynomials P and Q in $R = \mathbb{C}[x, y, z]$ are said to be (algebraically) equivalent if there is an algebraic automorphism f of R for which $f(P) = Q$. If there is a complex number c in $\mathbb{C}$ such that the zero set $V(P-c)$ is not isomorphic to the zero set $V(Q-c)$, then the two polynomials P and Q are not equivalent. We show, however, that the converse is not true. That is, there are examples of polynomials P and Q which are not equivalent, however the zero sets $V(P-c)$ and $V(Q-c)$ are isomorphic for all c. Moreover, we find families of polynomials which are analytically equivalent and also stably equivalent but not algebraically equivalent. We say that P and Q are analytically equivalent if there is an analytic isomorphism f of R for which $f(P) = Q$. We say they are stably equivalent if, when viewed as polynomials of 4 variables, they become equivalent.

These results use a theorem of L. Makar-Limanov describing the automorphism groups of hypersurfaces defined by an equation of the form $x^2y = p(z)$, where p is a polynomial of degree at least 2. The methods used are related to the techniques developed in an article by G. Freudenburg and L. Moser-Jauslin on embeddings of Danielewski surfaces.

Affine lines on affine surfaces and the Makar Limanov Invariant

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I will report on joint work with R. Gurjar, K. Masuda and M. Miyanishi on surfaces S with the MLi property. (A smooth affine surface is MLi if the Makar-Limanov invariant, the intersection taken over all additive actions of their rings of invariants, has dimension i.) We investigate the existence of open subsets isomorphic to the affine plane on such surfaces and, generalizing the Abyankar-Moh-Suzuki theorem, we settle the question whether an affine line on S is always a fiber component of a fibration of S by affine lines for ML0 surfaces whose Picard group is torsion and for ML1 surfaces. We also investigate the ascent and descent of the MLi property under proper maps.

Globalization of an old Theorem of Zariski

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I will describe the joint work with Abdallah Assi (On Quasihomogeneous Curves - preprint). Let the ground field be algebraically closed of characteristic zero. In a short paper (1966: Collected Works V.3, p. 475-480), Zariski characterized plane unibranch curves having maximum torsion to be exactly curves of the form $y^a - x^b$ with a, b coprime, after a suitable *local change* of variables. This torsion came out to be the length of the module of differentials of the integral closure modulo the module of differentials of the original coordinate ring $(\Omega(\overline{R})/\Omega(R))$. We show that this concept can be defined similarly for an affine curve with one place at infinity and prove a similar characterization, namely the length is maximal if and only if the curve is of Lin-Zaidenberg type, meaning after a suitable *affine change* of coordinates, it is of the form $y^a - x^b$ with a, b coprime. The well known Abhyankar Moh theory of plane affine curves with one place at infinity gives necessary conditions for such a curve to be rational, but the characterization of such curves has not been known. The relative module of differentials gives a new tool to study additional conditions on a plane curve with one place at infinity imposed by its rationality. We will describe additional calculations of this relative module of differentials.

Plain Jacobian Conjecture and Properties of the Puiseux Coefficients

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We formulate a certain "Finiteness Conjecture", which implies the plain Jacobian Conjecture and discuss an approach to the proof of this Finiteness Conjecture based on the study of Puiseux Coefficients.

Tame and wild automorphisms of polynomial algebras and free associative algebras

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Let F be a field of characteristic 0. It was proved by I. Shestakov and U. Umirbaev that the well-known Nagata automorphism of the polynomial algebra $F[x, y, z]$ is wild, that is, it cannot be decomposed into a product of elementary automorphisms. Now I have proved further results in this direction: 1) I described a set of defining relations for the group of tame automorphisms of the polynomial algebra $F[x, y, z]$; 2) I proved that the well-known Anick automorphism of the free associative algebra $F < x, y, z >$ is wild.

New bad lines in $R[x, y]$ and optimization of the Epimorphism Theorem

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This work is about one of the main problem in Affine Algebraic Geometry: the Abhankar-Sathaye (Embedding) Problem. Here I study the special case (in terms of dimension and codimension) of so called "lines" in $R[x, y]$, that is, polynomials f such that $R[x, y]/(f)$ is isomorphic to $R[z]$. The question is: are lines variables (= coordinates)? Quite a lot is known about this problem:
1. If R is a field a positive char., there exist bad lines (lines that are not variables) found by Nagata.
2. If R is a field of char. 0, then lines are variables; this is the Abhankar-Moh-Suzuki theorem.
Part 2. was generalized by Russell-Sathaye and by Bhatwadekar and part 1. has also some easy generalizations to rings of positive char. or having integers dividing 0. The main thing here is the quite unexpected discovery of new bad lines for rings R which are not of this latter type. This allows me to answer

completely the question, that is to say, which rings are "good" and which are "bad" in this context.

On Cancellation Problems

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We are going to discuss the 'embedding part' of the cancellation problem, and will also report some positive results for Cancellation Conjecture of Zariski for rings and fields.

The talk is based on two recent joint works with A. Belov and with A. Belov and L. Makar-Limanov, respectively.

Vénéreau polynomials and related fiber bundles

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The Vénéreau polynomials on $\mathbf{A}^4 = \mathbf{A}^4_{\mathbf{C}}$,

$$v_n := y + x^n(xz + y(yu + z^2)), \qquad n \geq 1,$$

have all the fibers isomorphic to the affine space $\mathbf{A}^3$. Moreover, for all $n \geq 1$ the map $(v_n, x) : \mathbf{A}^4 \to \mathbf{A}^2$ yields a flat family of affine planes over $\mathbf{A}^2$. It occurs that, over the punctured plane $\mathbf{A}^2 \backslash \{0\}$, this family is a fiber bundle. This bundle is trivial if and only if v_n is a variable of the ring $\mathbf{C}[x][y, z, u]$ over $\mathbf{C}[x]$.

This is an open question whether v_1 and v_2 are variables of the polynomial ring $\mathbf{C}^{[4]} = \mathbf{C}[x, y, z, u]$, whereas S. Vénéreau established that v_n is indeed a variable of $\mathbf{C}[x][y, z, u]$ over $\mathbf{C}[x]$ for $n \geq 3$. We will discuss another proof of this Vénéreau's result based on the above equivalence, as well as the relations to the Abhyankar-Sathaye Embedding Problem and to the Dolgachev-Weisfeiler Conjecture on triviality of flat families with fibers affine spaces.

Algebraic Combinatorics
(P. Hersh, Ch. Krattenthaler, V. Welker)

Contents

Shellability of noncrossing partition lattices

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We give a case-free proof that the lattice of noncrossing partitions associated to any finite real reflection group is EL-shellable. Shellability of these lattices was open for the groups of type D_n and those of exceptional type and rank at least three.

On the Kronecker Product $s_{(n-p;p)} * s_\lambda$

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The Kronecker product of two Schur functions s_λ and s_μ, denoted $s_\lambda * s_\mu$, is defined as the Frobenius characteristic of the tensor product of the irreducible representations of the symmetric group indexed by partitions of n, λ and μ, respectively. The coefficient $g_{\lambda,\mu,\nu}$ of s_ν in $s_\lambda * s_\mu$ is equal to the multiplicity of the irreducible representation indexed by ν in the tensor product. Let $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_l)$. We show that the coefficients in the expansion of $s_{(n-p;p)} * s_\lambda$ do not depend on n if $\lambda_1 - \lambda_2 \geq 2p$. In this case, we give an algorithm for expanding the Kronecker product $s_{(n-p;p)} * s_\lambda$, where p is a positive integer and $\lambda_1 - \lambda_2 \geq 2p$. We also give a simple combinatorial interpretation for $g_{\lambda,(n-p,p),\nu}$ if $l \geq 2p-1$ or if $\lambda_1 \geq 2p-1$; i.e., if λ is not a partition inside the $2(p-1)\times 2(p-1)$ square.

On cores of partitions and character separation

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Partitions and their p-cores play an important rôle in additive number theory and combinatorics, and on the algebraic side, in the p-modular representation theory of the symmetric groups and related groups (in the case when p is a prime) as well as in the representation theory of Hecke algebras. I will report on the investigation of the question whether a partition of n (or a bar partition, respectively) is characterized by all or even just a few of its p-cores (or p-bar cores, resp.), for primes $p \leq n$. In character theoretic terms, this asks for a separation of any two ordinary characters of the symmetric group S_n (or spin characters of their double covers, resp.) by p-blocks, where $p \leq n$ are suitable

primes. In recent joint work with G. Malle and J. Olsson, we have studied this separation problem not only for the symmetric and alternating groups and their covers, but also for groups of Lie type and sporadic groups (for a general finite group, a suitable selection of prime divisors p of the group order is required for the character separation).

Cycle-counting p,q-rook theory and the p,q,y-Stirling numbers of the second kind (preliminary report)

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In this preliminary report, we generalize several previously studied versions of rook theory by defining the cycle-counting p, q-rook numbers. In this model, we weight each rook placement by an expression involving the parameters p, q, and y, and several statistics on the placement. After the basic definitions and results are presented, we use the cycle-counting p, q-rook numbers of the triangular board to define the p, q, y-Stirling numbers of the second kind. We note how the basic cycle-counting p, q-rook theory results reduce in this case, giving versions of known theorems for the classical Stirling numbers of the second kind. Finally we discuss how the rook placement statistics simplify in this case; some have easy descriptions in terms of set partitions.

A random tiling model for two dimensional electrostatics

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We consider random lozenge tilings with a finite number of triangular holes. We define the correlation of such holes by including them in large lattice regions and considering an appropriate normalization of the number of tilings of the complement of the holes. We show that in the scaling limit the correlation is obtained from a multiplicative superposition principle that parallels two dimensional electrostatics. Our results apply for any finite collection of lattice triangular holes of even side. We also indicate how a lattice refinement parameter accounts for physical temperature.

2–enumerations of halved alternating sign matrices

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We compute 2–enumerations of halved alternating sign matrices with certain restrictions. The problem can be reduced to counting the number of perfect matchings of weighted halved Aztec diamonds and fortress graphs. This can be solved by repeated application of "urban renewal", a local graph transformation. Our results prove three conjectures by Jim Propp.

Inference functions and sequence alignment

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Statistical models are used in computational biology to draw conclusions from data. They give rise to several combinatorial problems. Sometimes the goal is to find the optimal alignment of a pair of DNA sequences, or to determine what parts of the genome will be translated into proteins. The functions that map each observation to its most probable explanation are called inference functions. They depend on the model parameters.

Even though the number of maps from the set of observations to possible values of the hidden data is doubly exponential, it turns out that most of these maps are not inference functions for any value of the parameters. I will show that for any graphical model with a fixed number of parameters, the number of inference functions is polynomial in the size of the model. The proof reduces the enumeration of inference functions to counting the vertices of a certain lattice polytope.

Then I will give applications of this result to optimal sequence alignment, and discus some open combinatorial problems that arise.

Nested set complexes and spaces of trees

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Nested set complexes are the combinatorial core of De Concini-Procesi wonderful compactifications of arrangement complements. They now have made a remarkable appearance in the context of spaces of trees. We will explore their significance for the topological combinatorics and combinatorial representation theory of spaces of trees and various generalizations.

The number of monotone triangles with prescribed bottom row
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We show that the number of monotone triangles with prescribed bottom row $(k_1, \ldots, k_n) \in \mathbb{Z}^n$, $k_1 < k_2 < \ldots < k_n$, is given by a simple product formula which remarkably involves (shift) operators. Monotone triangles with bottom row $(1, 2, \ldots, n)$ are in bijection with $n \times n$ alternating sign matrices.

The Genesis of the Macdonald Polynomial Statistics
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We discuss the empirical method that led the speaker to the discovery of a formula for the Macdonald polynomial involving generalizations of the permutation statistics inv and maj. (This conjectured formula has since been proven by Haiman, Loehr and the speaker - see the talk by M. Haiman).

A combinatorial formula for Macdonald polynomials
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We prove a combinatorial formula conjectured by Haglund for the Macdonald polynomial $\tilde{H}_\mu(x; q, t)$. Such a combinatorial formula had been sought since Macdonald introduced his polynomials in 1988. The new formula has various pleasant consequences, including the expansion of Macdonald polynomials in terms of LLT polynomials, a new proof of the charge formula of Lascoux and Schutzenberger for Hall-Littlewood polynomials, and a new proof (and more general version) of Knop and Sahi's combinatorial formula for Jack polynomials. In general, our formula doesn't yet give a new proof of the positivity theorem for Macdonald polynomials, because it expresses them in terms of monomials, rather than Schur functions. However, it does yield a new combinatorial expression for the Schur function expansion when the partition has parts less than or equal to 2, and there is hope to extend this result.

Rim hooks and quantum Schubert calculus

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The quantum product of Grassmannians can be computed using the classical rule of Littlewood and Richardson together with an algorithm on partitions called rim hook reduction. I define an involution on the set of tableaux appearing in such computations which links these two parts and clarifies their relationship.

Balancing Newton polytopes

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A d-dimensional simplicial complex is *balanced* if its graph is $(d+1)$-colorable. We study constructions for balanced triangulations of convex polytopes. In view of recent results of Soprunova and Sottile this yields lower bounds for the number of real solutions of certain sparse polynomial systems.

Generalizing the Combinatorics of Young Tableaux to Arbitrary Lie Type

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Young tableaux provide a combinatorial model for the irreducible characters of the Lie algebra of type A. Their very rich combinatorics has been widely studied, especially since the pioneering work of Lascoux and Schützenberger in the 1970s and 1980s. We present a simple combinatorial model for the irreducible characters of an arbitrary semisimple Lie algebra, which allows us to generalize much of the combinatorics of Young tableaux. More precisely, among the features of our model are: (1) a Littlewood-Richardson rule (for decomposing the tensor product of irreducible representations); (2) root operators (which give rise to the corresponding crystal graph structure, and generalize the coplactic operations on tableaux); (3) a generalization of the left and right keys of tableaux (related to Demazure characters); (4) an explicit combinatorial description (generalizing Schützenberger's "evacuation" procedure for tableaux) of the action of the longest Weyl group element on canonical bases. Our model has certain advantages over Littelmann paths; for instance, no explicit description of the latter involution is known in Littelmann's model.

Linear operators and functionals are tools for lattice paths enumeration

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A *simple* lattice path begins at the origin, takes steps $\langle i, j\rangle \in S$, the step set, from point (n, m) to $(n + i, m + j)$, and cannot intersect itself. The step set S however, may be infinite and the steps may be weighted. Furthermore, the path can be restricted by boundaries. We only consider one boundary, a straight line of positive integer slope. The boundary can be reached from points above it by steps from a special access step set. The special access set may or may not be a subset of the general step set, and it can be infinite as well. If it is empty, the lattice paths are restricted to points above the boundary. We enumerate the paths with the help of linear algebra; if the number of paths from the origin to (n, m) above the boundary is the value $p_n(m)$ of a polynomial of degree n, then the path recursion, given by the step set, defines a relationship between linear operators on polynomials, and the special access condition defines a linear functional on polynomials. Applying Rota's Finite Operator Calculus we determine the solution, the Sheffer sequence (p_n), from the problem specific operator equation and functional condition. Depending on the two step sets, the generating function of a solution will be rational or not. We will give examples of the latter case.

Variations on Cauchy's determinant and Schur's Pfaffian

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We present several identities of Cauchy-type determinants and Schur-type Pfaffians involving generalized Vandermonde determinants. These identities generalize Cauchy's determinant identity for

$$\det\left(1/(x_i + y_j)\right)_{1\le i,j\le n}$$

and Schur's Pfaffian identity for

$$\mathrm{Pf}\left((x_j - x_i)/(x_j + x_i)\right)_{1\le i,j\le 2n}.$$

Also we give an elliptic extension of Schur's Pfaffian identity and a Pfaffian-Hafnian analogue of Borchardt's identity. Finally we discuss several applications of these identities.

MacMahon's dream came true
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Coauthors: George E. Andrews (Pennsylvania State University)

In his famous book "Combinatory Analysis" MacMahon introduced Partition Analysis as a computational method for solving combinatorial problems in connection with systems of linear Diophantine inequalities and equations. After devoting hundred pages to various aspects of Partition Analysis, he starts to consider plane partitions as a natural application domain for his method. After discussing some special cases of the full generating function for plane partitions with restricted number of rows and columns, MacMahon writes: "Our knowledge of the Omega operation is not sufficient to enable us to establish the final form of result." This talk reports on recent joint work with George E. Andrews (PennState) which shows that - despite MacMahon's negative statement - Partition Analysis indeed is powerful enough to derive the full generating function.

Decreasing subsequences in permutations and Wilf equivalence
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In a recent paper, Backelin, West and Xin describe a map ϕ that recursively replaces all occurrences of the pattern $k(k-1)\cdots 1$ in a permutation by occurrences of the pattern $(k-1)\cdots 1k$. The resulting permutation contains no decreasing subsequence of length k. Extending the definition to full rook placements on a Ferrers board, the map can be used to prove the Wilf equivalence of $12\cdots k\tau$ and $k\cdots 21\tau$ for any pattern τ. We give a direct description of the bijection ϕ on which some phenomena (as commutability with taking the inverse permutation) become clear.

When is 0.999... equal to 1?
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In this talk I will illustrate how the summation package Sigma can assist in simplifying multi-sum expressions. More precisely, I show how a doubly infinite sum, numerically evaluated at between 0.999 and 1.001, turns out not to equal 1, but to be a sum of products of values of the zeta function.

Conjectures on intervals in subgroup lattices of finite groups

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The question "Is every finite lattice isomorphic to an interval in the lattice of subgroups of a finite group?" is open. There has been significant progress towards showing that the answer to this question is "no", obtained by examining lattices of height two. I will present three conjectures, a positive answer to any of these providing a negative answer to the original question. The strongest of these is that the order complex of the proper part of every interval in the subgroup lattice any finite group has the homotopy type of a wedge of spheres. I will show that if [H,G] is a minimal counterexample to any one of my conjectures, then G has a unique minimal normal subgroup N, N is nonabelian, and either N is simple or H is a complement to N in G.

Posets from Total Positivity

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We discuss a family of posets that arise from Lusztig's theory of total positivity. These posets describe the cell decomposition of the totally nonnegative part of a flag variety, and are intimately related to the Bruhat order. We give enumeration and shellability results, focusing in particular on the Grassmannian and the complete flag variety. One corollary is a new q-analogue of the Eulerian numbers, which specializes to the Naryana numbers, Eulerian numbers, and binomial coefficients.

Algebraic Cryptography (D. Goldfeld, M. Kreuzer, G. Rosenberger, V. Shpilrain)

Contents

Using rewriting systems in cryptography
Benjamin Fine
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TBA

Non-commutative Groebner Bases in Cryptography
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A non-commutative version of the cryptosystem Polly Two by Le Van Ly which is a sophisticated form based on the idea of the general algebraic public-key cryptosystem called Polly Cracker introduced in 1994 by Fellows and Koblitz. The public key is an ideal I in the non-commutative polynomial ring in several variables over a finite field F and a subset $g_1, ...g_r$ of normal forms with respect to I. The secret key is the Groebner basis G of I. In order to encrypt a message $m \in Fg_1 + .. + Fg_r$ one is choosing randomly a polynomial f in I and computes the cipher text $c = f + m$. The decryption of c is the reduction of c relative to G. One has to defend against various forms of intelligent linear algebra attacks which makes it difficult to suggest effective versions. We will discuss some advantages of this non-commutative system and suggest to consider also RSA over quaternions.

Algebraic Erasors for Public Key Cryptography
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One-way functions are critical primitives in cryptography. We introduce the concept of an algebraic erasor and show how it leads to a class of one-way functions which can be rapidly computed at low cost on small processors for use in public key cryptography.

Attacks on group-based cryptographic schemes

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TBA

Realizations of the Length Attack on AAFG1 Cryptosystem

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Recently a length attack on the AAFG1 Cryptosystem was proposed. In this talk, we describe a possible realization. This is important since it has been suggested that this type of attack is "probabilistic" and "requires a very large computational power". We show to the contrary that it is not probabilistic, and introduce results showing why it works specifically against the AAFG1 cryptosystem.

One can characterize the length attack as an ordered search problem in which most solutions can be found rather quickly with a reasonable complexity. Indeed, we will provide such results and extrapolate the modal and average complexity of a solution.

Finally, we will give our perspective on what properties a cipher in this algorithmic class must possess in order to be accepted by the cryptographic community as "secure".

Removing Commutativity from Classical Cryptography: A Combinatorial Group Theoretic Approach

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The idea I am dicussing in this talk, is removing commutativity from the classical cryptology schemes (which uses finite fields (special cyclic groups)); initiated by Anshel-Anshel-Goldfeld in 1999. We introduced polycyclic groups as the best new platform for cryptology. The novelty of our approach is that polycyclic groups are a natural generalization of cyclic groups with much more complex algorithmic structures this promises to be a more substantial platform and more secure than the existing cryptosystems. Note that nilpotent groups could be regarded as an example of polycyclic groups and the solvable groups

which are not polycyclic, are not appropriate. In this talk I will explain Eick-Kahrobaei cryptosystem.

An Extension of the Uniform Distribution to Infinite Groups from the Cryptographic Viewpoint

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Modern cryptography is deeply related to groups. Based on finite groups, there have been proposed various types of schemes and many of them are known to be secure. Compared to finite groups, in infinite groups there are only a few types of schemes (e.g. key agreement protocol or public key encryption) and none of them are not proved to be secure.

A natural question is how we can proceed one more step. An impediment to this seems to be connected with "probability". Indeed, the uniform distribution is popularly used in finite groups, but not available in infinite groups. Our motivation is that there is nothing discussed seriously for it in the literature on infinite-group-based cryptography.

As a first step for this line of research, we choose a particular probability-theoretic property, the so-called *right-invariance*, from finite groups, and formalize the notion in arbitrary groups. Next, we explore this property in infinite groups analyzing the structure of their σ-algebra. Lastly, we discuss probability measures for right-invariance property both in ideal case and in practical case, and show applications.

Using combinatorial group theory in cryptography

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TBA

Using the subgroup membership search problem in public key cryptography

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Most public key protocols based on nonabelian groups use the computational difficulty of either the conjugacy search problem or the word (search) problem. In this talk, we describe a cryptosystem whose security is based on the computational difficulty of the subgroup membership (search) problem: given a group G, a subgroup H generated by $h_1, ..., h_k$, and an element $h \in H$, find an expression of h in terms of $h_1, ..., h_k$.

Algebraic Cryptosystems and Side Channel Attacks

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Depending on the specific application, side channel attacks can be a crucial threat for encryption and signature schemes. Consequently, for established cryptographic proposals much effort has been invested in deriving efficient implementations that offer acceptable cryptographic security against simple and differential power analysis, timing attacks, etc.

Having in mind the goal of using algebraic cryptosystems—e.g., based on finitely presented groups or multivariate polynomials—in "real life" applications, it is natural to ask for their security with regard to side channel attacks. Using a braid group and a multivariate polynomial based signature scheme as example, the talk discusses possibilities and problems of side channel attacks on algebraic cryptosystems: for a multivariate polynomial based scheme, differential power analysis seems to offer a quite powerful attack tool. On the other hand, for a braid group based proposal applying a differential power analysis against a "naive" implementation seems to be less straightforward than one might expect.

Algebraic Cycles
(E. Friedlander, M. Levine, F. Morel)

Contents

Feyman integrals and zeta values: first steps towards a motivic viewpoint.

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We will report on how far we are by the time of the conference in trying to interpret geometrically ("motivically") the zeta values the physicists found via Feyman integrals.

Finiteness results for certain motivic cohomology groups

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This is a report on joint work in progress with Shuji Saito. We prove finiteness for certain motivic cohomology groups modulo n, viz., the groups $CH^d(X, 1, \mathbb{Z}/n)$ where X is a regular proper scheme of dimension d over $\mathbb{Z}$ and n is an integer. The elements in this group are represented by families of rational functions on curves (geometric or arithmetic) on X for which the sums of their divisors is divisible by n. We have to assume the Milnor-Bloch-Kato conjecture on the bijectivity of the Galois symbol for the Milnor K-group $K_3^M(F)/n$, i.e., modulo all primes p dividing n. Thus the result is unconditional for n a power of 2. We have a complete result if X is smooth and projective over a finite field. For the arithmetic case, i.e., X flat over $\mathbb{Z}$, we have a complete result for the case where d is at most 3 or if X has good reduction at all primes dividing n.

Characteristic classes in arithmetic Hodge cohomology

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We introduce arithmetic extension groups for vector bundles on arithmetic varieties which behave formally very similiar to the arithmetic Chow groups introduced by Gillet and Soulé. We construct characteristic classes for hermitian vector bundles in arithmetic Hodge cohomology.

T.B.A.

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T.B.A.

Higgs cohomology of local systems on Picard modular surfaces

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We prove L^2–vanishing results for certain local systems on Picard modular surfaces. This has applications to Chow-Kuenneth decompositions for the total space of compactified universal families of Abelian 3-folds.

Norm Varieties and Algebraic Cobordism

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Norm varieties are key objects relating Galois cohomology and cobordism. We define norm varieties and describe some constructions. Further we discuss degree formulas which form a major tool to handle norm varieties.

Special cycles on Shimura varieties

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The main focus of this talk will be on the study of algebraic cycles on Shimura varieties, particularly those "special cycles" which arise as sub-Shimura varieties. We consider the classes of such cycles in the cohomology of the Shimura variety and study their intersections and related intersection numbers. The use of non-abelian Galois cohomology serves as a suitable framework to analyze the role these special cycles play.

On the arithmetic of K3 surfaces

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I will discuss several recent results and constructions concerning K3 surfaces over countable fields.

Torsion cycles on complex projective manifolds

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We use a construction due to Kollár to construct torsion cohomology classes of any possible prime order on complex projective manifolds of fixed dimension, which are not algebraic, but become algebraic under small deformations. We also use similar degenerations to exhibit torsion cycles, non trivial modulo algebraic equivalence, and which sit in an arbitrarily large level of the Hiroshi Saito filtration on Chow groups.

Boundary motive of Shimura varieties

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In this talk, the *boundary motive* of a scheme X of finite type over a perfect field will be defined. By definition, it measures the difference between the *motive* and the *motive with compact support* of X. The basic properties of the boundary motive will be explained, and applied to *Shimura varieties*. The resulting formula should be seen as a motivic analogue of Pink's theorem on the direct images of étale sheaves in the *Baily–Borel compactification*.

Algebraic Geometry (Y. Tschinkel, B. Hassett)

Contents

Canonical Representations of Orthogonal Groups of Line-Bundle-Valued Ternary Quadratic Bundles over Schemes with Applications — Dedicated to Professor Martin Kneser

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Given a line-bundle-valued ternary quadratic bundle over any scheme, there is a functorial representation of its group of orthogonal similitudes in the Witt-invariant, which by definition is the degree zero part of the associated generalised Clifford algebra bundle. Local computations involving twisted even-exterior algebra bundles of rank 3 vector bundles and global scheme-theoretic methods lead to the canonical determination of this representation. The use of the notion of semiregularity introduced by Martin Kneser allows working over arbitrary schemes, regardless of the characteristics of the residue fields of its points. The applications of this computation are as follows.

Application 1: Degeneration Theory of Ternary Quadratic Forms and Rank 4 Azumaya Bundles:

The association of the isomorphism class of a quadratic bundle to its Witt-invariant induces a natural bijection, from the set of equivalence classes of line-bundle-valued quadratic forms on rank 3 vector bundles isometric up to tensoring by twisted discriminant bundles, to the set of isomorphism classes of schematic specialisations of rank 4 Azumaya bundles over any fixed scheme X. This statement is a limiting version of the following theorem of Max-Albert Knus in cohomology: the set of orbits of $\mathrm{Disc}(X)$ in the 1-cohomology of X in the fppf topology with values in $\mathrm{O}(3)$ is in bijection with the 1-cohomology with values in $\mathrm{PGL}(2)$.

The various orthogonal groups of a quadratic bundle are canonically determined in terms of the automorphisms of its even Clifford algebra. Any automorphism of the latter arises from a similarity, and in fact from an orthogonal transformation if its determinant is a square. The special orthogonal group is thus identified with the subgroup of automorphisms with trivial determinant. If X is integral and the quadratic form is semiregular at some point of X, then every automorphism of the even Clifford algebra has determinant 1 and is thus induced from a self-isometry; the orthogonal group is also seen to be a semidirect product in this case.

A specialised algebra arises from a honest quadratic form iff its determinant has a square root and arises from a bilinear form iff the line subbundle generated by 1 is a direct summand.

For a connected proper scheme of finite type over an algebraically closed field, the hypothesis of self-duality on a unital associative algebra bundle of square rank forces the algebra to be either globally Azumaya or to be nowhere-Azumaya. Hence the self-duality of the underlying bundle of the even Clifford algebra implies that the quadratic bundle is semiregular everywhere if it is semiregular even at a single point.

Application 2: Geometry of the Scheme of Specialisations of Azumaya Alge-

bra Structures on a rank 4 vector bundle and applications to Desingularisation

The multiplication table of every specialised algebra structure on any fixed free rank 4 vector bundle with fixed unit that is part of a global basis is computed explicitly. The key theorem is that the natural parameter space for specialisations of Azumaya algebra structures on a fixed (locally-free) rank 4 vector bundle is smooth and geometrically irreducible over the base scheme. (It is known that the smoothness does not hold for other higher ranks). This generalises theorems of Seshadri and Ramanan.

The smoothness result allows the construction of a generalised Seshadri desingularisation of the moduli space of semistable rank 2 degree zero vector bundles on a curve relative to a locally-universally-japanese (Nagata) base scheme.

It also allows the construction of a generalised Nori desingularisation of the Artin moduli space of invariants of several matrices in rank 2 over a locally-Nagata base scheme, along with the good specialisation property over the integers.

When the base scheme is the spectrum of an algebraically closed field, a canonical stratification of the variety of specialisations is obtained.

Experimental Results for the Poincaré Center Problem

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In 1885 Poincaré asked when the differential equation

$$\dot{y} = -\frac{x + p(x,y)}{y + q(x,y)}$$

has stable solutions in the neighbourhood of the equilibrium solution $(x, y) = (0, 0)$. He showed that for p and q polynomials of fixed degree the variety X of such differential equations is algebraic, by giving an infinite generating system of polynomial equations.

For p and q homogeneous of degree 2 the variety X has been described geometrically by various autors (Dulac 1908, Frommer 1933, ..., Schlomiuk 1993). In this talk these results are reviewed and some new results for the case p and q inhomogenous of degree 3 are obtained. The methods used are reduction to finite characteristic, computer algebra and syzygies.

Hyperelliptic Jacobians with Real Multiplication

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Let K be a field of characteristic p different from 2, and let $f(x)$ be a sextic polynomial irreducible over K with no repeated roots, whose Galois group is isomorphic to $\mathbb{A}_5$. If the jacobian $J(C)$ of the hyperelliptic curve $C : y^2 = f(x)$ admits real multiplication over the ground field from an order of a real quadratic field D, then either its endomorphism algebra is isomorphic to D, or $p > 0$ and $J(C)$ is a supersingular abelian variety. The supersingular outcome cannot occur when p splits in D.

Relative Gromov-Witten invariants and tropical geometry

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In complex geometry Caporaso and Harris have shown that the theory of relative Gromov-Witten invariants can be used to compute the numbers of plane curves of given genus g and degree d passing through $3d + g - 1$ general points. We will show how this result can be reinterpreted and reproven in the language of tropical geometry.

Asymptotic cohomological functions of toric divisors

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We study functions on the class group of a toric variety measuring the rates of growth of the cohomology groups of multiples of divisors. We show that these functions are piecewise polynomial with respect to finite polyhedral chamber decompositions. As applications, we express the self-intersection number of a T-Cartier divisor as a linear combination of the volumes of the bounded regions in the corresponding hyperplane arrangement and prove an asymptotic converse to Serre vanishing.

Stringy K-theory and stringy (quantum) cohomology for varieties with a finite group action

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For a variety with an action of finite group G, we define stringy K-theory, stringy cohomology and provide a Chern character between them. The idea behind these constructions is that for a quotient by a finite group there is a stringy construction of all the usual functors which take values in Frobenius algebras. This is done by taking into account the fixed point sets of all group elements which yields a group graded object. On this stringy data there is an action by the group G and the invariants of this action additively yield the equivariant data, e.g. the G-equivariant K-theory of X. There is, however, a new stringy multiplication which respects the group grading. One motivation for studying these stringy objects is that it is expected that the stringy invariants carry information about the possible desingularizations. This is for instance the case for a symmetric product of $K3$ surfaces and its resolution by the Hilbert scheme.

Stability conditions on irreducible singular curves of genus one

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Motivated by the study of Dirichlet branes in string theory, T. Bridgeland introduced the notion of a stability condition on a triangulated category. The main ingredient for this notion is a generalisation of Harder-Narasimhan filtrations for objects in a triangulated category.

We use this concept in order to gain a good understanding of the structure of the bounded derived category of coherent sheaves on a singular cubic curve. As a result we give a description of the group of exact auto-equivalences of this category, we describe all t-structures and the moduli space of stability conditions on it. Moreover, we describe all spherical objects in this category.

Our methods allow us to understand indecomposable objects in this category, which may be interesting from a representation theory perspective.

Stability of tri-canonical curves of genus 2

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In this talk, we prove that pseudo-stable curves with cusps are indeed Chow semistable in two different ways: one uses degeneration arguments and the other considers invariant theory of the Chow form itself directly. As a by-product, we completely classify the strictly semistable points in the moduli space.

Singular symplectic moduli spaces

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Moduli spaces of semistable sheaves on a K3 or abelian surface with respect to a general ample divisor are shown to be locally factorial, with the exception of symmetric products of a K3 or abelian surface and the class of moduli spaces found by O'Grady. Consequently, since singular moduli spaces that do not belong to these exceptional cases have singularities in codimension ≥ 4 they do not admit projective symplectic resolutions.

Motivic tubular neighborhoods

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We show how to construct a motivic version of the tubular neighborhood of a submanifold, as well as the punctured tubular neighborhood. We use this to define motivic versions of tangential base-points, and give as well applications to motivic constructions involving the moduli of curves.

Singular Principal Bundles on Algebraic Varieties

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Singular principal bundles were used by the speaker to construct and compactify the moduli space of Ramanathan-stable principal G-bundles over a polarized projective manifold $(X, \mathcal{O}_X(1))$ over the field of complex numbers, G being a semisimple linear algebraic group.

Meanwhile, these objects have been used also on singular varieties, esp. nodal curves (Bhosle/Schmitt), and on algebraic surfaces for obtaining an algebraic model for the Uhlenbeck compactification (Balaji). Other potential extensions concern positive characteristic and decorated principal bundles.

The speaker will give a survey of these topics.

An experimental approach to numerical Godeaux surfaces

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A (numerical) Godeaux surface is a minimal surface X of general type with $K^2 = 1$ and $p_g = 0$, hence also $q = 0$ and $H_1(X, \mathbb{Q}) = 0$. So in some sense these are the surfaces of general type with smallest possible invariants. Godeaux constructed a family of such surfaces as quotients of a quintic hypersurface by fix point free action of $\mathbb{Z}_5$. By the work of Miyaoka it is known, that torsion group $T = H^1(X, \mathbb{Z})$ is a cyclic group of order at most 5. The surfaces with $T = \mathbb{Z}_d$ for $d = 3, 4, 5$ have a moduli space which in each case consists of one 8-dimensional component by work of Reid and Miyaoka. For $T = \mathbb{Z}_2$ or $T = 0$ much less is known. Existence of such surface was proved by Rebecca Barlow using a complicated quotient construction.

Traditionally there are two approaches to construct numerical Godeaux surfaces: Either via a Godeaux approach as quotient of a simpler surface by a possibly non free group action, or via a Campedelli approach as a double plane branched along a curve with a specific configuration of singularities.

In this talk I present a third approach based on homological algebra.

Kummer surfaces in characteristic two

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The classical Kummer construction attaches to each abelian surface a K3 surface. As Shioda and Katsura showed, this construction breaks down for supersingular abelian surfaces in characteristic two. Replacing supersingular abelian surfaces by the selfproduct of the rational cuspidal curve, and the sign involution by suitable infinitesimal group scheme actions, I give a new Kummer-type construction in characteristic two. We encounter rational double points of type D_4 and D_8, instead of A_1. The resulting surfaces are supersingular K3 surfaces with Artin invariant one and two.

Cohomology of toric varieties and tropical calculus

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Given an orbifold toric variety obtained as a quotient of a vector space by a torus, we construct an explicit real complete intesection cycle in the complement of a hyperplane arrangement of the Lie algebra of this torus. The cycle represents the intersection pairing of the toric variety via a residue integral. The proof of the formula uses real algebraic degeneration methods related to "tropical calculus".

Projective integral models of Shimura varieties of Hodge type with compact factors

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Let (G, X) be a Shimura pair of Hodge type. We assume that each simple factor of the adjoint group of G, has simple, compact factors over the reals. Then we show that suitable quotients of finite type of the Shimura variety $Sh(G, X)$, have natural projective integral models over $\mathbb{Z}[\frac{1}{N}]$ (here $N > 2$ is arbitrary). This result: (i) can be interpreted as a substantial progress in the proof of a conjecture of Morita, and (ii) provides in arbitrary mixed characteristic the very first examples of general nature of projective varieties over number fields which are not embeddable into abelian varieties and which have Néron models over certain localizations of rings of integers of number fields.

Arakelov inequalities and the uniformization of certain rigid Shimura varieties

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Let Y be a non-singular projective manifold with an ample canonical sheaf, and let V be a rational variation of Hodge structures of weight one on Y with Higgs bundle $E(1,0)+E(0,1)$, coming from a family of Abelian varieties. If Y is a curve the Arakelov inequality says that the difference of the slope of $E(1,0)$ and the one of $E(0,1)$ is smaller than or equal to the degree of the canonical sheaf. We prove a similar inequality in the higher dimensional case. If the latter is an equality, as well as the Bogomolov inequality for $E(1,0)$ or for $E(0,1)$, one hopes that Y is a Shimura variety, and V a uniformizing variation of Hodge structures. This is verified, in case the universal covering of Y does not contain factors of rank >1. Part of the results extend to variations of Hodge structures over quasi-projective manifolds.

Dirac Operators, Clifford Analysis and Applications (K. Gürlebeck, M. Martin, J. Ryan, M. Shapiro)

Contents

Rational hyperanalytic functions

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We define rational functions when the complex numbers are replaced by the quaternions and when analytic functions are replaced by hyperanalytic functions. Our approach uses a solution of Gleason's problem in the hyperanalytic framework. This allows to define Schur functions and associated de Branges-Rovnyak spaces in the present setting.

Dirichlet and Hardy spaces of harmonic and monogenic functions

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We characterize the Dirichlet spaces $\mathbf{D}_p$ of monogenic Clifford algebra valued functions in the unit ball in $\mathbb{R}^{m+1}$ by the coefficients of a homogeneous series expansion. Further we characterize the Dirichlet space $D_p, 0 < p < 1$, of harmonic functions in the unit ball by their boundary behavoir and Carleson-type measures.

On the Hilbert transform and conjugate harmonic functions

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On the real line the Hilbert transform $\mathcal{H} : L_2(\mathbb{R}) \to L_2(\mathbb{R})$, given by

$$\mathcal{H}[f](x) = \frac{1}{\pi} \operatorname{Pv} \int_{-\infty}^{+\infty} \frac{f(t)}{x-t}\, dt$$

and the Poisson transform $\mathcal{P} : L_2(\mathbb{R}) \to \mathrm{Harm}^2(\mathbb{C}^+)$, given by

$$\mathcal{P}[f](x) = P(\cdot, y) * f(\cdot)(x) = \frac{1}{\pi} \int_{-\infty}^{+\infty} \frac{y}{(x-t)^2 + y^2}\, f(t)\, dt$$

are related by the well-known property that, for real-valued functions f, $\mathcal{P}[f]$ and $\mathcal{P}[\mathcal{H}[f]]$ are conjugate harmonic functions in the upper half plane $\mathbb{C}^+$, and constitute the real and imaginary parts of the holomorphic Cauchy integral $\mathcal{C} : L_2(\mathbb{R}) \to H^2(\mathbb{C}^+)$, given by

$$\mathcal{C}[f](z) = -\frac{1}{2\pi i} \int_{-\infty}^{+\infty} \frac{f(t)}{(x-t)+iy}\, dt = \frac{1}{2}\mathcal{P}[f] + \frac{i}{2}\mathcal{P}[\mathcal{H}[f]]$$

If Ω is a bounded, simply connected domain in the complex plane, with C^∞ smooth boundary, then the analogue of this property is precisely used to define the Hilbert transform on $\partial\Omega$. Indeed, take $u \in C^\infty(\partial\Omega)$ real-valued, then there exists a real-valued harmonic function $U \in C^\infty(\overline{\Omega})$ for which the restriction to the boundary $\partial\Omega$ is the given function u. Let $V \in C^\infty(\overline{\Omega})$ be the conjugate harmonic to U and let v be the restriction to the boundary $\partial\Omega$ of V, then v is called the Hilbert transform of u. This Hilbert transform maps $C^\infty(\partial\Omega)$ into itself and extends uniquely to a bounded linear operator on $L_2(\partial\Omega)$.

In this contribution, we investigate how the above relationship between the Hilbert transform and the notion of conjugate harmonic functions behaves in higher dimension within the framework of Clifford analysis. We first treat the special cases of the half space and the unit ball, passing then to a more general bounded domain in $\mathbb{R}^{m+1}$, with C^∞ smooth boundary.

Applications of Dirac Operators and Automorphic Forms in n Real Variables to Hilbert Spaces and Boundary Value Problems

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A new type of Automorphic forms in n Real Variables that satisfy Dirac type equations are used to study Boundary Value problems arising from Harmonic Analysis on some conformally flat manifolds and related Hilbert spaces. The results presented are partially joint work with John Ryan (University of Arkansas) and Denis Constales (Ghent University).

Integral and Maximal Operators in Spin Geometry

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The goal of this talk is to show that the singular integral operators associated with the fundamental solutions of Dirac operators on Dirac bundles are controlled by certain maximal operators. The inequality that quantifies the link involves an absolute constant that can be explicitly computed. As consequences of that inequality we will derive several quantitative Hartogs–Rosenthal-type theorems for Dirac operators concerning monogenic approximation on compact sets with respect to different natural norms on the space of sections of a Dirac bundle.

Fundamental domains in n real variables, and associated Dirac operators

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In this talk a construction of Ahlfors using Clifford algebras is used to introduce in n-real variables analogues of fundamental domains associated with the modular group and its subgroups. A Dirac operator for hyperbolic space is introduced and its properties of this operator in the context of these conformally flat manifolds are described.

Quaternion analytic methods for the treatment of Oseen's equation

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Let $G \subset \mathbb{R}^n$ $(n \geq 3)$ be a bounded domain with smooth boundary ∂G. We consider the following IBV-problem

$$\rho \partial_t u - \nu \Delta u + (\rho v \cdot \mathrm{grad}) u + \mathrm{div} p = f \quad \text{in} \quad G$$

$$\mathrm{div} u = 0 \quad \text{in} \quad G$$

$$u = g \quad \text{on} \quad \partial G,$$

which was obtained by C.W. Oseen by linearization of Navier-Stokes equations. Here v describes a solution of the corresponding Stokes system, ρ is the density of

the incompressible fluid and ν the dynamic viscosity. After semidiscretisation by the aid of a quaternionic operator calculus an iterative method will be derived.

Tensor Product of Resolutions and Applications to Biregular Functions

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We consider functions defined on n pairs of quaternionic variables (p_i, q_i) and which are left-regular in p_i and right regular in q_i for all $i = 1, \ldots, n$. We call these functions biregular, in an extension of the name which is usually reserved for functions of two quaternionic variables, left regular on one, and right regular on the other one. We show that there are some general properties of the tensor product of free resolutions which allow us to study the algebraic properties of these functions by reducing the analysis to the case of regular functions of several quaternionic variables.

Operator Algebras Related to the Bochner-Martinelli Integral

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The theory of one-dimensional singular integral equations with Cauchy kernel in the complex plane has essentially enriched the general Fredholm theory. It actually initiated the study of pseudodifferential operators on manifolds with singularities. However, singularities in higher dimensions are much more tricky than those in the complex plane. This motivates the study of concrete C^*-algebras generated by classical singular integral operators on higher-dimensional surfaces, which could give a powerful source of intuition to forecast the behaviour of general pseudodifferential operators. As but one example we show the C^*-algebra generated by the singular Bochner-Martinelli integral. In [1] the Clifford analysis is applied to derive an explicit formula for the square of the singular Bochner-Martinelli integral M over a smooth hypersurface S in $\mathbf{C}^n$. It reads $M^2 = 1/4 + \sum_j \bar{a}_j a_j$, where a_j are certain singular integral operators on S and the index j runs from 1 to $n(n-1)/2$. Had we a solution X of the operator equations $X^2 = -\sum_j \bar{a}_j a_j$ and $MX + XM = 0$, the operators $P^{\pm} = 1/2 \pm M + X$ would be two independent projections on $L^2(S)$, whose sum is $1 + 2X$ and the difference $2M$. Since $M^2 + X^2 = 1/4$ we would not change drastically the C^*-algebra generated by M, by adding the operator $X \approx \sqrt{1/4 - M^2}$ to the

generators. On the other hand, the structure of the C^*-algebra with identity generated by two orthogonal projections is well understood, cf. Halmos (1969), etc. The aim of this paper is to bring together two areas in which elliptic theory plays an important role. The first area is the multidimensional complex analysis studying qualitative properties of solutions to the overdetermined elliptic Cauchy-Riemann system. The second one is the geometric analysis which deals with Dirac operators, i.e., first order matrix factorisations of the Laplace operator. Our approach invokes the diversity of Clifford algebra structures in $\mathbf{C}^n$ to find an adequate representation of M^2. In this way we produce some concrete realisations of the algebra generated by the singular Bochner-Martinelli integral.

References

[1] R. Rosha-Chávez, M. Shapiro, and F. Sommen, *On the singular Bochner-Martinelli integral*, Integr. Equ. Oper. Theory **32** (1998), 354–365.

Quantization of symmetric domains including super-symmetry

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For hermitian symmetric domains (Cartan domains) including the flat Fock space we construct the so-called geodesic calculus which generalizes the standard quantization methods (Berezin calculus, Weyl calculus etc) in a uniform way, based on covariance properties of the geodesic symmetries of the underlying domain. For domains of rank one, a complete analysis including the spectral decomposition of the Berezin transform is given in terms of hypergeometric functions. These concepts and results are then extended to the super-symmetric situation involving Bergman spaces of super-holomorphic functions.

Discrete Geometry
(J.E. Goodman, E. Welzl, G.M. Ziegler)

Contents

Protein Docking using Elevation

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Given a smoothly embedded 2-manifold in 3-space, we define the elevation of a point as the height difference to a canonically defined second point on the same manifold, which is invariant under rigid motions. Elevation is used to define features such as lines of discontinuous or continuous but non-smooth elevation on surfaces. We give an algorithm for finding points of locally maximum elevation, which we suggest mark cavities and protrusions on molecular surfaces. By aligning these features on protein surfaces we present an efficient algorithm to generate a reasonably small but reliable set of coarse protein docking configurations, and then use an iterative algorithm to locally improve the docking configuration. A protein is considered as a rigid body in our approach, and the output produced can serve as input data for other local improvement methods that allow protein flexibility. We demonstrate the performance of our algorithm by testing our algorithm on a diverse set of protein complexes from the Protein Data Bank.

Points and Combinatorics

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A finite point set in the Euclidean plane is the underlying structure for many problems in discrete geometry. For several questions only their combinatorial properties have to be considered and so-called order types are a common tool to provide these combinatorial structure.

In this talk we report on a complete and reliable data base of all realizable order types in the plane (that is, planar point sets) of cardinality up to 11. Moreover we present a novel and efficient method for a complete extension to order types of larger cardinality in an abstract sense, that is, without the need to store or realize the sets.

Based on these results in the second part we present applications of this data base to various problems from discrete geometry. Questions concerning intersection properties, convexity, triangulations, polygonization, and others are addressed. This includes classic problems like searching for (empty) convex k-gons (happy end problem), decomposing sets into convex regions, counting structures like triangulations or pseudo-triangulations. As an outstanding result we have been able to determine the exact rectilinear crossing number for up to $n = 17$ and slightly improved their asymptotic upper bound.

Orthogonal Surfaces in Four and More Dimensions

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Orthogonal surfaces in 3-D are quite well understood. Mild nondegeneracy conditions allow to set them in correspondence to Schnyder woods and 3-connected planar graphs.

In higher dimensions the orthogonal surfaces with a generator set in general position are in a similar correspondence to simplicial polytopes.

Our aim is to understand larger classes of orthogonal surfaces. Some progress and some related problems are the topic of this talk.

The Nesterov rounding and perfectly centered polytopes

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Recently Y. Nesterov has shown that any convex body can be rounded very rapidly by taking the Minkowski sum of itself with a properly scaled dual. More specifically, the asphericity (the ratio of the outer radius over the inner radius) reduces to at least its square root. The purpose of our study is to obtain a combinatorial counterpart of the Nesterov rounding. In particular, we determine the face lattice of the Nesterov rounding applied to perfectly centered convex polytopes.

Here, we say a convex polytope is perfectly centered if every nonempty face intersects with its outer normal fan. We give closed formula for special cases including perfectly centered simplices and hypercubes. Our final goal is to understand the complexity of the Minkowski sum of several convex polytopes.

Linear Programming and Unique Sink Orientations

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I will introduce the framework of unique sink orientations (USO) as a new tool for dealing with linear programs (LP). For certain LP, the USO approach yields the fastest known deterministic combinatorial algorithm. We also obtain a unique canonical solution for any LP, even in the unbounded or the infeasible

case. Connections to quadratic programs and certain linear complementarity problems will be pointed out

Strong General Position for Simplicial Complexes
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In this paper we consider the concept of Strong General Position for simplicial complexes. We will define what is meant by strong general position and provide a proof of an inequality providing a bound on the number of disjoint simplexes in the complex that an affine plane may intersect. The proof handles the finite dimensional cases and then is generalized to the infinite dimensional case and to separable Hilbert Spaces. We will also discuss applications and examples.

Revlex-Initial 0/1-Polytopes
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We introduce revlex-initial 0/1-polytopes as the convex hulls of reverse-lexicographically initial subsets of 0/1-vectors. These polytopes are special knapsack-polytopes. It turns out that they have remarkable extremal properties. In particular, we use these polytopes in order to prove that the minimum numbers $f(d,n)$ of facets and the minimum average degree $g(d,n)$ of the graph of a d-dimensional 0/1-polytope with n vertices satisfy $f(d,n) \leq 3d$ and $g(d,n) \leq d+8$. We furthermore show that, despite the sparsity of their graphs, revlex-initial 0/1-polytopes satisfy a conjecture due to Mihail and Vazirani, claiming that the graphs of 0/1-polytopes have edge-expansion at least one.

On the vacancy phenomenon in finite sphere packings

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What is the minimum radius $r_n(k)$ of a spherical container in $\mathbb{R}^n$ that can hold k unit balls? The exact answer is known only in a few cases. For $n > 2$, all of the solved cases are essentially due to R.A. Rankin (1955), and they are limited to $k \leq 2n$. However small this number of cases is, some of them display an interesting phenomenon: the value of $r_n(k)$ can remain constant for several consecutive values of k (with n fixed). In other words, it can happen that if a spherical container is large enough to accommodate k unit balls, then there is still room in it for a few more. Specifically, Rankin's result is that $r_n(n+2) = r_n(2n)$, which shows that, for sufficiently large n, the vacancy ratio $\frac{m}{k+m}$, associated with the occurrence of $r_n(k) = r_n(k+m)$, can be arbitrarily close to $1/2$. Here we prove that this ratio cannot reach $1/2$, for any n. We then discuss the same phenomenon for packing balls, or translates of another body, in convex containers of various shapes.

All rational convex polytopes are 3-way transportation polytopes

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In this talk we discuss the following theorem:

Theorem. Any rational convex polytope is polynomial-time representable as a $3 \times r \times c$ line-sum transportation polytope. This universality result has important consequences in discrete optimization and statistics.

Valuations on Simplices

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A function $mu : \mathcal{S} \to \mathbb{R}$ defined on a class $\mathcal{S}$ of sets is called a *valuation* if

$$\mu(S) + \mu(T) = \mu(S \cup T) + \mu(S \cap T) \quad \text{for} \quad S, T, S \cap T, S \cup T \in \mathcal{S}.$$

The classical examples concern valuations on convex polytopes. A result of Volland and Groemer shows that any such valuation can be extended to a valuation on finite unions of convex polytopes.

Here the question is asked whether a valuation only defined on simplices can always be extended to a valuation on convex polytopes. The answer is *yes* and the proof combines classical tools from algebraic topology with a shelling type argument.

Volume bounds for lattice tetrahedra

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Douglas Hensley was the first to prove that for each d and k there exists a constant $V(d,k)$ such that the volume of any d-dimensional lattice polytope that contains k interior lattice points is at most $V(d,k)$. In this talk, we will prove the optimal value $V(3,k) = 12k + 8$ for the special case of lattice tetrahedra with empty facets that contain k interior lattice points.

A New Methodology in Geometric Transversal Theory

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We describe a new encoding of a family of mutually disjoint compact convex sets that captures many of its combinatorial properties and use it to give a new proof of the Edelsbrunner-Sharir theorem that a collection of n mutually disjoint compact convex sets in the plane cannot be met by straight lines in more than $2n - 2$ combinatorially distinct ways. The encoding generalizes our encoding of planar point configurations by "allowable sequences" of permutations. Since it applies as well to a collection of compact connected sets with a specified pseudoline arrangement $\mathcal{A}$ of separators and double tangents the result extends the Edelsbrunner-Sharir theorem to the case of geometric permutations induced by pseudoline transversals compatible with $\mathcal{A}$.

Strictly convex drawings of planar graphs
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Every three-connected planar graph with n vertices has a drawing on an $O(n^2) \times O(n^2)$ grid in which all faces are strictly convex polygons. These drawings are obtained by perturbing (not strictly) convex drawings, which are known to exist on $O(n) \times O(n)$ grids. The proof combines techniques from graph drawing and the geometry of numbers.

Convexity in Polyhedral Spaces
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Some fundamental ideas of convex geometry can be transported to topological spaces without linear structure or Riemann metric – e.g., polyhedral manifolds form an interesting class of examples, although much more general topological spaces could and should be considered in this context. The talk will focus on convex and combinatorial properties of immersed hypersurfaces in polyhedral and more general spaces. Results and conjectures that will be presented will mostly concern extremal structure of locally convex hypersurfaces.

This is a preliminary report on the work in progress.

Pseudo-triangulations, rigidity and planar graphs
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Pseudo-triangulations of polygons or planar point sets generalize triangulations and have been studied in Computational Geometry for ten years, with applications in visibility and kinetic data structures, among other things.

A turning point in the study of pseudo-triangulations came in 2000, when Ileana Streinu found very nice coonnections between them and rigidity of plane structures, and used these connections to give a second proof of the Carpenter's Rule Theorem (every simple polygon can be convexified by a continuous motion). Since then, the relation between pseudo-triangulations, planarity and rigidity has been investigated further, giving rise to, for example, the following results:

Theorem (Hass, Orden, Rote, Santos, Servatius, Servatius, Souvaine, Streinu, Whiteley): A planar graph is isostatic (i.e., minimally generically rigid) in the plane if and only if it is the graph of a pointed pseudo-triangulation.

Theorem (Orden, Santos, Servatius, Servatius): A planar graph is generically rigid in the plane if and only if it is the graph of a pseudo-triangulation.

Counting crossing-free configurations in the plane

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We derive improved upper and lower bounds on the number of crossing-free configurations of various kinds that are determined by a set of n points in the plane. For example, we show that the number of crossing-free perfect matchings in such a set is 10.52^n. We also consider (crossing-free) perfect bipartite matchings, partitions, hamiltonian paths and cycles, and "safe" hamiltonian paths.

Isothetic parallelotopes and the binary intersection property

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Let $\mathcal{F} = \{C_\lambda\}$ be a family of convex polytopes in E^d, $d \geq 2$. We say that $\mathcal{F}$ has the strong binary intersection (SBI) property if for any set $\{v_\lambda\}$ of vectors in E^d the family of translates $\mathcal{F}' = \{v_\lambda + C_\lambda \mid C_\lambda \in \mathcal{F}\}$ has the binary intersection property (Helly number two, in other terminology), i.e., from the fact that any two elements of $\mathcal{F}'$ have a point in common it follows that the members of $\mathcal{F}'$ have a point in common. We prove that a family $\mathcal{F}$ with at least five members has the SBI property if and only if the members of $\mathcal{F}$ are isothetic parallelotopes, i.e., the edges of these parallelotopes are parallel to some d linearly independent directions of E^d.

Halving the colors of a Kneser coloring
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Given a $(2n + k)$-element set P, color the n-subsets of A by $k + 2$ colors so that any pair of disjoint n-subsets have different colors (a Kneser coloring). Then for any partition of the colors into two "halves" C_1 and C_2 (whose sizes differ by at most 1) there is a partition of P into two sets P_1 and P_2 whose n-subsets realize the colors (and only those colors) of C_1 and C_2, respectively, and moreover, both P_1 and P_2 are at least $1/4$ the size of P. This strengthens a 1982 result of Fan. We give two proofs: a topological proof that depends on the Lusternik-Schnirelmann-Borsuk theorem, and a constructive combinatorial proof that depends on Fan's generalization of Tucker's lemma. Finally, we give generalizations for more than $k+2$ colors and suggest social applications of this result.

On the frontiers of polynomial computations in tropical geometry
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We study some basic algorithmic problems concerning the intersection of tropical hypersurfaces in general dimension: deciding whether this intersection is nonempty, whether it is a tropical variety, and whether it is connected, as well as counting the number of connected components. We characterize the borderline between tractable and hard computations by proving $\mathcal{NP}$-hardness and $\#\mathcal{P}$-hardness results even under various strong restrictions of the input data, as well as providing polynomial time algorithms for various other restrictions.

k-Sets and Topological Invariants of Plane Curves
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A k-set of a finite point set in Euclidean space is a subset of cardinality k that can be spearated from its complement by a hyperplane. These are basic and well-studied objects in discrete and computational geometry, with numerous, and sometimes surprising, relations to other problems, such as Groebner bases, g-vectors of convex polytopes, or rectilinear crossing numbers of complete graphs. At the same time, a number of fundamental questions are still open, most notably: What is the maximum number of k-sets that an n-point set in d-space

can have (where d is considered constant and k, n tend to infinity)? Even in the plane, there remains a wide gap between the currently best lower and upper bounds of $n \cdot \exp(\sqrt{\log k})$ and $nk^{1/3}$, respectively. The upper bound is proved by analyzing the number of crossings between objects closely related to k-sets, so-called k-edges (these are pairs of points from the ground set such that the line they span dissects the remaining points into parts of size k and $n-2-k$, respectively). The collection of k-edges of a point set naturally decomposes into locally convex closed cycles. Motivated by the analysis of crossings, we study other topological invariants of these cycles (interpreted as plane curves), such as the Whitney index (or global winding number) and the so-called $J^{\pm}$ invariants of plane curves introduced by Arnold' in the early 1990's. The partial results I could obtain so far do not yield any improved bounds for the number of k-sets, but I would like to make the case that this viewpoint is interesting and deserves further study.

Ehrhart polynomial and successive minima

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We investigate the zeros of the Erhart polynomial for centrally symmetric convex bodies and show that there are close relations to Minkowski's successive minima.

Functional Analytic and Complex Analytic Methods in Linear Partial Differential Equations (R. Meise, B.A. Taylor, D. Vogt)

Contents

Divergent power series solutions of partial differential equations

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Many partial differential equations have power series solutions that diverge. Very recent results show that some, but not all, of them can be summed, either using the technique of k-summability in the sense of *J.-P. Ramis*, or the more powerful method of multisummability founded by *J. Ecalle*. The general theory then implies that the sum is an analytic function that solves the PDE, and is asymptotic to the formal solution as one, or several, variables tend to the origin in a certain (poly-)sector in the complex space of corresponding dimension. Whether or not a more sophisticated method exists that can sum all such power series, with the sum having the same natural properties, is an open question.

The role of the Radon transform in inverse conductivity type problems

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The Radon transform plays a very important role in the monitoring of traffic flow in networks. This problem is akin to the inverse conductivity problem in continuous media, often known as the inverse Dirichlet-to-Neumann problem. We will discuss how known results in the continuous case can lead to obtaining useful results about network monitoring.

The dual of the space of holomorphic functions on locally closed convex sets

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Let $H(Q)$ be the space of all the functions which are holomorphic on an open neighbourhood of a convex locally closed subset Q of C^N, endowed with its natural projective topology. The strong dual $H(Q)'$ of each of these spaces can be canonically identified, via the Laplace transform, with a weighted (LF)-space of entire functions on C^N, i.e. $H(Q)'$ is isomorphic to a Hausdorff countable inductive limit of Fréchet spaces of entire functions defined by weighted supnorms. We study when the topology of this weighted inductive limit of Fréchet

spaces can be described by weighted sup-seminorms. We derive necessary as well as sufficient conditions for the projective description to hold algebraically or topologically. In particular, we have algebraic and topological projective descriptions if Q is strictly convex at the relative boundary in a certain sense. The behaviour of the corresponding inductive limit of spaces of continuous functions is also investigated.

Limit varieties and existence of continuous linear right inverses for constant coefficient partial differential operators

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It is known from work of Meise, Taylor, and Vogt that the existence of a continuous linear right inverse for a constant coefficient partial differential operator $P(D)$ on $C^\infty(R^3)$ can be characterized by a Phragmén-Lindelöf condition on the variety $V(P)$ of the symbol of the operator. Recently, we have given a geometric characterization of this Phragmén-Lindelöf condition. There, two types of conditions come up, namely specially crafted hyperbolicity conditions and Phragmén-Lindelöf conditions on limit varieties. In the talk, we will indicate how these hyperbolicity conditions can be replaced by some more Phragmén-Lindelöf conditions on limit varieties. It should be noted that, while the variety $V(P)$ is a surface, the limit varieties are curves. Hence the result can be interpreted as a reduction of dimension.

Holomorphic dependence of solutions of linear pde on spaces of distributions and splitting of short exact sequences

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Let $\Omega \subseteq \mathbb{R}^d$ be a convex set and let $P(D) : \mathcal{D}'(\Omega) \to \mathcal{D}'(\Omega)$ be a (necessarily surjective) linear partial differential operator with constant coefficients. We show that if (f_λ) is a family of distributions depending holomorphically on $\lambda \in U$, U a Stein manifold, then there exists another family $(u_\lambda) \subseteq \mathcal{D}'(\Omega)$ depending holomorphically on $\lambda \in U$ such that

$$P(D)u_\lambda = f_\lambda \qquad \text{for every } \lambda \in U.$$

Some other analogous parameter dependence results are proved as well.

The proofs are based on the splitting theory (which is also presented here) for short exact sequences of the form

$$0 \longrightarrow X \longrightarrow Y \longrightarrow E \longrightarrow 0,$$

where X, Y, E are projective limits of sequences of duals of nuclear Fréchet spaces. In particular, we characterize pairs (X, E) for which each sequence of the form above splits whenever E is either a nuclear Fréchet space or the dual of such a space and X is ultrabornological.

Boundary value problems on piecewise domains

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We examine the inhomogeneous Dirichlet problem on a piecewise smooth domain. In particular, we are interested in the behavior of the solution near a singular part of the boundary. We obtain an asymptotic expansion of the solution with higher order terms exhibiting increasing degrees of smoothness up to the boundary.

Pseudodifferential operators and time-frequency analysis

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We characterize the compactness on $L^2(R^d)$ of pseudodifferential operators as introduced by Weyl and having symbols in the modulation class $M^{\infty,1}(R^{2d})$ using time-frequency methods. Since localization operators can be represented as Weyl operators, we give a complete characterization of those localization operators $L^F_{\varphi,\psi}$ that are compact on $L^2(R^d)$ for each pair of windows $\varphi, \psi \in \mathcal{S}(R^d)$

Convolution equations for ultradifferentiable functions and ultradistributions

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We characterize surjectivity of convolution operators on spaces of ultradifferentiable functions and ultradistributions of Beurling type in the sprit of Hörmander's convexity conditions. This completes results of Bonet, Galbis and Meise. In contrast to the classical approach our proofs only use properties of ultradistributions and functional analytic tools.

Mean value and microlocal characterization of pluriharmonic and separately harmonic functions.

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Plurihamonic and separately harmonic functions satisfy integral identities that extend the Gauss mean value property for harmonic functions. We consider the inverse problem of characterizing such function spaces by mean value properties for restricted classes of contours. This involves microlocal analysis and geometric properties of the characterizing contours.

Corona type decomposition in a locally convex weighted-sup space of holomorphic functions

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Assume that D is a subset of $\mathbb{C}^n, n > 1$ defined by a smooth function r, which is non-degenerate on bD. The symbol $HW(D)$ stands for the algebra of all holomorphic functions, which can be estimated by some power of $\big|\log|r(z)|\big|$. This space appears naturally, when one studies regularity of the Bergman projection.

We shall characterize these tuples $g_1, \dots, g_m \in HW(D)$, for which there exist functions $f_1, \dots, f_m \in HW(D)$ such that

$$1 = \sum_{k=1}^{m} f_k(z) g_k(z)$$

for $z \in D$.

Although the problem bears some resemblance to the celebrated corona problem, the solution is much easier. Basically, one can make use of the method introduced by Hörmander in his study of the algebra A_p.

In the talk we intend to cover the case of strictly pseudoconvex domains and convex domains of finite type.

Surjective partial differential operators and almost regular elementary solutions

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We will discuss the class of partial differential operators $P(D)$ with constant coefficients which are surjective on the space $A(U)$ of real analytic functions defined on an open subset U of $\mathbb{R}^n$. These operators can be characterized by the existence of hyperfunction shifted elementary solutions on U which are real analytic near an arbitrary compact subset of U. For halfspaces U this characterization can be improved considerably: we then obtain an elementary solution on $\mathbb{R}^n$ which is real analytic on U. The characterization implies that $P(D)$ is surjective on $A(\mathbb{R}^n)$ if P(D) is surjective on $A(U)$ for some $U \neq \emptyset$. Further inheritance properties will be studied. We will also discuss the connection of surjective partial differential operators to locally hyperbolic operators and to the extension of analyticity for zero solutions of $P(D)$. The proofs are based on the $Proj^1-$ functor of Palamodov and the solvability of a certain overdetermined system of partial differential operators on non convex sets.

Schottky Type Estimates for Meromorphic Solutions of Partial Differential Equations

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We give a Schottky type estimate for meromorphic solutions of certain linear and non-linear partial differential equations. Relations with normal families of meromorphic functions in complex domains of C^n and the logarithmic partial derivatives will be also given.

Spectral Riemann Surfaces for a Class of Tri-diagonal Matrices

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For a large class of tri-diagonal matrices the Spectral Riemann Surfaces (SRS) are analyzed and it is proven that they are irreducible.

Anisotropic modules over a polynomial algebra

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For a given a linear mapping $p : X \to Y$ of spaces of finite dimension we define spaces Φ of smooth functions (distributions) f in X with an anisotropic growth property: f grows slowly or decays fast along fibers of p, this mapping is proper on the support of f, the pull down of the support is bounded and so on. The space Φ is still a module over the algebra of translation invariant differential operators on X. The problem of injectivity and flatness of modules of this kind will be discussed.

Explicit extension maps in intersections of non quasi-analytic classes

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We deal with projective limits of classes of functions and obtain that
(a) the Tchebichev polynomials constitute an absolute Schauder basis in the nuclear Fréchet space $E_{(M)}([-1,1]^r)$;
(b) there is no continuous linear extension map from $\Lambda^r_{(M)}$ into $E_{(M)}([-1,1]^r)$;
(c) under some additional assumption on M, there is an explicit extension map from $E_{(M)}([-1,1]^r)$ into $D_{(M)}([-2,2]^r)$ by use of a modification of the Tchebichev polynomials.

These results extend those of Mityagin in the C^∞-case and of Beaugendre in a similar but less general case.

Clifford analysis in the Hermitian setting

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In this paper we present special systems with values in a complex Clifford algebra which transform under the unitary group in several complex variables. In particular we are interested in basic function theoretic properties such as the decomposition of complex polynomials in Hermitian spherical monogenics and versions of the Cauchy-Kowalewski extension theorem. These systems were earlier considered in a different context in [1] and [2] and give rise to a generalization of the Martinelli-Bochner formula.

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Effective algorithms for the construction of noetherian operators

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The Fundamental Principle of Ehrenpreis-Palamodov provides an integral formula for the general solutions of systems of linear partial differential equations with constant coefficients. The formula is based on the existence of suitable operators (noetherian operators) which give a differential membership criterion for a given ideal/module. In this talk I will discuss recent work towards the effective construction of such operators. I will show how to use modern techniques from the theory of Groebner bases to provide actual algorithms, which can be easily coded.

Phragmén-Lindelöf conditions and properties of linear partial differential operators

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We survey some connections between properties of constant coefficient linear partial differential operators that are equivalent to the validity of certain estimates for plurisubharmonic (psh) functions on the algebraic varieties of the symbols of the operators. There are several different sets of estimates that correspond to different properties of the operators, such as surjectivity on various function spaces or the existence of linear continuous solution operators. The estimates are called Phragmén-Lindelöf conditions because of their analogy with the classical theorem of Phragmén and Lindelöf that gives a uniform bound in terms of $|\text{Im } z|$ for subharmonic functions of the form $\log |f(z)|$ where f is entire, bounded by one on the real axis, and of exponential rate of growth. Recent joint work with R. Braun and R. Meise about the geometric properties of varieties that satisfy two of these Phragmén-Lindelöf conditions, the ones called SPL and PL(ω), will be outlined. For varieties of dimension 1 and 2, these geometric conditions provide a complete characterization of the algebraic varieties that satisfy the two conditions.

Partial differential operators modulo smooth functions

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For a constant coefficient linear partial differential operator $P(D)$ on $\mathcal{D}'(\Omega)$ we provide new characterizations when

$$\mathcal{D}'(\Omega) \times \mathcal{E}(\Omega) \to \mathcal{D}'(\Omega),\ (u, f) \mapsto P(D)u + f$$

is surjective and when it has a continuous linear right inverse. Both results are in the spirit of a celebrated result of Meise, Taylor, and Vogt who characterized right invertibility of $P(D)$ on $\mathcal{D}'(\Omega)$ by properties of fundamental solutions.

Algebraic tomography; about Abel and Abel-Radon transforms and their inversion

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The Abel-Radon tranform can be thought as the Radon transform of "thin sets". It is deeply connected with the concepts of finite trace and multidimensional residues. The usual setting is the projective setting ; we will discuss here other geometric situations (analyzed from the intrinsic point of view) such as toric ones. We will also analyse the crucial role of particular differential operators and the "rigidity" the GAGA principle implies for particular differential systems linked with Abel's inverse theorem. The lecture will be based on joint work in progress with C.A. Berenstein and A. Vidras and on recent approaches due to B. Fabre and M. Weimann.

Harmonic transfinite diameter of a compactum in $\mathbb{R}^{p+2}$

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By analogy with the classical approach in $\mathbb{C}^n$ (F. Leja) we define the *harmonic transfinite diameter* $d^h(K)$ of a compact set K in $\mathbb{R}^{p+2}$, $p \geqslant 0$. Using a construction similar to [1], we introduce the notion of the *main harmonic Chebyshev constant* $\tau^h(K)$ defined as the geometric mean of *directional harmonic Chebyshev constants* of K. On the other hand, the notion of Lh-Green function [2] leads to a certain natural definition of *Lh-capacity* $C^h(K)$. We discuss the connection among these concepts. In particular, it is shown that, under certain restrictions, $d^h(K) = \tau^h(K)$. Applying this equality to spheroids in $\mathbb{R}^3$ we obtain an explicit formula for their harmonic transfinite diameters; the evaluation is based on some special asymptotics of the associated Legendre functions suggested in [2] and the formula describing the relation between spherical and spheroidal harmonics [3].

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Function Spaces and their Operators (E. Albrecht, R. Mortini, W. Ross)

Contents

Preduals of Q_p spaces and Carleson imbeddings for weighted Dirichlet spaces

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We prove a weak factorization result for the predual of the space Q_p on the unit disc, that is, we show that functions in this space can be written as sums of products of functions in given weighted Dirichlet and Bergman spaces with the usual control on the norms. With this representation we investigate the relation between Q_p and Carleson inequalities for functions in weighted Dirichlet spaces and, in particular, we prove a characterization of bounded Q_p-functions in terms of pointwise multipliers between such spaces. Our approach is based on imbeddings in vector-valued sequence spaces and yields also atomic decompositions of the predual of Q_p.

Stability of bases and frames of reproducing kernels in model subspaces

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Let Θ be an inner function. We study the problem of stability of Riesz bases and frames of reproducing kernels in the model subspaces $K_\Theta = H^2 \ominus \Theta H^2$ of the Hardy class H^2 under small perturbations. Our approach is based on the recently obtained estimates of derivatives in the model subspaces.

Hyponormal operators and weak forms of supercyclicity

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An operator T on a Hilbert space H is said to be N-supercyclic (resp. weakly supercyclic) if it admits a subspace E of dimension N (resp. of dimension 1) such that the orbit of E under T is norm-dense (resp. weakly dense) in H. We study whether or not a hyponormal operator may be N-supercyclic or weakly-supercyclic. This leads us to connections with thin sets of Harmonic Analysis.

Sampling and interpolation in weighted spaces of analytic functions

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We discuss sampling and interpolation theorems in large (radial) weighted Bergman and Fock spaces.

Large linear manifolds of noncontinuable boundary-regular holomorphic functions

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Let G be a domain in the complex plane. We denote by $H_e(G)$ the set of all holomorphic functions on G having G as its domain of holomorphy.

In 1884 Mittag–Leffler discovered that $H_e(G)$ is not empty. In 1933 Kierst and Szpilrajn [4] showed that for the unit disc $\mathbb{D}$ the above property is generic, in the sense that $H_e(\mathbb{D})$ is residual. Recently Kahane [3] and Bernal [1] have generalized this result to any domain G and to subspaces X of holomorphic functions on G satisfying some conditions. In particular X can be considered as the space $A^\infty(G)$ of boundary-regular holomorphic functions on G.

In 2005 Bernal, Calderón and Luh [2] prove that if G is a domain in the complex plane satisfying adequate topological or geometrical conditions then there exists a large (dense or closed infinite-dimensional) linear submanifold of $A^\infty(G)$ all of whose nonzero members are not continuable across any boundary point of G.

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A new approach to the invertibility of a class of Wiener-Hopf operators

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The invertibility of Wiener-Hopf operators in $L_2(\mathbb{R})$ with symbol G, where G is a 2×2 matrix function whose entries are essentially bounded functions in $\mathbb{R}$, is studied by analysing the solutions of an associated Riemann-Hilbert problem. It is shown that for certain classes of symbols G all the solutions to that problem can be obtained by a simple transformation of a particular one and can be used to obtain the invertibility of T_G as well as its inverse. We apply this method to some concrete examples.

Extension of vector valued holomorphic and harmonic functions

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We present a unified approach to study extensions of vector valued holomorphic or harmonic functions from the existence of weak or weak*-holomorphic or harmonic extensions. Several recent results due to Arendt, Nikolski, Enflo, Smithies, Bierstedt, Holtmanns and Grosse-Erdmann are extended. An open problem posed by Grosse-Erdmann is solved in the negative. Using the extension results we prove existence of Wolff type representations for the duals of certain function spaces.

Refined polar decomposition for complex symmetric operators

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The class of complex symmetric operators includes all normal, Hankel, and compressed Toeplitz operators. It also includes the Volterra operator and many integral and differential operators. We discuss a refinement of the classical polar decomposition for such operators and several applications.

Lacunary summability and analytic continuation of power series
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In this talk summability methods of weighted mean type are going to be discussed which are generated by lacunary sequences. A result on the summability of the geometric series is proved which has far-reaching consequences with respect to general analytic continuation of power series into their α-Mittag-Leffler-star, to overconvergence as well as to the universal behavior of trigonometric series in the sense of Menshov.

Strong Dunford-Pettis Sets and Elton's Trichotomy
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J. Elton used an application of Ramsey theory to show that if X is an infinite dimensional Banach space, then c_0 embeds in X, ℓ_1 embeds in X, or there is a subspace of X which fails to have the Dunford-Pettis property. Bessaga and Pelczynski showed that if c_0 embeds in X^*, then ℓ_∞ embeds in X^*. Emmanuele and John showed that if c_0 embeds in $K(X,Y)$, then $K(X,Y)$ is not complemented in $L(X,Y)$. Classical results from Schauder basis theory are used in a study of Dunford-Pettis sets and strong Dunford-Pettis sets to extend each of the preceding theorems.

The parabolic compactification and its application to the approximation of unbounded functions
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The properties of a compactification that maps the n dimensional Euclidean space onto a "parabolic bowl" are studied. Explicit formulas of the induced bijection are derived. The explicit formulas of an induced metric are also obtained. These formulas are instrumental in obtaining rational approximations for unbounded functions. An extension to the celebrated theorem of Weierstrass is obtained. It is shown that an unbounded function on a closed interval can be approximated by rational functions. An extension to Fourier type theorems is also obtained. It is shown that an unbounded periodic function can be approximated by quotients of trigonometric polynomials. The approximations do

not require the approximated function to possess a restricted order of growth. Neither do they require that the approximated function possess any amount of smoothness. Moreover, the numerator and denominator, in an approximating quotient, are guaranteed not to vanish simultaneously. Furthermore, some of the proposed approximations are guaranteed to be bounded whenever the approximated function is bounded.

Frequently hypercyclic operators on Banach spaces

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We study some properties of the dynamical system associated with a bounded operator T on a separable complex Banach space X: hypercyclicity (there exists a vector which has a dense orbit under the action of T), frequent hypercyclicity (there exists a vector x with the property that the set of integers n such that $T^n(x)$ belongs to U has positive lower density for any non empty open subset U of X), existence of gaussian measures with respect to which T defines a measure-preserving ergodic transformation, etc... We consider some extensions to the Banach space setting of results which were obtained previously in the Hilbert space setting.

Kernels of Toeplitz operators and extremal functions

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A Toeplitz operator on a Hardy space is a truncated multiplication operator, which means that it multiplies elements of the Hardy space by a fixed essentially bounded function and projects the product back to the Hardy space (when possible). Toeplitz operators play an important role in different areas of mathematics,such as stochastic processes, polynomial approximation, and free interpolation etc. In addition to the spectral properties of the operator, the study of properties such as injectivity and left invertibility (hence surjectivity) is also of interest. It turns out that the extremal function associated with the kernel of a Toeplitz operator contains quite a bit of information about these properties. We will present a couple of results in this context; some of them going back to Hitt, Hayashi and Sarason, but will also discuss some newer ones.

Compactness properties of multiplication operators

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We present several characterizations of weak compactness and complete continuity of multiplication operators acting on spaces like $L^1(\mu)$, $L^\infty(\mu)$, and the classical Hardy space H^1. We also indicate how these results generalize to multiplication operators on general von Neumann algebras, their preduals, etc.

Boundary properties of uniform Frostman Blaschke products

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A Blaschke product $B(z) = \prod_{n=1}^{\infty} \frac{|a_n|}{a_n} \frac{a_n - z}{1 - \overline{a_n} z}$ is uniform Frostman if the quantity

$$\sigma(B) = \sup_{\zeta \in \mathbb{T}} \sum_{n=1}^{\infty} \frac{1 - |a_n|^2}{|\zeta - a_n|}$$

is finite. Frostman showed that the sum is finite at $\zeta \in \mathbb{T}$ if and only if B and all of its subproducts have radial limits at ζ. The uniform Frostman condition $\sigma(B) < \infty$ imposes strong geometric constraints on the zero set of B. In particular, it is a finite union of interpolating sequences, and meets every Stolz region in a finite number of points, the number bounded by a constant depending only on $\sigma(B)$.

We discuss the boundary zero spectra of uniform Frostman Blaschke products and the limit properties of functions in the star-invariant subspaces K_B^p determined by these Blaschke products.

Function theory on bounded varieties

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By a bounded variety we mean the intersection of some one dimensional variety with a bounded domain in C^n. Consider for example the intersection V of $\{z^2 = w^2\}$ with the bidisk. This is just two disks with a common center. It is easy to see that the obstruction to a finite set in V being the zero set of a rational inner function is given by one real number, as is the obstruction to a real-valued function on ∂V being the real part of a holomorphic function on V.

When one looks at more complicated varieties, such problems become harder to resolve. Operator theory is very useful in shedding light on the function theoretic questions that arise. I shall discuss several examples.

Linear Relations in the Calkin Algebra for Composition Operators
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We consider linear relations in the Calkin algebra for composition operators and related questions: When is a finite linear combination of composition operators, acting on the Hardy space or the standard weighted Bergman space on the unit disk, a compact operator?

Mean-periodicity and cyclicity of entire functions
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Every entire function $\Phi(w) = \sum_{\nu=0}^{\infty} a_\nu w^\nu$ of exponential type induces an infinite order differential operator $T = \Phi(D) = \sum_{\nu=0}^{\infty} a_\nu D^\nu$ on the space of entire functions. An entire function is called mean-periodic, if it belongs to the kernel of some $T \neq 0$. We shall investigate the dichotomy of mean-periodicity and (hyper-)cyclicity of entire functions.

Condition Numbers of Large Matrices and Analytic Capacities
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Bounds for condition numbers CN(T) of nxn matrices T satisfying an A-functional calculus are expressed in terms of the A-analytic capacity of the spectrum. In the case of the Besov spaces A= B(s,p,q) this leads to a sharp asymptotic for CN(T) as n tends to infinity. The Beurling-Carleson capacity and peripheral spectrum effects are also considerd.

Carleson potentials and analytic embedding in the unit ball of C^n

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We present a simple proof of the analytic Carleson Embedding Theorem on the unit ball in C^n. The only technical tool used is Green's formula. The starting point is that every Carleson measure gives rise to a bounded function with certain nice properties that itself gives rise to a new, related Carleson measure that allows for a simple embedding. The proof improves the best known embedding constant for small dimension drastically, but does not give good constants for large dimension.

Operators generating maximal radial cluster sets

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Given a complex-valued function F defined on the unit disk $\mathbb{D}$ and a subset A of $\mathbb{D}$, the *cluster set* of F along A at the point t_0 of the boundary $\mathbb{T}$ of $\mathbb{D}$ is defined as follows:

$$C_A(F,t_0)=\{\omega\in\widehat{\mathbb{C}}:\ \exists(z_n)_n\subset A \text{ with } z_n\to t_0 \text{ and } F(z_n)\to\omega\}.$$

When A is the radius ending at t_0, the *radial cluster set* of F at t_0 is the set $C_\varrho(F,t_0):=C_A(F,t_0)$. Several authors have studied the existence of holomorphic functions with maximal cluster sets (equal to $\widehat{\mathbb{C}}$).

In this talk we will present sufficient conditions on an operator T acting on $H(\mathbb{D})$ to enjoy the property that the image by T of "most" functions $f\in H(\mathbb{D})$ have maximal radial cluster set at any boundary point. We will also show that many classical operators have the behavior mentioned.

Zero Sets of Analytic Functions

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We discuss some old and new questions and results concerning zero sets of functions in certain spaces of analytic functions.

Isometries among the composition operators

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We characterize all composition operators that are isometries (surjective or not) of the following spaces (in the increasing order of difficulty): Hardy spaces H^p and Bergman spaces A^p, the Dirichlet space D, and the Bloch space B, with some surprising examples in the case of B. This complements the well known results of Nordgren, Shapiro, Cima, Wogen, and others.

Toeplitz operators on the Bloch spaces

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We will consider the boundedness and the compactness of general, measure induced Toeplitz operators on the Bloch type spaces. We give conditions that are a generalization of the well known conditions for boundedness and compactness of the multiplication operators on the Bloch type spaces.

Geometric Analysis (V. Nistor, E. Schrohe)

Contents

A Continuous Field of C^*-algebras and the Tangent Groupoid for Manifolds with Boundary

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For a smooth manifold X with boundary we construct a semigroupoid $\mathcal{T}^- X$ and a continous field $C_r^*(\mathcal{T}^- X)$ of C^*-algebras which extend Connes' construction of the tangent groupoid.

We show asymptotic multiplicativity of h-scaled truncated pseudodifferential operators with smoothing symbols and compute the K-theory of the associated symbol algebra.

A gluing formula for a numerical invariant of spin manifolds

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Let M be a compact manifold with a fixed spin structure χ. For any conformal class $[g]$, let $\lambda(M, [g], \chi)$ denote the infimum of the first nonnegative eigenvalue of the Dirac operator on (M, g, χ) over all metrics in $[g]$ of volume 1. Furthermore, we define $\tau(M, \chi)$ to be the supremum of $\lambda(M, [g], \chi)$ over all conformal classes.

These invariants are tightly related to the Yamabe problem, Schoen's σ-constant, the positive mass theorem, constant mean curvature surfaces in $\mathbf{R}^3$ and constant mean curvature hypersurfaces in Calabi-Yau manifolds.

The τ-invariant is positive if and only if (M, χ) carries a metric without harmonic spinors. There are several results supporting C. Baer's conjecture that $\tau(M, \chi) > 0$ unless if there is an index theoretical obstruction.

We derive a gluing formula for the τ-invariant.

If time permits, we will mention how analysis on non-compact asymptotically hyperbolic manifolds fits naturally into the results stated above.

An index theorem in Haefliger cohomology of foliations

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We review Gysin maps in K-theory for smooth algebras of foliations and define Gysin maps in Haefliger cohomology. We then show the compatibility of these maps with the Chern character. This allows us to deduce an index theorem in Haefliger cohomology.

A K-theory proof of the cobordism invariance of the index

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It is a well-known fact that the Fredholm index of twisted signature operators on compact manifolds is invariant under cobordism. We give here a proof of cobordism invariance for the index of general elliptic pseudodifferential operators whose symbol classes satisfy a certain condition in K-theory.

Our proof relies on properties of the push-forward map in K-theory. We consider embeddings of manifolds with boundary and show that the condition for cobordism invariance is preserved under push-forward, so that the problem can be reduced to $\mathbb{R}^n$.

This result holds also on noncompact manifolds, where here the operators are assumed to be multiplication outside a compact set. In particular, we extend the invariance of the index with respect to the push-forward map, and obtain as a by-product an extension of the K-theory index formula of Atiyah and Singer for these operators.

A Lipschitz estimate for Berezin's operator calculus

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F.A. Berezin introduced a general "symbol calculus" for linear operators on reproducing kernel Hilbert spaces. For the particular Hilbert space of Gaussian square-integrable entire functions on complex n-space, I obtain Lipschitz estimates for the Berezin symbols of arbitrary bounded operators. Additional properties of the Berezin symbol and extensions to more general reproducing kernel spaces are discussed.

Spectral theory of fat graphs
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A fat graph is a family of manifolds with boundary, depending on a parameter ϵ, modelled on the ϵ-neighborhood of a graph embedded in Euclidean space. We are interested in the behavior of the spectrum of the Laplacian as ϵ tends to zero. For Neumann boundary conditions (or for closed manifolds) the leading asymptotic behavior of the eigenvalues was described by Exner and Post in 2003. We consider the case of Dirichlet boundary conditions. It turns out that this carries some new aspects compared to the Neumann case, in particular the relation to a scattering problem becomes essential.

Trace defect formulas for manifolds with and without boundary
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One trace functional on all classical pseudodifferential operators A on a closed manifold is the noncommutative residue res(A) introduced by Wodzicki and Guillemin. This does not extend the standard trace, but so does Kontsevich and Vishik's canonical trace TR(A), defined in particular cases. The functional TR(A) identifies with the coefficient $C_0(A,P)$ of $(-\lambda)^{-1}$ in the trace expansion of $A(P-\lambda)^{-1}$ with an auxiliary elliptic operator P. Generally, $C_0(A,P)$ is not a trace on A independent of P, but the trace defects $C_0(A,P)-C_0(A,P')$ and $C_0([A,A'],P)$ are residues of related operators (Okikiolu, Kontsevich-Vishik, Melrose-Nistor).

Thanks to a simplified proof of this, based directly on resolvents (avoiding complex powers), we can show extensions of the trace defect residue formulas to operators on manifolds with boundary.

Tangent spaces of singular manifolds
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We will describe a notion of tangent spaces for singular manifolds and extend to this setting the duality in K-theory between the algebras of continuous functions on a manifold and on its cotangent space.

Moreover, we will explain how these tangent spaces and their K-theory are related to analysis of elliptic operators on singular manifolds.

Generalized Bergman kernels on symplectic manifolds

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We establish the near diagonal asymptotic expansion of the generalized Bergman kernel of the renormalized Bochner-Laplacian on high tensor powers of a positive line bundle over a compact symplectic manifold. The asymptotic in the Kähler case plays a crucial role in the recent work of Donaldson on the existence of Kähler matrics with constant scalar curvature.

The Bergman kernel is defined here as the smooth kernel of the projection on the spectral space corresponding to small eigenvalues of the renormalized Bochner-Laplacian. Our approach is inspired from the local index theory, especially the works of Bismut-Lebeau.

If time permits, we also discuss some applications (calculation of the density of states of the Bochner-Laplacian, a symplectic version of the convergence of the induced Fubini-Study metric, as well generalizations for non-compact or singular manifolds).

K-Theory of pseudodifferential operators with semiperiodic symbols

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Let $\mathfrak{A}$ denote the smallest C*-subalgebra of the algebra of all bounded operators on $L^2(\mathbb{R})$ containing: (i) all multiplications $a(M)$ by functions $a \in C[-\infty,+\infty]$, (ii) all multiplications by 2π-periodic smooth functions, and (iii) all operators of the form $F^{-1}b(M)F$, where F denotes the Fourier transform and $b \in C[-\infty,+\infty]$. It is known that the principal symbol mapping extends to a surjective C*-homomorphism $\sigma : \mathfrak{A} \to C(X)$, where X is a certain compactification of $\mathbb{R} \times \{-1,+1\}$. It is also known that $\mathfrak{E} = \ker\sigma$ contains the compact ideal $\mathfrak{K}$ and that the quotient $\mathfrak{E}/\mathfrak{K}$ is isomorphic to $C(S^1 \times \{-1,+1\}) \otimes \mathfrak{K}$. Using the explicit form of these two isomorphisms, we are able to compute the connecting mappings in the cyclic exact sequence in K-theory associated to the homomorphism σ and then prove that $K_0(\mathfrak{A}) \cong \mathbb{Z}$ and $K_1(\mathfrak{A}) \cong \mathbb{Z} \oplus \mathbb{Z}$.

The isomorphism $\mathfrak{E}/\mathfrak{K} \cong C(S^1 \times \{-1,+1\}) \otimes \mathfrak{K}$ can be extended to a C*-homomorphism $\gamma : \mathfrak{A}/\mathfrak{K} \to C(S^1 \times \{-1,+1\}) \otimes \mathfrak{B}$, where $\mathfrak{B}$ denotes the algebra of bounded operators on $L^2(\mathbb{Z})$. We prove that the image of γ is isomorphic to the direct sum of two copies of the crossed product $C[-\infty,+\infty] \times_\alpha \mathbb{Z}$, where α denotes the automorphism on $C[-\infty,+\infty]$ defined by $(\alpha f)(x) = f(x+1)$, $f \in C[-\infty,+\infty]$, $x \in \mathbb{R}$. Using the Pimsner-Voiculescu exact sequence, we then compute the K-theory of the image of γ. That leads to a second proof that $K_0(\mathfrak{A})$ is isomorphic to $\mathbb{Z}$ and that $K_1(\mathfrak{A})$ is isomorphic to $\mathbb{Z} \oplus \mathbb{Z}$.

A topological index theorem for manifolds with corners

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We define an analytic index and prove a topological index theorem for a non-compact manifold M_0 with poly-cylindrical ends. We prove that an elliptic operator P on M_0 has an invertible perturbation $P+R$ by a lower order operator iff its analytic index vanishes. As an application, we determine the K-theory groups of groupoid C^*–algebras of manifolds with corners.

The spectrum of the magnetic Laplacian and integrality conditions

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We study the magnetic Laplacian on Riemannian manifolds X with ends of a special type (conformally cusp). We discuss conditions for the vanishing of the essential spectrum and asymptotic laws for the distribution of eigenvalues. We find in particular that the magnetic Laplacian has pure-point spectrum if the magnetic field B defines a relative 2-cohomology class with integral coefficients.

The geometry of the calculus of Fourier integral operators

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Let $\Phi : L^2(X) \to L^2(Y)$ be a Fourier Integral Operator and let A_X and A_Y denote the algebras of pseudodifferential operators on X and Y. A natural object to consider is the $A_Y - A_X$ bimodule $M = A_Y \Phi A_Y$, which carries the geometric information about the original operator. Since the algebras of pseudodifferential operators admit microlocal description via symbol calculus, the same kind of study can be applied to the bimodule M. We will construct the microlocal bimodules associated to this situation and explain the kind of geometry involved in their study. As examples of applications we'll give homological interpretation of the composition of Fourier Integral Operators and of their traces. An important case where this kind of operators appear is the construction of Guillemin and Sternberg of Fourier Integral projections associated to coisotropic submanifolds of $T * X$. we will apply the above methods to give a formula for the index of the operators of this type.

Homology of formal deformations of proper étale Lie groupoids

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In the talk, we determine the cyclic homology theory of formal deformation quantizations of the convolution algebra associated to a proper étale Lie groupoid. Using the thus obtained description of cyclic cohomology of the deformed convolution algebra, we give a complete classification of all traces on this formal deformation.

rho-invariants and index theory

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We explain the relevance of index theory for the understanding of the geometric properties of certain rho-invariants associated to a closed odd dimensional manifold with fundamental group Γ; we shall analyze both the torsion-free case and the case where Γ has torsion. This is joint work with Thomas Schick.
In the last part of the talk I shall explain how the theory can be extended to the foliated case; this is work in progress with Moulay Benameur.

Some applications of K-homology to elliptic theory on singular manifolds

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We discuss several recent results in elliptic theory on singular manifolds, which have a very simple form when formulated in terms of K-homology. These results include a classification of elliptic operators on manifolds with edges modulo stable homotopies; computation of K-groups of some algebras of pseudodifferential operators; computation of the obstruction to Fredholm perturbations.

Operators on infinite cones when the base is a manifold with edges

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The talk refers to a joint paper with D. Calvo (Torino) on operators on corner manifolds with exit to infinity, Preprint 2005/01 of the University of Potsdam.

In several applications of the analysis on manifolds with higher (regular) singularities it is necessary to study operators on infinite cones with cross sections that are again manifolds of that type. The calculus of operators on manifolds with smooth edges contains such operators as an element of the operator-valued edge symbolic structure; then the base of the cone is smooth.

A typical observation in this case is that those operators at infinity behave like operators in standard Sobolev spaces in the Euclidian space (more precisely, in conical sets) at infinity. However, if the base has singularities, then the associated cone also has singularities which are now going to infinity along the axial variable.

We consider the situation that the base is a manifold with edges and show that the typical corner degenerate operators from an associated higher wedge induce on the cone at infinity an operator in the framework of an exit calculus on such a singular cone. In particular the corner-degenerate ellipticity 'in the finite' entails the ellipticity of induced operators on the respective cones, now with respect to an exit-symbolic hierarchy that controls edge-degeneracy and subordinate edge symbols up to infinity.

H_∞-calculus for pseudodifferential operators with mildly regular symbols

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The existence of a bounded H_∞-calculus in Sobolev and Hölder spaces is investigated for elliptic pseudodifferential operators with mildly regular symbols. Applications concern the Dirichlet-Neumann operator for bounded domains with boundary of Hölder smoothness $1 + r$, $0 < r < 1$.

Geometric optics and the wave equation on manifolds with corners

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I will describe the propagation of smooth (C^∞) and Sobolev singularities for the wave equation on smooth manifolds with corners M equipped with a Riemannian metric g. That is, for $X = M \times \mathbb{R}_t$, $P = D_t^2 - \Delta_M$, and $u \in H^1_{loc}(X)$ solving $Pu = 0$ with homogeneous Dirichlet or Neumann boundary conditions, the appropriate wave front set $\mathrm{WF}_{\mathrm{b}}(u)$ of u is a union of maximally extended generalized broken bicharacteristics. Since the latter follow the rules of geometric optics, i.e. those of classical dynamics, this result is a facet of the classical-quantum correspondence, namely that singularities of solutions of the wave equation follow geometric optics. This result is a smooth counterpart of Lebeau's results for the propagation of analytic singularities on real analytic manifolds with appropriately stratified boundary.

I will indicate the key ideas of the proof, such as microlocalization with respect to the appropriate ps.d.o. algebra, $\Psi_{\mathrm{b}}(X)$, and gaining b-regularity (i.e. conormal regularity) relative to $H^1_{loc}(X)$ via positive commutator estimates. Certain aspects of this problem are related to N-body scattering.

Geometric Topology and Group Theory
(C. McA. Gordon, C. Hog-Angeloni, W. Metzler)

Contents

Explicit exotic free 2–complexes for generalized quaternion groups

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Previously we have announced the explicit construction of a free algebraic $(G, 2)$-complex A with Euler characteristic 1 not of 3-manifold type, i.e., not homotopy equivalent to the spine complex of any closed 3-manifold, for $G = Q_{28}$. At the heart of this example is a stably free nonfree ZG-module P for which we give an explicit isomorphism $P \oplus ZG \cong ZG \oplus ZG$, while

$$P/ < N > \ncong ZG/ < N > .$$

Based on work of Swan, we extend this to the generalized quaternion groups Q_{4n} of order $4n$, for odd n containing at least one prime other than $3, 5, 11$, or 13. We hope that our examples, particularly their explicit nature, improve the chances to tackle an open question raised by C. T. C. Wall. If for one such group Q_{4n} there is no CW-complex K with that fundamental group such that the chain complex of $\widetilde{K}$ is homotopy equivalent to the corresponding A as above, then such A is a counterexample to Wall's D_2-problem.

Group Homology with Coefficients in a Novikov-Ring

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This is a little propaganda for group homology with Novikov-Ring Coefficients as a tool for group theoretic results. Some time ago Ralph Strebel and I have established a description of the Geometric Invariant of a group G in terms of vanishing of homology of G with coefficients in the various Novikov-Rings (with respect to the epimorphisms $G \to Z$). This can be viewed as a new link between finiteness properties and homological dimension and that point of view has recently been applied, by Dessislava Kochloukova, to establish that in a knot-like group G the commutator subgroup G', if finitely generated, is free (Rapaport Strasser Conjecture).

The conjugacy problem in free-by-hyperbolic groups

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Theorem 1. The conjugacy problem in [finitely generated free]-by-cyclic groups is solvable.

Note that not all [finitely generated free]-by-cyclic groups are hyperbolic. It has even been announced by M.R. Bridson and L. Reeves, that they fail to be automatic, in general.

Let F be a free group and ϕ an automorphism of F. Two elements $u, v \in F$ are said to be *ϕ-twisted conjugate*, denoted $u \sim_\phi v$, if there exists $g \in F$ such that $(g\phi)^{-1}ug = v$. The equivalence relation $\sim_\phi$ was first introduced by K. Reidemeister, and has an important role in Nielsen fixed point theory.

Theorem 2. There exists an algorithm to recognize if two given elements of a finitely generated free group are ϕ-twisted conjugate for a given automorphism ϕ.

We call a subgroup G of $Aut(F)$ *orbit decidable* if, given two elements $u, v \in F$, one can recognize whether there exists an automorphism $\phi \in G$ such that $u\phi$ is conjugate to v in F.

Theorem 3. Let G be a split extension of a finitely generated free group F by a torsion free hyperbolic group H. Then the conjugacy problem in G is solvable iff the canonical image of H in $Aut(F)$ is orbit decidable.

Using a construction of C.F. Miller, we prove that there exists a finitely generated recursively presented subgroup H of $Aut(F_3)$ which is not orbit decidable. This is in contrast to the fact that each finitely generated subgroup of $Aut(F_2)$ is orbit decidable. Some problems on orbit decidability will be discussed.

Shadow-complexity of 4-manifolds

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We recall the definition of Turaev shadow of a closed 4-manifold and define a notion "complexity" of closed 4-manifolds based on these objects which mimics Matveev's Complexity of 3-manifolds. The number of 4-manifolds with bounded complexity turns out to be finite so that we can give a list of the "simplest" ones.

Rigidity theorems for hyperbolic manifolds with geodesic boundary

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Let $n > 2$. Mostow's rigidity Theorem asserts that two compact hyperbolic n-manifolds without boundary having the same fundamental group are isometric. We recall the notion of *quasi-isometry* for finitely generated groups and, building on results in geometric group theory, we extend Mostow's result to the case of manifolds with non-empty geodesic boundary. It is well-known that the fundamental groups of any two compact hyperbolic n-manifolds without boundary are quasi-isometric to each other. On the contrary, we prove that two compact hyperbolic n-manifolds with non-empty geodesic boundary are commensurable if and only if their fundamental groups are quasi-isometric. A similar result was obtained by R. E. Schwartz for non-compact complete finite-volume hyperbolic n-manifolds.

Turaev-Viro ideals

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Invariants of Turaev-Viro type are defined as a state sum over colorings of 2-strata of special 2-polyhedra, P. Variables are (1) the weight of a colored 2-stratum, and (2) so-called $6j$-symbols associated to the 6-tuples of colored 2-strata around vertices of P. In order to obtain an invariant of (a) spines of 3-manifolds, or (b) an invariant under Andrews-Curtis moves, the variables must satisfy certain polynomial equations. The representation theory of Quantum Groups provides solutions of equations (a), and by work of Timo Stey also of (b) after reduction to some finite fields. In addition, one might think of coloring the edges of P as well, which increases both the number of the variables and of the polynomial equations. Examples again arise from some Quantum Groups.

The 3-manifold invariants derived from Quantum Groups are quantum invariants in the sense of Quinn's axioms, in particular they are multiplicative under connected sum. By work of Quinn and Bobtcheva, when obtaining an invariant under Andrews-Curtis moves by reduction of a Quantum invariant, the reduced invariant only depends on the homology. Hence, there is no hope to detect Andrews-Curtis counterexamples using those invariants. Therefore I studied a more direct approach: I avoid to solve the equations and work only with the polynomials. Namely, the equations generate an ideal TV in a polynomial ring, and the coset $s(P)$ of the state sum modulo TV is an invariant of P. By the theory of Groebner bases, given a monomial order on the variables, $s(P)$ has a computable normal form. It turns out that $s(P)$ is not multiplicative

under connected sum, hence there remains the possibility to detect Andrews-Curtis counterexamples. Groebner bases also allow to compute new solutions for the edge colouring approach.

Symmetric union presentations for 2-bridge ribbon knots

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Symmetric unions have been defined as generalizations of Kinoshita-Terasaka's construction in 1954. They are given by diagrams which look like the connected sum of a knot and its mirror image with additional twist tangles inserted near the symmetry axis. Because all symmetric unions are ribbon knots, we can ask how big a subfamily of ribbon knots they form. It is known that all 21 ribbon knots with crossing number less or equal 10 are symmetric unions. In this talk we extend our knowledge about symmetric unions: we prove that the family of symmetric unions contains all known two-bridge ribbon knots. The question, however, whether the three families of two-bridge ribbon knots, found by Casson and Gordon in 1974, are a complete list of all two-bridge ribbon knots, is still open.

Fake surfaces and cohomology of groups

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We propose a different geometric approach to the question regarding the freeness of the cohomology group $H^2(G; ZG)$, G finitely presented, via the study of certain cochains which are key to detecting the thickenability of a fake surface to a 3-manifold. In particular, we give a necessary condition for a contractible 2-dimensional CW-complex to be the universal cover of a compact CW-complex and show, as a consequence, that if G admiots a finite 2-dimensional $K(G, 1)$-complex then $H^2(G; ZG)$ is free abelian.

Growth of minimal word length in Garside groups

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The Garside group, as a generalization of the braid groups and the Artin groups of finite type, is defined as the group of fractions of a Garside monoid.

In the talk, we will give an estimate of the growth of the minimal word length of powers of elements in Garside groups, when the generating set is the set of simple elements. A direct application is that the set of translation numbers in Garside groups is discrete. It gives an affirmative answer to the question of Gersten and Short for the case of Garside groups. The original question is for biautomatic groups.

2-polyhedra in smooth 4-manifolds

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Let a k-skeleton P of a smooth n-manifold M be a k-dimensional subpolyhedron such that the complement of its regular neighborhood is made of handles higher than k. By a Theorem of Matveev, if $k = n-1$ and P has a nice local structure (i.e. it is *special*) then P determines M.

The same result in codimension two could seem hopeless: infinitely many 3-manifolds share the same 1-skeleton, no matter how nice it is. We show that, quite surprisingly, things get better in dimension 4: a 2-dimensional polyhedron is the locally flat 2-skeleton of finitely many smooth closed 4-manifolds. *Locally flatness* is the local nice property needed in this case. This result is proved using a general theorem on Dehn surgery along links.

Roots of knotted graphs and orbifolds

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A root of a knotted graph G in a 3-manifold M is a collection of simpler knotted graphs which can be obtained from (M, G) by compressions along essential spheres and which admits no further essential compressions. We present a simple proof that a root exists and is unique. This result generalizes several results of different authors on decompositions of 3-manifolds, knots, cobordisms, and orbifolds.

Euler characteristics of automorphism groups of free products

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We present an elegant formula for the euler characteristic of the automorphism group of a free product of finite groups. The same combinatorial techniques lead to similar formulas for related automorphism groups.

The Finitary Andrews-Curtis Conjecture

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Let G be a group, $d_G(G)$ the minimal number of generators of G as a normal subgroup, $k \geq d_G(G)$, and $N_k(G)$ the set of all k-tuples of elements in G which generate G as a normal subgroup. Then the *Andrews–Curtis graph* $\Delta_k(G)$ of the group G is the graph whose vertices are tuples from $N_k(G)$ and such that two tuples are connected by an edge if one of them is obtained from another by an elementary Nielsen transformation or by a conjugation of one of the components of the tuple. Two tuples $U, V \in N_k(G)$ are AC-equivalent if they belong to the same connected component of $\Delta_k(G)$.

Famous Andrews-Curtis Conjecture from algebraic topology asks whether the graph $\Delta_k(F)$ is connected for a free group F of rank k.

It is known that the Andrews-Curtis graph $\Delta_k(G)$ is not connected in general (there are counter examples in abelian groups G for $k = d_G(G)$).

Theorem (*Finitary Andrews-Curtis Conjecture*) *Let G be a finite group and $k \geq \max\{d_G(G), 2\}$. Then two tuples U, V from $N_k(G)$ are AC-equivalent if and only if they are AC-equivalent in the abelianization $\mathrm{Ab}(G) = G/[G, G]$, i.e., the connected components of the AC-graph $\Delta_k(G)$ are precisely the preimages of the connected components of the AC-graph $\Delta_k(\mathrm{Ab}(G))$.*

Rigidity in R^3

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We say that a subset $A \subset X$ is *rigid* in X if for any homeomorphism $f\colon X \to X$, such that $f(A) = A$ we have $f|_A = id_A$. In the first part of the talk we shall give a survey of known examples of rigid sets in R^3. Among them are also wild Cantor sets. Heretofore it was unknown if such examples which also have simply connected complement can be constructed. Moreover, previous constructions of wild Cantor sets in R^3 with simply connected complement, in particular the Bing-Whitehead Cantor sets, had strong homogeneity properties. This suggested it might not be possible to construct such sets that were rigid. In the second part of the talk we shall present a new result (joint work with D.J. Garity and M. Željko) that in fact uncountably many topologically distinct examples exist (Cantor sets $X, Y \subset R^3$ are said to be *topologically distinct* or *inequivalent* if there is no homeomorphism of R^3 to itself taking X to Y).

New topologically slice knots

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In the early 1980's Mike Freedman showed that all knots with trivial Alexander polynomial are topologically slice (with fundamental group $\mathbf{Z}$). We will give the first new examples of topologically slice knots. In fact, we give a sufficient *homological* condition under which a knot is slice with fundamental group $(a, b \mid aba^{-1} = b^2)$. These two fundamental groups are known to be the only *solvable ribbon* groups. Our homological condition implies that the Alexander polynomial equals $(t-2)(t^{-1}-2)$ but also contains information about the metabelian cover of the knot complement (since there are many non-slice knots with this Alexander polynomial).

On the rank problem of 3-manifold groups

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The rank of a group G is the minimal number of generators needed to generate G. In this talk we discuss recent progress on the rank problem for 3-manifold groups; in particular, we show that the rank of the fundamental group of a closed hyperbolic 3-manifold is computable.

An infinite commutator product is not automatically trivial in homology

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Homology groups are abelian groups, therefore all commutators are trivial. On the other hand, they are also classical groups, i.e. something like "infinite products" are not defined. However for homology groups of topological spaces it can happen that an infinite commutator product of paths can be composed and gives a continuous compact path again. In such a case there is not any group-theoretic necessity for such a path to present the trivial element in the first homology group. Indeed we can prove that Griffiths' space already provides such an example. Our current research goes into the direction of looking for a wild two-complex all of whose non-trivial elements in the first homology group are of the type "infinite commutator products", and we hope to find uncountably many of them. Depending on our research progress till June, this might already be incorporated into the talk.

Group Theory
(L.-C. Kappe, R.F. Morse, G. Rosenberger)

Contents

Conjugacy Classes and Finite p-groups

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Let G be a finite group. Denote by $[a] = \{g^{-1}ag \mid g \in G\}$ the conjugacy class of a in G, and by $|[a]|$ the size of $[a]$. If the subset X of G is G-invariant, i.e $X^g = \{x^g \mid x \in X\} = X$ for all $g \in G$, then X is the union of m distinct conjugacy classes for some integer m. Set $\eta(X) = m$.

Given any conjugacy classes $[a]$ and $[b]$, we can check that the product $[a][b] = \{xy \mid x \in [a], y \in [b]\}$ is a G-invariant set. In this talk, we will explore the relation between $|[a]|$ and $\eta([a][a^{-1}])$.

The main result of the talk is the following

Theorem A. Let G be a finite p-group and $a \in G$. Assume that $|[a]| = p^n$. Then the product $[a][a^{-1}]$ of the conjugacy class of a in G and the conjugacy class of the inverse of a in G, is the union of at least $n(p-1)+1$ distinct conjugacy classes of G, i.e. $\eta([a][a^{-1}]) \geq n(p-1)+1$.

Given any prime p and any integer $n \geq 0$, we can provide examples of a p-group G and a conjugacy class $[a]$ of G such that $|[a]| = p^n$ and $\eta([a][a^{-1}]) = n(p-1)+1$. Thus the bound in Theorem A is optimal.

An application of Theorem A is the following

Theorem B. Let n be a positive integer. Then there exists a finite set S_n of positive integers such that for any nilpotent group G and any conjugacy class $[a]$ of G with $\eta([a][a^{-1}]) \leq n$, we have that

$$|[a]| \in S_n.$$

We can prove that given any prime p, there exist a supersolvable group and a conjugacy class $[a]$ of G with $|[a]| = p$ and $\eta([a][a^{-1}]) = 2$. Thus the previous result does not remain true assuming the weaker hypothesis that the groups are supersovable.

Theorem C. Let p be a prime number. Let G be a finite p-group and $[a]$ be a conjugacy class of G. Then one of the following holds:

i) $|[a]| = 1$ and $\eta([a][a^{-1}]) = 1$.
ii) $|[a]| = p$ and $\eta([a][a^{-1}]) = p$.
iii) $|[a]| \geq p^2$ and $\eta([a][a^{-1}]) \geq 2p-1$.

Given a fix prime $p > 2$, observe that Theorem C implies that there are "gaps" among the possible values that $\eta([a][a^{-1}])$ can take for any finite p-group and any conjugacy class $[a]$ in G.

The adjoint group of a radical ring

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The set of all elements of an associative ring R forms a semi-group with neutral element 0 under the operation $r \circ s = r + s + rs$ for all $r, s \in R$, the *adjoint semi-group* of R. The group of all invertible elements of this semi-group is called the *adjoint group* of R and is denoted by R°. The ring R is said to be *radical* if $R = R^\circ$, which means that R coincides with its Jacobson radical. Obviously such a ring does not contain an identity element for multiplication. If a ring R is embedded in any way in a ring R_1 with identity, then R° is isomorphic with the subgroup $1 + R$ of the group of units of R_1.

Some relations between the ring-theoretical properties of the radical ring R and the group-theoretical properties of its adjoint group R° will be discussed. For instance, it can be shown that if the radical ring R is nilpotent of class n, hypercentral or locally nilpotent, then R° is a nilpotent of class n, hypercentral or locally nilpotent, respectively. Also, every radical ring, whose adjoint group is soluble, must be Lie-soluble. A radical ring R is an n-Engel ring for some natural number n if R° is an m-Engel group for some natural number m depending only on n, and conversely.

Some of these theorems have analogues for local and semi-local rings and their multiplicative groups.

On the generalized Whitehead problem for hyperbolic groups

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Let G be a group. We will say that for G the *Whitehead problem of the first kind* is solvable, if given two finite tuples of elements $(g_1, \dots, g_n)$ and $(h_1, \dots, h_n)$ of G, we can decide, whether there exists an automorphism $\alpha \in G$ such that $g_i\alpha = h_i$ for each i.

We will say that for G the *Whitehead problem of the second kind* is solvable, if given two finite tuples of elements $(g_1, \dots, g_n)$ and $(h_1, \dots, h_n)$ of G, we can decide, whether there exists an automorphism α of G such that $g_i\alpha$ is conjugate to h_i for each i (the conjugators may be different).

For free groups of finite rank the Whitehead problem of the first and of the second kinds were solved by J. Whitehead and J. McCool.

Let $U = (u_1, \dots, u_k)$ be a tuple of elements of G and α be an automorphism of G. Denote $U\alpha = (u_1\alpha, \dots, u_k\alpha)$. A tuple V is said to be conjugate to the tuple U if there exists an inner automorphism β of G, such that $U\beta = V$.

We will say that for G the *generalized Whitehead problem* is solvable, if given two finite tuples $(U_1, \dots, U_n)$ and $(V_1, \dots, V_n)$ of ordered finite subsets of G, we

can decide, whether there exists an automorphism α of G such that $U_i\alpha$ is conjugate to V_i for each i.

Note that if for G the generalized Whitehead problem is solvable, then for G the Whitehead problems of the first and of the second kinds are solvable. We prove the converse statement for torsion free hyperbolic groups.

Theorem 1. Let G be a hyperbolic torsion free group and suppose that for G the Whitehead problem of the second type is solvable. Then for G the generalized Whitehead problem is solvable.

Corollary. The generalized Whitehead problem for any free group of finite rank is solvable.

Theorem 1 was proven with the help of the following theorem, which is interesting itself.

Theorem 2. Let H be a torsion free δ-hyperbolic group with a fixed finite generator set X. Then there exists a constant $C = C(\delta, |X|)$ such that if ϕ is an endomorphism of H and $\phi(h)$ is conjugate to h for any element h of length at most C, then ϕ is an inner automorphism.

Highly transitive imprimitivities

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This is a brief account of some recent answers to questions asked by Vaughan Jones about imprimitive permutation groups associated with subfactors of von Neuman algebras. Of particular interest are examples of a group G containing two maximal subgroups H and K such that $G \neq HK$, and such that the action of G on the space of cosets of $H \cap K$ has small rank (few suborbits). The rank 6 case turns out to correspond to the action of the collineation group on flags of a Desarguesian projective plane, and a special case of interest for rank 7 corresponds to the action of a 4-transitive group on ordered pairs of distinct points. Some other new (and unexpected) fundamental properties of groups will be described along the way.

Computing with polycyclic groups

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This talk describes recent developments in the area of practical algorithms for polycyclic groups, their implementations and applications.

It has been known for some time that many interesting problems can be solved algorithmically in polycyclic groups. Recently, there has been interest in finding effective algorithms for such problems in polycyclic groups; that is, algorithms which are designed such that their implementation yields results on non-trivial and interesting examples and is relatively fast.

For example, effective algorithms for computing complements and extensions, finite subgroups and subgroups of finite index and for solving the conjugacy problem for elements and subgroups in polycyclic groups are implemented in the Polycyclic Package of the computer algebra system GAP. An overview on these and other algorithms of the Package is given in the talk.

Methods for polycyclic groups apply to finitely generated nilpotent groups and, as they extend naturally to polycyclic-by-finite groups, to crystallgraphic and almost crystallographic groups. Some example applications are included in the talk.

Computing group cohomology on the PC

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We shall describe a practical computer method for calculating the integral cohomology of a finite group G. The method is based on the notion of a "homotopical syzygy" and involves the construction of a reasonably small CW-space X on which G acts freely.

Characterizing Injectors in Finite Soluble Groups

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In *Finite Soluble Groups*, Doerk and Hawkes proposed the problem of finding a group-theoretic description of the injectors of a finite soluble group, i.e., a characterization that does not involve Fitting sets. We present a variety of such characterizations using two new concepts, one related to the way a subgroup

might or might not cover the elements of a chief series, and one related to the concept of pronormality.

The Tame Automorphism Group of an Elementary Free Group
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An automorphism of a group G is called tame if it is induced by a free group automorphism. The automorphism group $\mathrm{Aut}(G)$ is tame if each automorphism is tame. Zieschang and Rosenberger use the term almost quasi-free for a group G with a tame automorphism group. In this talk we examine the relationship between the class of elementary free groups and being almost quasi free. The class of elementary free groups consists of those groups with the same elementary or first order theory as the class of free groups. The solution of the Tarski problem by Kharlampovich and Myasnikov and independently by Sela allows for the complete classification of the elementary free groups. This class is wider than the class of free groups alone and contains for example the class of surface groups. It is known that a surface group is almost quasi free.

On groups all of whose elements have prime power order
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The locally finite (not necessarily locally soluble) groups defined in the title are described.

Nearrings and Triply Factorized Groups
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Triply factorized groups, i.e. groups which can be written as $G = A \ltimes M = B \ltimes M = AB$ for two subgroups A and B and a normal subgroup M of G play an important rôle in the theory of factorized groups.

Sysak describes a method to construct triply factorized groups using radical rings. Moreover, for every triply factorized group $G = A \ltimes M = B \ltimes M = AB$ with abelian groups A, B, and M and with $A \cap B = 1$ there is a radical ring from which G can be constructed using Sysak's method. This construction is generalized using nearrings. On the other hand, given a triply factorized group $G = A \ltimes M = B \ltimes M = AB$ with $A \cap B = 1$, one can find a nearring, with which the group can be constructed.

Residual Solvability of Groups
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Residual Properties of groups is a term introduced by Philip Hall in 1954. Let X be a class of groups; a group G is residually-X if and only if for every non-trivial element g in G there is an epimorph of G to a group in X such that the element corresponding to g is not the identity. In the literature, studying the residual solvability of groups was pioneered by Gilbert Baumslag in his celebrated paper in 1971; when he showed that positive one-relator groups are residually solvable. I have studied the notion of residual solvability and verified this property for several structures of groups. In this talk I will give an overview of some of these results; from generalised free products to one-relator groups.

Autocommutators and the autocommutator subgroup
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It is well known that the set of commutators is not equal to the commutator subgroup and numerous examples with this property are in the literature. A similar phenomenon should occur for autocommutators and the autocommutator subgroup. But so far, no example appears in the literature.

We show that for a finite abelian group the set of autocommutators is equal to the autocommutator subgroup. With the help of GAP we obtain a group

of order 64 in which not every element of the autocommutator subgroup is an autocommutator. This group is of minimal order with this property.

The Conjugacy Problem in HNN-extensions: regular elements and black holes

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We show that the Conjugacy Problem in HNN-extensions and amalgamated products (under very natural conditions on the groups involved) can be divided into two parts: the *Regular Part* and the *Black Hole*. The Regular Part is very big (in some precise sense) and the Conjugacy Problem to regular elements is easy. The Black Hole is very small and the Conjugacy Problem for its elements is either hard or undecidable. As an illustration of this technique, I will discuss the Miller's construction of HNN extension of a free group, where the Conjugacy Problem is undecidable, and its possible applications in cryptography.

Bell groups

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The class of Bell groups has been introduced by L.-C. Kappe and studied by several authors. It includes several classes of groups, such as groups of finite exponent, n-abelian groups and Levi groups. We shall describe the structure of locally graded Bell groups and prove the existence of infinite simple sections of finite exponent in non locally graded Bell groups. In locally graded case, the structure of Bell groups is in a certain sense completely determined by the structure of finite Bell groups.

The talk is partially based on joint results with C. Delizia and C. Nicotera.

Computations with amalgams of unitary groups

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In the 1970s Kok-Wee Phan published a series of theorems that describe certain classical groups as amalgams of small unitary groups. These results are used in the classifcation of finite simple groups. Recently, they have been reproved and extended with the help of geometric methods in a project of Gramlich, Hoffman and Shpectorov.

The talk describes how computational methods were used to show that the theorems are also valid in cases where the geometric methods were not applicable, namely in cases with small dimension and small characteristic.

Saturated formations closed under Sylow normalizers

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In the theory of finite groups it is well known that local properties, such as those of p-subgroups and their normalizers, influence the global structure of the groups. A vast classical theory rests on this fact. In particular a classical result of G. Glauberman states that a group is a p-group, for some prime p, provided its Sylow subgroups are self-normalizing. An extension of this result by M.G. Bianchi, A. Gillio and P. Hauck says that a group is nilpotent if its Sylow normalizers, i.e. the normalizers of Sylow subgroups, are nilpotent. Other related results can be also found in the literature. In this context we are interested in the following question: which properties of the Sylow normalizers are inherited by the whole group? We show that a finite soluble group possesses nilpotent Hall subgroups for well-defined sets of primes if and only if its Sylow normalizers satisfy the same property. In fact this property of groups provides a characterization of the subgroup-closed saturated formations whose elements are characterized by the Sylow normalizers belonging to the class, in the universe of all finite soluble groups.

Generating sets of free products and other free constructions

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Grushko's theorem (or its proof) states that any generating tuple T of a free product $A * B$ is Nielsen equivalent to a tuple $T' = (a_1, ..., a_k, b_1, ..., b_l)$ with a_i in A for and $b_i i$ in B for all i. The tuple T' is clearly not unique. In this talk we describe the extent of this uniqueness. In particular we show that if T is reducible then T' is unique up to Nielsen equivalence of the subtuples $(a_1, \ldots, a_k)$ and $(b_1, \ldots, b_l)i$. The proof is based on the construction of a graph of A-graphs associated to a generating tuple. We further discuss how this technique can be applied in more general situations.

Hilbert Functions and Syzygies
(U. Nagel, I. Peeva, T. Römer)

Contents

Stability properties of syzygy bundles on projective space

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Let $f_1, ..., f_n$ be homogeneous polynomials which generate an ideal primary to the irrelevant ideal. We consider the first kernel of a resolution of the ideal as a vector bundle on the projective space and ask for its stability properties in the sense of Mumford-Takemoto. Though resolutions of ideals are a main object of study in commutative algebra and though stability properties of vector bundles are fundamental in the construction of moduli spaces, there is not much known about their interplay.

We present results in the generic case (due to G. Hein) and in the case where the polynomials are monomials, in which case we give a combinatorial criterion for the semistability of the corresponding first syzygy bundle. Using restriction theorems for semistable bundles (Bogomolov, Flenner, Mehta, Ramanathan, Langer), we also obtain results for the computation of tight closure in complete intersection rings of dimension two.

Cohomology of partially ordered sets

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We study the cohomology of the Alexandrov topology underlying a partially ordered set P with coefficients in a sheaf $\mathcal{S}$ of rings. Examples of such structures naturally arise in connection with simplicial complexes or similar combinatorial objects. In the case of a simplicial complex and the natural choice of $\mathcal{S}$, the ring of global sections is the Stanley-Reisner ring of the complex, and the main goal is to generalize Hochster's formula. It computes the local cohomology of the ring of global sections in terms of the local cohomology of the stalks and the cohomology of the poset. The generalization allows one to prove results of Yuzvinsky on the Cohen-Macaulay property of section rings in the "right" conceptual framework.

For technical reasons sheaves of rings and modules are represented by so-called RP-algebras and modules over them.

Koszul homology and the Castelnuovo-Mumford regularity of the powers of an ideal

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We will present some recent results on Castelnuovo-Mumford regularity of the powers of an ideal. The proof of some of these results uses approximation complexes, and the understanding of those is very much connected to the one of Koszul homology. Part of the talk will be dedicated to duality results for the Koszul homology of ideals, with special attention to dimensions one and two. Connected results on the regularity of Tor modules will also be explained.

Graded algebras associated to singularities, and their Hilbert functions

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We associate a graded ring T_X to a resolution of singularities of the spectrum Y of the local ring of a characteristic zero surface singularity spec(R). We show that T_X is a a finitely generated R algebra if and only if Y is a rational singularity. We consider the Poincare' series associated to T_X and show that in many cases it is rational, even if T_X is not finitely generated.

Secant Varieties of Segre-Veronese embeddings of Products of the Projective Line

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In this talk I will explain the connection between computing the Hilbert function of certain fat point schemes in $\mathbb{P}^n$ and finding the dimensions of the higher secant varieties of the Segre- Veronese embeddings of products of $\mathbb{P}^1$. We find all deficient Secant varieties for these embeddings for two and three factors.

On the radical of a monomial ideal

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Algebraic and combinatorial properties of a monomial ideal and its radical are compared.

The Multiplicity Conjecture in Low Codimensions

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We establish the multiplicity conjecture of Herzog, Huneke, and Srinivasan about the multiplicity of graded Cohen-Macaulay algebras over a field, for codimension two algebras and for Gorenstein algebras of codimension three. In fact, we prove stronger bounds than the conjectured ones, allowing us to characterize the extremal cases. This may be seen as a converse to the multiplicity formula of Huneke and Miller that inspired the conjectural bounds.

On the minimal free resolution of varieties of almost minimal degree in small codimension

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A nondegenerate, irreducible projective variety X in $\mathbb{P}^r_K$ is called of almost minimal degree provided $degX = codimX + 2$. Let I_X denote its defining ideal. We will discuss the possible Betti diagrams of I_X of varieties of almost minimal degree, in particular those of small codimension. As a main result it turns out that there is only a finite number of possible Betti diagrams. In the case X is not arithmetically Cohen-Macaulay there is in addition a bound on the dimension of X. The results grow out of a recent joint work with M. Brodmann (Universität Zürich).

Computing the higher direct image complex of a coherent sheaf

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The higher direct image complex of a coherent sheaf (or finite complex of coherent sheaves) under a projective morphism is a fundamental construction that can be defined via a Cech complex or an injective resolution, both inherently infinite constructions. Using exterior algebras and relative versions of theorems of Beilinson and Bernstein-Gel'fand-Gel'fand, we give an alternate description in finite terms.

Using this description we can give explicit descriptions of the loci in the base spaces of flat families of sheaves in which some cohomological conditions are satisfied—for example, the loci where vector bundles on projective space split in a certain way, or the loci where a projective morphism has higher dimensional fibers.

Our approach is so explicit that it yields an algorithm suited for computer algebra systems.

Multiplicity Conjectures

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If S is a standard graded R- algebra, then the multiplcity of S can be computed from the shifts in a graded resolution of S over R. We will discuss the conjectures on the bounds for multiplicities of graded R-algebras in terms of the shifts in their graded resolutions and some recent developments.

History of Mathematics, with a special workshop on Mathematics and War (T. Archibald, M. Epple, J. McCleary, N. Schappacher)

Contents

The Female Mathematician Emmy Noether: A Life Between Outstanding Achievements and "Disrespectful Company"

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Emmy Noether has been called the 'mother of Modern Algebra,' but in no ways did her life fit the gender roles of the day. In 1909 she was the second German woman to earn a Ph.D. in Mathematics in Germany. Only six years later, Hilbert and Klein recognized her genius and invited her to Göttingen, yet even they could not secure her a full professorship, due to her gender. The obituary of Noether written by her friend and college Hermann Weyl is the impetus for my research. He says, 'if we in Göttingen chaffingly referred to he as "der Noether" (with the masculine article), it was also done with a respectful recognition of her power as a creative thinker who seemed to have broken through the barrier of sex.' I will contextualize her life with the background of the feminist movements of the day and the idea, popular in Germany during this time, of 'the third gender,' which included female students. I will also compare Noether's life to the life of Maria von Linden, who received a Ph.D. in the natural sciences in 1895 and wrote her memoirs at the end of her life. Her memoirs deal with many of the same subjects that Noether encountered in her own life. I will then compare her work to her life, as well as discuss a novel about the experience of a contemporary female scientist to connect Noether's life to our society today. Noether was able to be accepted by her fellow male mathematicians by ignoring her gender and concentrating solely on her mathematical ideas.

Stefan Banach and the Weigl Institute: Banach During World War II

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The record of Stefan Banach's experience during World War II is slim. We know that during the Nazi Occupation he worked in a factory in Lwów which produced a typhus vaccine, but the details of that experience are not well-known. This presentation will hopefully add to this record by discussing the recollections of Waclaw Szybalski, professor emeritus, McArdle Laboratory for Cancer Research, University of Wisconsin, who supervised Banach at the factory. The nature of Banach's work at the factory will be discussed.

Banach's story is intimately linked to that of the relatively unknown "Schindleresque" factory owner who employed Banach, Rudolf Weigl, creator of the typhus vaccine, who in 2003 was honored by Yad Vashem as Righteous Among the Nations. Weigl's institute served not only as a refuge to members of the Lwów intelligentsia during the occupation, but also as a center of resistance, both militarily and culturally.

Banach's mathematics will not be discussed, except in very broad terms.

World War I and Mathematics in the U.S.
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The late entry of the United States into the war meant that the development of a full wartime system of science did not take place (as compared for example with Germany and France). Nevertheless, there was an extensive mobilisation of mathematical talent in support of the war effort both domestically and overseas. The requirements of the war drove the content of research in certain directions, most notably ballistics and aeronautics, and with these the numerical solution of differential equations and other numerical methods to speed approximate calculation. In this paper we examine such efforts, in particular those of F. R. Moulton of Chicago, considering their effects on mathematics in the U. S. during and after the war.

Two female mathematicians from Austria - and how WW2 changed their lives and works
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The political situation in Germany had a very strong influence on the lives of the two most widely known female mathematicians from Austria, Hilda Geiringer (-Pollaczek, -von Mises) and Olga Taussky (-Todd). They had to leave their country and struggle for a new career. In this talk I will focus on the modifications of the research and teaching activities of the two women which were brought about World War II.

Felix Hausdorff, his life and works

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Felix Hausdorff (1868-1942) has left a permanent mark in the history of 20th century mathematics. His collected works and some correspondence and hitherto unpulished material are being published in nine volumes by Springer Verlag; of these, volumes 2,4,7 have already appeared and volume 5 should appear soon. In our talk, we shall give a broad survey of Hausdorff's life and work, highlighting the unusual challenge met by the edition of Hausdorff's Collected Papers.

From WWII to the Cold War: Mathematics as a universal and polymorphic tool for action

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In the 1980s, the historiography of science emphasized the importance of the military-industrial complex stressing in particular the role of the physicists. In the past few years, the interest of historians has rather shifted to mathematicians and engineer-mathematicians and to their conceptual tools, methods and relevance. The lecture proposes a concise survey of these more recent results.

Three fields emerge in new configurations : 1) (So-called) Applied Mathematics (fluid mechanics, engineering sciences and computing). 2) Mathematical tools for social management and economics. 3) Cybernetics (systems englobing humans as well as machines, von Neumann's work on brain modeling).

New institutional structures symbolize new conceptions of the mathematical tool; the Rand Corporation is the best example. I propose an analysis of the main features of the work done, and of the main cultural orientations of the mathematicians working there.

Dickson's 'Gems': An Archive Speaks

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The influential American mathematician Leonard Dickson proved essential to the consolidation and growth of the American mathematical research community in the opening decades of the twentieth century. His voluminous publication record (more than 300 manuscripts and 18 books over a 40-year career), dogged work ethic, and seminal mathematics combined with his fiercely independent personality to propel American mathematics forward as American science developed in general. From just before World War I through the subsequent Interwar Years, Dickson engaged in a flourishing correspondence with the Carnegie Institution of Washington. This rare collection of letters written in his hand (Dickson burned his papers when he retired), not only puts a very personal face on an otherwise intensely private man but also provides insights into the American mathematical community during this time.

French mathematicians through the First World War

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It is well-known that WWI killed many promising scientists, who were sent to the Front. It is also obvious that the war was a traumatic event for all those who experienced it. What are less obvious are its concrete effects on the survivors and on their professional developments. The talk will follow some French mathematicians through and after the war and contextualize their post-war mathematical involvment from the perspective of their WWI activities. The work reported here takes place in the framework of a joint project CNRS-British Academy on "Mathematics, Mathematicians and the First World War".

New Developments in Mathematics in Post War USA: The Significance of WW II

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In this talk I will focus on how mathematics benefited from the war situation not only financially but also scientifically. The scientific mobilisation in the USA during World War II prepared a path for mathematicians to get involved with new research areas in so-called applied mathematics. The establishment in the post war period of these new research areas in academia was actively promoted

through the military-science connection and by this move into the universities the research directions in some areas of mathematics proper was also influenced. I will discuss how the scientific mobilisation and the following post war military financing of science in the USA influenced research activities in mathematics through the cases of Operations Research (OR), game theory, and mathematical programming as the new areas of mathematical research and linear inequality theory and the theory of convexity in pure mathematics.

Hassler Whitney, the applied mathematics panel, and airborne weapons accuracy

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The Applied Mathematics Panel (AMP) was established in late 1942 to provide mathematical expertise to the divisions of the National Defense Research Committee. It employed academic mathematicians at several sites. Hassler Whitney, then at Harvard, joined the group at Columbia working on questions concerning fire control systems, that is, systems which control the aiming of weaponry, especially on aircraft and rockets. His involvement was typical of the problems handled by the AMP. I will discuss his main report from its inception to its presentation and reception by the military engaged in aerial warfare. This talk is based on documents found in the US National Archives which include his formal diary of a meeting with the Advisory Panel for the Aircraft Fire Control Section of the Naval Ordnance Test Station at Inyokern, California, as well as an impassioned letter to Warren Weaver from Whitney on the manner in which to realize the suggestions implied by mathematical results. I plan to present some of the results of the main report, AMP Note 21, written by Whitney to illustrate how a problem passed through the AMP from question to report to presentation to the military, and finally action.

'The state puts mathematics to a test in the war': The DMV and the Organization of Mathematical Research in World War II

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In the years before the outbreak of the World War II, the professional policies of the DMV had efficiently been co-ordinated with political goals of party and government offices. During the war, the organization of mathematical research relevant to the war became one of the prime tasks of the DMV and its president, Wilhelm Süss. Among the various efforts made at the time, we will focus on the foundation of the Mathematical Institute in Oberwolfach and the

co-operation with the German Physical Society (DPG) to improve the organization of research important to the war.

Einstein's Interactions with Mathematicians
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In a letter to Paul Ehrenfest, Einstein once contrasted two approaches to theoretical physics: one based on technical virtuosity, the other on fundamental principles. While he saw himself as an exponent of the second style, Einstein's orientation in fact shifted markedly over the course of his career, a change that reflects his interactions with several leading mathematicians. Beginning with his reaction to Minkowski's formalism for SRT, we trace some of the most signicant of these mathematical influences.

The Indian Wars, Eugenics, and Statistics: A Broader View of Scientific Racism Before the Outbreak of WWII
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Racial theories figured to devastating effect in the "Indian Wars" of the American West, and a half-century later in the "Final Solution" in Nazi Germany. Arguments surfaced from the across the political spectrum in late 19th century America in support of eradicating the native population. When the Minneconjou followers of Chief Big Foot were shot down at Wounded Knee Creek in 1890, marking the end of the war on the plains, US laws were already excluding immigrants on the basis of race and ethnicity. The British anthropologist Francis Galton coined the term "eugenics" in the 1880's. The US eugenics movement was very strong through the early part of the 20th century and was followed closely by adherents in Europe. Sterilization and miscegenation laws appeared in numerous states. Two of the most prominent figures in the history of statistics, Karl Pearson and Ronald Fisher both held positions in England as Professors of Eugenics in the decades before the start of WWII. By the mid 30's, when National Socialism was tightening its grip on Germany, eugenics had become a fixture in the intellectual landscape in the US and Europe. The rigor that mathematics brought to the eugenics movement through the development and study of statistics made it all the more accepted as a serious branch of science. In this talk I will look a little wider than Stefan Kühl did in his excellent book on the links between American eugenics and National Socialism by including discussion of American racial attitudes during the "Indian Wars" and

the possible role that mathematics played in legitimizing the broader eugenics movement before the outbreak of WWII.

Homotopy Theory
(P. Goerss, H. W. Henn, S. Schwede)

Contents

Algebraic K-theory of ring spectra and Bott periodicity
Christian Ausoni
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One can construct infinite families of classes in the algebraic K-theory of a number ring R by mapping its units into K_1R and using Bott periodicity. We show that similar constructions hold also for more general structured ring spectra.

Invertible modules for some commutative S-algebras
Andrew Baker
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Coauthors: Birgit Richter

I will describe some classes of examples of commutative S-algebras R for which every invertible R-module M has M_* invertible as an R_*-module. In particular, this applies to: a large class of connective spectra; periodic spectra with R_* coherent, multiplicative residue fields and small global dimension; even periodic spectra with R_0 Noetherian complete and regular.

On the convergence of the Eilenberg-Moore spectral sequence
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tba

Buildings, elliptic curves, and the stable homotopy groups of spheres
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I will describe a dense arithmetic subgroup of the second Morava stabilizer group using isogenies of elliptic curves. This arithmetic group acts on the building for $GL_2(\mathbb{Q}_\ell)$ with finite stabilizers, giving a decomposition of the $K(2)$-local sphere similar to one obtained by Goerss, Henn, Mahowald, and Rezk.

Interpolation categories for homology theories
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For a homological functor from a triangulated category to an abelian category satisfying some technical assumptions we construct a tower of interpolation categories. These are categories over which the functor factorizes and which capture more and more information according to the injective dimension of the images of the functor. The categories are obtained by proving the existence of truncated versions of resolution or E_2-model structures. Examples of functors fitting in our framework are given by every generalized homology theory represented by a ring spectrum satisfying the Adams-Atiyah condition. The constructions are closely related to the modified Adams spectral sequence and give a very conceptual approach to the associated moduli problem and obstruction theory. As application we establish an isomorphism between certain $E(n)$-local Picard groups and some Ext-groups.

On the homology of some groups with coefficients in their Steinberg representation
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In the first part of this talk, we will show how the homology of some groups G with coefficients in their Steinberg representation $St(G)$ is linked to various problems. In the second part, we will show how the study of the special case $G = GL_n(\mathbb{Z}[1/2])$ gives informations on exotic cycles, i.e. cycles wich are not in the image of the map in mod 2 homology induced by the inclusion of diagonal matrices in G.

Calculations in $K(2)$-local homotopy theory
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We discuss applications of the decomposition of the $K(2)$-local sphere constructed by Goerss, Henn, Mahowald and Rezk.

Multiple disjunction for spaces of smooth embeddings

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Multiple disjunction results amount to "higher order excision" for certain kinds of mapping spaces. The main application of such results is to establish a sequence of homotopy theoretic approximations to embedding spaces which can be shown to converge in the limit when one is in a codimension at least three situation.

Although the results I will present were first announced in the late 1990s, the complete proof has still not appeared.

In this talk I will give the status of the project, an overview of the proof (which is a mix between pseudoistopy theory, surgery and homotopy theory). I will will also give a taste of the homotopy theoretic details.

Generalized bordism theories and E_∞ structures

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We show that a quasi simplicial spectrum with a commutative cup pairing admits the structure of an E_∞ symmetric ring spectrum on its realization. Examples come from theories of bordism type like the symmetric L-theory. As a consequence, we can generalize the signature of oriented manifolds to an E_∞ map from the oriented topological bordism to the symmetric L-theory spectrum.

An intuitive picture of the homotopy of L_2S^0

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Using the calculations of Shimomura and Yabe and the small resolution of Goerss, Henn, Mahowald and Rezk I will give a picture of the homotopy of the L_2S^0.

The multiplication on MU and BP

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How nice is the multiplication on BP? How nice a map is the Quillen idempotent?

A^1-algebraic topology

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In this talk I will give a survey of basic aspects of A^1-algebraic topology over a base field, emphasizing recent advances in computation of A^1-homotopy groups and A^1-homology groups.

Dyer-Lashof algebra for Morava E-theory

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We discuss recent work whose goal is to understand power operations in Morava E-theories, and in particular the conjecture that these algebras are Koszul algebras.

Fundamental groups of symplectically aspherical manifolds

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A smooth manifold is called symplectically aspherical if it admits a symplectic form ω with $\omega|_{\pi_2(M)} = 0$. Such manifolds were introduced by Floer and play an important role in symplectic topology.

It is easy to see that, unlike in the case of closed symplectic manifolds, not every finitely presented group can be realized as the fundamental group of a closed symplectically aspherical manifold. In the talk we discuss the fundamental groups of closed symplectically aspherical manifolds. We find some properties of symplectically aspherical groups, i.e., obtain restrictions for groups to be symplectically aspherical, and we present some examples of symplectically aspherical groups.

We introduce two classes of fundamental groups $\pi_1(M)$ of symplectically aspherical manifolds M. The first one consists of fundamental groups of such M with $\pi_2(M) = 0$, while the second with $\pi_2(M) \neq 0$. Relations between these classes are discussed. We show that several important (classes of) groups can be realized in both classes, while some groups can be realized in the first class but not in the second one. Also, we notice that there are some interesting dimensional phenomena in the realization problem.

The above results are framed by a general study of symplectically aspherical manifolds. For example, we find some conditions which imply that the Gompf sum of symplectically aspherical manifolds is symplectically aspherical, or that a total space of a bundle is symplectically aspherical.

Hopf Algebras and Quantum Groups
(S. Montgomery, H.-J. Schneider)

Contents

Hopf algebras in differential and difference Galois theories

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M. Takeuchi (1989) gave a beautiful, Hopf-algebraic formalization of the Picard-Vessiot theory for differential equations. The speaker together with A. Masuoka (2005) extended Takeuchi's results so that the Picard-Vessiot theory for difference equations is involved as well. In this talk some applications and subsequent results will be discussed, including the speaker's answer to the solvability problem.

Hopf algebroids and their comodule algebras

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The notion of Hopf algebroids has been invented jointly with K. Szlachányi by equipping Takeuchi's $\times_R$-bialgebra (equivalently, Lu's bialgebroid) with an antipode. The resulting structure involves two (a left and a right) bialgebroids, related by the antipode.

Hopf algebroids can be considered as the generalisation of Hopf algebras to non-commutative base rings. E.g. the theory of integrals has been developed in analogy with Hopf algebras. Maschke type theorems state that a Hopf algebroid is (co)separable over its non-commutative base ring if and only if there exist normalised integrals in (on) it. A Larson-Sweedler-Pareigis type theorem has been proven about the equivalence of a Hopf algebroid to be a Frobenius extension of the base ring to the existence of non-degenerate integrals. Such Frobenius Hopf algebroids were shown to be self-dual in the sense that the dual w.r.t. the non-commutative base ring carries also a (Frobenius) Hopf algebroid structure.

Similarly to Hopf algebras, a most important application of the theory of Hopf algebroids is the study of their comodule algebras. They give rise to entwining structures over non-commutative rings hence to corings. A comodule algebra for a Hopf algebroid H is termed an H-Galois extension of its coinvariants if both corings, corresponding to the coactions of the constituent left and right bialgebroids, are Galois corings, i.e. both canonical maps are bijective. For example, any depth 2 balanced Frobenius extension of algebras is a Hopf algebroid Galois extension.

Kreimer-Takeuchi and Schneider type theorems state that if the antipode of a Hopf algebroid H is bijective and H is either finitely generated and projective as a module for the base ring, or H is coseparable as a coring then under some flatness assumption the surjectivity of any of the two canonical maps is sufficient for an H-comodule algebra to be an H-Galois extension of its coinvariants.

Following Doi, a Morita context has been associated to any comodule algebra for a Hopf algebroid. This can be used to derive sufficient and necessary conditions for the Galois property.

The relative Chern-Galois character

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The Chern character in non-commutative geometry is a collection of maps from the K-groups of an algebra to (even) cyclic homology of this algebra. In recent work [T Brzeziński, PM Hajac, *The Chern-Galois character*, C. R. Acad. Sci. Paris Ser. I **338** (2004), 113–116], a mapping has been constructed form the K_0-group of a coalgebra C (over a field) to the K_0-group of the base algebra of special kind of a colagebra-Galois extension (known as a *principal extension*) with the structure coalgebra C. Followed by the Chern character this gives rise to a family of maps from the K_0-group of a coalgebra to even cyclic homology of the base algebra. Such a family is termed a *Chern-Galois character*.

In this talk we report on the extension of the Chern-Galois theory to corings and relative cyclic homology. This is done in the framework of entwining structures over non-commutative rings. Recall that such a structure consists of an R-ring A, R-coring C and an R-bimodule map $\psi : C \otimes_R A \to A \otimes_R C$, satisfying certain conditions. In particular we construct a family of Abelian group maps from the K_0-group of an R-coring C to even relative cyclic homology groups (introduced by L Kadison) of the coinvariant subalgebra B of A. The construction is illustrated by examples coming for Hopf-algebroid extensions, in particular, those induced by depth 2 extensions of algebras.

Galois corings applied to partial Galois theory

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Partial Galois extensions were recently introduced by Dokuchaev, Ferrero and Paques. We introduce partial Galois extensions for noncommutative rings, using the theory of Galois corings. We associate a Morita context to a partial action on a ring.

Indecomposable representations for quantum SL(2) at roots of 1.
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We study finite-dimensionsal comodules for the $C = k_\zeta[SL(2)]$, the quantized coordinate Hopf algebra of SL(2) at the root of one ζ of odd order over a field k of characteristic zero. In earlier work we described the injective indecomposable comodules for C. This yields the Gabriel quiver Q for C, and a subcoalgebra of the path coalgebra kQ that is Morita-Takeuchi equivalent to C. This subcoalgebra is special biserial in the sense that finite-dimensional subcoalgebras are duals of special biserial algebras. We use techniques from the theory of special biserial algebras to describe all finite-dimensional noninjective comodules as string comodules built out of Weyl comodules and their duals. We also describe the almost split sequences and the Auslander-Reiten quiver.

Quantized modules over basic Lie superalgebras
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For every semi-simple Lie algebra one can construct the Drinfeld-Jimbo algebra U. This algebra is a deformation Hopf algebra defined by generators and relations. To study the representation theory of U, Drinfeld used the KZ-equations to construct a quasi-Hopf algebra A. He proved that particular categories of modules over the algebras U and A are tensor equivalent. Analogous constructions of the algebras U and A exist for basic Lie superalgebras. However, Drinfeld's proof of the above equivalence of categories does not generalize to Lie superalgebras. In this talk, we will discuss an alternate proof for basic Lie superalgebras. Our proof utilizes the Etingof-Kazhdan quantization of Lie (super)bialgebras. It should be mentioned that the above equivalence is very useful. For example, it has been used in knot theory to relate quantum group invariants and the Kontsevich integral. Moreover, from this work, it follows that all highest weight modules of a basic Lie superalgebra can be deformed to modules over the Drinfeld-Jimbo type superalgebra.

The classification of finite dimensional quasi-Hopf algebras with radical of prime codimension

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In my talk I will explain the following joint result with P.Etingof, and describe its proof.

Theorem. Let A be a finite dimensional quasi-Hopf algebra whose radical is a quasi-Hopf ideal of prime codimension p. Then either A is twist equivalent to a Hopf algebra, or it is twist equivalent to $H(2)$, $H_{\pm}(p)$, $A(q)$, or $H(32)$.

Twisted homology of quantum groups

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Cyclic homology and cohomology were discovered by Connes and Tsygan in the early 1980's, and since then have come to play a central role in Connes' formulation of noncommutative differential geometry, representing an extension of de Rham cohomology to various categories of noncommutative algebras. The very simplest formulation of cyclic cohomology arises by considering linear functionals (abstract integrals) on noncommutative differential calculi - the analogue of the graded algebra of differential forms on a manifold.

Quantum groups also appeared in various guises from the early 1980's onwards, with the first example of a "compact quantum group" in the C*-algebraic setting being Woronowicz's "quantum SU(2)". For compact quantum groups, the appropriate differential calculi to study are covariant under the natural action of the quantum group, and "integrals" now give rise to cocycles twisted by an automorphism of the algebra. This was developed into the theory of twisted cyclic cohomology by Kustermans, Murphy and Tuset.

In joint work with Ulrich Krähmer (Humboldt University, Berlin), we calculated twisted Hochschild and cyclic homology for the quantum SL(2) group. This calculation puts known examples of differential calculi and twisted cocycles in a general framework, and very strikingly shows that the "dimension drop" phenomenom in Hochschild homology widely encountered when passing from the classical to the quantum situation can be overcome by twisting via a specific family of automorphisms arising very naturally from the canonical Haar state on the associated compact quantum SU(2) group.

We will discuss these results and extensions to larger classes of quantum groups.

On representation theory of matrix quantum groups of type A
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A quantum groups of type A is defined in terms of a Hecke symmetry. We show in this paper that the representation category of such a quantum group is uniquely determined as an abelian braided monoidal category by the bi-rank of the Hecke symmetry.

LDS permutations
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An LSD permutation is a permutation which is lexicographically smallest in its descent class (when written as words). These permutations have nice combinatorial properties with repect to the (left) weak order and also nice properties with respect to the comultiplications and multiplications on MPR, the Malvenuto, Poirier, Reutenauer Hopf algebra of permutations. In particular they are useful in constructing an algebra retraction of the canonical inclusion of Hopf algebras of NSymm, the Hopf algebra of noncommutative symmetric functions, into MPR, and a coalgebra section of the canonical Hopf algebra projection of MPR onto QSymm, the Hopf algebra of quasisymmetric functions. All this takes place over the integers.

Arithmetic root systems and Nichols algebras of diagonal type
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Nichols algebras of diagonal type play an essential role in the method of Andruskiewitsch and Schneider to classify finite dimensional pointed Hopf algebras. The problem of the classification of finite dimensional Nichols algebras of diagonal type can be reduced to a combinatorial question about arithmetic root systems. The usefulness of this correspondence is explained and a complete list of examples is presented in the rank 3 case.

On Hopf algebra structures over operads

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We study $\mathcal{P}$-Hopf algebras with one coassociative cooperation over different operads $\mathcal{P}$. For example, we consider the Loday-Ronco dendriform Hopf algebra and its isomorphisms with the noncommutative planar Connes-Kreimer Hopf algebra and with a Hopf algebra of Brouder and Frabetti. The space of primitive elements is not closed under $\mathcal{P}$-algebra operations. Starting with a set of primitive generators, we are interested in the operations needed to generate exactly the primitive elements. We focus on Hopf algebra structures over free operads like the operad Mag freely generated by a noncommutative nonassociative binary operation and like the operad of Stasheff polytopes. We prove Poincaré-Birkhoff-Witt type theorems and relate the dimensions of $\mathrm{Prim}\mathcal{P}(n)$ to log-Catalan numbers and other integer sequences.

Dynamical Quantum Groups, The Super Story

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We develop the super analog of the theory of dynamical r-matrices, and dynamical quantum groups. We provide interesting examples and construction results.

Semisimple Hopf algebras of dimension p^n

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In this talk we will discuss the classification of semisimple Hopf algebras of dimension p^n with an abelian group of grouplike elements of index p. We are going to use abelian extensions of Hopf algebras, bicrossed products and Schur multipliers. We will mostly concentrate on the case of $p = 2$.

Hopf Galois extensions up to homotopy

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Hopf Galois extensions are noncommutative analogues of principal fibre bundles with structural group replaced by a Hopf algebra. I'll discuss a concept of homotopy for Hopf Galois extensions and show how it allows a certain classification of such extensions. In particular, we determine all Hopf Galois extensions up to homotopy in the case when the Hopf algebra is a Drinfeld-Jimbo quantum enveloping algebra.

Gauge equivalence of some twisted quantum doubles

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We discuss recent work (joint with Chris Goff and Richard Ng) concerning gauge equivalences among twisted quantum doubles $D^{\omega}(G)$ for (nonabelian) finite groups G, with an emphasis on the role played by the cohomology of G.

Tensor categories attached to double groupoids

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We discuss the construction of a quantum groupoid and, a fortiori, of a tensor category, out of a double groupoid satisfying a filling condition and a perturbation datum given in a joint work with N. Andruskiewitsch. This generalizes a celebrated construction in Hopf algebra theory associated to matched pairs of finite groups. Several important classes of examples of tensor categories happen to fit into this construction. We show how the intrinsic combinatorics of double groupoids reflect into 'Hopf-theoretic' features of the associated quantum groupoids, in particular in the computation of certain invariants such as a pivotal group-like elements and quantum and Frobenius-Perron dimensions.

Representations Parameterized by a Pair of Characters

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Let U and A be algebras over a field k. We study algebra structures H on the underlying tensor product $U \otimes A$ of vector spaces which satisfy $(u \otimes a)(u' \otimes a') = uu' \otimes aa'$ if $a = 1$ or $u' = 1$. For a pair of characters $\rho \in \mathrm{Alg}\,(U, k)$ and $\chi \in \mathrm{Alg}\,(A, k)$ we define a left H-module $L(\rho, \chi)$. Under reasonable hypotheses the correspondence $(\rho, \chi) \mapsto L(\rho, \chi)$ determines a bijection between character pairs and the isomorphism classes of objects in a certain category ${}_H\underline{\mathcal{M}}$ of left H-modules. In many cases the finite-dimensional objects of ${}_H\underline{\mathcal{M}}$ are the finite-dimensional irreducible left H-modules.

We apply these general results to a wide class of pointed Hopf algebras which arise in the Andruskiewitsch-Schneider program for determining the structure of pointed Hopf algebras with commutative coradical.

Higher Frobenius-Schur indicators for quasi-Hopf algebras

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The classical Frobenius-Schur indicators are invariants of an irreducible complex representation of a finite group.

In the study of semisimple Hopf algebras, the Frobenius-Schur indicator of a simple module —introduced by Linchenko and Montgomery— has proved to be a very useful tool. The generalization of degree two indicators to semisimple quasi-Hopf algebras was done by Mason and Ng. Higher indicators for semisimple Hopf algebras were studied by Kashina, Sommerhäuser, and Zhu.

We report on the higher indicators for semisimple quasi-Hopf algebras — their definition, basic properties, and some examples and applications.

The Goldie Theorem for H-semiprime algebras

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In this talk I would like to discuss recent joint work with F. Van Oystaeyen. The main result establishes the existence of quasi-Frobenius classical right quotient rings of H-semiprime right Noetherian H-module algebras for a certain class of Hopf algebras H. There are applications to the semiprimeness problem for smash product algebras $A\#H$.

Yetter-Drinfel'd Hopf algebras over abelian groups

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We review recent progress on the structure theory of Yetter-Drinfel'd Hopf algebras over abelian groups.

Galois theory for Frobenius Hopf algebroids

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For H a Frobenius Hopf algebroid over the noncommutative base algebra R we study H-Galois extensions M/N. Such extensions can be characterized, without reference to H, as the balanced Frobenius extensions of depth 2. Many results of Hopf-Galois theory over finite dimensional Hopf algebras generalize to this situation. Motivated by a construction of Lu and Brzezinski-Militaru, we propose that braided commutative algebras in Yetter-Drinfeld categories over H are 'scalar extensions' for Hopf algebroids and bialgebroids. The Galois quantum groupoid of M/N happens to be the scalar extension of every H for which M/N is H-Galois.

One-sided quantum groups

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Recently, we have constructed a left quantum group, i.e., there is a left antipode but no right antipode(to appear, J.Algebra).The algebra is generated by four comatrix units, but satisfies only some of the relations satisfied by quantum SL(2). We report on our efforts to obtain one-sided Hopf algebras by variations on quantum SL(n) for n greater than 2.

Some observation on set-theoretical solutions to the Yang-Baxter equation

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The notion of braided set was introduced by Etingof, Schedler and Soloviev in 1999, as well as its structure (semi)group. The present talk will give some observation on relations among the ESS theory, T. Gateva-Ivanova and M. Van den Bergh's work on skew polynomial rings with binomial relations (1998) and W. Rump's recent decomposition theorem for square-free symmetric sets, from the viewpoint of matched pairs of groups.

Skew derivations and deformations of algebras

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Kharchenko constructed a Hopf algebra H generated by automorphisms and skew derivations of a given algebra A. In some cases, H (or a suitable quotient) determines certain deformations of A through the existence of universal deformation formulae based on H. A classical example is given by a polynomial ring A and the universal enveloping algebra H of a Lie algebra of derivations; in this case only the identity automorphism of A is used. We give some examples arising from finite abelian groups of automorphisms of particular algebras.

A finite number of defining relations of the elliptic Lie (super)algebras with rank more than or equal to two

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In the talk, I will give a universal construction of the elliptic Lie (super)algebras $\mathbf{g}(R)$ associated with the elliptic root systems R with rank more than or equal to two by using a finite number of generators and defining relations. Here what 'universal' means that for a Lie (super)algebra $\mathbf{g}'$ having an elliptic root system R as its real-root system, there exists a canonical surjective map $f : \mathbf{g}(R) \to \mathbf{g}'$ (we need some modification in case $R = A_\ell^{(1,1)}$). Moreover it turns out that $f : [\mathbf{g}(R), \mathbf{g}(R)] \to [\mathbf{g}', \mathbf{g}']$ is a universal central extension surjective map.

Mathematical Physics (L. Erdös, M. Loss)

Contents

A model for the study of the quantum decoherence.

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Decoherence is the mechanism invoked in order to explain the disappearance of quantum features in the macroscopic world. It is widely known that the superposition principle in quantum mechanics gives rise to interference terms in the probability distributions associated to quantum states. By decoherence one means the suppression of such terms, induced by the time evolution. The action of some external environment is generally recognized to be responsible for such effect. We present a derivation of the phenomenon of decoherence from a model consisting of one heavy particle interacting with a large number of light particles, that model the environment. We give an explicit estimate of the depression of the interference terms induced on the heavy particles by the scattering with the light one, in the limit of vanishing mass ratio.

Generalized Hardy inequality for the magnetic Dirichlet forms

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We obtain lower bound for the magnetic Dirichlet form in dimensions ≥ 2. For $d = 2$ the results generalize a well known bound by the magnetic field strength: we replace the actual magnetic field B by a non-vanishing effective field. We also extend the Laptev-Weidl inequalities to the case of Aharonov-Bohm magnetic potentials with multiple singularities. In the case $d \geq 3$ we establish that the magnetic form is bounded from below by the magnetic field strength, if one assumes that the field does not vanish and its direction is slowly varying.

Electron/positron field for relativistic atoms in the Hartree-Fock approximation

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We present some rigorous results concerning a conjecture due to Mittleman connecting the ground state energy for relativistic atoms obtained by two methods: The solutions of the so-called Dirac-Fock equations and the minimization of the energy functional derived from a formal Hamiltonian in no-photon Q.E.D. We will in particular emphasize the Hydrogen case.

Entropy-entropy dissipation inequalities and sharp rates of relaxation for a thin film type equation

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Building on recent work of Laugesen, we prove sharp entropy-entropy dissipation bounds for a class of thin film type equations, and use them prove a sharp bound on the rate of relaxation in the Sobolev norm H^1.

Large time behavior of dissipative kinetic equations-new results

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Kinetic equations with a collision term (denoted by Q) write

$$\partial_t f + v \cdot \nabla_x f = Q(f), \tag{.1}$$

where $f \equiv f(t,x,v) \geq 0$ is the density of particles which at time t and point x move with velocity v.

A general method for obtaining explicit estimates for the large time behavior of (.1) in a bounded domain (with boundary conditions) has been devised by L. Desvillettes and C. Villani (it makes use of the so-called entropy/entropy dissipation method and of a concept called "hypocoercivity").

We wish to present some of the latest developments of this method, and to illustrate them on a simple transport equation like

$$\partial_t f + v \cdot \nabla_x f = \sigma \, (\int_{v \in S^2} f \, \frac{dv}{4\pi} - f), \tag{.2}$$

where $v \in S^2$ and σ is an opacity which can depend on certain parameters.

We shall also explain how analogous ideas can help to obtain explicit estimates for the large time behavior of reaction-diffusion equations like

$$\partial_t a_i - d_i\, \partial_{xx} a_i = (-1)^i\, (a_1\, a_3 - a_2\, a_4), \qquad i = 1, .., 4 \tag{.3}$$

$$\partial_x a_i(t, 0) = \partial_x a_i(t, 1) = 0,$$

where $a_i \equiv a_i(t, x) \geq 0$ is the density of species i at time $t > 0$ and point $x \in]0, 1[$.

Problems in Mathematical Physics originating in Bohmian Mechanics

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I shall introduce Bohmian Mechanics, which is a Quantum Theory without observers, i.e. the physically problematical notions of observer or observable are not elements of the theory. The theory is about point particles in motion. The statistical mechanics of Bohmian Mechanics leads to POV-measures and to the usual Quantum Formalism. I shall focus mainly on the foundations of scattering theory which presents formidable problems for mathematical physics, going well beyond the asymptotic analysis of the S-matrix formalism.

Strong magnetic field limit for the magnetic Dirac Hamiltonian

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In this talk I will present a recent joint work with J. Dolbeault and M. Loss about how large a constant magnetic field can be before a relativistic electron loses stability. We will also see that near the threshold, the ground state of magnetic Dirac Hamiltonians is in a symmetric state which corresponds (in some sense) to the lowest Landau level.

Stone-von Neumann Theorem in Quantum Geometry

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The configuration space of quantum geometry is the compact space $\overline{\mathcal{A}}$ of distributional connections in a principal fibre bundle P with compact structure group. The corresponding Weyl algebra $\mathfrak{A}$ is generated by the continuous functions on $\overline{\mathcal{A}}$ and the pull-backs of certain homeomorphisms on $\overline{\mathcal{A}}$. The latter ones correspond to the left translations generated by the momenta in quantum mechanics. Recently, it has been shown that there is (up to unitary equivalence) only one regular representation of $\mathfrak{A}$ having a cyclic and diffeomorphism invariant vector. Additional assumptions concern the dimension of the base manifold M of P (at least three) and how the action of diffeomorphisms on M is lifted to the representation space. In this talk, the main ideas of the proof are going to be discussed.

Limiting Absorption Principle for the Standard Model of Non-Relativistic QED

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For atoms and molecules with static nuclei and non-relativistic electrons that are coupled to the quantized radiation field in Coulomb gauge (standard model of non-relativistic QED), we prove a limiting absorption principle in a neighborhood of the ground state energy and we derive local decay for the photon dynamics as a corollary. In particular we prove absence of (excited) eigenvalues and absolute continuity of the spectrum near the ground state energy, a region that has evaded all previous investigations. – This is joint work with Jürg Fröhlich and Israel Michael Sigal.

The mean-field approximation to Quantum Electrodynamics. The no-photon case

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Starting from a first-priciple QED Hamiltonian, in Coulomb gauge, neglecting photons, we show that, in Hartree-Fock approximation, this Hamiltonian has a minimizer although it is a priori ill defined. We make sense out of it by means of an infinite volume limit.

On the controllability of nonlinear Schrödinger equations

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We consider the *bilinear control problem* for the nonlinear *Hartree–Schrödinger equation* (which plays a prominent rôle in quantum chemistry), and for the nonlinear *Gross–Pitaevskii equation* (of the theory of *Bose–Einstein condensates*), both with the standard unbounded dipole bilinear control term (usually a laser field). In both cases we can show the noncontrollability of these equations in the sense that for each reasonable initial data and any given time $T > 0$, the set of *non-reachable states* at time T is dense in the state space manifold, and furthermore, that there is an L^2–open subset in the state space manifold at time T. This means that both systems are not exactly and not even *approximately* controllable at any time T. This result is analogous to the noncontrollability result of *Ball/Marsden/Slemrod* for linear evolution systems with bounded control terms. The proof uses Fourier transform and the Hardy–Littlewood estimates for Riesz potentials in the Hartee case, whereas in the the Gross–Pitaevkii case some sort of *coherent state transform* is applied.

The future asymptotic behaviour of the Einstein-Vlasov system in locally spatially homogeneous spacetime

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We consider the Einstein-Vlasov system coupled to a scalar field with a non-negative potential in locally spatially homogeneous spacetime, as an expanding cosmological model. It is shown that solutions of this system exist globally in time. When the potential of the scalar field is of an exponential form, the cosmological model corresponds to accelerated expansion. The system shows the causal geodesic completeness of the spacetime towards the future. The asymptotic behaviour of solutions of this system in the future time is analysed in various aspects, which shows power-law expansion.

Infrared finite algorithms in Q.E.D.

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We consider a nonrelativistic electron moving in the Coulomb field of a single nucleus of unit charge and interacting with the soft modes of the quantized electromagnetic field. Our main concern is how to rigorously control the higher order corrections to the scattering amplitudes in the low energy regime (Rayleigh scattering). In fact Taylor expansion is ill-defined when no infrared regularization is adopted. We develop a proper perturbation theory and provide an asymptotic expansion up to any order in the coupling constant. This physically sensitive result (towards a rigorous analysis of metastable states) requires a mathematical technical work for the asymptotic expansion of the ground state. Concerning this expansion, we use a scaling analysis based on the iteration of the analytic perturbation.

On the effective action in many-fermion systems

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The effective action contains all information about the correlation functions of a quantum field theoretical system. We study it for many-fermion systems used to describe electrons in conductors, such as the Hubbard model. We prove that, for a two-dimensional system with a regular, curved Fermi curve, and for temperatures above a temperature that is exponentially small in the interaction strength, the effective action can be obtained by convergent expansions. Besides the usual terms leading to forward and exchange scattering, it contains a Cooper pairing term. The proof uses a combination of tree and arch expansions and determinant bounds. We also remark on higher dimensions and on the uniqueness of KMS states for these models.

The Bogoliubov-Dirac-Fock model for molecules

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The Bogoliubov-Dirac-Fock (BDF) model is a mean-field approximation of no-photon QED. A ground state of the BDF energy in the charge sector -N, if it exists, can be written as a sum of two projectors. The first one, of infinite rank and charge zero, is interpreted as the Dirac sea in the BDF mean field. The second one, of rank N, represents a system of N electrons, and is solution of a system of unprojected Dirac-Fock equations, corrected by a vacuum polarization term. We prove the existence of such a ground state near a collection of fixed nuclei, in several particular situations.

Uniqueness of Energy Minimizing Solutions of the Dirac-Fock Equations

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Esteban and Séré showed that the Dirac-Fock equations have solutions which are energy minimizing in the non-relativistic limit. In the case when the atom – in a certain sense – is closed shell, e.g., when it has two electrons, we give an alternative simple proof of this fact, that does not only allow to show uniqueness of the solutions but also gives explicit estimates for the occuring coupling constants. In fact, we can cover certain physical ranges on the Sommerfeld fine structure constand α and the atomic number Z.

The ground state energy of the two component charged Bose gas

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In 1967 F. Dyson conjectured an asymptotic formula for the quantum mechanical ground state energy of a gas of charged particles in the limit of a large number of particles. The formula, which is based on the Bogolubov pair approximation is given in terms of the solution to a non-linear Schrödinger equation. A crucial assumption is that the particles obey either no statistics at all or obey Bose statistics. A consequence of the formula is that such a gas of particles is unstable. Dyson already concluded this in 1967 without the exact formula. The aim of my talk is to give an overview of a recent proof of Dyson's conjecture. Part of this work is a collaboration with E. Lieb.

The relativistic Scott correction for molecules

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We prove the Scott correction for the ground state energy of molecules when the kinetic energy $T(p)$ of the electrons is treated relativistically ($T(p) = \sqrt{p^2 + m^2} - m$). The proof uses the coherent state calculus introduced by Solovej and Spitzer to give a simpler proof of the non-relativistic Scott correction.

Diophantine tori and spectral asymptotics for non-selfadjoint operators

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We study spectral asymptotics for non-selfadjoint perturbations of self-adjoint pseudo-differential operators, in the semiclassical limit $\hbar \to 0$. Using microlocal quasimodes located near diophantine tori, we obtain a complete description of the spectrum in a small complex window, which is more accurate than what was possible with similar ingredients in the self-adjoint case. The result applies in particular when the unperturbed (self-adjoint) operator is already a small perturbation of a completely integrable system.

I will present the main ideas and show how they apply to the Laplacian on surfaces of revolution.

Mathematics Education
(G. Törner, A. Schoenfeld)

Contents

'Doing Mathematics': performance and assessment

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'Doing mathematics' is a complex process, involving much more than skills in symbol manipulation - otherwise, anyone with a sophisticated calculator could 'do mathematics'. Research has revealed five dimensions of performance: *knowledge and skills; strategies and tactics* for tackling problems; *monitoring and control; beliefs, and disposition* to think about problems mathematically; all integrated as *mathematical practices*. These are important both in pure mathematical investigations and in using mathematics to model practical situations. Assessment of mathematical performance needs to recognize this complexity - and to avoid the misconception that assessing the elements separately assesses mathematics. Further, if assessment is to support and reward a set of curriculum goals, it must reflect these in a balanced way. These points will be explained with examples of tasks, scoring schemes and student work from high-stakes assessment in, and between, various countries.

Using a Personal Response System to Engage Students

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The Institute for Mathematics Learning (IML) at West Virginia University (WVU) is working to help students succeed in calculus and before level courses. At WVU, College Algebra historically had D, F, Withdraw (DFW) rates that fluctuated between 40 percent and 60 percent. Within the past five years, the implementation of interactive laboratories, web homework quizzes, and curriculum reform, have helped the DFW rate fluctuate between 30 percent and 40 percent. Currently it is the goal of the IML to stabilize DFW rates to 30 percent, while maintaining the integrity and rigor of the course. While students now actively participate in weekly laboratory sessions, it is believed that work still needs to be done to engage students during lecture. Because of the large number of students enrolled in each section of the course, it is a challenge to find a teaching method which can engage each student during each class. This presentation will summarize preliminary results of the implementation of a Personal Response System (PRS) in a large sectioned course of College Algebra to encourage active student participation in the classroom.

The role of metacognition in teaching and learning mathematics

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In the last ten years of international discussions about mathematics education, it has increasingly been discussed to make reflection and metacognition a central component of mathematics teaching. We will analyse components of metacognition that are employed during understanding of mathematical concepts and procedures. We will develop a theoretical model and apply it to the analysis of teaching scenes. All scenes have in common that within a mutually shared discursive lesson culture pupils discuss the interplay of external and internal, mental representation, of the things being said and those being meant.

What aspects of elementary mathematics are most important in nurturing young mathematicians

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(Note: The expression "young mathematicians" in the title is to be interpreted broadly.) In many western countries, school mathematics has remained superficially stable in recent decades; yet the underlying character of what is taught and what is expected of students has shifted dramatically. The pedagogical rhetoric justifying this shift in emphasis often stresses "understanding", "enjoyment", and "solving problems"; yet (at least in the UK) the result has been reduced competence, ignorance of what makes elemantary mathematics tick, and an inability to solve simple two-step problems. We will report briefly on the evidence for this diagnosis before attempting an anlysis of those central aspects of elementary mathematics which we have systematically neglected, yet which are most important for nurturing a truly mathematical sensibility in a large number of students at school level.

Proof and proving in mathematical classroom

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This lecture will present practical attempts to develop methodology for exploring, understanding and using the proof in concrete situation. We think that involving proof methodology will develop more solving approaches to the theorems or tasks and will increase students understanding of they need to know and be able to do.

We will introduce proof definition, different types of mathematical proof and solve some concrete tasks using mentioned proof types

Simulation experiences and concepts of mathematics

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Numerical simulations appear in mathematics education mainly in the form of computer-based tools designed for the exploration or visualization of mathematical phenomena. In neighboring sciences computer-based simulations are widely accepted as a scientific means and are seen as the most promising growth market for jobs requiring mathematical skills.

Simulations differ from mathematical modeling processes in that they are representations of the mathematical world, and as representations are mimetic of it. Although they cannot be accepted for mathematically rigoros proofs, they can be used for activities in mathematics education that resemble those in professional lives with a mathematical background: the understanding and the creation of appropriate tools rather than the sole use of commercial programs, the bridging of gaps of mathematical knowledge and theories by simulating them with computers, and building up mathematical intuition with computer-based experiments in interdisciplinary contexts.

Such activities contradict the traditional way mathematics is seen and taught as a connected net of knowledge. In this project, students in secondary education and pre-service teachers at the university are given tasks of that kind for dynamic geometry software, computer algebra systems, and spreadsheet programs. Their views on mathematics and their attitudes towards computers are observed at different stages of their work. More precisely, environments using Monte Carlo methods are compared with classical approaches; and in geometric simulations of elementary algebra problems, students are confronted with digital visualizations which contradict the mathematical theory.

In the survey the confidence in one's own mathematical abilities is compared to the attitude to computers and their role in mathematics. Conditions for a

successful work on simulations are elaborated; the students' descriptions indicate, for instance, that already the analysis of elementary simulation tasks can be a challenge to students' command of language in mathematical discussions. We discuss how frameworks in mathematics education could enable students to perform activities involving simulations.

Structure in Diversity: Initiation into Mathematical Practice in Classrooms from Germany, Hong Kong and the United States

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The presentation reports some results of six case studies of two secondary classrooms (pupils aged 13 - 15) in each country that draw on a sub-sample of data from the Learner's Perspective Study (The 'LPS' studies the practices and associated meanings in eighth-grade mathematics classrooms in ten countries). Each case study details classroom context, discusses the day-to-day experience of observed lessons as seen by teacher and students and portrays lesson structure and mathematical topics across ten lessons. In addition, it compares and contrasts teacher's and students' views of pedagogy, reconstructs how relevance and meaning of the mathematics were intended to develop by the teacher and how they were seen as developing by the students. Finally, framing, classification and mathematical reasoning are analysed. The study also identifies important similarities in the function of classroom events (such as 'Student at the Front'), students' practices and perceptions across classrooms. The research goal was to theorise and empirically to illustrate affordances and constraints of intentional self-initiated learning situations. The discourse in the classrooms most of the time appeared clearly structured and constrained. Even in so-called inquiry-based lessons the teacher had the power to sanction the discourse. Since the classrooms in the study substantially differ in terms of student demography, curriculum tradition, student achievement, and cultural context, the similarities support generalisation beyond the cases studied.

Promises and Perils of PISA

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Although PISA has gotten a lot of attentiuon in many countries, nad particularly Germany, it still a discussion that is not going very deep, but stays mainly at the policy-level. Content discussions are limited and focus on one or two items or so. It is time to look at the content of PISA in some more detail: what is the instrument, and can it be improved? The prsenter is Chairman of the International mathematics Expert Group of OECD/PISA.

Proof in a College Geometry Class

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As teachers, many of us struggle to help our students produce careful, rigorous proofs. In order to help them, it is useful to identify which aspects of proof are essential for being able to construct one. In this talk we propose the notion of "key idea" to characterize one essential aspect of proof that plays a major role in proof production. We will define "key idea" and show, using excerpts from a college geometry class, some of the roles it can play in both promoting and inhibiting the development of a proof.

Reasoning and proof in geometry: Effects of a learning environment based on heuristic worked-out examples

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In this presentation, we argue that heuristic worked-out examples are an adequate learning environment for mathematical argumentation and proof. It enhances the traditional worked-out examples that turned out to be efficient for the learning of algorithmic problem solving. The basic idea of heuristic worked-out examples is providing students with opportunities to explore, recognize, and use explicitly different phases in the process of performing a proof. The results of an intervention study with 243 students from grade 8 suggest that this learning environment might be more efficient than regular mathematics instruction on proof. The ability to give correct mathematical argumentation and to generate a proof for a specific hypothesis is based on several aspects like knowing

mathematical concepts, knowing heuristic strategies and being able to use them, having metacognitive control strategies available, and understanding the nature of mathematical proof. Empirical studies indicate that students lack one or more of these facets of proof. In this study we investigated to what extent learning to prove can be fostered by heuristic worked-out examples. We addressed the question, whether this learning environment is of special use for low-achieving or high-achieving students. Comparing the mean posttest scores of the experimental and the control group we found a significant difference: the experimental group performed much better in the posttest than the control Summarizing the analysis of the posttest results the experimental group performed significantly better than the control group. Moreover, students from the experimental group performed significantly better on complex proofs. We found a positive effect on the achieve-ment of students learning with heuristic worked-out examples (in comparison to a control group receiving traditional mathe-matics instruction).

Aktive Mathematik – Describe, Compute, Understand: A Program for (Continuing) Teacher Education

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Aktive Mathematik is an official project of the DFG Research Center's Matheon 'Mathematics for Key Technologies' and is recognized by the Berliner Landesinstitut für Schule und Medien (LISUM) as a continuing education program for teachers. As the name suggests, Aktive Mathematik provides an environment in which the participants solve practical problems using mathematics. The approach is not to present the required material and then search for an application, rather a practical problem is proposed. The participants find (and deal with) in a natural way the mathematics required for its solution. Although recognized as a continuing education program, Aktive Mathematik is an integrated program for practicing and future teachers. This contribution presents some of the key features of Aktive Mathematik and discusses some of the ramifications of this approach.

Problem solving research and practice in the US, 1975-2005

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In the 1970s and 1980s, research in mathematical problem solving resulted in new understandings of what it means to be good at problem solving. It showed that the following are important:

(i) the knowledge base,

(ii) knowledge of problem solving strategies (heuristics)

(iii) 'control' (monitoring and self-regulation, ormetacognition)

(iv) beliefs, and the practices that give rise to them.

What was lacking was a sense of mechanism - a description of how and why the problem solver makes the choices he or she makes, while engaged in problem solving. Twenty years later, we have a rigorous ways of thinking about such issues, and the core of a robust theory. I will describe these later results in a much more dynamic setting: that of a teacher engaging in the problem solving actions of trying to teach effectively.

I will also describe the practical impact of the research. In the U.S., 'reform' curricula with a focus on processes such as those described above were developed. These were controversial, leading to the 'math wars.' American school mathematics curricula are still in flux, and the issues still controversial.

3-Dimensional Dynamic Geometry

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Now computer representations using all the possibilities of computer graphics for synthetic geometry of space do exist besides its traditional representations. The dynamic 3D-geometry or the drag-mode-geometry in space plays a further-reaching role among synthetic geometry in the virtual space than the geometry of the 2-dimensional dynamic geometry systems: geometric constructions in space e.g. such of Euclid (cf. Book XI-XIII) are now executable, which in the past have been confined to an execution in imagination and had to be represented by the methods of descriptive geometry in the plane. The prototypic Cabri 3D (Laborde, Bainville 2004) overcomes this confinement and supports in general the synthetic geometric work (generating, visualizing, manipulating, modifying of spatial configurations) and the spatial perception in the virtual space thanks to its software ergonomic facilities and its geometric options. - The traditional geometric topics synthetic space have to learn a new adequate treatment resp. a re-evalution in the context of the teaching and learning of synthetic spatial geometry by the use of this cognitive computer tool.

Predicative versus functional thinking

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A particular interest for invariances on the one hand and variability on the other hand as seen in stationary and moving objects respectively has often led people to more or less severe disagreements. The notions of *predicative thinking* versus *functional thinking* describe a cognitive pattern that tries to explain the preference or even special capability for either one of the two view points. Meanwhile, there are not only numerous qualitative experimental results that prove the usefulness of this theoretical construct, but also an EEG-study and several studies involving eye-movement analysis that emphasise quantitative evidence. As aspects of predicative thinking have been studied quite frequently in cognitive psychology, there is an accumulated need for studies of functional thinking. Seen from a historical point of view, two approaches to the formation of mathematical knowledge can be distinguished: classical Greek substantiated inferential knowledge and ancient oriental functional knowledge. We see a connection to our investigations.

Problem Solving by Generalization

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It is quite natural to consider specialization as a powerful problem solving strategy: one hopes that an insight gained by looking at a special case will be helpful in solving the problem in general, or that some technique which conquers a special case can be transferred to the general situation. But it may seem odd to consider generalization - the opposite of specialization - as a useful problem solving strategy, too. It turns out, however, that many particular problems are easier to solve when cast in a more general form. In my talk, I will discuss some examples of this at the undergraduate university level.

Problem solving in German mathematics education (1975 - 2005) - some comments from a German perspective of view

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It is self-evident, that in Germany as in many other Western countries mathematics learning is partially regarded as a continuous process of solving mathematical problems. Further, in (German) mathematics literature one can find many substantial contributions. Contrary to USA, however, problem solving as an independent strand has never played a major role in the various German curricula over the last 30 years. The author will focus this question and offers some remedies to change the situation.

Some undergraduate students' errors that may be related to confusing a set with the collection of its elements

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As the first step of a project on learning difficulties in elementary set theory, we carried out a study aimed at identifying some of the difficulties encountered by a group of 21 students (mathematics or computer science majors) taking a course on logic and set theory. In the presentation, we shall discuss one of the difficulties that we observed, namely confusing a set with the collection of its elements, i.e. failing to fully grant sets the status of objects. This difficulty may be related to the following three types of errors that we observed in the students' first assignment: 1) confusing the relations of belonging and inclusion, 2) confusing the union of two sets A and B with the set whose elements are A and B, and 3) adding or deleting curly brackets. We shall present excerpts from the students' work illustrating these three types of errors and explain how they can be related to confusing a set with the collection of its elements. Furthermore, we shall draw some parallels with the historical development of the notion of set.

Heuristics in Ancient Arabic Mathematics

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Ibn al Haitham, ibn Sinan and al Sijzi (10th century) have written quite interesting treaties on mathematical heuristics, which might be very useful for modern educational goals. Some drafts are presented and discussed in modern educational environments, including modern textbooks.

Modules and Comodules
(S.R. Lopez-Permouth, R. Wisbauer)

Contents

Co-endoprime Comodules

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In this talk we present and characterize (completely) co-endoprime, co-endosemiprime comodules of corings over arbitrary base rings and study the structure of comodules satisfying these conditions.

We study the relations between these concepts and other (co)primeness and (co)semiprimeness conditions for (co)modules in the literature.

In addition we introduce the notions of co-endoprimitive (co-endosemiprimitive) comodules and study their relations with simple (semisimple) and co-endoprime (co-endosemiprime) comodules.

Cogalois Theory, Clifford extensions, strongly graded algebras, and Hopf Algebras

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The aim of this talk is to present some interesting connections of *Cogalois Theory* with *Clifford extensions, strongly group graded algebras*, and *Hopf algebras*.

Cogalois Theory is a fairly new theory that investigates field extensions, finite or not, possessing a Cogalois correspondence. This theory is somewhat dual to the very classical one known as *Galois Theory* investigating field extensions possessing a Galois correspondence.

The concepts of *Clifford system* and *Clifford extension* were invented in 1970 by *Everett C. Dade*. Dade also introduced ten years later the concept of *strongly group graded algebra*.

In this talk we analyze first the basic concepts of *Cogalois Theory* like *G-radical, G-Kneser*, and *G-Cogalois field extension* in terms of *Clifford extensions* and *strongly group graded algebras*. We describe then the Kneser and Cogalois field extensions in terms of *Galois H-objects* appearing in *Hopf algebras*.

Cotensor Coalgebras and Hereditary Coalgebras in Monoidal Categories.

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We introduce the concept of cotensor coalgebra in an abelian monoidal category. In this setting, we investigate the relation between hereditary coalgebras which are colimits of coseparable coalgebras and some cotensor coalgebras.

Ring and Module Hulls

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In this talk we discuss various concepts of the hull of a ring or module, where the hull is from a certain class of rings or modules, respectively. Existence or uniqueness results on hulls from various classes (including extending, FI-extending, continuous, etc) are presented. Examples are provided to illustrate the theory.

Galois coverings, Morita equivalence and smash extensions of categories over a field

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We consider categories over a field k in order to prove that smash extensions and Galois coverings with respect to a finite group coincide up to Morita equivalence of k-categories. For this purpose we describe processes providing Morita equivalences called contraction and expansion. We prove that composition of these processes provides any Morita equivalence, a result which is related with the karoubianisation (or idempotent completion) and additivisation of a k-category.

Local morphisms in noncommutative algebra

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In commutative algebra, a morphism $\varphi\colon R \to S$ is local if $\varphi(M) \subseteq N$. Here $(R, M), (S, N)$ are local commutative rings. For us, a morphism $\varphi\colon R \to S$ is local if $r \in R$ and $\varphi(r)$ invertible in S imply r invertible in R. Here R and S are not necessarily commutative rings. The two notions coincide for local commutative rings. We shall see some properties and applications of this concept in a noncommutative setting. The main application will be to endomorphism rings of objects in Grothendieck categories, in particular when these endomorphism rings are semilocal, that is, semisimple artinian modulo the Jacobson radical.

Simple Functors on the Category of flat modules

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We develop a method for studying indecomposable flat cotorsion modules in terms of simple subfunctors of continuous functors from Flat-R to Ab. Several consequences are deduced. For instance, we show that the class of indecomposable flat cotorsion modules forms a set that "purely cogenerates" the category of flat modules over the ring R. And therefore, it determines the structure of Flat-R. We also discuss the notion of a Spectrum for the category Flat-R.

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Tilting modules are of finite type

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A right R-module T_R is said to be a tilting module if the class of modules generated by T_R coincides with $T_R^{\perp} = \operatorname{Ker}\operatorname{Ext}_R^1(T_R, -)$.

In this talk we want to present the result that tilting modules are of finite type. That is, if T_R is a tilting module then there exists a set $\mathcal{S}$, consisting of finitely presented right R-modules of projective dimension at most one, such that

$$T_R^{\perp} = \mathcal{S}^{\perp} = \bigcap_{S \in \mathcal{S}} \operatorname{Ker}\operatorname{Ext}_R^1(S, -).$$

Localization and Representation Theory of Coalgebras

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The Representation Theory of Coalgebras is a recent theory whose purpose is the knowledge of a class of non necessarily finite dimensional coalgebras from the point of view of the Representation Theory of Artinian Algebras. Therefore the strategy which is usually employed is analogous to the classical one, that is, to describe coalgebras and its category of comodules by means of quivers and its representations. In this context, the first step must be to get a version for coalgebras of the famous Gabriel's theorem: *every basic finite dimensional algebra, over an algebraically closed field, is the path algebra of a quiver with relations.*

Following this idea, Woodcock (in 1997) proves that every pointed coalgebra is an admissible subcoalgebra of a path coalgebra. Later Simson (in 2001) introduces the notion of path coalgebra of a quiver with relations. That definition is consistent with the classical theory because in such case the category of comodules is equivalent to the category of nilpotent linear representations of the quiver. Then the following question is raised: *is any basic coalgebra, over an algebraically closed field, isomorphic to the path coalgebra of a quiver with relations?* Unfortunately, this is not always true. Examples are given by the authors (in 2005); also a criterion to decide whether or not an admissible subcoalgebra is a path coalgebra of a quiver with relations. Nevertheless these examples are of wild comodule type and therefore the problem is reformulated: *is any basic tame coalgebra, over an algebraically closed field, isomorphic to the path coalgebra of a quiver with relations?*

Depth two bimodules and the endomorphism ring theorem for Galois extensions

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We sketch a theory of left bialgebroids and their Galois extensions, a duality with right-handed versions of these extensions, and their characterization as left depth two, balanced or faithfully flat extensions (the non-Frobenius generalization of work by the author, Balint, Szlachanyi and Nikshych). The endomorphism ring theorem says that the left endomorphism ring is a left Galois extension of the over-ring of a right depth two extension. There are several possibilities opening up with this including a practical generalization of depth two to bimodules.

Construction of Hopf algebras by means of finite dimensional dual Yd-quadruples

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Let H be a Hopf algebra, let R be a coalgebra in the category of Yetter-Drinfel'd modules ${}^H_H\mathcal{YD}$ and let $\xi : R \otimes R \to H$ be a normalized 1-cocycle. Some results on the algebraic structure of R and consequently of $R\#_\xi H$ are presented.

Purity in categories of modules and comodules

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Notions around purity (pure-injectivity = algebraic compactness, various spectra, ...) have been used in both algebraic and model-theoretic investigations. Essentially everything in this circle of ideas that works for modules works in rather general additive categories. I will try to illustrate the scope of these ideas and results and will give examples of applications in specific contexts.

Tame/wild dichotomy for coalgebras, quadratic forms and comodules via nilpotent representations of quivers

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Part 1. Let K be an algebraically closed field and C a K-coalgebra. We introduce the concepts of tame comodule type and of wild comodule type of a coalgebra C. We prove a week version of Drozd tame/wild dichotomy theorem for coalgebras and a complete version of it for a wide class of coalgebras.

Part 2. We show how the quiver representation technique can be applied in the study of the category of C-comodules, and in particular, in classifying the indecomposable comodules of finite dimension over a coalgebra. We shall indicate a role of path colgebras of bound quivers and almost split sequences in the study of coalgebras and comodules. We also study comodule theoretical properties of K-coalgebras C by means of the shape of the left Gabriel quiver ${}_CQ$ of C. In particular, we study left pure semisimplcity of coalgebras by means of ${}_CQ$.

Part 3. We introduce the class of Euler coalgebras C (including interesting coalgebras of infinite global dimension) and we study them by means of an Euler integral quadratic form $q_C : K_0(C) \to \mathbb{Z}$, where $K_0(C) \cong \mathbb{Z}^{(I_C)}$ is the Grothendieck group of C. Examples and applications of q_C to the study of C-comodules will be given.

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Topological linear compactness for Grothendieck categories. Theorem of Tychonoff and applications to coalgebras

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Tychonoff's theorem is a classical result for linear compact modules over rings, which does not remain true for general Grothendieck categories. We obtain a positive answer for Grothendieck categories having a set of small projective generators. This result applies for rigth semiperfect coalgebras, graded rings and rings with local units. Moreover, we study the linear compactness of the dual algebra of a coalgebra. For this algebras the discrete linear compactness is equivalent to the noetherian property, and when the coalgebra is almost connected the topological linear compactness is equivalent to the almost noetherian property. We also show that if this algebra has a right Morita duality it has a self-duality.

Dimension of a Class of Baer *-Rings Defined by a Relaxed Set of Axioms

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In previous work (Dimension and Torsion Theories for a Class of Baer *-Rings, to appear in the Journal of Algebra), I generalize some known results on finite von Neumann algebras, by purely algebraic proofs, to a certain class C of finite Baer *-rings. I define the dimension of any module over a ring from C and prove that this dimension has the same properties as the dimension for finite von Neumann algebras. The class C is defined via nine axioms two of which are particulary strong. In this talk, I will demonstrate that the remaining seven axioms are sufficient for obtaining all properties of the dimension.

Cohomology for Comodules: Separable and Maschke functors.

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The notion of a Maschke Functor was first introduced and studied by S. Caenepeel and G. Military. One of the remarkable facts is that every separable functor is a Maschke functor and the converse is true in some particular and interesting cases, such as the forgetful functor $\mathcal{M}_H \to \mathcal{M}_k$, where H is an Hopf algebra over k. In the proper formulation, this last statement goes back to a classical result of M. Sweedler.

Generalising a cohomological treatment of comodules over corings by F. Guzman to the framework of comonads, we furter investigate the relation between separable and Maschke functors. In particular we obtain the result that for a large class of (forgetful) functors the separability of such a functor is equivalent with the fact that a closely related functor is Maschke.

Endo-coprime Modules Applied to Coalgebras

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In this note we define endo-coprime modules, that is modules which are coprime over its ring endomorphism and observe some related properties. The main purpose of this work is to apply the similar technique to define coprime coalgebra C by consider it as a right comodule over itself and as a module over its dual algebra.

On Simple-Injective Rings

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If M_R and N_R are right R-modules, M is called *simple-N-injective* if, for every submodule L of N, every R-homomorphism $\gamma : L \to M$ with $\gamma(L)$ simple extends to N. A ring R is called *right simple-injective*, if R_R is simple-R-injective. Every semiprimary right simple-injective ring is right self-injective, and every left perfect left and right simple-injective ring is quasi-Frobenius. There are examples of left perfect left simple-inective rings that are neither left self-injective nor right simple-injective, and it has been conjectured that left perfect right simpe-injective rings are right self-injective. It has also been left open whether left Kasch left simple-injective rings are semiperfct or right Kasch.

In this talk we provide a partial positive answer to the conjecture on left perfect right simple-injective rings, and negative answers to the questions on left Kasch left simple-injective rings.

On strongly clean matrix rings

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A ring R is called strongly clean if every element of R is the sum of an idempotent and a unit that commute. Strongly clean rings are the "additive analogs" of strongly regular rings, because a ring R is strongly regular if and only if every element of R is the product of an idempotent and a unit that commute. Examples of strongly clean rings include local rings and all strongly pi-regular rings (a result of Burgess and Menal). But the 2 by 2 matrix ring over the localization of Z at 2 is not strongly clean (this was observed by Sanchez Campos and Wang-Chen, independently, answering two questions of Nicholson). In this talk, we present various new results towards the question when a matrix ring is strongly clean.

Multiplicative Arithmetic of Integral Domains and Monoids (S.C. Chapman, F. Halter-Koch, U. Krause)

Contents

Conic divisor classes of normal affine monoids

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The divisor class group of a normal affine monoid M (or the monoid algebra $K[M]$ over a field K) contains certain elements which are "close" to the trivial class and for a geometric reason have been called *conic*: they are given by the elements of $\mathrm{gp}(M)$ that are contained in a parallel translate of the cone $C(M) = \mathbb{R}_+M$ in $\mathbb{R}M = \mathbb{R}\otimes\mathrm{gp}(M)$. The conic divisor classes represent Cohen-Macaulay modules over $K[M]$, and they correspond to the full-dimensional open cells in the decomposition $\mathcal{D}$ of the torus $\mathbb{R}M/\mathrm{gp}(M)$ that is defined by the integral parallel translates of the support hyperplanes of $C(M)$. In particular the number of conic classes is finite. The conic divisor classes appear in the decomposition of $(1/n)M$, $n \in \mathbb{N}$, over M. Their multiplicities in these decompositions is determined by the Ehrhart polynomials of the cells of $\mathcal{D}$. This allows one to give rather precise information on the Hilbert-Kunz function of M (or $K[M]$).

Monoids with Almost Unique Factorization

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In this talk, we will explore (commutative, cancellative) monoids that are "nearly" unique factorization monoids. In particular, we will consider HFMs (monoids where any two factorizations of the same element have the same length), and OHFMs (where any two equal length factorizations are the same). As it turns out, HFMs are rather commonplace in the setting of integral domains; they occur naturally as the multiplicative monoid of the nonzero elements of a half-factorial domain (HFD). On the other hand, it has recently been shown that OHFMs that are not UFMs cannot occur as the multiplicative monoid of the nonzero elements of any domain. It is the case, however, that in the general class of monoids, OHFMs are fairly easy to construct.

We will explore some structure theorems concerning OHFMs that highlight their relationship to both HFMs and UFMs. In particular, we will show that OHFMs are essentially UFMs with a unique "syzygy" applied. As a consequence, great restrictions are placed on the nature of the non-prime irreducible elements of an OHFM.

Additive categories and Krull monoids

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We will present some results about direct-sum decompositions in arbitrary additive categories. For an additive category C, the behavior of direct-sum decompositions may be described via a functor of C into a category D in which direct-sum decompositions have a particularly good behavior. For instance, D could satisfy the Krull-Schmidt property. If F has suitable properties and C is locally small, the isomorphism classes of the direct summands of an object of C form a Krull monoid with respect to the addition induced by direct sum.

Examples of star and semistar operations

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Let D be an integral domain with quotient field K. The purpose of this talk is to discuss the relations between the (semi)star operation $\tilde{\star}$ [called the stable (semi)star operation] and $\star_a$ [called the e.a.b. (semi)star operation] canonically associated to a given (semi)star operation $\star$ on D. These operations can be defined by using the (semi)star Nagata function ring $\mathrm{Na}(D,\star)$ and the (semi)star Kronecker function ring $\mathrm{Kr}(D,\star)$ as follows, for each D-submodule E of K,

$$E^{\tilde{\star}} := E\mathrm{Na}(D,\star) \cap K\,, \qquad E^{\star_a} := E\mathrm{Kr}(D,\star) \cap K\,.$$

Moreover, we will discuss the relation between the notion of *a.b.* (Krull's *arithmetisch brauchbar*) star operation and the notion of *e.a.b.* (Gilmer's *endlich arithmetisch brauchbar*) star operation and we will construct an example to show that these notions are effectively different.

w-divisoriality, w-stability and related properties.

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Divisoriality, stability, #-property, RTP-property and factorization of ideals are strictly related in the class of Prüfer domains.

These notions have been recently extended to wider classes of domains by means of star operations. In this talk we intend to show that they still have significant connections in the class of v-coherent domains.

The Diophantine inequality $ax \mod b \leq cx$

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The set of integer solutions to the inequality $ax \mod b \leq cx$ is a numerical semigroup. We show how to solve this inequality (and thus find a system of generators of this numerical semigroup). We will briefly talk about how to characterize those numerical semigroups that are of this form, as well as their properties. Finally, we will discus some open problems related to these inequalities.

Non-Unique Factorizations in Monoids and Domains

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The theory of non-unique factorizations has its origin in the theory of algebraic numbers. Only in the eighties of the previous century, a further starting point was laid by investigations of factorization properties of (abstract) integral domains. The main objective of factorization theory is to describe and to classify the various phenomena of non-uniqueness of factorizations in an integral domain in terms of its algebraic invariants.

An atomic monoid is a commutative cancellative semigroup with identity element such that every element has a factorization into atoms (irreducible elements). The multiplicative semigroup of non-zero elements in a noetherian domain is an atomic monoid. Let H be an atomic monoid, $a \in H$ and $a = u_1 \cdot \ldots \cdot u_k$ a factorization of a into atoms $u_1, \ldots, u_k$ of H. Then k is called the length of the factorization, and $\mathsf{L}(a) = \{k \in \mathbb{N} \mid a \text{ has a factorization of length } k\} \subset \mathbb{N}$ denotes the set of lengths of a. Sets of lengths (and all invariants derived from them, as for example the elasticity) are the best investigated invariants of the

theory. A simple observation shows that, either all sets of lengths are singletons, or for every $N \in \mathbb{N}$ there is some $a \in H$ such that $|\mathsf{L}(a)| \ge N$, and moreover, if H is the multiplicative semigroup of non-zero elements in a noetherian domain, then all sets of lengths are finite. A main finiteness result states that, among others, in orders of algebraic number fields all sets of lengths are essentially finite unions of arithmetical progressions (with universal bounds for all involved parameters).

A central point in the theory is the observation that most problems of non-unique factorizations are purely multiplicative in nature. Thus a canonical procedure is to construct multiplicative models and suitable transfer principles, which allow to transfer arithmetical properties from auxiliary monoids back to the domains of arithmetical interest.

The monoid of zero-sum sequences in a finite abelian group (introduced by W. Narkiewicz in the seventies) plays a crucial role. It connects arithmetical problems in Krull domains (e.g., rings of integers) with additive group theory and combinatorial number theory. Results from these areas have far reaching applications in factorization theory.

In the sixties and seventies of the previous century, P. Rémond and W. Narkiewicz initiated the study of the asymptotic behavior of counting functions associated with non-unique factorizations. Consider the ring of integers of an algebraic number field with class group G and some integer $k \in \mathbb{N}$. It is well-known that, in case $|G| > 1$, "almost all" elements have more than k distinct factorizations, and that in case $|G| > 2$, "almost all" elements have factorizations of more than k distinct lengths. We present a result showing that sets of lengths of "almost all" elements are arithmetical progressions with difference 1.

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Factorizations of powers in orders of algebraic number fields

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Let R be an order in an algebraic number field. For a non-zero non-unit $a \in R$ we denote by $\mathsf{L}(a)$ the set of all positive integers k such that a is a product of exactly k irreducible elements of R. Using standard terminology, we call $\mathsf{L}(a)$ the *set of lengths* of a.

In the talk recent progress on the following problem is presented: Given a non-zero non-unit a of R, what is the structure of $\mathsf{L}(a^n)$ if n grows? Our first result asserts that there are non-negative rational numbers κ^+ and κ^-

(depending on a) for which the functions $B^+(n) := \max \mathsf{L}(a^n) - \kappa^+ n$ and $B^-(n) := \min \mathsf{L}(a^n) - \kappa^- n$ are bounded. Furthermore, and this is our main result, B^+ and B^- are *eventually periodic* functions, that is, there exist non-negative integers n_0 and N such that $B^*(n+N) = B^*(n)$ for all $n \geq n_0$, where $*$ is $+$ or $-$. As an application of these results we prove that there exist constants N, B such that for all $n, m \geq B$ with $n \equiv m \bmod N$ the sets of lengths $\mathsf{L}(a^n)$ and $\mathsf{L}(a^m)$ are equal (up to a shift and up to the length of a well understood periodic part).

Generalized going down follows from going down.

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Let D be a ring extension of R. D is called a generalized going down extension (GDD) of R if for any prime ideal Q of D contracting to a prime ideal P of R and a chain of prime ideals contained in P, we can always find a chain of prime ideals contained in Q that contracts to the given chain. In this talk, we give a purely algebaic proof that GDD follows from GD. This is the dual of the known result that GU implies GGU.

New Development on t-Clifford Regularity of Integral Domains

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This paper seeks ring-theoretic conditions of an integral domain R that reflect in the Clifford t-regularity property or Boolean t-regularity property of its t-class semigroup $\mathcal{S}_t(R)$, that is, the semigroup of the isomorphy classes of the nonzero (integral) t-ideals of R with the operation induced by t-multiplication. Precisely, in Section 2, we characterize pseudo-integrally closed domains with Boolean t-class semigoup. In Section 3, we investigate Noetherian-like settings where the Clifford and Boolean t-regular properties of $\mathcal{S}_t(R)$ coincide with the t-move of (Lipman and Sally-Vasconcelos) stability conditions; a main feature is that the Clifford property forces $t-$locally Noetherian domains to be one t-dimensional Noetherian domains.

Intersections of valuation rings

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If D is an integral domain with quotient field F, then an *overring* R of D is a ring R with $D \subseteq R \subseteq F$. If D is a Noetherian domain of Krull dimension > 1, then there is no comprehensive description of the overrings of D. Indeed, there is no shortage of difficult problems associated to this topic. For example, an understanding of overrings of Noetherian domains is central to local uniformization, Hilbert's 14th problem, affineness of open sets of projective schemes, and rings of invariants.

On a more elementary level, a classical result of Krull is that an intersection of valuation overrings of a domain is an integrally closed domain. Beyond this, it is often difficult to describe the structure of these intersections in more detail. We consider two different types of intersections of valuation overrings– one "sparse" and the other "dense"– in which a positive description is possible. In both cases the intersections yield Prüfer domains. The sparse intersections arise as certain finite character intersections. The dense intersections are the holomorphy rings of function fields over real closed fields. The ideal theory for these two classes of intersections proves to be very different. As an application we examine finite character intersections of valuation overrings of Noetherian domains of Krull dimension 2.

On the integral closure of a half-factorial domain.

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In this talk we discuss Jim Coykendall's question whether the integral closure of a half-factorial domain is half-factorial if it is atomic.

Weakly half-factorial subsets of finite abelian groups and arithmetical applications

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An atomic monoid H is called half-factorial if for every element $a \in H$ all factorizations of a into atoms (irreducible elements) have the same lengths. A subset $G_0 \subset G$ of an abelian group is called a half-factorial set if the block monoid $\mathcal{B}(G_0)$, the monoid of zero-sum sequences in G_0, is a half-factorial monoid. For

a Krull monoid the problem of deciding whether the monoid is half-factorial can be transferred to the problem of deciding whether the set of classes containing primes is a half-factorial subset of the class group. In case G is a finite abelian group, it is well-known that a subset $G_0 \subset G$ is half-factorial if and only if the cross number (a weighted length) of each minimal zero-sum sequence in G_0 is equal to 1. To investigate half-factorial sets, J. Śliwa introduced the notion of weakly half-factorial sets: A subset $G_0 \subset G$ is called weakly half-factorial if the cross number of each minimal zero-sum sequence in G_0 is a positive integer.

In this talk we characterize the structure of weakly half-factorial subsets of finite abelian groups; in particular, we give a formula for the maximal cardinality of a weakly half-factorial subset. These results can be applied in investigations of the arithmetic of Krull monoids with finite class groups (in particular, of rings of integers of algebraic number fields); and we discuss some of these applications.

The monoid of finitely generated modules over a one-dimensional local domain

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Coauthors: Alberto Facchini, Wolfgang Hassler, Lee Klingler

Let $(R, \geqslant)$ be a one-dimensional Noetherian local integral domain whose $\geqslant$-adic completion S is reduced. The monoid H of isomorphism classes of finitely generated R-modules is a Krull monoid sitting naturally inside the free monoid $\mathbb{N}^{(\Omega)}$, where Ω is the cardinality of the set of isomorphism classes of indecomposable finitely generated S-modules. We determine the homogeneous linear equations over $\mathbb{Z}$ that define H as a submonoid of $\mathbb{N}^{(\Omega)}$. These defining equations depend only on the cardinality of $R/\geqslant$, on the number of minimal prime ideals in S, and on whether or not R is a Dedekind-like ring.

Bounding the ranks of modules over one-dimensional rings

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We consider indecomposable finitely generated torsion-free modules over one-dimensional, reduced, commutative Noetherian rings with finite normalization. Suppose that there exists a positive integer N_R so that, for every indecomposable R-module M and every minimal prime ideal P of R, the dimension of M_P, as a vector space over the field R_P, is less than or equal to N_R. In addition suppose that R contains a field, not of characteristic 2, 3, or 5, and that the residue fields mod the maximal ideals of R are perfect. It follows from

recent results for the local case by Nicholas Baeth for R a *domain* that $N_R = 6$. If M is an indecomposable module over a ring R of bounded representation type with more than one minimal prime ideal, however, and if the vector space dimensions of the M_P over the localizations R_P at the minimal primes P differ sufficiently, then the vector space dimensions can be arbitrarily large.

Let n be an integer ≥ 8. We show that if M is a finitely generated torsion-free R-module such that the vector space dimensions of M_P over R_P (over all minimal primes P) are between n and $2n-8$, then M decomposes non-trivially. For each $n \geq 8$, we exhibit such a ring R and an indecomposable R-module for which the relevant dimensions range from n to $2n-7$. We also find some bounds in the non-equicharacteristic case.

Bhargava domains, intersection of D-algebras

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Let D be a domain with quotient field K. We denote by $\mathrm{Int}(D)$ the ring of integer-valued polynomials.

For each $x \in D$,$x \neq 0$, we consider the ring

$$\mathbb{B}_x(D) = \{f \in K[X] \mid \forall a \in D, f(xX+a) \in D[X]\}.$$

These rings, called Bhargava domains, are subrings of $\mathrm{Int}(D)$ containing $D[X]$. These rings can be seen as an intersection of D-algebras of finite type:

$$\mathbb{B}_x(D) = \bigcap_{a \in D} D\left[\frac{X-a}{x}\right].$$

We will show that for a Krull domain D, $\mathbb{B}_x(D)$ is a finitely generated D-algebra. For instance, $\mathbb{B}_2(\mathbb{Z}) = \mathbb{Z}[X/2] \cap \mathbb{Z}[(X-1)/2] = \mathbb{Z}[X, X(X-1)/2]$.

Nonlinear Elliptic Boundary Value Problems (T. Bartsch, Z.-Q. Wang)

Contents

On a Class of Schrödinger-Type Equations with Indefinite Weight Functions.

David G. Costa
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We investigate the solvability of a class of Schrödinger-type equations with indefinite weight functions and a subcritical Sobolev nonlinearity. We examine the common effect of the properties of the Nehari manifold and the fibrering maps on existence and multiplicity of solutions.

Peak solution ideas and many solutions of equations

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We discuss some results on the existence of many solutions of non-linear elliptic equations with small diffusion and then show how changes of variables can turn a number of other problems into problems of this form. These methods frequently give many more solutions than standard variational techniques and provide significant new results on some old problems.

Boundary Value Problems for the Seiberg-Witten Equations

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It is shown that the non-homogeneous Dirichlet and Neuman problems for the 2^{nd}-order Seiberg-Witten equation on a compact 4-manifold X admit a regular solution once a a special condition is satisfied. The approach consists in applying the elliptic techniques to the variational setting of the Seiberg-Witten equation. The gauge invariance of the functional allows to restrict the problem to the Couloumb subspace of configuration space. The coercivity of the SW-functional, when restricted into the Coulomb subspace, imply existence of a weak solution. The regularity then follows from the boundness of L^{∞}-norms of spinor solutions and the Gauge Fixing Lemma.

Stationary energy models for semiconductor devices with incompletely ionized impurities

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We deal with two-dimensional stationary energy models for semiconductor devices, which contain incompletely ionized impurities. We reduce the problem to a strongly coupled nonlinear system of four equations, which is elliptic in nondegenerated states. Heterostructures as well as mixed boundary conditions have to be taken into account. For boundary data which are compatible with thermodynamic equilibrium there exists a thermodynamic equilibrium. Using regularity results for systems of strongly coupled linear elliptic differential equations with mixed boundary conditions and nonsmooth data and applying the Implicit Function Theorem we prove that in a suitable neighbourhood of such a thermodynamic equilibrium there exists a unique stationary solution, too.

Geometry beyond limits

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In my lecture I report on various limit problems involving the p-Laplace and related operators as $p \to \infty$ and $p \to 1$. The limit problems lead to interesting geometrical questions. One of the results says that the first (and positive) eigenvalue λ_p and eigenfunction u_p of

$$\Delta_p u + \lambda_p |u_p|^{p-2} u_p = 0 \quad \text{in } \Omega, \qquad u = 0 \quad \text{on } \partial\Omega,$$

converge to the Cheeger constant $\lambda_1 = h(\Omega)$ and a function u_1 amost all of whose level sets $\{u_1 > t\}$ are Cheeger sets of Ω, i.e. they minimize the ratio of perimeter over volume among all subsets of Ω. Cheeger sets are interesting geometrical objects. These and related results were obtained in part with my coauthors M.Belloni, V. Ferone, V.Fridman, P.Juutinen and T. Lachand-Robert.

Another result (with H.Shahgholian) deals with minimizers u_p of the functional

$$E_p(v) = \int_{\mathbb{R}^n} \frac{1}{p} |\nabla v|^p + \frac{p-1}{p} \chi_{\{v>0\}} \, dx$$

(among $v \in W^{1,p}(\mathbb{R}^n)$ with $v \equiv 1$ on K) as $p \to 1$ or $p \to \infty$. They are p-harmonic in their support (minus K) and satisfy $u_p = 0$ as well as Bernoulli's condition $|\nabla u_p| = 1$ on the free boundary of their support. For $p = 1$ this free boundary minimizes surface area among all sets that contain K, and for $p \to \infty$ the support minimizes volume among all sets containing a 1-neighbourhood of K.

Free boundary value problems for nonlinear degenerate elliptic equations arising in transonic 2-dimensional Riemann problems

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We discuss existence results and regularity results for nonlinear degenerate elliptic equations with free boundary and mixed boundary problems. As an application, we also present model problems which arise in the study of transonic 2-dimensional Riemann problems in compressible gas dynamics.

Branches of positive solutions of a quasilinear elliptic equation

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Coauthors: Markus Lilli

We prove existence of an unbounded global branch (i.e. connected set) of weak solutions of a second order quasilinear equation depending on a real parameter on an arbitrary (possibly non-smooth) bounded domain Ω in $\mathbb{R}^N$ with a Leray-Lions operator as the leading part. The branch is obtained as a limit set of a sequence of solution branches of the equation restricted to smooth domains which approximate Ω. In particular, this approach allows us to state sufficient conditions which ensure the existence of a branch consisting entirely of nonnegative solutions but are not strong enough to enforce that all solutions are nonnegative. This can be used to prove a new existence result in the case of critical growth in derivatives of lower order.

Classical Solutions for Non-Elliptic Euler-Lagrange Equations via Continuation

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We prove existence of classical solutions of an Euler–Lagrange equation arising from a 1–d non–convex variational problem in nonlinear elasticity. Therefore we consider a physically reasonable stored–energy density W such that $W(\nu)$ goes to infinity for $\nu \to 0$ and $\nu \to \infty$. We introduce a singular perturbation in order to obtain an elliptic EL–equation and we prove existence of solutions by Leray–Schauder degree. Moreover the solution is strictly bounded away from 0 and by the continuation method we derive certain features of the solution which allows us to pass to the limit in some appropriate Sobolev–space.

Schrödinger equations with concave and convex nonlinearities

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We obtain the existence of infinitely many nodal solutions for the Schrödinger type equation on $\mathbb{R}^N$: $-\Delta u + V(x)u = f(x, u)$ with $u \in H^1(\mathbb{R}^N)$. Here, $V \in C(\mathbb{R}^N, \mathbb{R})$, $V(x) \geq 1$, $\int_{\mathbb{R}^N} (V(x))^{-1}\, dx < +\infty$. The nonlinearity f is symmetric in the sense of being odd in u, and may involve a combination of concave and convex terms.

Connecting Continua and Curves of Equilibria of the Cahn-Hilliard Equation on the Square

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We state an alternative for paths of equilibria of the Cahn-Hilliard equation on the square, bifurcating from the trivial solution at eigenfunctions of the form $w_{ij} = cos(\pi ix)\cos(\pi jy)$, for $i, j \in \mathbb{N}_0$. We show that the paths either return to the bifurcation point m_{ij}, or they are connected with the bifurcation point-m_{ij}. For fixed mass $m_0 = 0$ we furthermore prove that the continua bifurcating from the trivial solution at eigenfunctions of the form $w_{i0} + w_{0i}$ or w_{ij}, for $i, j \in \mathbb{N}$ are smooth curves.

Symmetry properties of positive solutions to nonlinear second order finite difference boundary value problems

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Are positive solutions of finite difference boundary value problems $\Delta_h u = f(u)$ in D_h, $u = 0$ on ∂D_h as symmetric as the domain? To answer this question we show by examples that almost arbitrary non-symmetric solutions can be constructed. This is in striking difference to the continuous case, where by the famous Gidas-Ni-Nirenberg theorem positive solutions inherit the symmetry of the underlying domain. We give approximate symmetry theorems for solutions on equidistantly meshed n-dimensional cubes: explicit estimates depending on the data are given which show that the solutions become more symmetric as the

discretization gets finer. The quality of the estimates depends on whether or not $f(0) < 0$. The one-dimensional case stands out in two ways: the proofs are elementary and the estimates for the defect of symmetry are $O(h)$ compared to $O(1/|\log(h)|)$ in the higher dimensional case.

Prescribing scalar curvature on S^3

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Which functions K on the sphere S^3 occur as scalar curvature of metrics g conformally equivalent to the standard round metric g_0?
This is equivalent to solving a nonlinear elliptic equation with critical Sobolev exponent,

$$-8\triangle u + 6u = K(x)u^5,\ u > 0 \ \text{ in } S^3.$$

We obtain a priori estimates for solutions. The usual non-degeneracy assumption, $\triangle K(y) \neq 0$ at any critical point y of K, is replaced by a new condition, which is necessary and sufficient for the existence of a priori estimates, when the curvature function K is a positive Morse function. We compute the Leray-Schauder degree of the problem and get existence results when K satisfies an index-count condition.

Elliptic and parabolic spectral problems with the p-Laplacian

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We treat a canonical spectral problem for the Dirichlet p-Laplacian near the first eigenvalue λ_1. We give a precise asymptotic formula for large solutions of the spectral problem corresponding to the Fredholm alternative, thus obtaining a priori bounds under various conditions imposed on the right-hand side of the equation

$$-\Delta_p u - \lambda|u|^{p-2}u = f(x), \quad x \in \Omega.$$

We will discuss also the case when $f(x,u)$ depends on the unknown function u. Finally, we will formulate an antimaximum principle for the parabolic problem

$$\frac{\partial u}{\partial t} - \Delta_p u - \lambda|u|^{p-2}u = f(x), \quad (x,t) \in \Omega \times (0,T).$$

Multiplicity results for superlinear Dirichlet problems via Morse theory

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Coauthors: Jiabao Su

We present some new results on the existence of multiple solutions for semilinear elliptic BVPs. In particular we are concerned with superlinear problems. The methods make use of a combination of homological linkings and Morse theory. This is a joint work with J. Su.

On the shape of extremal functions in Poincaré-Sobolev-type inequalities

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We study properties of extremal functions, which, for subcritical or critical $p > 2$, minimize the quotient $\|\nabla u\|_2/\|u\|_p$ among all functions $u \in H^1(B_1(0)) \setminus \{0\}$ with average zero, i.e., with $\int_{B_1(0)} u = 0$. Here $B_1(0)$ is the unit ball in $\mathbb{R}^N$. We show that the minimizers are nonradial but axially symmetric with respect to a line passing through the origin. Further information on the shape of these functions is derived from monotonicity properties which we also prove. Finally, we address the question whether the minimizing functions are odd with respect to the reflection at the hyperplane perpendicular to the symmetry axis.

Spikes for the Gierer-Meinhardt System – Analysis and numerical simulation

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We consider pattern formation for the Gierer-Meinhardt system in a two-dimensional, bounded and smooth domain. In particular, we are interested in existence and stability of stationary multiple spikes. Analytical results for the steady states will be completemented by numerical simulations of the dynamics.

Critical Point, Anti-Maximum Principle and Semipositone p-Laplacian Problems

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We use Nehari manifold to extend the Anti-maximum principle of Laplacian operator to an existence theorem for p-Laplacian ($p \neq 2$), then consider the existence of nonnegative solutions to semipositone($f(0) < 0$) quasilinear elliptic problems $-\Delta_p u = \lambda f(u), x \in \Omega; u > 0, x \in \Omega; u = 0, x \in \partial\Omega$.

Another related existence result for positive solution of superlinear semipositone problems(p=2) is given by using critical point theory and shooting method.

On Homotopy Continuation Method for Computing Multiple Critical Points

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Motivated by examples carried out by a numerical (Newton or Euler-Newton) homotopy continuation method for finding multiple critical points, some mathematical results of the homotopy continuation method on its invariance in group actions and its continuation in Morse index are established. By using the Nehari (solution) manifold and a manifold of inflection points, those results can clearly explain what have happened in our numerical examples and can also be used to greatly enhance the performance of a numerical homotopy continuation method for finding desirable critical points.

A homotopy continuation method has be proposed in the literature to find multiple critical points of a nonlinear functional J by using eigenfunctions of a linearized operator of ∇J as initial solutions. The results presented in this talk show that this method in general is not dependable.

Nonlinear Waves (H. Koch, D.I. Tataru)

Contents

Quadratic Derivative Nonlinear Schrödinger Equations

Ioan Bejenaru
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The aim of this work is to complete the local well-posedness theory for the quadratic nonlinear Schrödinger equation in the case when the nonlinearity contains derivatives. A simple way to visualize this class of nonlinearities is to look at the equation $iu_t - \Delta u = |\nabla u|^2$ in $\mathbb{R}^n \times \mathbb{R}$. We work with $n = 2$ and prove that if the initial data has some spherical symmetry stucture we obtain a sharp result.

A Glimpse on Almost Periodic Waves

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The presentation will be centered on the following items:
1. A brief history (Muckenhoupt,Bochner,von Neumann,Sobolev:1928-1945) of the early contributions.
2. Periodic solitons in parabolic and hyperbolic structures.
3. Wave-like solutions for higher order PDE (using Garding's estimate).
4. A Hilbert space approach with applications to PDE (using qualitative differential inequalities).

L^p boundedness of the wave operator for the one dimensional Schrödinger operator with rough potentials and applications

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We prove the L^p boundedness for all p of the wave operator intertwining the free with the perturbed one-dimensional Schrödinger operator $-u''+V(x)u$. We assume that $< x >^2 V(x)$ is integrable, or, alternatively, that $< x > V(x)$ is integrable and zero is not a resonance. This improves earlier results of Artbazar-Yajima and Weder. As applications, we prove the optimal decay rate for several one dimensional evolution equations with rough variable coefficients, and the global existence of small nonlinear waves fot the semilinear Klein-Gordon equation on a Schwarzschild background.

Null form structure and well-posedness results for Dirac-Klein-Gordon and Dirac-Maxwell equations (Part I)

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We describe the algebraic structure of the system of equations obtained by coupling a Dirac spinor field with a scalar field or an electromagnetic field. By analyzing the first iterate we show that the system possesses a null-form structure which is intrinsic in the spinor structure and was not fully exploited before.

Smoothing estimates for the Schrödinger equation with small magnetic potential

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We prove smoothing estimates for the Schrödinger equation with small magnetic potential depending only on space variables and having a decay growth $-1-\varepsilon$, where $\varepsilon > 0$. This assumption can be rewritten in a weaker and scale invariant form and will enable one to derive scale invariant smoothing estimates for the Schrödinger equation with small magnetic potential. Applications to Strichartz type estimates will be discussed too.

On geodesic exponential maps of the Virasoro group

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We study the geodesic exponential maps corresponding to Sobolev type right-invariant (weak) Riemannian metrics $g(k)$ with $k = 0, 1, ...$ on the Virasoro group Vir and show that for $k = 2, 3, 4, ...$, but not for $k = 0, 1$, each of them defines a smooth Frechet chart of the unital element in Vir. The geodesic exponential map for $k = 0$ corresponds to the KdV equation and hence is not a local diffeomorphism near the origin.

Stable manifolds for unstable NLS in 1-d.

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We discuss a recent result on existence of certain global solutions for the full range of L^2-supercritical NLS in 1-d of the form $iu_t + u_x x = -|u|^2 au$, $a > 2$. The initial data of these solutions form a codimension 1 manifold in a suitable function space.

The Einstein-Vlasov system with a nonlinear scalar field in surface symmetries

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The system describes the evolution of self-gravitating collisionless matter and scalar waves within the context of general relativity. We study the system in the cases of surface symmetries using an areal time coordinate with the sources generated by a distribution function and a nonlinear scalar field, subject to the Vlasov and wave equations respectively. We prove that solutions of this system exist globally in time and the geodesic completeness of the spacetime towards the future and the asymptotic behaviours of solutions in the future time are analysed when the potential of the scalar field has a specific form.

Global solutions for the 1-dimensional Zakharov system with rough data

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Consider the (1+1)-dimensional Cauchy problem for the Zakharov system

$$\begin{aligned} iu_t + u_{xx} &= nu \\ n_{tt} - n_{xx} &= (|u|^2)_{xx} \\ u(0) = u_0, n(0) &= n_0, n_t(0) = n_1 \end{aligned}$$

where u is a complex-valued and n a real-valued function defined for $(x,t) \in \mathbf{R} \times \mathbf{R}^+$.

The Zakharov system was introduced to describe Langmuir turbulence in a plasma.

We have conservation of: $\|u(t)\| \equiv M$ and the energy ($A := -\partial_x^2$)

$$E(u,n) := \|u_x(t)\|^2 + 1/2(\|n(t)\|^2 + \|A^{-1/2}n_t(t)\|^2) + \int_{-\infty}^{\infty} n(t)|u(t)|^2\,dx$$

E is only defined for $(u_x, n, A^{-1/2}n_t) \in L^2$.

Our aim is to show the existence of a unique global solution for less regular data.

We use the Fourier restriction norm method and especially the so-called I-method. Here the mapping I is a suitably defined smoothing operator which maps H^s to H^1 for a fixed $s < 1$. The main point is to show that the growth in time of $E(Iu, In)$ (which no longer is conserved) is controllable.

Nonlinear waves and Einstein geometry

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The talk will focus on the recent results for small amplitude solutions of semilinear wave equations on black hole backgrounds.

Justification of the Nonlinear Schrödinger equation for the evolution of gravity driven 2D surface water waves

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In 1968 V.E. Zakharov derived the Nonlinear Schrödinger equation for the 2D water wave problem in case of no surface tension, i.e. for the evolution of gravity driven surface water waves, in order to describe slow temporal and spatial modulations of a spatially and temporarily oscillating wave packet. Since this time the question remained open if solutions of the 2D water wave problem behave as predicted by the Nonlinear Schrödinger equation. Here we answer this question positively. This is joint research with C.E. Wayne (Boston)

Null form structure and well-posedness results for Dirac-Klein-Gordon and Dirac-Maxwell equations (Part II)

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Coauthors: D. Foschi, P. D'Ancona

We discuss almost optimal low regularity results for the Dirac-Klein-Gordon system and the Dirac-Maxwell system in Lorentz gauge.

Critical Regularity for Yang-Mills Equations on High Dimensional Minkowski Space

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Coauthors: Joachim Krieger

This talk is about work of Jaochim Krieger and myself on the critical Sobolev regularity problem for non-abelian gauge fields. I will discuss the overall strategy for attacking this problem and how it fits in with previous work on the critical regularity for the wave-maps equations. Specifically, I will explain the concept of "microlocal geometric renormalization" and how it relates to the gauge structure of the equations, as well as some of the estimates one must deal with once this renormalization is implemented.

On a multidimensional model for the dynamic combustion of compressible reacting gases

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In this work we present results on a multidimensional model for the dynamic combustion of compressible reacting gases formulated by the Navier Stokes equations in Euler coordinates. For the chemical model we consider a one way irreversible chemical reaction governed by the Arrhenius kinetics.

The existence of globally defined weak solutions of the Navier-Stokes equations for compressible reacting gases is established by using weak convergence methods, compactness and interpolation arguments in the spirit of Feireisl and P.L. Lions. In addition, we present conditions on the initial data yielding blow up of smooth solutions to the multidimensional Navier Stokes and Euler Equations.

The semiclassical resolvent on nontrapping scattering manifolds
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Coauthors: Andrew Hassell

We explicitly construct a parametrix for the semiclassical resolvent on nontrapping manifolds with asymptotically conic ends. The construction has applications to energy decay for the wave equation and to the structure of solutions to the Schrödinger equation.

Energy estimates of free boundary problems of the Euler equation with surface tension
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Coauthors: Jalal Shatah

We consider the evolution of a finite volume of invicid fluid in the n-dimensional vancuum with surface tension and without gravity. The evolution of the fluid boundary and velocity field are determined by a free boundary problem of the Euler's equation. Viewing this as a Hamiltonian PDE, we define a scale of functionals as "energies" . These energies bound high Sobolev norms of the mean curvature of the boundary of the fluid as well as velocity field. Thus we establish regularity of solutions for a short time depending on the initial data. Using these estimates we prove that as the surface tension goes to zero solutions of our problem converge to solutions of the zero surface tension problem considered by S. Wu, and by D. Christodoulou and H. Lindblad.

Quantum Knot Invariants
(A. Beliakova, U. Kaiser)

Contents

Infinitely many knots can be detected with polynomial complexity of degree four

Thomas Fiedler
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We introduce a new technique in knot theory which comes from singularity theory. There are two main applications: we give an algorithm which detects the unknot, the trefoil, the figure eight knot... with quartic complexity with respect to the number of crossings . We construct new calculable knot invariants which contain Vassiliev invariants as a particular case. At least in the case of the simplest knots we prove that the new invariants form a complete set of invariants.

Link Invariants arising from Lie superalgebras

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The Jones, Kauffman, and HOMFLY knot invariants are examples of invariants arising from finite dimensional representations of Lie algebras. Invariants arising from Lie algebras can be extended to Lie superalgebras. These new invariants are more powerful than invariants arising from Lie algebras. In this talk, we will discuss some new developments involving invariants arising form Lie superalgebras. For example, the Links-Gould invariant is a two variable invariant which after a variable reduction, is the Alexander-Conway polynomial. Another example of a two variable invariant arises from the Lie superalgebra D(2,1;alpha). The latter invariant is not contained in the class of invariants arising from Lie algebras. We will discuss how these invariants can be studied through the Kontsevich integral and their corresponding weight systems.

Integral Lattices in TQFT

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We find explicit bases for naturally defined lattices over a ring of algebraic integers in the $SO(3)$-TQFT-modules of surfaces at roots of unity of odd prime order. Some applications relating quantum invariants to classical 3-manifold topology are given.

Asympotics of the Turaev-Viro invariant

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We investigate the asymptotics of the Turaev-Viro invariants of 3-manifolds when the complex parameter is equal to -1. We show it is related to the Reidemeister torsion.

Quantum flat PSL(2,R)-connections on punctured surfaces

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Based on Penner coordinates, extended to the moduli space of irreducible flat PSL(2,R)-connections on punctured surfaces, a quantum theory is developed. It leads to an infinite dimensional projective unitary representation of the surface mapping class groups.

An analytic version of the Melvin-Morton-Rozansky Conjecture

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For a knot K and the n-dimensional sl_2-module the colored Jones polynomial, normalized so that the unknot takes value 1, is denoted by $J(K, n; q)$, where q is the quantum parameter. The limit of $J(K, n; q)$ when q goes 1, n goes to infinity such that $a = q^n$ kept constant, is equal to the inverse of the Alexander polynomial evaluated at a. This is the Melvin-Morton-Rozansky conjecture, proved by Bar-Natan and Garoufalidis. However, in the original version, the above limit is understood in the realm of power series: The limit of a sequence of power series (in a) is obtained by taking the limit the coefficients of each individual power. Here we prove a stronger statement: The power series limit can be replaced by the uniform limit of a sequence of analytic functions (in a) in a small neighborhood of 0.

Surgery formulae for 3–manifold invariants based on configuration spaces.

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Kontsevich defined an invariant Z of rational homology 3–spheres using configuration space integrals. G. Kuperberg and D. Thurston proved that Z is a universal invariant for integral homology spheres in the sense of Ohtsuki, Goussarov and Habiro. We shall discuss the behaviour of Z under surgery on knots and boundary links. In particular, we shall present some surgery formulae together with their direct (sketched) proofs from the Kontsevich-Kuperberg-Thurston definition.

Integral TQFT and Perturbative expansion

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We show that the integral SO(3)-TQFT's studied in previous joint work with Pat Gilmer have a perturbative expansion as the order of the root of unity goes to infinity. We obtain a new 'universal' representation of the Torelli group which gives a TQFT interpretation of Ohtsuki's power series invariant of homology spheres. As a byproduct, we obtain a purely skein-theoretical construction of this invariant.

Topology of words

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We introduce a topological approach to words. Words are approximated by Gauss words and then studied up to natural modifications inspired by homotopy transformations of curves on the plane.

Ordinary Differential, Difference, and Dynamic Equations (W. Balser, M. Bohner, D. Lutz)

Contents

Pachpatte Inequalities on Time Scales

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In the study of dynamic equations on time scales we deal with certain dynamic inequalities which provide explicit bounds on the unknown functions and their derivatives. Most of the inequalities presented are of comparison or Gronwall type and, more specifically, of Pachpatte type.

On the Asymptotic Analysis of Schrödinger Equations with Oscillating Potential

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We are interested in a family of second order linear differential equations of the form

$$y'' - \left[x^{\beta} p(x^{1+\alpha}) + cx^{-2}\right] y = 0,$$

where $p(t)$ is a real–valued 1–periodic function with mean zero, α and β are real parameters satisfying certain conditions, and c is any real number. In 1983, A. Its obtained asymptotic solutions by reducing the given equation to an equation of Hill's type with amplitude decreasing to zero.

Here we use a different technique, based on the reduction of linear systems to L–diagonal form, which leads to a complete asymptotic representation of the solutions. It also gives rise to new techniques for solving such equations which are in some sense natural generalizations of the classic regular and irregular singular differential equations.

Transformation theory of symplectic dynamic systems on time scales

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A symplectic dynamic system on a time scale is the first order linear dynamic system whose fundamental matrix is symplectic whenever it has this property at one point. Symplectic dynamic systems cover a large variety of dynamic equations on time scales, including the second order Sturm-Liouville equation and linear Hamiltonian systems. We are going to discuss various aspects of thransformation theory of symplectic systems, including the Prüfer and trigonometric transformations for these systems, and their applications.

Properties of generalized matrix Riccati equations of stochastic control

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We study the solutions of stochastic matrix Riccati-type differential equations of the form $-\frac{d}{dt}X = A^*X + XA + Q + P_{11}(X) - [S + XB + P_{12}(X)] \times [R + \Pi_{22}(X)]^{-1}[S + XB + Pi_{12}(X)], X(t_f) = X_f$, and the correcponding algebraic matrix equations and difference equations. Here the matrix operator $Pi = (P_{i,j})$ is linear and positive. It turns out that these differential equations have several nice properties of standard matrix Riccati equations. In particular we explain the influence of stochasic stabilizability and detectability on the existence of a stabilizing solution.

Singularities of overstable solutions

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Given a singularly perturbed complex first order ODE depending on a control parameter, we describe the type and the location of singularities of some solutions. In particular, giving a positive answer to a question of J. L. Callot, we show that these singularities are regularly spaced, and that they move one to the next as the control parameter surrounds a value of overstability.

The Schrödinger harmonic oscillator equation — discrete and periodic

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The Schrödinger equation for the harmonic oscillator and its background algebraic ladder formalism are invariant under Fourier transform. We will generalize this theory to the Pontryagin dual group pairing of $h\mathbb{Z}$ and $1/h \cdot \mathbb{S}$ for $h > 0$ ($\mathbb{S}$ unit circle). It will be shown that the algebraic formalism is preserved, becomes even more beautiful. The limit $h \to 0$ brings back the well–known theory for the group $\mathbb{R}$.

Legendre, Jacobi, and Riccati type conditions for a time scales variational problem with application to impulsive control

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We consider a time scale quadratic problem J with piecewise right-dense continuous coefficients and fixed endpoints. Such problems allow mixing of continuous- and discrete-time problems. We introduce a new notion of a generalized conjugate point involving dynamic systems and comprising as special cases those known for the continuous- and discrete-time settings. We identify a type of a strengthened Legendre condition and use it to establish characterizations of the nonnegativity and positivity of J in terms of (i) the nonexistence of such conjugate points, (ii) the natural conjoined basis of the associated Jacobi dynamic equation, and (iii) a solution of the corresponding Riccati dynamic equation. These results furnish second order necessary optimality conditions for a nonlinear time scales variational problem. At the end of the talk we present an example illustrating how the results apply to an optimal impulsive control problem (IC) and we show how this problem can be reduced to a variational problem over a time scale. Then we use the results developed for this latter case to find the optimal solution for (IC).

A Gronwall like inequality and continuous dependence on time scales

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We establish a Gronwall like inequality comparing the solutions of a dynamical equation on different time scales and then use it to prove the continuous dependence of such solutions on time scales. Regresivity is not used explicitly

Oscillation of differential and difference equations

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We will deal mainly with the following aspect of oscillation: counting the number of zeros or, more general, of focal points of solutions of differential and difference equations in a fixed finite interval.

In the first part of the talk we give an overview of old and recent results concerning the oscillation of so-called Hamiltonian differential systems, which

include e.g. higher order Sturm-Liouville equations. Here, the system is assumed to be controllable (or normal). In the second part we discuss the corresponding results for discrete equations, more precisely, for symplectic difference systems, which include Hamiltonian difference systems and also higher order Sturm-Liouville difference equations. Moreover, we compare the results and their proofs for the continuous and discrete equations.

In the third part we present new results on the non-oscillation of differential systems without assuming controllability and of difference systems. This leads to the characterization of positive definiteness and particularly of positive semidefiniteness of the corresponding quadrativ functionals. Finally, in the last part we discuss a Sturmian separation theorem.

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Ordinary linear differential systems with a unique critical time

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In the case of a unique critical time equal to one we compare the analysis of singularities in the Laplace plane (Stokes phenomenon) and in the Borel plane (allien derivatives). We sketch the case of a unique critical time not equal to one.

On the generalized Riemann-Hilbert problem with irregular singularities

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The generalized Riemann-Hilbert Problem extends the classical RH-problem to the case of irregular singularities. The data for this inverse problem consist of a number of prescribed singular points $\{a_1, \ldots, a_n\}$ and corresponding "generalized monodromy data". These include a representation of the fundamental

group $\pi_1(\mathbf{P}^1(\mathbf{C}) \setminus \{a_1, \ldots, a_n\}$ - to be realized as a monodromy representation - but also prescribed Stokes matrices and Poincaré rank at each singularity. In joint work with the late Andrey Bolibrukh and with Stéphane Malek, we have given sufficient conditions for the existence of a linear differential system with such data, and almost solved the problem in dimension two and three. Our results have applications in differential Galois theory, where they give sufficient conditions for a given linear algebraic group over $\mathbf{C}$ to be the differential Galois group over $\mathbf{C}(\mathbf{z})$ of a differential system with the smallest possible number of singularities, and where the singularities are all fuchsian but one, at which the Poincaré rank is minimal too.

Basic Partial Difference Equations: The Example of Similarity Solutions to the Basic Diffusion Equation

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A discrete version of the diffusion equation is given, containing basic difference operators on so-called basic linear grids. We investigate the concept of discrete similarity solutions to this equation and elucidate analogies to the continuum scenario.

Monomial multisummability and doubly singular linear differential equations

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Consider a linear doubly singular differential equation of the form

$$\varepsilon^r x^{s+1} \frac{dy}{dx} = A(\varepsilon, x)y \ ,$$

where A is an analytic matrix valued function of ε and x. Under certain (rather general) conditions, we show that it has a formal fundamental solution $H(\varepsilon, x)x^{J(\varepsilon)}exp(Q(\varepsilon, x))$, where Q, J are diagonal and might have a pole at $\varepsilon = 0$ or $x = 0$ and H is monomially multisummable in (ε, x), i.e. the sum of formal power series in ε, x that are summable with respect to some monomial $\varepsilon^{r_i}, x^{s_i}$.

The latter monomial summability means that the series can be written as $F(\varepsilon^{r_i}, x^{s_i})(\varepsilon, x)$, where $F(t)$ is some 1-summable series in the classical sense having coefficients in the space of functions analytic at $\varepsilon = x = 0$.

Representations and Cohomology of Groups and Algebras (D. Benson, H. Krause)

Contents

Orbifolds and Group Cohomology

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In this talk we discuss cohomological calculations for orbifolds which relate to problems in group cohomology.

The Dade group of a p-group

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Let k be a field of positive characteristic p, and let P be a finite p-group. I would like to expose the recent results I proved, giving the structure of the Dade group $D(P)$ of endo-permutation modules. An essential tool for this is the classification of endo-trivial modules made by J. Carlson and J. Thévenaz in a series of fundamental papers.

An important step in the proof is a result which may be of independent interest, giving an explicit description of the kernel of the map from the Burnside group $B(P)$ to the group $R_{\mathbb{Q}}(P)$ of rational representations, as a *biset functor*.

The final theorem is a presentation of $D(P)$ by explicit generators and relations. This is a generalization of Dade's Theorem to the case of a non-abelian p-group P.

Hall algebra of an elliptic curve

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In this work we study the Hall algebra of an elliptic curve defined over a finite field and show that the group of exact equivalences of the derived category of coherent sheaves acts on its Drinfeld double by algebra homomorphisms.

We consider also its certain Hopf subalgebra which we call elliptic Heisenberg algebra and describe its generators and relations.

Affine Quivers, Polyhedral Groups and Representation Type

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According to a fundamental theorem by Drozd, the class of finite-dimensional algebras over an algebraically closed field k may be subdivided into the disjoint subclasses of representation-finite, tame, and wild algebras. Algebras of *finite representation type* possess (up to isomorphism) only a finite number of indecomposable modules. A representation-infinite algebra is *tame* if in each dimension all but finitely many isoclasses of indecomposables occur in a finite number of one-parameter families. Since the representation theory of an algebra that does not belong to one of these classes is at least as complicated as that of any other algebra, there seems to be no hope of classifying the indecomposable modules of these so-called *wild* algebras.

Due to the historical origins of the representation theory of non-semisimple associative algebras, group algebras of finite groups have often served as a paradigm for related classes of algebras such as reduced enveloping algebras of restricted Lie algebras or distribution algebras of infinitesimal group schemes. By the same token, much of the initial work in abstract representation theory has focused on the study of hereditary algebras.

The purpose of this talk is to present methods and results concerning the classification of cocommutative Hopf algebras of finite and tame representation type. Being equivalent to representations of finite group schemes, one discerning feature of the module categories of these algebras is the presence of tensor products. In my talk, I will explain some of the ramifications of this additional structure by discussing support varieties, linkage principles and McKay quivers. While the former play an important rôle in the treatment of infinitesimal groups, the latter relate the representation type of finite group schemes to that of hereditary algebras: The blocks of tame finite algebraic groups are either Nakayama algebras or Morita equivalent to certain generalizations of trivial extensions of path algebras of affine quivers of type $\tilde{A}, \tilde{D}, \tilde{E}$. The binary polyhedral groups associated to these quivers largely determine the reduced parts of the underlying finite group schemes.

The moduli space of 4-dimesional Lie algebras

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We will show that the moduli space of complex 4-dimensional Lie algebras is essentially an orbifold, given by the natural action of the symmetric group Σ_3 on the complex projective space $\mathbb{P}^2(\mathbb{C})$. In addition, there are two exceptional

complex projective lines, one of which has an action of the symmetric group Σ_2, and 6 exceptional points. The moduli space is glued together by the miniversal deformations, so deformation theory determines the geometry of the space.

Duality in topology and modular representation theory.
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Work of Dwyer, Greenlees and Iyengar has shown that if one formulates the Gorenstein condition in a homotopically invariant fashion it applies to so-called brave new commutative rings, and that it often implies a duality statement which includes many known interesting examples in topological contexts, together with some new ones.

The cohomology ring of a finite group has a Gorenstein-like duality property first established in the almost Cohen-Macaulay case by Benson and Carlson. This property is inherited by localizations of the cohomology ring, where it suggests an underlying structural property of complexity quotient categories investigated by Benson and Krause. The talk will describe how the framework of Dwyer, Greenlees and Iyengar can be adapted to apply to these complexity quotient categories to give a conceptual formulation of the conjectured structural properties, and how a homotopically invariant form of local duality gives a proof.

The classification of 2-compact groups
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In this talk I'll announce and explain a proof of the classification of 2-compact groups, hence completing the classification of p-compact groups at all primes p. A p-compact group, as introduced by Dwyer-Wilkerson, is a homotopy theoretic version of a compact Lie group, but with all its structure concentrated at a single prime p. Our classification states that there is a 1-1-correspondence between connected 2-compact groups and root data over the 2-adic integers, as defined in the talk. As a consequence we get the conjecture that every connected 2-compact groups is isomorphic to a product of the 2-completion of a compact Lie groups and copies of the exotic 2-compact group DI(4), constructed by Dwyer-Wilkerson. The major new input in the proof over the proof at odd primes (due to Andersen-Grodal-Moeller-Viruel) is a thorough analysis of the concept of a root datum for 2-compact groups and its relationship with the maximal torus

normalizer. With these tools in place we are able to produce a proof which to a large extent avoids case-by-case considerations.

Relating polynomial representations in different degrees

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The representation theory of the general linear groups $GL_n(k)$ (and similarly of the symmetric groups) over an infinite field of prime characteristic p is still very little understood. Numerical information like dimensions or characters of simple modules or tilting modules, let alone the structure of non semi-simple representations are only known in some special cases.

Let k be an infinite field of prime characteristic. The category of homogeneous polynomial representations of degree r of (classical or quantum) $GL_n(k)$ is equivalent to the category of representations of (classical or quantised) Schur algebras $S_k(n,r)$. Schur algebras are quasi-hereditary algebras. We exploit the quasi-hereditary structure of Schur algebras to construct two types of isomorphisms, which are compatible with the quasi-hereditary structure: namely, between certain good quotients and certain good centraliser subalgebras of Schur algebras in different degrees,

$$\begin{array}{lrcl} (1) & eS(n,r)e & \simeq & fS(n,d)f, \\ (2) & S(n,r)/I & \simeq & S(n,d)/J. \end{array}$$

These isomorphisms imply equivalences of quotient categories and subcategories of $GL_n(k)$-modules. As a consequence, unknown and known invariants – like dimensions, decomposition numbers, Cartan numbers, cohomology – can be identified. Main examples of (1) and (2) are the following:

$$\begin{array}{lrcl} (1) & eS(n,r)e & \simeq & fS(n,r+ap^d)f, \\ (2) & S(n,r)/I_{\Pi} & \simeq & S(n,nm-r)/I_{\hat{\Pi}} \end{array}$$

with free choice of parameters n, r, a, d, Π. The isomorphism (2) extends work by James and by Beilinson-Lusztig-McPherson.

The graded Lie superalgebra structure on the Hochschild cohomology of truncated polynomial algebras

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The Hochschild cohomology of an associative algebra carries the structure of a graded Lie superalgebra induced by the Gerstenhaber bracket. We give a precise description of this structure for truncated polynomial algebras $k[X]/(X^n)$. In the modular situation where $n = p$ is the characteristic of the ground field k, this generalizes a result of C. Strametz on the first Hochschild cohomology space (where the famous p-dimensional Witt algebra occurs). In particular, we give explicit formulae for the Lie superbracket and classify all graded superideals of this infinite-dimensional modular graded Lie superalgebra.

A remark on the Calabi-Yau property

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A minimal A_∞-algebra (of finite total dimension, over a field of characteristic 0) is said to be Calabi-Yau if it admits an A_∞-inner product, i.e. a non degenerate symmetric pairing $\langle , \rangle$ such that

$$\langle a_0, m_n(a_1, \ldots, a_n)\rangle$$

is cyclically superinvariant for all $n \geq 1$ and all homogeneous a_i. This property is not preserved under A_∞-isomorphisms. We show that a minimal A_∞-algebra is A_∞-isomorphic a Calabi-Yau algebra iff it admits a non degenerate cyclic cocycle.

Reed-Muller Codes and the fourth cohomology of a finite group

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Orbifold conformal field theory suggests a number of interesting new applications of group cohomology, in particular of the groups $H^4(G, \mathbb{Z})$. We discuss in particular how one can use binary codes to study the case when G is a sporadic simple group.

Application of the Frobenius-Schur indicator function

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Let G be a finite group. We outline a number of novel uses for the classical Frobenius-Schur indicator function ν in characteristic 2. For instance, we show that a principal indecomposable module P that affords a quadratic geometry has a principal character Φ such that $\nu(\Phi) > 0$. In fact, we can give a precise criterion for $\nu(\Phi)$ to be nonzero in terms of the primitive idempotents (in the group algebra) that correspond to iP.

Our approach is module theoretic. We study various modules for the group G wr S_2, where S_2 is the symmetric group of degree 2. This is an extension of Green's idea of regarding the group algebra as a G-bimodule. Our approach also yields the following theorem:

There is a multiplicity preserving bijection between the projective components of the permutation module of G acting by conjugation on its involutions and the real 2-blocks of G that have defect zero.

Miniversal deformations and the Moduli space of isomorphism classes of algebras

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The moduli space of isomorphism classes of algebras on a space of fixed dimension is determined by considering the action of the group of automorphisms on the variety given by the relations determining the algebra structure, which are quadratic in the case of Lie or associative algebras. The cohomology of the algebra gives the tangent space at a point in this moduli space, but the miniversal deformations really tell the whole picture of how the space is glued together. Recently, the authors gave a complete decomposition of the space of

all 4 dimensional Lie algebras. We will use these results to illustrate how to give a nice picture of such a moduli space.

Varieties for modules for some non-cocommutative Hopf algebras
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I will introduce "rank varieties" for modules for a special class of non-cocommutative Hopf algebras, using an appropriate analogue of a shifted cyclic subgroup. The construction allows one to recover rank varieties for certain truncated polynomial algebras as considered by Erdmann and Holloway. The relationship between the rank varieties and the varieties arising from the action of the cohomology ring will be discussed. This is joint work with Sarah Witherspoon.

On the classification of automorphic products and generalized Kac-Moody algebras
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We use Serre duality to derive some classification results for automorphic products and generalized Kac-Moody algebras.

Koszul categories and regular components.
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Let Λ be a finite dimensional algebra over a field k. To any connected regular component of the Auslander-Reiten quiver of Λ we associate a Frobenius Koszul category with radical cube zero. We discuss how the shape of the component is related to properties of this Frobenius Koszul category.

Isomorphisms of small group rings

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Fix a commutative ring R as domain of coefficients. The isomorphism problem asks in general whether a given group G is determined (up to isomorphism) by the structure of its group algebra RG. Remarkably, for finite groups, there is essentially only one instance of this problem that is still (wide) open, the so-called modular isomorphism problem: is an arbitrary p-group determined by its modular group algebra over the prime field k with p elements?

We will report on some (modest) recent progress on this problem. Let H be a given finite p-group. Call a p-group E with a normal, elementary abelian subgroup V contained in the Frattini subgroup of E such that the quotient E/V is isomorphic to H a *covering* of H. To any covering E of H one can associate a certain quotient of the group ring kE, the so-called *small group ring* $s(E, V)$, which still has kH as quotient. In this talk we will describe precisely – in terms of a certain action of the outer automorphism group of kH – all those coverings E of H that give rise to isomorphic small group rings.

Orbit closures for derived module categories of finite dimensional algebras

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Let A be a finite dimensional algebra over an algebraically closed field. Using triangles I will define a notion of degeneration for the bounded derived category of A and give a characterization in terms of orbit closures. I will also discuss how the geometry of the orbit closures depends on the quasi-isomorphism class of a complex.

Polynomial functors of prime degree

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One defines for an additive functor a cross effect as the kernel of the natural mapping from the images of a sum to the sum of the images. A functor is polynomial if some iterated cross effect vanishes. We explain how one can use the representation theory of symmetric groups to show that polynomial functors of prime degree from free abelian groups to the p-adic integers can be identified with the modules of a special classical order of finite lattice type.

Set Theory (J.D. Hamkins, P. Koepke, B. Löwe)

Contents

Recent results on the generic absoluteness programme

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We present some quite recent results on generic absoluteness under several classes of projective forcing notions. In particular, we provide exact consistency strengths for canonical generic absoluteness of $L(\mathbb{R})$ under various classes of ccc and proper forcing extensions. We also present some applications of these results in Descriptive Set Theory and Combinatorics.

Stationary subsets of $\mathcal{P}_\kappa\lambda$ with respect to the ground model

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We are interested in the following problems: When is $\mathcal{P}_\kappa\lambda \cap V$ stationary and/or co-stationary in a model W extending V? and its cousin, If $\kappa^{<\kappa} = \kappa$ in W, when is $\mathcal{P}_{\kappa^+}\lambda \cap V$ κ-stationary and/or co-κ-stationary? Preservation of the κ-stationarity of $\mathcal{P}_{\kappa^+}\lambda \cap V$ is exactly what is needed to characterize certain distributive laws in Boolean algebras in terms of games. Although stronger, in a sense it is easier to see when κ-stationarity of the gound model is preserved, due to a Kueker-type theorem for $< \kappa$-ary functions. We present some conditions under which κ-stationarity of the ground model is preserved. On the other hand, it seems to us easier to make $\mathcal{P}_{\kappa^+}\lambda \setminus V$ stationary than *kappa*-stationary, owing to the finite nature of first order logic, and even this requires large cardinals when $\kappa > \omega$ and no new ω-sequences are added. Still, we are quite interested in making $\mathcal{P}_{\kappa^+}\lambda \setminus V$ κ-stationary, as this is related to an open problem regarding games and distributive laws. Towards this, we present an equiconsistency result, due to Sy Friedman and ourselves, for when $\mathcal{P}_{\aleph_2}\aleph_3 \setminus V$ is stationary.

Constructions related to a problem of Efimov

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We consider the problem if every infinite Hausdorff compact space must have a convergent sequence of support a nonseparable Radon measure. This is related to a problem of Efimov which asked the same with containing a copy of beta omega in place of supporting a nonseparable Radon measure. The former is a stronger property. We show that a counterexample exist under CH. We also

show a related construction done under diamond of a compact space with no convergent sequences in which all Radon measures are uniformly regular. The existence of such a space answeres a question of Mercourakis. The problem if there are Efimov spaces under PFA is still open.

Classifying Automorphisms of the Measure Algebra
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Many dynamical systems carry invariant measures that allow them to be studied statistically. The statistical behavior is captured by the conjugacy class of the associated measure preserving transformation. This talk discusses recent progress in the project of classifying the conjugacy relation on measure preserving systems using the tools of descriptive set theory.

Morasses and Finite Support Iterations
Bernhard Irrgang
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We introduce a method of thinning out a forcing such that it gets a chain condition. As an application we force a thin-very tall superatomic Boolean algebra.

Specializing Aronszajn trees without adding reals and preserving some weak diamonds
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Coauthors: Saharon Shelah

We answer the question whether the weak diamond for the covering relation of the Lebesgue null sets implies that there is a Souslin tree. Forcings with side conditions and completeness systems are combined with genericity games.

Projective equivalence relations and inner model theory
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Inner model theory can be exploited to answer key questions concerning projective equivalence relations E. A typical question is: suppose E to be thin (i.e., there is no perfect set of pairwise E-inequivalent reals); how many equivalence classes can E have?

Dedekind-finite Structures
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A set is Dedekind finite if it has no countably infinite subsets. Infinite such sets are only relevant in set theory without the axiom of choice. We discuss recent results concerning the algebraic structures whose domains are Dedekind finite sets.

Mutual Stationarity
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We survey some work around Foreman and Magidor's notion of *mutual stationarity* of a sequence of sets.
Definition *A sequence* $\mathcal{S} = \langle S_\alpha | \alpha < \delta \rangle$ *with* $S_\alpha \subseteq \kappa_\alpha$ *where* $\delta < \kappa_0 < \cdots < \kappa_\beta < \kappa_{\beta+1} < \cdots$ *is a sequence of regular cardinals, is called* mutually stationary *if every algebra* $\mathcal{A}$ *on* $\sup \kappa_\alpha$ *has a subalgebra* $\mathcal{B} \subset \mathcal{A}$ *satisfying:* $\kappa_\alpha \in |\mathcal{B}| \rightarrow \sup\{|\mathcal{B}| \cap \kappa_\alpha\} \in S_\alpha$.

Let $cof_{\omega_1} =_{df} \{\alpha | \alpha \in On \wedge cf(\alpha) = \omega_1\}$. In joint work with Peter Koepke we have shown the following two theorems relating independent choices of stationary sets independently to this notion of the sequence as a whole being mutually stationary:
Theorem 1 *If every sequence of stationary sets* $S_n \subset \kappa_n \cap cof_{\omega_1}$ *for* $n < \omega$ *is mutually stationary then there is an inner model with* $\sup\{\kappa_n\}$ *a measurable cardinal.*
Theorem 2 *If every sequence of stationary sets* $S_n \subset \aleph_n \cap cof_{\omega_1}$ *for* $n < \omega$ *is mutually stationary then there is an inner model with infinitely many measurable cardinals of Mitchell order* $o(\omega_1)$.

(It should be noted that it is not known to be consistent with ZFC whether every independently chosen sequence of stationary sets $S_n \subset \aleph_n \cap cof_{\omega_1}$ for

$1 < n < \omega$, is mutually stationary. It is consistent by a theorem of Cummings-Foreman-Magidor that there is a sequence κ_n for $n < \omega$ for which every such choice of stationary sets S_n is mutually stationary, relative to the consistency of the existence of a measurable cardinal, thus rendering Theorem 1 an equiconsistency result.)

If one varies the cofinalities in the choice of the S_n sets larger cardinals are necessary. As sample:

Theorem 3 *Suppose* $S_n = \aleph_n \cap \omega$ *if* $n \cong 0, 1 mod 4$ *and* $S_n = \aleph_n \cap \omega_1$ *otherwise. Then there is an inner model with a strong cardinal.*

Spectral Analysis of Differential and Difference Operators (E. Korotyaev, B. Mityagin, G. Teschl)

Contents

Ferromagnetism of the Hartree-Fock-z Approximation of the Hubbard Model in the Limit of Large Coupling

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Coauthors: Elliott Lieb (Princeton University), Marcos Travaglia (Mainz University)

In the Hartree-Fock-z approximation for the Hubbard model, the variation is restricted to those Slaterdeterminants which are eigenvectors of the z-component of the total spin, $S_z = \sum_x n_{x,\uparrow} - n_{x,\downarrow}$. Given a chemical potential $0 < \mu < 4d$, where $d \geq 1$ is the spatial dimension of the lattice, it is shown that the ground state of the Hartree-Fock-z approximation is given by the fully saturated ferromagnet, provided the coupling constant $U > 0$ is sufficiently large (but finite).

Weyl-Titchmarsh theory for singular finite difference Hamiltonian systems

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We discuss the theory of matrix-valued Weyl-Titchmarsh M-functions for self-adjoint Hamiltonian finite difference systems with separated boundary conditions.

Spectral gaps of 1D periodic Schrödinger and Dirac operators

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The spectra of 1D periodic Schrödinger and Dirac operators have band structure. The asymptotic behavior of the corresponding spectral gap sequences is closely related to the potential smoothness. We discuss asymptotic formulas for spectral gaps in the case of special potentials (trigonometric polynomials or entire functions).

Properties of Coulombic wavefunctions and electron densities

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Recently [1] it was shown that the electronic wavefunctions ψ of atoms and molecules have a representation $\psi = \mathcal{F}\Phi$ where $\mathcal{F}$ is an explicit universal factor, locally Lipschitz, and independent of the eigenvalue and the solution ψ itself. Φ is locally $C^{1,1}$. This presentation turns out to be optimal.

As a consequence of these results new regularity results concerning the one-electron density can be shown. They include for instance a non-spherical generalisation of Kato's cusp condition for the density at the nucleus.

[1] *Comm. Math. Phys.*, 255, 183-227, 2005.

Spectral theory and nodal domains

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Consider a Schrödinger operator on a bounded domain $\Omega \subset \mathbb{R}^d$ with Dirichlet boundary condition. We investigate several relations between the spectrum and the nodal domains of the eigenfunctions or abstract versions of them. In particular we find a natural generalisation of Courant's nodal theorem. In addition spectral conditions are given which force abstractions of nodal sets to be actual nodal sets of eigenfunctions.

Resonances for slowly varying perturbations of the periodic Schrödinger equation

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The talk is devoted to the computation of the width of the resonances for a slowly varying perturbation of a periodic operator. The study takes place in dimension one. The perturbation is assumed to be analytic and local in the sense that it tends to a constant at $+\infty$ and at $-\infty$; these constants may differ. Modulo an assumption on the relative position of the range of the local perturbation with respect to the spectrum of the background periodic operator, we show that the width of the resonances is essentially given by a tunneling effect in a suitable phase space.

The conformal spectral theory for Schrödinger operator with periodic matrix potentials

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We consider the Schrödinger operator on the real line with a $N \times N$ matrix valued periodic potential, $N > 1$. The spectrum of this operator is absolutely continuous and consists of intervals separated by the gaps. We define the Lyapunov function, which is analytic on the N-sheeted Riemann surface. On each sheet the Lyapunov function has the standard properties of the Lyapunov function for the scalar case. The Lyapunov function has branch points (resonances, complex or real numbers). We determine the asymptotics of the periodic, anti-periodic spectrum and the resonances at high energy (in terms of the Fourier coefficients of the potential). We show that there exist two type of gaps: i) a stable gap, the endpoints are periodic and anti-periodic eigenvalues, ii) a resonance (unstable) gap, the endpoints are resonances (real branch points), iii) the existence of resonance gaps is proved. Moreover, the following results are obtained: 1) we define the quasimomentum as an analytic function on the Riemann surface; various properties and estimates of the quasimomentum are obtained, 2) we construct the conformal mapping, the real part is integrated density of states and the imaginary part is the Lyapunov exponent. We obtain various properties of this conformal mapping, which are similar to the case N=1, 3) we determine various new trace formulae for potentials and the integrated density of states, the Lyapunov exponent, 4) a priori estimates of gap lengths in terms of potentials are obtained.

Cantor spectrum of Lebesgue measure zero for one-dimensional quasicrystals

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This talk is concerned with one-dimensional quasicrystals. We present an ergodic theoretic approach to Cantor spectrum of Lebesgue measure zero for such models. We then discuss recent extensions obtained in joint work with David Damanik.

Scattering theory for Jacobi operators with quasi-periodic background
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We will consider inverse scattering theory for Jacobi operators which are short range perturbations of quasi-periodic background operators. Necessary and sufficient conditions for given scattering data to determine a unique Jacobi operator are presented.

The asymptotic behavior of eigenvalues of a modified Jaynes-Cummings model
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We obtain the asymptotic behavior of eigenvalues of Jacobi matrices corresponding to a modified Jaynes-Cummings model with additive and multiplicative modulations using a successive diagonalization method.

Hill's Potentials in Weighted Sobolev Spaces and their Spectral Gaps
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We describe a new, short proof of some facts relating the gap lengths of the spectrum of a potential q of Hill's equation, $-y''+qy=\lambda y$, to its regularity. For example, a real potential is in a weighted Gevrey-Sobolev space if and only if its gap lengths, γ_n, belong to a similarly weighted sequence space. An extension of this result to complex potentials is proven as well. We also recover Trubowitz results about analytic potentials. — The proof essentially employs the implicit function theorem.

Rank One Perturbations of Jacobi Matrices with mixed Spectra

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Let A be a self-adjoint operator and φ its cyclic vector. In this work we study spectral properties of rank one perturbations of A

$$A_\theta = A + \theta\langle\varphi, \cdot\rangle\varphi$$

in relation to their dependence on the real parameter θ. We find bounds on averages of spectral measures for semi-infinite Jacobi matrices and give criteria which guarantee existence of mixed spectral types for θ in a set of positive Lebesgue measure

The Douglas-Kroll-Heß Method: Convergence and Block-Diagonalization of the Dirac Operator

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We show that the Douglas-Kroll block-diagonalization method for the Dirac operator with Coulomb potential is convergent in norm resolvent sense for coupling constant αZ less than 0.38191 which corresponds to atomic number 52. Moreover, we give an explicit expression for the corresponding block-diagonalized Dirac operator.

Unitary Anderson models

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Unitary operators displaying a band structure have recently appeared in different contexts. They describe the quantum dynamics of certain models in solid state physics, but also appear naturally in the study of orthogonal polynomials on the unit circle. Here we will present some results for unitary analogs of one-dimensional Anderson models, in which randomness is introduced through multiplicative perturbation of a deterministic unitary operator by i.i.d. random phases. We discuss results on positivity and vanishing of the Lyapunov exponents as well as localization properties.

The form boundedness problem for the general second order differential operator

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A complete characterization of form boundedness is given for the general second order partial differential operator with real- or complex-valued distributional coefficients. Related compactness properties, as well as inequalities of Trudinger type for quadratic forms are obtained. In particular, explicit analytic criteria of form boundedness are given for the magnetic Schrödinger operator. This is joint work with V. Maz'ya.

Invariant measure and Lyapunov exponent for Schrödinger operator with gamma-distributed potential

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Consider random complex continued fraction $[0, a_1, ..., a_n]$, where $a_k = b_k e^{iu}$ with b_k independent identically gamma distributed and u fixed in $[-\pi/2, \pi/2]$. To this continued fraction there corresponds a fractional linear transformation $G_u(z) = 1/(a + z)$. We show that in the limit when u -¿ $\pm\pi/2$, the invariant measure for the product of random matrices associated to the map G_u converges weakly to the invariant measure for the product of transfer matrices of a 1-dim discrete Schrödinger operator with gamma-distributed random potential. The result generalizes well known examples of invariant measures which can be computed explicitly (including Letac-Seshadri result and the case of Cauchy distribution for Schrödinger operators) and yields a new class of examples where both the measure and the Lyapunov exponent of the associated product of random (transfer) matrices admits explicit representation.

Stochastic Analysis on Metric Spaces
(L. Saloff-Coste, K.Th. Sturm, W. Woess)

Contents

Diffusions of moduli and polygons, SLE(κ) and SLE(κ, ρ)

Robert Bauer
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We discuss the possible candidates for conformally invariant random non-self-crossing curves which begin and end on the boundary of a multiply connected planar domain, and which satisfy a Markovian-type property. We consider both, the case when the curve connects a boundary component to itself (chordal), and the case when the curve connects two different boundary components (bilateral). We establish appropriate extensions of Loewner's equation to multiply connected domains for the two cases. We show that a curve in the domain induces a motion on the boundary and that this motion is enough to first recover the motion of the moduli of the domain and then, second, the curve in the interior. For random curves in the interior we show that the induced random motion on the boundary is not Markov if the domain is multiply connected, but that the random motion on the boundary together with the random motion of the moduli forms a Markov process. In the chordal case, we show that this Markov process satisfies Brownian scaling and discuss how this limits the possible conformally invariant random non-self-crossing curves. We show that the possible candidates are labeled by a real constant and a function homogeneous of degree minus one which describes the interaction of the random curve with the boundary. We show that the random curve has the locality property if the interaction term vanishes and the real parameter equals six.

We also discuss SLE(κ, ρ) in the context of moduli diffusions and show that it corresponds to a diffusion of polygons.

Rough Path Integration and ODE's

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Given a rough path, X, in the sense or Terry Lyons, we will introduce a space of "integrands" which may be integrated relative to X. We will use this integral to give another (natural) proof of the existence of solutions to ordinary differential equations driven by rough paths.

Limit Theorems for Free Convolutions and Characterization of Distributions

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The classical theory of convolution of probability measures and their limit behavior by Gnedenko, Khintchin and Kolmogorov will be reviewed in comparison to analogous recent results we obtained in free probability theory, which in some cases exhibit surprising differences, especially concering the arithmetic of convolutions. We extend classical work of Linnik and Zinger (1970) on the Gaussian characterization of the distribution of independent random variables X_j such that the two linear forms

$$L_{r1} = U_1X_1 + \cdots + U_nX_n, \qquad L_{r2} = U_{n+1}X_1 + \cdots + U_{2n}X_n$$

are independent, beyond the results of Darmois–Skitovich (for i.i.d sequences U_j of coefficients independent of the others) and discuss some recent conjectures for comparable characterizations in the case of free convolutions.

Stochastic integration with respect to Poisson random measures

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In this talk I want to give a survey about stochastic integration with respect to Poisson random measures in Banach spaces. It has been shown, that in a wide range of problems encountered e.g. in finance mathematics, physics and engineering the underlying noise is discontinuous, and/or having long tails. Here Poisson random measures appear in the most important non-Gaussian models, when noises differ signifactly from the ideal Gaussian one.

Due to the special features of the Poisson random measures, it may be that the p-variation is finite for $1 \leq p < 2$. Hence, one can define a stochastic integral in L^p sense, taking values in certain Banach spaces, called M-type p Banach spaces, in which most of the probabilistic theorems necessary for defining a stochastic integral, are valid. Typical examples are Hilbert spaces or $L^p(\mathcal{O})$, where $p \in (1, 2)$ and $\partial\mathcal{O}$ smooth. Most of the important features, like the Itô-formula or certain inequalities, remain valid.

First, I will give a short survey about Lévy processes and Poisson random measures in Banach spaces. Then, I will outline M-type p Banach spaces, the relation to certain geometric properties and stochastic integration in this spaces. Finally, as example, SPDE driven by Poisson random measure will be considered.

The talk will be based on the works Hausenblas (2004a), (2004b) and Hausenblas, Seidler (2004)

References

Hausenblas, E. (2004a) *Existence, Uniqueness and Regularity of Parabolic SPDEs driven by Poisson Random Measure*, submitted

Hausenblas, E. (2004b) *A Note on the Itô Formula of Stochastic Integrals in Banach Spaces*, submitted.

Hausenblas, E., Seidler J. (2004) *Maximal Inequality for Stochastic Convolutions driven by Martingals and Random measures*, submitted.

Non-local symmetric operators and harmonic functions

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We consider non-local Dirichlet forms and corresponding harmonic funcions. The assumptions on the kernel in the symmetric form allow for very general kernels. The jump process related to the forms under consideration may have jump intensities whose size depends on the position of a particle or the direction of the jump.

We prove pointwise estimates of harmonic functions and discuss Harnack inequalities. As an example, we prove the existence of a discontinuous harmonic function.

Conformal invariance, brownian loops, and measures on random paths

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There has been considerable progress in the last five years in understanding scaling limits of random lattice paths in two dimensions. I will review some of this work and then discuss some of the important open questions in this area. I will also discuss the following questions: What is the analogue of the Schramm-Loewner evolution (SLE) in non-simply connected domains and in three dimensions? What one parameter families of discrete processes can one define that should have SLE as a limit?

Stochastic analysis applications to hypoelliptic heat kernel inequalities

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I will discuss the existence of "L^p-type" gradient estimates for second order hypoelliptic heat kernels on manifolds. Stochastic calculus methods transfer this problem to one of determining certain infinite dimensional estimates. In particular, one is able to show that "L^p-type" gradient estimates hold for $1 < p < \infty$, and the $p = 2$ gradient estimate implies a Poincaré estimate in this context. The case $p = 1$ (which would imply a logarithmic Sobolev inequality) is still under investigation.

Universality in the parabolic Anderson model

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We discuss the spatially discrete heat equation in a random i.i.d. potential with localised initial datum, usually called the parabolic Anderson model. The emphasis is on the question, which features of the potential distribution influence the qualitative long-term behaviour of the solution of the problem.

Morse Theory from a Function Space Viewpoint

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Given a compact manifold M and h a Morse function on it, we consider the Witten deformation of the usual exterior derivative on form and the associated Witten Laplacian. Interpreting the heat kernel of the Witten Laplacian via a Feynman-Kac type formula and using a construction of a supersolution for a linear PDE in the Euclidean space, we show how one can localize the heat kernel around the critical points and prove the Morse inequalities. We will discuss also the atempts to cover a more general result due to Witten, Helffer and Sjostrand.

Scaling limits for the UST on the discrete torus

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The typical distance between two points in the uniform spanning tree (UST) on the complete graph K_m is on the order of $m^{1/2}$, and Aldous showed that a suitable scaling limit of the UST is the Brownian continuum random tree. We show that for $d \geq 5$, the scaling limit of the UST on the discrete torus $\mathbb{Z}_n^d$ is again the Brownian continuum random tree. This verifies a conjecture of Pitman.

Stochastic differential equations with non Gaussian additive noise on Banach spaces

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Ito integrals of random Banach valued functions w.r.t. compensated Poisson random measures (cPrm) are discussed in [Ru]. The Levy - Ito decomposition Theorem claims that any additive process is uniquely decomposed in a continuous semimartingale driven by a Brownian motion and a pure jump semimartingale driven by a jump martingale obtained by an Ito integral w.r.t. a cPrm. In [ARu] we prove that the Levy -Ito decomposition theorem holds also on separable Banach spaces of type 2. (It holds also on general separable Banach spaces (see Dettweiler [Dett]) but in this case the integral w.r.t. a cPrm is not defined in terms of an Ito integral) . These results [ARu], [Ru] permit us [MRu2] to define non Gaussian additive noise and to study [MRu] stochastic differential equations (SDE)with non Gaussian additive noise on separable Banach spaces. Existence and uniqueness is proven under local Lipshitz conditions for the drift and noise coefficients. The Ito formel for Banach valued functions applied to the solutions of such SDEs is proven in [RuZ]. This permits us to analyze solutions of others SDEs [MRu] .

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Mass Transportation, Equilibration for Nonlinear Diffusions, and Ricci Curvature

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We will give a survey on recent developments in optimal mass transportation. Among others,

- We explain how nonlinear diffusions on $\mathbb{R}^n$ or on a Riemannian manifold M are related to gradient flows of certain functionals S on $P_2(M)$, the L_2-Wasserstein space of probability measures on M.
- We show how convexity properties of S on $P_2(M)$ imply functional inequalities (like Talagrand inequ., log. Sobolev inequ.) and equilibration of the underlying diffusion on M.
- We introduce and analyze generalized Ricci curvature bounds for metric measure spaces (M, d, m), based on convexity properties of the relative entropy $Ent(.|m)$. These bounds are stable under convergence.
- We construct a canonical stochastic process on the the Wasserstein space $P_2(\mathbb{R})$ which may be characterized as the 'uniform distribution' with weight function $\exp(-Ent(.|m))$.

Simple random walk on a class of fractal-like trees

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In 1995 E. Burioni and D. Cassi studied simple random walks on fractal-like trees. These infinite trees are defined recursively and are radial with respect to the root: Starting with a single root, d paths of length k^n are attached to each leaf at the n-th step.

In this talk we generalize their construction and study simple random walk on this class. We prove an asymptotic expansion of the return probabilities of the root. This asymptotics exhibit logarithmic oscillations and answer the question of recurrence and transience depending on d and k.

Existence of non-trivial harmonic functions on Cartan-Hadamard manifolds of unbounded curvature

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The Liouville property of a complete Riemannian manifold M (i.e., the question whether there exist non-trivial bounded harmonic functions on M) has attracted a lot of attention. In particular, for Cartan-Hadamard manifolds the necessity of lower curvature bounds is still an open problem. We discuss examples of such manifolds of unbounded curvature where the limiting angle of Brownian motion degenerates to a single point on the sphere at infinity, but where nevertheless the space of bounded harmonic functions is as rich as in the non-degenerate case.

Percolation on nonunimodular graphs

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It is one of the central questions in percolation theory whether for any transitive graph there are infinite clusters for critical Bernoulli percolation. While the amenable case is unsolved for many basic examples (such as Z^3), the fact that there are no infinite clusters was proved for nonamenable unimodular graphs by Benjamini, Lyons, Peres and Schramm. The nonunimodular case remained open, since the so called "Mass Transport Principle" is not really effective in this context. We show that there are no infinitely many infinite clusters at

critical percolation for nonunimodular graphs. Other similarities and surprising differences compared to the unimodular case are also presented.

Subtree Prune and Regraft: a reversible real tree valued Markov process

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The real trees form a class of metric spaces that extends the class of trees with edge lengths by allowing behavior such as infinite total edge length and vertices with infinite branching degree. A well-known example for an R-tree is David Aldous's Brownian continuum random tree (CRT), i.e. the tree inside a standard Brownian excursion.

We use Dirichlet form methods to construct and analyze a reversible Markov process whose stationary distribution is the Brownian CRT. This process is inspired by the subtree pruning and regrafting Markov chain that appears in phylogenetic analysis.

A key technical ingredient in this work is the use of a Hausdorff–Gromov type distance to metrize the space whose elements are compact real trees equipped with a probability measure. Also, the investigation of the Dirichlet form relies on a new path decomposition of the Brownian excursion.

Topology of Manifolds (M. Kreck, A. Ranicki)

Contents

On the Farrell-Jones Conjecture

Arthur Bartels
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tba

Identifying Those Links In Solid Tori Which Are Braids Made of Braids

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Suppose $\overline{\gamma}$ is a braid in an unknotted solid torus $A \subset S^3$ which is an irreducible link L. Assume L is a braid made of braids. Then L has a prime decomposition, $\overline{\gamma} = \overline{\gamma}_j|\overline{\gamma}_{j-1}|\cdots|\overline{\gamma}_2|\overline{\gamma}_1$, where each $\overline{\gamma}_i, i = 1, \cdots, j$ is not a braid made of braids. That is, L may be written as a product of prime braids. If L is entirely composed of braids made of braids then it admits a prime decomposition as above on each of the components. This result has applications to the Neilsen-Thurston classification problem. Using work of Moran we show how a braid made of braids may be written as a braid word without referring to the braid diagram. We also show how the product above is related to the usual braid product. Utilizing these results we indicate how to tell if a given link in a solid torus is in fact a braid made of braids or is entirely composed of braids made of braids.

Topological T-duality and topological stacks

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The topology of T-duality for spaces with a free circle action and a twist is by now well understood. In this talk we consider the case of circle actions with fixed points. Using the language of topological stacks we show how the results on T-duality can be extended.

Chain bundles and the classification of manifolds I

Diarmuid Crowley
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Notwithstanding the impressive accomplishments of modified surgery (see especially Hambleton-Kreck), the frontier of our knowledge remains the classification of 2q/(2q-1)-dimensional (q-1)-smoothings. We present new conjectures and results in modified surgery based on the algebraic surgery of Ranicki and Weiss. The first talk will include the central theorems, some new classifications results and some restatements of existing classifications from our point of view. The second talk contains a sketch of the proofs and some related topics.

On the isomorphism conjecture in L-theory

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I will discuss the Farell-Jones isomorphism conjecture in L-theory for specific fundamental groups and discuss geometric applications.

Remarks on iterated Browder-Livesay invariants and assembly

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There will be reviewed the construction of iterated Browder-Livesay invariants, and relations to the surgery assembly map will be discussed.

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Elliptic Cohomology II

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On the signature of string manifolds

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Nielsen coincidence theory in higher codimensions and Hopf-Ganea invariants

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In classical fixed point and coincidence theory the notion of Nielsen numbers has proved to be extremely fruitful. We extend it to pairs (f_1, f_2) of maps between manifolds of arbitrary dimensions. This leads to estimates of the minimum numbers $MCC(f_1, f_2)$ (and $MC(f_1, f_2)$, resp.) of pathcomponents (and of points, resp.) in the coincidence sets of those pairs of maps which are homotopic to (f_1, f_2). Furthermore, we deduce finiteness conditions for $MC(f_1, f_2)$. As an application we compute both minimum numbers explicitly in various concrete geometric sample situations.

The Nielsen decomposition of a coincidence set is induced by the decomposition of a certain path space $E(f_1, f_2)$ into pathcomponents. Its higher dimensional topology captures further crucial geometric coincidence data. The resulting obstructions turn out to be closely related to certain Hopf-Ganea invariants.

Smoothing local loop spaces

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Given a finite p-local or p-complete loop space, we show it is the *pi*-localization or p-completion of a smooth manifold.

Lefschetz numbers in instanton Floer homology

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The instanton Floer homology is a homology theory which associates with every homology sphere eight abelian groups, and with every cobordism of homology spheres a homomorphism of these groups. We study Lefschetz numbers of such homomorphisms.

It is well known that the Lefschetz number of a product cobordism equals twice the Casson invariant of the homology sphere. We show that the Lefschetz number of a finite order mapping cylinder equals twice the equivariant Casson invariant and evaluate it explicitly in terms of classical knot invariants.

In general, we identify the Lefschetz number of any homology cobordism from a homology sphere to itself with the Furuta-Ohta invariant, which is a version of the degree zero Donaldson polynomial. We conjecture that the mod 2 reduction of one half times this Lefschetz number is independent of the cobordism; if true, this would imply the failure of the triangulation conjecture for higher dimensional topological manifolds and shed light on the structure of homotopy $S^1 \times S^3$.

We propose an approach to proving the above conjecture and outline our progress to date.

Chain bundles and the classification of manifolds II

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We sketch the application of the theory of chain bundles by A. Ranicki and M. Weiss to the modified surgery theory of M. Kreck.

Elliptic Cohomology via Conformal Field Theories, Part 2

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This is Part 2 of a report on our project with the eventual goal to relate elliptic cohomology to conformal field theories. The first part will be given by Peter Teichner. We will outline the construction of spaces CFT_n consisting of 3-tier super symmetric conformal field theories of degree n. These spaces are intimately related to modular forms: associating to a CFT of degree n its partition function gives a map from the set of components of CFT_n to integal modular forms of degree n (weight n/2). We expect that the spaces CFT_n fit together to form an ring spectrum CFT and hence give a multiplicative cohomology theory. We expect further that CFT is homotopy equivalent to the spectrum TMF of topological modular forms constructed by Hopkins and Miller.

Elliptic Cohomology via Conformal Field Theories, Part 1

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This is Part 1 of a report on our project with the eventual goal to relate elliptic cohomology to conformal field theories. The second part will be given by Stephan Stolz. We will outline the construction of spaces CFT_n consisting of 3-tier super symmetric conformal field theories of degree n. These spaces are intimately related to modular forms: associating to a CFT of degree n its partition function gives a map from the set of components of CFT_n to integal modular forms of degree n (weight n/2). We expect that the spaces CFT_n fit together to form an ring spectrum CFT and hence give a multiplicative cohomology theory. We expect further that CFT is homotopy equivalent to

the spectrum TMF of topological modular forms constructed by Hopkins and Miller.

GAMM-SIAM: Algebraic Approaches to Preconditioning (H. Fassbender, A. Frommer)

Contents

Recent advances in preconditioning large systems of equations

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Many problems in industrial applications involve the solution of large sparse linear systems and require numerical solvers that are fast, robust and memory efficient. Except for a few specific application areas where one is able to construct special adapted preconditioning methods (e.g. multigrid), in general one has to rely on black box methods which only allow minor changes. Often one prefers direct methods because of their robustnes and since modern sparse direct solvers are well understood and quite efficient. In contrast to this the design of robust preconditioning methods still is a challenge.

In this talk we will discuss recent developments in matrix preconditioning methods that have significantly improved iterative methods, in particular those based on approximate multilevel decompositions.
Some of the most interesting improvements are maximum weight matching [3] and its symmetric variants [4,5], inverse–based factorizations [2]. We will demonstrate how these novel approaches can be used in symmetrically structured problems like the Anderson model of localization [1] or device simulation (Maxwell equation).

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Extensions of the Parametrized Block Ordering Algorithms for Preconditioning

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Incomplete factorization is one of the most important algebraic preconditioning techniques for iterative methods to solve linear systems of equations.

Usually, dynamic strategies for dropping entries are applied, thus needing dynamic data structures and introducing housekeeping overhead.

We suggest an alternative approach which determines permutations *a priori* and then applies dropping to the permuted matrix. Then the comple te *LU* decomposition of the so reduced matrix is computed. We use an extension of the PABLO and TPABLO permutation schemes of Szyld et al. to obtain a block decomposition of the matrix with diagonal blocks which are relatively full. We also care for getting large diagonal entries by using bottelneck transversals. We finally use a maximum spanning tree on an appropriate quotient graph.

The advantage of our approach is that no dynamical data structures are needed, and that we can rely on BLAS3 operations for a large part of the computation. Results of many numerical experiments will be presented.

Domain Decomposition based Hierarchical Matrices for Black-Box Preconditioning

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Hierarchical matrices provide a data-sparse way to approximate fully populated matrices. In this talk we exploit hierarchical matrix techniques in the framework of (recursive) domain decompositions with an interior boundary, also known as *nested dissection*. Typically, an index cluster tree forms the basis for the structure of a hierarchical matrix. We introduce a new cluster tree construction which yields a block structure that achieves three goals with respect to a subsequent LU-factorization: 1) many large blocks remain zero; 2) non-zero blocks allow an efficient approximation; 3) the hierarchical LU factorization is parallelizable. We will then construct preconditioners based on such an incomplete LU-decomposition to accelerate the iterative solution of linear systems of equations. We will illustrate our new preconditioner with several numerical examples including convection-dominated partial differential equations.

Algebraic updates of preconditioners for solving similar linear algebraic systems

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Many applications like computational fluid dynamics, structural mechanics and numerical optimization provide sequences of systems of linear algebraic equations with similar coefficient matrices. For example, such systems can arise as a result of a nonlinear iteration.

The talk will deal with algebraic updates of approximations to the system matrices which may make computation of subsequent preconditioners more efficient. One possible approach is to exploit an approximate pattern to get the new preconditioner [3]. Another possibility is to directly update the old preconditioner based on one of more alternative strategies. In particular, we will generalize the approaches from [1] and [2]. We will present some possible algorithmic procedures and numerical experience with them.

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GAMM-SIAM: Control Theory (P. Benner)

Contents

Algorithmic Mechanics on Lie Groups

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Many constrained optimization problems are formulated naturally as optimization problems on classical Lie groups and homogeneous spaces. Considerations of faster convergence and better dynamical behavior lead us to embedding certain classical algorithms such as gradient flow in second order equations of mechanics. Specifically we consider mechanical systems on Lie groups wherein the objective function does double duty in determining stiffness and damping. In this talk, we investigate the basic equations for certain appealing objective functions and the asymptotic behavior of the associated mechanical systems. Applications to numerical linear algebra are discussed.

Optimal control problems with pointwise state constraints

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Technical processes are often described by systems of partial differential equations. Technical requirements lead to pointwise bounds for the solutions of these PDEs. The optimization of such processes can be described by optimal control problems with pointwise state constraints.

This class of optimal control problems is characterized by challenging theoretical and numerical difficulties. The fist part of the talk is devoted to known positive and negative results. A new approach to overcome the problems is proposed in the second part.

Input-to-state stability of large interconnected systems and applications in transport networks

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We provide a generalized version of the *nonlinear small-gain theorem* for the case of more than two coupled input-to-state stable systems. For this result the interconnection gains are described in a nonlinear gain matrix and the small gain condition requires bounds on the image of this gain matrix. The condition

may be interpreted as a nonlinear generalization of the requirement that the spectral radius of the gain matrix is less than one. We give some interpretations of the condition in special cases covering linear gains and linear systems.

The results are interpreted in the stability analysis of transport networks.

An introduction to infinite-dimensional systems theory

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Using a simple partial differential equation, we illustrate how techniques from functional analysis and control theory can be combined to show existence and uniqueness of a solution. We concentrate on the question which of the boundary variables (of the pde) can be choosen as inputs (free variables) and which as outputs. We show that one combination is quite obvious, once you consider the energy associated to the pde. Furthermore, we show that the other choices can be obtained by using a feedback loop on the system associated to the first combination.

GAMM-SIAM: Mathematical Problems of Mechanics (F. Pfeiffer, J. Scheurle)

Contents

Interior perturbations for viscous fluid flows

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The method of interior perturbations is a technique devised by the author for solving a wide class of differential equations that arise in continuum mechanics. In this method, coupled perturbation sequences are set up across interior boundaries within the overall domain; and the resulting intermediate solutions (if convergent) are then embedded within coupled perturbation sequences across other interior boundaries which enclose the previous ones. The procedure is made possible by the presence of two independent continuity requirements, which allow for two types of boundary condition at an interior boundary, one for use in determining the solution on each side of the interface. Organization of the overall solution, involving the entire system of boundaries, can be represented by means of a lattice structure which is closely related to the concept lattices of Ganter and Wille. Here we apply the method to the equation for steady, incompressible, stratified, unidirectional viscous flow, with viscosity exhibiting arbitrary spatial variations perpendicular to the flow. The two continuity requirements are continuity of the flow velocity and stress vectors throughout the domain. A thorough framework is presented which enables the systematic handling of any viscosity function, when partitioned in any way (i.e. when any set of interior boundaries is set up within the domain). Examples of calculations for selected viscosity functions are presented and discussed.

Complementarities in Non-Smooth Dynamics

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Multibody structures with unilateral contacts are efficiently modelled by a rigid body approach including complementarities. An active contact is always accompanied by constraint forces, a passive contact not. For example, a contact is either closed including a constrained force, or it is open without a constraint force. Stiction is accompanied by a constraint force in tangential direction, sliding not. This establishes complementarities and from that a set of equations of motion with an additional set of unequality constraints in the form of complementarities. Including also impacts with friction we come out with measure equations and certain differential inclusions. The presentation will consider the problem of modelling large systems with unilateral contacts, from the standpoint of mechanics and mathematics, it will give some indications of the numerical problems involved, and it will consider some typical examples from industry.

Dynamical Aspects of Shape Memory Alloys

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A special feature of shape memory alloys is the occurence of material phase transitions as the temperature varies. Mathematially speaking, this means that the form of the free energy associated to such a material qualitatively changes as a function of temperature. In particular, considered as a function of the material strains it is non-convex within certain ranges of the temperature as opposed to the standard theory of elasticity.

In this talk, we consider a mathematical model based on the theory of thermo-visco-elasticity that describes the dynamics of deformations of a class of shape memory alloys. We discuss the existence and stability of vibrational solutions that are due to the shape memory effect and parametrically forced by time-periodic fluctuations of the temperature.

A Modeling Study of Clattering Impacts of A Three Dimensional Object

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When an electronic device drops to the floor at uneven level, the rapid successions of clattering sequence are important for their shock response to circuits, displays and disk drives. This talks deals with both analytical and numerical analysis of multiple impacts of drops to the ground. A three-dimensional computational dynamics code with continuous contact model has been developed to simulate the multiple impacts of a falling rigid body with the ground. Results from the computational model as well as analytic analysis from a discrete contact dynamics impact model indicate that subsequent impacts might be larger than initial ones in some situations. The differential equation based model is shown to be realistic in impact sequence and laid a foundation for detailed finite element analysis of the interior impact response of an electronic device.

GAMM-SIAM: Multiscale Problems, Oscillations in Partial Differential Equations and Homogenization (A. Mielke, T. Hou)

Contents

Homogenization and two-scale models for phase transitions with microstructures

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Many phase transition problems exhibit complex microstructures, important examples are dendritic and eutectic microstructures in liquid-solid phase transitions or microstructures arising in epitaxial growth. We survey results obtained by the application of homogenization techniques to phase transition problems with varying microstructure. Due to the changing microstructure the homogenization typically leads to a two-scale model that consists of macroscopic homogenized equations on the large scale and local microscopic problems for the evolution of the microstructure on the small scale. The lecture adresses the formal derivation of the models, their mathematical analysis and their rigorous justification via estimates for the model error as well as numerical examples for simple situations.

Spectral Resolution of a Velocity Field on the Boundary of a Lipschitz Domain

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We regard an open quantum system which is embedded into a flow. The system is driven by this flow acting on the boundary of the spatial domain designated to quantum mechanics. We investigate the spectral properties of the corresponding essentially non-selfadjoint Schrödinger-type operator.

A geometrically exact Cosserat shell-model including size effects and avoiding degeneracy in the thin shell limit. Rigourous justification via Gamma-convergence for the elastic plate.

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We are concerned with the derivation of the Γ-limit to a three-dimensional geometrically exact Cosserat model as the relative thickness $h > 0$ of a flat domain tends to zero. The Cosserat bulk model involves already exact rotations as a second independent field. It is shown that the Γ-limit based on a natural scaling assumption consists of a membrane like energy contribution and a homogenized transverse shear energy both scaling with h, augmented by an additional curvature stiffness due to the underlying Cosserat bulk formulation,

also scaling with h. No specific bending term appears in the dimensional homogenization process. The formulation exhibits an internal length scale L_c which survives the homogenization process.

A major technical difficulty, which we encounter in applying the Γ-convergence arguments, is to establish equi-coercivity of the sequence of functionals as the relative thickness h tends to zero. Usually, equi-coercivity follows from a local coerciveness assumption. While the three-dimensional problem is well-posed for the Cosserat couple modulus $\mu_c \geq 0$, equi-coercivity forces us to assume a strictly positive Cosserat couple modulus $\mu_c > 0$. The Γ-limit model determines the midsurface deformation m in $H^{1,2}(\omega, R^3)$. For the case of zero Cosserat couple modulus $\mu_c = 0$ we obtain an estimate of the $\Gamma - \liminf$ and $\Gamma - \limsup$, without equi-coercivity which is then strenghtened to a Γ-convergence result for zero Cosserat couple modulus. The classical linear Reissner-Mindlin model is almost the linearization of the Γ-limit for $\mu_c = 0$ apart from a stabilizing shear energy term.

Justification of the Nonlinear Schrödinger equation in spatially periodic media

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The dynamics of the envelopes of spatially and temporarily oscillating wave packets advancing in spatially periodic media can approximately be described by solutions of a Nonlinear Schrödinger equation. Here we prove estimates for the error made by this formal approximation using Bloch wave analysis, normal form transformations, and Gronwall's inequality.

GAMM-SIAM: Numerical PDEs/Equations with Inherent Conditions (R. Jeltsch, M. Lukacova-Medvidova, J. Mac Hyman)

Contents

Boundary-integral simulations of droplet solidification

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We develop a boundary-integral type method for simulations of solidification of a liquid droplet surrounded by air and cooled locally at the surface. There are three moving interfaces in the problem: solid-liquid, air-liquid, and solid-air. Our approach describes evolution of all three in time in such a way that local conditions at tri-junctions and global mass balance are satisfied. The shapes of the solidified particles and their dependence on the ratio of the densities of the two phases are studied. At final stages of solidification, a cusp is formed in agreement with some related experimental observations. Mesh refinement strategies for dealing with this type of singularity are discussed.

Computing representations of curl-free surface fields

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The numerical solution of eddy current problems can be basedcan be based on a coupling of boundary elements and finite elements. Stability of the discrete problem entails using divergence free discrete surface currents.

Those can be obtained by means of surface stream functions augmented by a basis of the discrete co-homology space H^1 of the surface of the conducting region. By duality, such basis fields arise from non-bounding edge cycles of the triangulated surface Γ_h that are bounding relative to the non-conducting exterior region. The latter constraint is an immediate consequence of Ampere's law.

This accounts for the interest in the automatic construction of such cycles. The talk will first present a graph-theoretic algorithm that yields a cycle basis of the homology group $H_1(\Gamma_h)$. Then, the concept of linking numbers from algebraic topology is used find cycles that comply with the constraint. Adaptive numerical Quadrature can be used to compute the linking numbers with an effort of $O(N^2)$, where N is the number of edges of the surface mesh.

Numerical surface reconstruction from gradient field data

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In optical metrology the following problem occurs: How to reconstruct an object's surface given its gradient field only? Hence, one seeks to recover a function when only its first derivative information is known. Additionally, the data is noisy and one has to deal with large data sets of size 1,000,000 or more.

To solve the problem we developed a Hermite-Birkhoff interpolant employing radial basis functions which interpolates the gradient field. The object's surface then is obtained by the analytic antiderivative of the interpolant. We created an algorithm that allows to cope with large data sets.

We present the method and give some examples from industrial applications.

The GLM Divergence Correction Method for Elliptic Constraints in Computational Electromagnetics

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The charge conservation laws are in general not strictly obeyed in computational electromagnetics, due to the presence of various types of numerical errors. In this talk we describe the generalized Lagrangean multiplier method (GLM) to control these errors. The main problem that numerical errors of the elliptic constrainst may increase in time and produce unphysical solution is due to the fact that these constraints are only loosely coupled to the hyperbolic evolution equations. The exact situation is that the charge conservation is satisfied for all times, if the initial data satisfy the constraints. If the initial data do not satisfy the constraints or any error is introduced during the calculation no solution of the Maxwell system can exist. The GLM approach is based on a reformulation of the Maxwell equations to a form by which a coupling of the hyperbolic and the elliptic part is introduced. The exact solution of the Maxwell equations is a solution of the modified system, but the equations allow charge now conservation errors and have a mechanism to prevent their increase.

We start to explain the method at a very simple test problem without physical relevance and show then the extension to the Maxwell, the MHD and the Maxwell-Vlasov equations. The latter system of equations describes the self-consistent motion of charged particles in electromagnetic fields. Here the charge conservation errors are introduced by the approximation of the movement of the

charged particles. Results of the numerical simulation of pulsed plasma thrusters for satelites are shown.

Divergence-free Adaptive Mesh Refinement for Cell-Centered Finite Volume Data

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A number of hyperbolic conservation laws have intrinsic constraints like vanishing divergences or constant curl. Popular examples are Maxwell's equations, the equations of magnetohydrodynamics and Einstein equations. In these equations typically the divergence of a vector field needs to be preserved.

Constraint preserving numerical methods are available in various versions for structured and un-structured meshes. The realization of divergence-preserving prolongation and restriction on adaptive grids is typically a question on its own. Existing procedures rely on staggered meshes with edge data.

This talk presents new procedures for divergence-free prolongation and restriction in adaptive mesh simulations based on *cell-centered* rectangular data structures. The results are specially designed for the use with commonly available divergence-preserving cell-centered finite volume methods.

The divergence-free prolongation is theoretically established using a null-space preservation approach. This approach yields a whole class of prolongation formulas which have been discussed and evaluated. The final optimized second order prolongation operator transforms a coarse solenoidal vector field into a fine solenoidal vector field according to a concrete discrete divergence operator.

For a divergence-free restriction procedure it is proposed to combine the restriction and conservation correction of the adaptive mesh refinement algorithm into a single step. Beside the simplification of the algorithm itself this provides the possibility of performing a divergence-free restriction. Following the idea of restricting the update instead of the solution the classical fix-up procedure is extended to the entire grid and results in an indirect divergence-free restriction procedure.

Poster Session

Contents

Weighted (PLB)- and (LF)-spaces of continuous functions
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For a double sequence $\mathcal{A} = ((a_{n,k})_k)_n$ of strictly positive continuous functions (weights) on a locally compact space X we define the weighted (PLB)-spaces $\mathcal{A}C(X)$ and $\mathcal{A}_0C(X)$ and the (LF)-spaces $\mathcal{V}C(X)$ and $\mathcal{V}_0C(X)$. In general these spaces are not equal. $\mathcal{A}C(X) = \mathcal{V}C(X)$ holds algebraically if and only if condition (B) of D. Vogt is satisfied. To get a similar result in the case of o-growth conditions we need the additional hypothesis that $(\mathcal{A}_n)_0C(X)$ is complete for each n. If all steps $(\mathcal{A}_n)_0C(X)$ are complete we can even prove that $\mathcal{A}_0C(X) = \mathcal{V}_0C(X)$ holds algebraically and topologically if and only if the conditions (B) and (wQ) are satisfied. The special case of sequence spaces is also treated.

Fredholmness of Toeplitz operators and corona problems
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The invertibility of a Toeplitz operator T_G can be related to a pair of corona problems whose data satisfy a Riemann-Hilbert equation associated with T_G. We study the Fredholm properties of T_G when a solution to that Riemann-Hilbert problem is known, to which the corona theorem does not apply.

The generalized Kochen-Specker theorem (and a half way around)
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The Kochen-Specker theorem shows the non-existence of phase space models of quantum theory. A new proof, clarifying the situation for all von Neumann algebras, is presented. We will also show how Stone spectra of von Neumann algebras and observable and antonymous functions defined on them can partly restore a phase space picture yet.

On the approximation of the Jacobi Polynomials

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New approximations of the Jacobi polynomials $P_n^{(\alpha,\beta)}(x)$ are provided on the ray $(1,\infty)$. The approximations are given explicitly in terms of some expressions derived from a coefficient of a related hypergeometric equation and in terms of certain perturbation terms. The perturbation terms are essentially resolvent series that are absolutely convergent. These series converge uniformly for all positive n, α and β in some semi infinite interval and for x in the interval $[1,\infty)$. They are shown to converge faster then a geometric series, where the ratio of successive terms is $\pi^2/32$. We thus also demonstrate, that it is possible to approximate the Jacobi polynomials in the vicinity of $x = 1$ as well as on the entire interval $[1,\infty)$ without resorting to Bessel functions.

Critical points at infinity and blow up of solutions of autonomous polynomial differential systems via compactification

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Critical points at infinity for autonomous differential systems are defined and used as an essential tool. R^n is mapped onto the unit ball by various mappings and the boundary points of the ball are used to distinguish between different directions at infinity. These mappings are special cases of compactifications. It is proved that the definition of the critical points at infinity is independent of the choice of the mapping to the unit ball.

We study the rate of blow up of solutions in autonomous polynomial differential systems of equations via compactification methods. To this end we represent each solution as a quotient of a vector valued function (which is a solution of an associated autonomous system) by a scalar function (which is is a solution of a related scalar equation).

A new technique for the asymptotic integration of matrix differential equations with oscillatory coefficient matrix

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A new technique for the asymptotic integration of first order linear differential matrix equations is derived. New results on asymptotic integration are obtained where Levinson's theorem is shown to be a corollary. The new technique is devised for differential equations with an "oscillatory coefficient matrix function". The relevance of this work to the adiabatic approximation theorem in quantum mechanics is discussed.

Ernst Steinitz and Friedrich Wilhelm Levi - German Jewish mathematicians and their families in the 19th and 20th centuries

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Ernst Steinitz (1871-1928) worked in Breslau, Berlin, and Kiel in the areas of field theory, polyhedra, and combinatorics. After his death in 1928 no Nachruf was published in Germany. During the Nazi regime his wife was killed. His son escaped to Palestine. Friedrich Wilhelm Levi (1888-1966) was born in Mühlhausen (Alsace) and belonged to a famous Jewish family of the Pfalz region. In 1935, Levi had to leave the Leipzig University; he emigrated to British India. He helped very much to build up Indian mathematics. In 1952, Levi came back to Germany and worked in Freiburg and Berlin. In both cases of Steinitz and Levi the interrelation of biography and work as well as of mathematics and politics related to war is discussed.

A construction with CH of a subset of the reals with a smaller ordertype which has a similarity decomposition

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Let c be the cardinality of the set $\mathbb{R}$ of real numbers. A subset S of $\mathbb{R}$ is said to have a similarity decomposition if it has the same cardinality as $\mathbb{R}$, and if it can be decomposed into c subsets which are all order-isomorphic to S. In 1953 Seymour Ginsburg came across the question whether there exist subsets of $\mathbb{R}$ with an ordertype less than that of $\mathbb{R}$, which have a similarity decomposition. Using CH we show that such sets do exist.

Updown Categories

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A poset is a category in which (1) there is at most one morphism between objects, and (2) at most one of Hom(c,c') and Hom(c',c) is nonempty for c≠c'. An updown category satisfies (2) but not (1), allowing the covering relations to have multiplicities and the objects to have nontrivial automorphism groups; we also assume a grading on the set of objects. We develop a theory of updown categories, incorporating Stanley's differential posets and the author's weighted-relation posets. Important concepts are complementation, "up" and "down" operators D and U on the vector space generated by the objects, generating functions, and conditions on the commutator $[D, U]$. We illustrate with examples, including the updown categories with subgraphs, monomials, integer partitions, and rooted trees as objects.

Common Random Fixed Points of Random Multivalued Operators

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Let (X, d) be a complete metric space. Denote the family of all nonempty closed and bounded subsets of X by $CB(X)$ and the Hausdorff metric induced by d on $CB(X)$ by H. In 1974, S. Reich posed the following question: Let T be a multivalued mapping of X into $CB(X)$ such that

$$H(Tx, Ty) \leq k[d(x, y)]d(x, y)$$

for all x, y in X with $x \neq y$, where the function $k : (0, \infty) \to [0, 1)$ satisfies $\limsup_{r \to t^+} k(r) < 1$ for each $t > 0$. Then does T have a fixed point in X? N. Mizoguchi and W. Takahashi, in 1989, gave an affirmative answer to the above question under the hypothesis "$\limsup_{r \to t^+} k(r) < 1$ for every $t \in [0, \infty)$". An alternative proof to their result has been sought, in 1995, by P.Z. Daffer and H. Kaneko while T.H. Chang has derived it, in 1995, from a fixed point theorem for a multivalued map T satisfying the following contractive condition "$H(Tx, Ty) \leq \phi(\max\{d(x, y), D(x, Tx), D(y, Ty), 1/2[D(x, Ty) + D(y, Tx)]\})$, where $\phi : R^+ \to R^+$ (set of all nonnegative reals) satisfies certain properties and $D(a, B) = \inf\{d(a, b) : b \in B\}$".

The Prague School of Mathematicians led by A. Spacek, in 1950s, initiated the study of random fixed point theory which constitutes stochastic generalization of the classical or deterministic fixed point theory. The literature on this subject is very rich and it has led to remarkable new results with applications to probabilistic models in applied problems.

In this talk, the existence of random fixed point of a multivalued mapping and random coincidence point of hybrid multivalued mappings on a complete separable metric space (i.e., Polish space) X with values in $CB(X)$ satisfying one of the above mentioned generalized contractive conditions, will be demonstrated. In these results, there will be special emphasis on the feature that no additional condition is imposed on any of the functions to obtain its measurability. As applications, some theorems on random approximation will be presented.

On the effective teaching of mathematics to non-math majors

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We discuss the effective teaching of mathematics to undergraduate students, especially to students whose majors are not mathematics. We will focus upon the scope, methods and some examples. Related data obtained from Handong Global University will be presented and analyzed.

The Bell Polynomials Identity and Binomial Random Graphs

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We establish combinatorial identity for a sum involving binomial and multinomial coefficients which is closely allied with the Bell polynomials. It is shown how the identity arises from the study of binomial distributions corresponding to random graphs.

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Polynomial almost-periodic factorization of symbols of a class of finite-interval convolution operators

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The Wiener-Hopf factorization of a class of triangular matrix functions with polynomial almost-periodic entries is studied. Explicit formulas for the factors are obtained which give the inverses of the finite-interval convolution operators with symbols in that class.

Exponential decay for the solution of a nonlinear viscoelastic equation

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In this work we are concerned with the following nonlinear viscoelastic problem

$$\begin{cases} u_{tt} - \Delta u + \int_0^t g(t-\tau)\Delta u(\tau)d\tau + a(x)u_t + |u|^\gamma u = 0, \quad \text{in } \Omega \times (0,\infty) \\ u(x,t) = 0, \ x \in \partial\Omega \ , t \geq 0 \\ u(x,0) = u_0(x), \ u_t(x,0) = u_1(x), \ x \in \Omega, \end{cases}$$

where Ω is a bounded domain of $\mathbb{R}^n$ $(n \geq 1)$ with a smooth boundary $\partial\Omega$, $\gamma > 0$, g is a positive function, and $a : \Omega \to \mathbb{R}^+$ is a function, which may be null on a part of Ω.

Under the condition that $a(x) \geq a_0 > 0$ on $\omega \subset \Omega$, with ω nonempty and satisfying some geometry restrictions and

$$-\xi_1 g(t) \leq g'(t) \leq -\xi_2 g(t), \ t \geq 0,$$

such that $||g||_{L^1((0,\infty))}$ is small enough, an exponential decay result has been established by Cavalcanti *et al* using a piecewise linear multiplier method. This result has been later improved by the same author using method.

In this work, we introduce a new functional, which allows us to prove a similar result under weaker conditions on both a and g In fact in our work, the damping function a is allowed to vanish identically on the whole domain Ω, which shows that the damping caused by the integral term is strong enough to stabilize the system.

Moreover. with a slight modification in the proof, the exponential result can be pushed to the situation where a source term is competing with the internal damping.

An integrable hierarchy and its parametric solutions

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A generalized Camassa-Holm hierarchy is presented and this hierarchy is proved to be integrable in the sense of Lax pair. The relation between the PDE hierarchy and the constrained Hamiltonian system is discussed. A 3 by 3 spectral problem and its adjoint problem are introduced. Furthermore, the solutions for the whole hierarchy are obtained.

Lightface Indescribable Cardinals and Forcing Axioms

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Σ^1_3-absoluteness for *ccc* forcing means that for any *ccc* forcing P,

$$H_{\omega_1}{}^V \prec_{\Sigma_2} H_{\omega_1}{}^{V^P}.$$

"ω_1 inaccessible to reals" means that for any real r, $\omega_1{}^{L[r]} < \omega_1$. To measure the exact consistency strength of "Σ^1_3-absoluteness for *ccc* forcing and ω_1 is inaccessible to reals", we introduce a weak version of a weakly compact cardinal, namely, a (lightface) Σ^1_2-indescribable cardinal; κ has this property exactly if it is inaccessible and $H_\kappa \prec_{\Sigma_2} H_{\kappa^+}$.

Secondary Cones of Delone Subdivisions and their Application

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We describe extensions of the classical theory of L-types due to Voronoi. We in particular consider positive definite quadratic forms which are invariant with respect to a given finite matrix group G and having a fixed associated Delone subdivision. These polyhedral secondary cones give a face to face tiling of the Bravais space $B(G)$ associated to G. It turns out that there are only finitely many nonequivalent cones for each G. As an application of a systematic enumeration we find new locally optimal, best known covering and packing-covering lattices in dimensions $d \geq 6$.

Constructing triangulations and their shellings for point configurations

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Let $A_n = \{a_1, \ldots, a_n\} \subset R^d$ for $n = d+1, ..., N$, and let the convex hull $[A_{d+1}]$ of A_{d+1} be a d-simplex. Assume that a triangulation T_n of the point configuration A_n and a shelling L_n of the triangulation T_n have been constructed. We show how to construct a triangulation T_{n+1} of the point configuration A_{n+1} and a shelling L_{n+1} of the triangulation T_{n+1}. Let H_n^- be a set of facets of the triangulation T_n that are visible from a_{n+1}. Then $T_{n+1} = T_n \bigcup \{[F, a_{n+1}] \ : \ F \in H_n^-\}$ is a triangulation of the point configuration A_{n+1}.

If facets in H_n^- are facets of the polytope $[A_n]$, then Bruggesser-Mani construction (see [1], [2, pp. 240-243]) yields a shelling order $F_1, ..., F_m$ of the elements in H_n^-. This order generates the shelling

$$L_{n+1} = (L_n, [F_1, a_{n+1}], ..., [F_m, a_{n+1}])$$

of the triangulation T_{n+1}. If there exists a facet in H_n^- that is not a facet of the polytope $[A_n]$, then it is more difficult to construct a shelling L_{n+1} of the triangulation T_{n+1}. Our goal is the following result.

Theorem. The triangulation T_N and its shelling L_N can be constructed in time $O(N^{\lfloor d/2 \rfloor + 1} \log N)$.

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References

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Strong Necessary Conditions - an alternative to the Euler equation in theory of Non-Linear Partial Differential Equations

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A concept of strong necessary conditions for extremum of functional has been applied to analysis of integrability of Non-Linear Partial Differential Equations (NLPDE). In case of one integrable NLPDE the analysis leads to the auto-Bäcklund transformations and in the case of integrable coupled system of NLPDE's to the Bogomolny equations (the Bogomolny decomposition). A

general form of the second order NLPDE with a derivative-less non-linear term has been considered. In the case of a coupled system of equations the general conditions for the existence of the Bogomolny decomposition are derived. In the case of an uncoupled system of equations the Bogomolny equations become the Bäcklund transformations. It has been found a denumerable classes of coupled systems possessing the Bogomolny relationship. The strong necessary conditions concept reduces the derivation of the Bäcklund and the Bogomolny equations to an algorithm.

Hilbert Space and Variational Methods for Singular Quadratic Functionals Applied to Singular Second Order Linear Differential Equations.

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The purpose of this paper is to develop a unified theory for the study of singular second order linear differential equations. This development is a generalization of the α-admissible functions described by Marston Morse and Walter Leighton, on p. 275, **Singular quadratic functionals**, *Trans. Amer. Math. Soc.* **40** (1936), no. 2, 252-286. Magnus R. Hestenes provides a development in **Singular Quadratic Variational Problems**, *Journal of Optimization Theory and Applications* **41** (1983), no. 1, 123-137, where on pp. 123-124 he examines a singular quadratic functional in the form of the second variation $J(x) = \int_a^b \{r(t)(x'(t))^2 + 2q(t)x'(t)x(t) + p(t)(x(t))^2\}dt$ with $r > 0$ a.e. and $p \geq 0$ on (a,b). Junior Stein, **Hilbert space and variational methods for singular selfadjoint systems of differential equations**, *Bull. Amer. Math. Soc.* **80** (1974), no. 4, 744-747, takes a similar but different approach. The Euler differential equation for this functional is a singular second order linear differential equation. The approach in this paper is different from that of Hestenes. It requires $r > 0$ a.e., but not $p \geq 0$ on (a,b). The fundamental idea here is to compare the extremals of the second variation with those of an appropriate norm. Other studies of singular quadratic functionals include those of John Chellevold in 1951 (Ph.D. thesis) and 1952, Edmond C. Tomastik in 1965 (Ph.D. thesis) and 1966, Junior Stein in 1971 (Ph.D. thesis) and 1973, Marston Morse in 1973, and Zuzana Došlá and Ondřej Došlý in 1995.

Axisymmetric Ivantsov type traveling waves in generalized 3-D Mullins-Sekerka

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In this poster, we discuss the existence problem of axisymmetric Ivantsov type solutions for generalized 3-dimensional Mullins-Sekerka equation. The generalized two-phase Mullins-Sekerka equation models a general class of phase transitions with anisotropic surface energy. The Ivantsov type solutions are traveling waves whose needle-shaped interfaces are moving along the axis at a constant velocity within a cylindrical domain. The existence of at least one axisymmetric needle solution is obtained through a Leray-Schauder argument of a singular integral transformation.

Weighted Fréchet spaces of holomorphic functions

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This article deals with weighted Fréchet spaces of holomorphic functions which are defined as countable intersections of weighted Banach spaces of type H^∞. We characterize when these Fréchet spaces are Schwartz, Montel or reflexive. The quasinormability is also analyzed. In the latter case more restrictive assumptions are needed to obtain a full characterization.

Walks on Planes Paved by Binary Tiles

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Let us imagine that we are going to walk on an infinite "binary" plane — a plane paved by 2 by 2 "binary tiles" where a binary tile is in fact a screen with only two displays: L or R. Whenever we step onto a screen the letter on it changes. If the letter is L then we turn around to the left, otherwise we turn around to the right. We postulate that we can only move to the screen in front of us in each step after turning around. In this talk we shall study what can happen if we walk on the planes paved by regular patterns of blocks of screens. We will also present some conjectures.