Wednesday, 06. July 2022

09:00 - 10:00
Track: Plenary
Type: Ceremony
Room: Room 1
Chair: Carlos E. Kenig
Chair: Helge Holden

Opening

10:15 - 11:15
Track: Plenary
Type: Award
Room: Room 1

Fields Medal Award Lecture 1

11:30 - 12:30
Track: Plenary
Type: Award
Room: Room 1

Fields Medal Award Lecture 2

12:30 - 14:00
Track: Other
Type: Break
Room: Room 1

Note: lunch break extended to 14:00

14:00 - 15:00
Track: Plenary
Type: Award
Room: Room 1

Abacus Medal Lecture

15:15 - 16:15
Track: Plenary
Type: Award
Room: Room 1

Fields Medal Award Lecture 3

16:30 - 17:30
Track: Plenary
Type: Award
Room: Room 1

Fields Medal Award Lecture 4

Thursday, 07. July 2022

10:15 - 11:15
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Tamar Ziegler
Plenary Speaker: David Kazhdan

On the Langlands correspondence for curves over local fields

An exposition of recent results and (mostly) conjectures attempting to construct an analog of the theory of automorphic functions on moduli spaces of bundles on curves over local fields (both archimedian and non-archimedian).

11:30 - 12:30
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Carlos E. Kenig
Plenary Speaker: Marie-France Vignéras

Emmy Noether Lecture: Modular representations of p-adic groups

The theory of complex representations of reductive p-adic groups, for instance $GL(2,Q\_\{p\})$ where $Q\_\{p\}$ is the p-adic completion of Q, is an essential part of the Langlands program. Its links with number theory and geometry requires to study representations in vector spaces over fields different from the field of complex numbers, or even in modules over commutative rings, for instance over finite fields or over $Z[1/p]$. We will give an overview of the main problems in this area and of recent progress towards some of them.

13:15 - 14:00
Track: Geometry
Type: 5. Geometry
Room: Room 1
Moderator: Eleny Ionel
Sectional Speaker: Kai Cieliebak

Lagrange multiplier functionals and their applications in symplectic geometry and string topology

I will discuss the role of Lagrange multiplier functionals in mathematics and physics. The main focus is on Rabinowitz' action functional and its usage in symplectic geometry, as well as recent applications in string topology and the study of closed geodesics.

13:15 - 14:00

Track: Probability
Type: Special Sectional Lecture
Room: Room 2
Moderator: Sergey Fomin
Sectional Speaker: Elchanan Mossel

Combinatorial Statistics and the Sciences

Combinatorial Statistics studies inference in discrete stochastic models. Inference of such models plays an important role in the sciences. We survey research in Combinatorial Statistics involving broadcasting on trees. We review the mathematical questions that arise in the analysis of this process and its inference via "Belief Propagation". We discuss the mathematical connections to statistical physics, the social sciences, biological sciences and theoretical computer science.

13:15 - 14:00

Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 3
Moderator: Nancy Lopes Garcia
Sectional Speaker: Gabor Lugosi

Mean estimation in high dimension

We discuss the statistical problem of estimating the mean of a random vector based on independent, identically distributed data. This classical problem has recently attracted a lot of attention both in mathematical statistics and in theoretical computer science and numerous intricacies have been revealed. We present some of the recent advances, focusing on high-dimensional aspects.

13:15 - 14:00

Track: Mathematics of Computer Science
Type: 14. Mathematics of Computer Science
Room: Room 4
Moderator: Irit Dinur
Sectional Speaker: Maria-Florina Balcan

Learning Theoretic Foundations of Data-driven Algorithm Design

In this talk, I will give an overview of recent work that uses and expands learning theoretic models and techniques in order to put data-driven algorithm design on firm foundations. The classic theory of computing approach to analyzing algorithms for solving combinatorial problems assumes worst case instances of the given problem, about which the algorithm designer has no prior information. Since for many problems such worst-case guarantees are quite weak, practitioners often employ a data-driven algorithm design approach; specifically, they use machine learning and instances of the problem from their specific domain to learn a method that works well in that domain. Unfortunately, classic formalisms for algorithm design cannot be used to provide performance guarantees for such data-driven algorithmic techniques. In this talk, I will describe recent work that uses and expands learning theoretic perspectives to provide strong performance guarantees for data-driven algorithm design.

13:15 - 14:00
Track: Analysis
Type: 8. Analysis
Room: Room 5
Moderator: Giovanni Alberti
Sectional Speaker: Xiumin Du

Weighted Fourier extension estimates and applications

I will talk about some recent results on weighted Fourier extension estimates and their applications in PDEs and geometric measure theory.

13:15 - 14:00
Track: Mathematical Physics
Type: 11. Mathematical Physics
Room: Room 6
Moderator: Kasia Rejzner
Sectional Speaker: Matthew Hastings

Gapped Quantum Systems: From Higher Dimensional Lieb-Schultz-Mattis to the Quantum Hall Effect

We consider many-body quantum systems on a finite lattice, where the Hilbert space is the tensor product of finite-dimensional Hilbert spaces associated with each site, and where the Hamiltonian of the system is a sum of local terms. We are interested in proving uniform bounds on various properties as the size of the lattice tends to infinity. An important case is when there is a spectral gap between the lowest state(s) and the rest of the spectrum which persists in this limit, corresponding to what physicists call a "phase of matter". Here, the combination of elementary Fourier analysis with the technique of Lieb-Robinson bounds (bounds on the velocity of propagation) is surprisingly powerful. We use this to prove exponential decay of connected correlation functions, a higher dimensional Lieb-Schultz-Mattis theorem, and a Hall conductance quantization theorem for interacting electrons with disorder.

13:15 - 14:00
Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 8
Moderator: Bernhard Keller
Sectional Speaker: Olivier Wittenberg

Some aspects of rational points and rational curves

Various methods have been used to construct rational points and rational curves on rationally connected algebraic varieties. We survey recent advances in two of them, the descent and the fibration method, in a number-theoretical context (rational points over number fields) and in an algebro-geometric one (rational curves on real varieties), and discuss the question of rational points over function fields of p-adic curves.

13:15 - 14:00

Track: Number Theory
Type: 3. Number Theory
Room: Room 9
Moderator: Christophe Breuil
Sectional Speaker: Raphaël Beuzart-Plessis

Relative trace formulae and the Gan-Gross-Prasad conjectures

In this talk, I will report on some recent progress that have been made on the so-called Gan-Gross-Prasad conjectures through the use of relative trace formulae. In their global aspects, these conjectures, as well as certain refinements first proposed by Ichino-Ikeda, give precise relations between the central values of some higher-rank L-functions and automorphic periods. There are also local counterparts describing branching laws between representations of classical groups. In both cases, approaches through relative trace formulae have shown to be very successful and have even lead to complete proofs, at least in the case of unitary groups. However, the works leading to these definite results have also been the occasion to develop further and gain new insights on these fundamental tools of the still emerging relative Langlands program.

13:15 - 14:00

Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 10
Moderator: Xu-Jia Wang
Sectional Speaker: Galina Perelman

Formation of singularities in nonlinear dispersive PDEs

In this survey talk, I will review various results on the problem of singularity formation for some canonical dispersive equations, mostly of Schrödinger type.

13:15 - 14:00

Track: Dynamics
Type: 9. Dynamics
Room: Room 11
Moderator: Barbara Schapira
Sectional Speaker: Aaron Brown

Lattice subgroups acting on manifolds

I will discuss recent progress concerning rigidity properties of smooth actions on manifolds by lattices subgroups in higher-rank Lie groups.

14:15 - 15:00

Track: Geometry
Type: 5. Geometry
Room: Room 1
Moderator: Eleny Ionel
Sectional Speaker: Kathryn Mann

Groups acting at infinity

Studying rigidity of group actions by understanding behavior "at infinity" is an idea dating back to Selberg and Mostow. My recent work has exploited this perspective in the topological rather than algebraic setting to prove rigidity results for families of group actions that are basic examples in geometric topology: the actions of hyperbolic groups on their boundaries, actions of surface fundamental groups and mapping class groups on the circle, and actions built out of Anosov flows on 3-manifolds. My talk will survey recent rigidity and classification results and explain some of the unifying themes of this work.

14:15 - 15:00

Track: Combinatorics
Type: 13. Combinatorics
Room: Room 2
Moderator: Sergey Fomin
Sectional Speaker: Alexander Scott

Graphs of large chromatic number

The chromatic number has been a fundamental topic of study in graph theory for more than 150 years. Graph colouring has a deep combinatorial theory and, as with many NPhard problems, is of interest in both mathematics and computer science. An important challenge is to understand graphs with very large chromatic number. The chromatic number tells us something global about the structure of a graph: if G has small chromatic number then it can be partitioned into a few very simple pieces. But what if G has very large chromatic number? Is there anything that we can say about its local structure? We will discuss recent progress and open problems in this area.

14:15 - 15:00

Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 3
Moderator: Nancy Lopes Garcia
Sectional Speaker: Oleg Lepski

Theory of adaptive estimation

This talk is an introduction to the modern theory of adaptive estimation. In particular I introduce a universal estimation procedure based on a random choice from collections of estimators satisfying few very general assumptions. In the framework of an abstract statistical model we present an upper bound for the risk of the proposed estimator (oracle inequality). The basic technical tools here are a commutativity property of some operators and upper functions for positive random functionals. Since the obtained result is not related to a particular observation scheme many conclusions for various problems in different statistical models can be derived from the single oracle inequality.

14:15 - 15:00

Track: Logic
Type: Special Sectional Lecture
Room: Room 4
Moderator: Irit Dinur
Sectional Speaker: Georges Gonthier

Computer proofs: teaching computers mathematics, and conversely

Lecture on the state of the art of computer-assisted proofs
Abstract:
There has been much progress in using computers to construct and process mathematical proofs in recent years, from the old four-color puzzle, the seminal Odd Order theorem, to Hales' proof of the Kepler conjecture. This has come about as a range of computer science and software engineering methods were applied to the structure of the mathematical language, as we will show. This has even led to new mathematical insights, such as synthetic homotopy type theory.

14:15 - 15:00

Track: Analysis
Type: 8. Analysis
Room: Room 5
Moderator: Giovanni Alberti
Sectional Speaker: Pablo Shmerkin

Slices and distances: two problems of Furstenberg and Falconer

I will survey the history and recent developments around two old problems: the slicing $\times 2, \times 3$ conjecture of H. Furstenberg in ergodic theory, and the distance set problem in geometric measure theory introduced by K. Falconer. While these two problems are on the surface rather different, I will discuss a common viewpoint that involves "multiscale projections" and analyzing fractals through a combinatorial description in terms of "branching numbers".

14:15 - 15:00

Track: Mathematical Physics
Type: 11. Mathematical Physics
Room: Room 6
Moderator: Kasia Rejzner
Sectional Speaker: Jonathan Luk

Singularities in general relativity

The Einstein equations governing general relativity admit solutions which are singular. In this talk, we survey some recent mathematical progress in understanding these singularities. In particular, we discuss the constructions of various singular solutions to the Einstein vacuum equations and explain the singularity structure in the interior of generic dynamical black holes.

14:15 - 15:00

Track: Geometry
Type: 5. Geometry
Room: Room 7
Moderator: Sebastien Boucksom
Sectional Speaker: Xiaohua Zhu

Kähler-Ricci flow on Fano manifolds

The Kähler-Ricci flow is simply the Ricci flow restricted to Kähler metrics on a Kähler manifold M. If M is a Fano manifold, we usually consider the following normalized flow,
(0.1)
$\partial\omega(t) / \partial t = -\mathrm{Ric}(\omega(t)) + \omega(t)$, $\omega(0) = \omega_{\{0\}}$,
where $\omega(t)$ denote the solutions of Kähler-Ricci flow with initial metric $\omega_{\{0\}}$ in $2\pi c_{\{1\}}(M)$. Then the flow preserves the Kähler class, i.e., $[\omega(t)] = 2\pi c_{\{1\}}(M)$ for all t. In particular, the flow preserves the volume of $\omega(t)$. It is well-know that the solutions of (0.1) exist for any times $t > 0$ and their smooth limits (if exists) are Kähler-Ricci solitons. Because of obstructions, a Fano manifold may not admit any Kähler-Ricci soliton in general. Thus, the flow (0.1) may develop singularity. It makes the investigation more complicated, when studying the limit behavior of the flow. In this talk, we will introduce some basic tools as well as some recent developments of the Kähler-Ricci flow, including Perelman's fundamental estimates in Kähler-Ricci flow, the smooth convergence of Kähler-Ricci flow, the progress on Hamilton-Tian conjecture and the Kähler-Ricci flow on G-manifolds with singular limits.

14:15 - 15:00

Track: Algebra
Type: 2. Algebra
Room: Room 8
Moderator: Bernhard Keller
Sectional Speaker: Irena Peeva

Minimal Free Resolutions over Complete Intersections

Motivated by applications in Invariant Theory, Hilbert introduced an approach to describe the structure of modules by free resolutions. We will discuss resolutions over local or graded commutative rings. Over such rings, every finitely generated module has a minimal free resolution and it is unique up to an isomorphism. Hilbert's Syzygy Theorem shows that minimal resolutions over a polynomial ring are finite. Most minimal resolutions over quotient rings are infinite. The asymptotic structure of resolutions over a hypersurface can be described completely via matrix factorizations. In general, the structure of infinite resolutions can be quite complex; for example, there exist minimal resolutions whose generating functions are not rational. We will discuss the structure of minimal free resolutions over complete intersections. The study of such resolutions started with Tate's elegant construction of the resolution of the residue field. The lecture will focus on recent results by Eisenbud-Peeva.

14:15 - 15:00

Track: Number Theory
Type: 3. Number Theory
Room: Room 9
Moderator: Christophe Breuil
Sectional Speaker: Ana Caraiani

The cohomology of Shimura varieties with torsion coefficients and applications

Shimura varieties are certain highly symmetric algebraic varieties that generalise modular curves and that play an important role in the Langlands program. In this talk, I will survey certain vanishing conjectures and results about the cohomology of Shimura varieties with torsion coefficients, under both local and global representation-theoretic conditions. I will illustrate the geometric ingredients needed to establish these results using the toy model of the modular curve. I will also mention several applications, including to (potential) modularity over CM fields.

14:15 - 15:00

Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 10
Moderator: Xu-Jia Wang
Sectional Speaker: Pierre Cardaliaguet
Sectional Speaker: Francois Delarue

The master equation for mean field games

Mean field game theory was initiated a little more than fifteen years ago with the aim of simplifying the search for Nash equilibria in games with a large number of weakly interacting players. Since then, a lot has been done. In particular, the analysis of the master equation, a nonlinear second order partial differential equation stated on the space of probability measures describing the evolution of the value of the mean field game, has seen significant progress. In this talk, we will first present results obtained in a joint work with Lasry and Lions that explain how the master equation appears as the limit, as N tends to infinity, of a Nash system of N coupled Hamilton-Jacobi equations arising in differential game theory. Convergence is rigorously proven when the master equation has a classical solution, which is for instance the case under appropriate monotonicity conditions. In mean field game theory, this result is important as it permits to justify the passage from finite to infinite games, with a quantified rate of convergence and an appropriate form of propagation of chaos. However, the master equation is not expected to have a smooth solution in full generality. We will also review more recent results on suitable notions of solutions to the master equation. Some of them are specifically devoted to the so-called potential case, when the mean field game is the first order condition of a mean field control problem, i.e. a control problem set on the space of probability measures. We will address the Hamilton-Jacobi equation associated with the mean field control problem and explain how it may help for the analysis of the master equation. We will conclude the talk with some open questions.

14:15 - 15:00

Track: Dynamics
Type: 9. Dynamics
Room: Room 11
Moderator: Barbara Schapira
Sectional Speaker: Jon Chaika
Sectional Speaker: Barak Weiss

The horocycle flow on the moduli space of translation surfaces

We survey some results on the dynamics of the horocycle flow on the moduli space of translation surfaces. We outline proofs of some recent results, obtained by the authors in collaboration with John Smillie, and pose some open questions.

15:30 - 16:30
Track: Plenary
Type: Special Plenary Lecture
Room: Room 1
Chair: Carlos E. Kenig
Plenary Speaker: Frank Calegari

30 years of modularity: number theory since the proof of Fermat's Last Theorem

Lecture suitable for a broad audience on developments stemming from the works of Wiles and Taylor-Wiles on modularity of elliptic curves and Fermat's last Theorem

Abstract:
Almost 30 years ago, Andrew Wiles shook the mathematical world by announcing a proof of Fermat's Last Theorem. The key ideas behind the proof transformed algebraic number theory and the Langlands program in particular. In the first half of the talk, I shall give a gentle introduction to the problem of reciprocity in Langlands program. I shall then explain what progress we have made over the past three decades, and where we stand today.

Friday, 08. July 2022

10:15 - 11:15

Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Helene Esnault
Plenary Speaker: Alexander Kuznetsov

Homological algebraic geometry

The idea of studying the geometry of an algebraic variety through the structure of its derived category of coherent sheaves goes back to the pioneering works of Bondal and Orlov on the verge of the millennium. One of the central concepts of this approach is that of a semiorthogonal decomposition. In my talk I will overview the (rapidly developing) story of semiorthogonal decompositions, touching on some of its most fascinating aspects: (1) Semiorthogonal components with interesting properties and their geometric significance; (2) Categorical extensions of classical geometric constructions (homological projective duality, categorical joins and cones, categorical resolutions of singularities); and (3) Completely new constructions such as categorical absorptions of singularities.

11:30 - 12:30

Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Mikhail Kapranov
Plenary Speaker: Michel van den Bergh

Noncommutative crepant resolutions

A crepant resolution- if existing- is in in some sense the best possible smooth approximation to a singular algebraic variety. Crepant resolutions admit natural non-commutative analogues. During the lecture I will discuss how these appear in various contexts.

13:15 - 14:00

Track: Mathematics of Computer Science
Type: Special Sectional Lecture
Room: Room 1
Moderator: Salil Vadhan
Sectional Speaker: Huijia (Rachel) Lin
Sectional Speaker: Amit Sahai

The Mathematics of Hiding Secrets in Software

At least since the initial public proposal of public-key cryptography based on computational hardness conjectures (Diffie and Hellman, 1976), cryptographers have contemplated the possibility of a "one-way compiler" that translates computer programs into "incomprehensible" ones that compute the same function. In this talk, we will describe a rigorous formulation of this goal known as indistinguishability obfuscation (*iO*), which seeks to convert any given computer program into a pseudo-canonical form. Over the past decade, it has been demonstrated that *iO* is a "master tool" for achieving a large variety of cryptographic goals. Finally, we present our recent result, obtained jointly with Aayush Jain, constructing *iO* with mathematically provable security from three well-studied computational hardness conjectures in cryptography.

13:15 - 14:00
Track: Geometry
Type: 5. Geometry
Room: Room 2
Moderator: Thomas Schick
Sectional Speaker: Richard Bamler

Some recent developments in Ricci flow

Ricci flows are a powerful geometric-analytical tool, as they have been used to prove important results in low-dimensional topology. In the first part of this talk I will focus on Ricci flows in dimension 3. I will briefly review Perelman's construction of Ricci flow with surgery, which led to the resolution of the Poincare' and Geometrization Conjectures. Then I will discuss recent work of Lott, Kleiner and myself on an improved version of this flow, called "singular Ricci flow". This work allowed us to resolve the Generalized Smale Conjecture, concerning the topology of diffeomorphism groups, and a conjecture concerning the contractibility of the space of positive scalar curvature metrics on 3-manifolds. In the second part of the talk, I will focus on Ricci flows in higher dimensions. I will present a new compactness theory, which can be used to study the singularity formation of the flow, as well as its long-time asymptotics. I will discuss these and some further consequences. I will also convey some intuition of the new terminology that had to be introduced in connection with this compactness theory.

13:15 - 14:00
Track: Dynamics
Type: 9. Dynamics
Room: Room 3
Moderator: Herbert Spohn
Sectional Speaker: Mariusz Lemanczyk

Furstenberg disjointness, Ratner properties and Sarnak's conjecture

In 2010 Peter Sarnak formulated the celebrated conjecture on the orthogonality of the arithmetic Möbius function with all continuous observables in deterministic topological dynamical systems. In the talk I will present an account on a recent research around the conjecture staying most of the time on the ergodic theory aspects of it.

13:15 - 14:00
Track: Probability
Type: 12. Probability
Room: Room 4
Moderator: Marta Sanz-Sole
Sectional Speaker: Jinho Baik

KPZ limit theorems

One-dimensional interacting particle systems, 1+1 random growth models, and two-dimensional directed polymers define two-dimensional random fields. The KPZ universality conjectures that an appropriately scaled height function converges to a model-independent universal random field for a large class of models. We survey some of the limit theorems and discuss changes that arise when we consider different domains. In particular, we present recent results on periodic domains. We also comment on integrable probability models, integrable differential equations, and universality.

13:15 - 14:00
Track: Lie Theory and Generalizations
Type: 7. Lie Theory and Generalizations
Room: Room 5
Moderator: Angela Pasquale
Sectional Speaker: Tasho Kaletha

Representations of reductive groups over local fields

We discuss progress towards the classification of irreducible admissible representations of reductive groups over non-archimedean local fields and the local Langlands correspondence.

13:15 - 14:00
Track: Analysis
Type: 8. Analysis
Room: Room 6
Moderator: Marianna Csornyei
Sectional Speaker: Gideon Schechtman

The number of closed ideals in the algebra of bounded operators on Lebesgue spaces

View Abstract

13:15 - 14:00
Track: Analysis
Type: 8. Analysis
Room: Room 7
Moderator: Harald Helfgott
Sectional Speaker: Konstantin Tikhomirov

Quantitative invertibility of non-Hermitian random matrices

The problem of estimating the smallest singular value of random square matrices is important in connection with matrix computations and analysis of the spectral distribution. In this talk, we consider recent developments in the study of quantitative invertibility in the non-Hermitian setting, and review some applications of this line of research.

13:15 - 14:00

Track: Numerical Analysis and Scientific Computing
Type: 15. Numerical Analysis and Scientific Computing
Room: Room 8
Moderator: Slawomir Solecki
Sectional Speaker: Jan S. Hesthaven

Structure-preserving model order reduction of Hamiltonian systems

The development of reduced order models for complex applications promises rapid and accurate evaluation of the output of complex models under parameterized variation with applications to problems which require many evaluations, such as in optimization, control, uncertainty quantification and applications where near real-time response is needed. However, many challenges remain to secure the flexibility, robustness, and efficiency needed for general large scale applications, in particular for nonlinear and/or timedependent problems.

We discuss the recent developments of projection-based model order reduction (MOR) techniques targeting Hamiltonian problems. Hamilton's principle completely characterizes many high-dimensional models in mathematical physics, resulting in rich geometric structures, with examples in fluid dynamics, quantum mechanics, optical systems, and epidemiological models. MOR reduces the computational burden associated with the approximation of complex systems but classic reduction approaches do not guarantee conservation of the delicate dynamics of Hamiltonian problems, resulting in reduced models plagued by instability or accuracy loss.

By approaching the reduction process from the geometric perspective of symplectic manifolds, the resulting reduced models inherit stability and conservation properties of the high-dimensional formulations. We first introduce the general principles of symplectic geometry, including symplectic vector spaces, Darboux' theorem, and Hamiltonian vector fields. This setting is used as a starting point for the development of different structure-preserving reduced basis (RB) algorithms. We also briefly discuss extensions to problems posed on noncanonical Hamiltonian form.

We conclude by discussing the extension of structure preserving models within a framework of nonlinear reduced order models in which a local basis allows to maintain a small basis even for problems with a slowly decaying Kolmogorov n-width such a transport dominated problems. We demonstrate the efficiency of such techniques for nonlinear transport dominated problems, including for the Poisson-Vlasov problem of kinetic plasma physics.

13:15 - 14:00

Track: Stochastic and Differential Modelling
Type: 18. Stochastic and Differential Modelling
Room: Room 9
Moderator: Felix Otto
Sectional Speaker: Hyeonbae Kang

Quantitative analysis of field concentration in presence of closely located inclusions of high contrast

In composites consisting of inclusions and a matrix of different materials, some inclusions are located closely to each other. If the material property of inclusions is of high contrast with that of the matrix, field concentration occurs in the narrow region between closely located inclusions. Understanding the field concentration quantitatively is important in the theory of composites and imaging since it represent stress or field enhancement. Last thirty years or so have witnessed significant progress in analyzing this phenomena of field concentration: optimal estimates and asymptotic characterization capturing the field concentration have been derived in the contexts of the conductivity equation (or anti-plane elasticity), the Lamé system of linear elasticity, the Stokes system. This talk is to review some of them in a coherent manner.

13:15 - 14:00
Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 10
Moderator: Oleg Lepski
Sectional Speaker: Cun Hui Zhang

Second and higher order statistical methods in some once differentiable problems

In a number of recent developments, second and higher order methods of statistical inference have been proposed in some once differentiable problems. We consider three specific examples. In the first problem, second order Stein's formula as a special form of twice Gaussian integration by parts corrects the bias of the Lasso and other convex regularized estimators in high-dimensional linear regression via an unbiased estimating equation. With an associated central limit theorem as a special form of the Poincaré inequality for the once differential function in Stein's formula, the de-biased estimator is proven to achieve asymptotic normality and efficiency in regular statistical inference of linear functionals of the regression coefficient vector. In a related problem, the second order Stein methods justify the use of a scaled Mallow's C_{p} as a selector of an estimator in the Lasso solution path to achieve the performance of the oracle minimizer of the prediction loss within a regret of smaller order than the minimax convergence rate. In the second problem, bootstrap methods have been developed to approximate the distribution of the component-wise maximum of a sum of independent random vectors in high-dimension. A soft-max function was used to smooth the maximum in Lindeberg's and Slepian's interpolations between the sample and bootstrapped versions of the maximum. More recently, the un-smoothed maximum was directly used in the interpolation to achieve sharper convergence rates and to reduce the sample size requirement for the statistical consistency of bootstrap. This motivates a number of second and higher order Gaussian anti-concentration inequalities. In the third problem, a high order unbiased statistical expansion is developed in the estimation of a general functional of a high-dimensional mean vector. The formula systematically and explicitly solves the associated de-bias problem of all orders. In particular, the method directly provides optimal convergence rates in the estimation of the absolute and fractional norms of a high-dimensional mean vector and other non-smooth additive functionals in the Gaussian sequence model and under low-moment conditions on the noise based on independent and identically distributed observations.

13:15 - 14:00
Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 11
Moderator: Daniel Huybrechts
Sectional Speaker: Barbara Fantechi

A classical view on derived algebraic geometry

Since the turn of the millennium, higher categorical methods have been developed and successfully applied to a number of geometrical contexts, including algebraic geometry. We present some remarks on the necessity of bridging the gap between those who are fluent in the new language, and those who would benefit from it while working in a classical context, as well as suggesting possible approaches to do so.

14:15 - 15:00

Track: Control Theory and Optimization
Type: Special Sectional Lecture
Room: Room 1
Moderator: Salil Vadhan
Sectional Speaker: Nikhil Bansal

Algorithmic aspects of discrepancy theory

Discrepancy theory is a subfield of combinatorics with several applications in mathematics and computer science. However, most results in this area were based on non-constructive approaches such as the pigeonhole principle and counting arguments involving volume of convex bodies. Recently, several algorithmic methods have been developed based on discrete Brownian motion, convex geometry and optimization, leading to interesting new connections and progress. In this talk, I will give a flavor of these ideas and developments.

14:15 - 15:00

Track: Topology
Type: 6. Topology
Room: Room 2
Moderator: Thomas Schick
Sectional Speaker: Roman Mikhailov

Homotopy patterns in group theory

The talk will be about the homotopical or homological nature of certain structures which appear in classical problems about groups, Lie rings and group rings.

14:15 - 15:00

Track: Dynamics
Type: 9. Dynamics
Room: Room 3
Moderator: Herbert Spohn
Sectional Speaker: Michela Procesi

Stability and recursive solutions in Hamiltonian PDEs

In the context of Hamiltonian Partial Differential Equations on compact manifolds (mainly tori), I shall discuss the existence of special recursive solutions, close to an elliptic fixed point, which are superposition of oscillating motions, together with their stability/instability properties. One can envision such equations as chains of harmonic oscillators coupled by a small non-linearity, thus one expects a complicated interplay between chaotic and recursive phenomena due to resonances and small divisors, which are studied with methods from KAM theory. I shall concentrate mainly on the stability properties close to the fixed point as well as the existence and stability of quasi-periodic and almost-periodic solutions.

14:15 - 15:00

Track: Probability
Type: 12. Probability
Room: Room 4
Moderator: Marta Sanz-Sole
Sectional Speaker: Laurent Saloff-Coste

Breaking heat kernel estimates into pieces

In order to estimate the heat kernel on a Riemannian manifold, one may try to cut the manifold into nice pieces that are easier to study and attempt to glue back the pieces together. In Brownian motion terms, one can try to understand Brownian motion within each piece and then explore how the process move from pieces to pieces. This talk describes results obtained using this general line of reasoning.

14:15 - 15:00

Track: Lie Theory and Generalizations
Type: 7. Lie Theory and Generalizations
Room: Room 5
Moderator: Angela Pasquale
Sectional Speaker: Weiqiang Wang

What is an i-quantum group and what is it good for?

Quantum groups were the subject of Drinfeld's ICM lecture in 1986, and have found since then spectacular applications in math physics, representation theory, quantum topology, and so on. iQuantum groups arise from quantum symmetric pairs introduced by G. Letzter around 2000. We shall explain why it is natural to view i-quantum groups as a vast generalization of quantum groups. Then we shall discuss some recent developments and applications of i-quantum groups.

14:15 - 15:00

Track: Number Theory
Type: 3. Number Theory
Room: Room 7
Moderator: Harald Helfgott
Sectional Speaker: Alexander Gamburd

Arithmetic and dynamics on varieties of Markoff type

The Markoff equation $x^2 + y^2 + z^2 = 3xyz$, which arose in his spectacular thesis (1879), is ubiquitous in a tremendous variety of contexts. After reviewing some of these, we will discuss (briefly) Hasse principle, asymptotics of integer points, and (in some detail) recent progress towards establishing forms of strong approximation on varieties of Markoff type, as well as ensuing implications, diophantine and dynamical.

14:15 - 15:00

Track: Logic
Type: 1. Logic
Room: Room 8
Moderator: Slawomir Solecki
Sectional Speaker: Natasha Dobrinen

Ramsey theory of homogeneous structures

Ramsey theory on relational structures has been investigated ever since Ramsey proved his seminal theorem. While a multitude of classes of finite structures have been shown to possess the Ramsey property, such as finite linear orders and finite ordered graphs, analogues for infinite structures have proven more elusive: Initiated by Sierpinski in the 1930's, it was not until 1979 that the Ramsey theory of the rationals as a linearly ordered structure was completely understood; the Ramsey theory of the Rado graph was only completed in 2006. The main reason for this is that methods for Ramsey theory on finite structures are in general not sufficient for discovering Ramsey properties of their homogeneous (infinite) counterparts, i.e., Fraisse limits. Furthermore, while methods used for the rationals and Rado graph aided in a few other results, those methods were not sufficient for infinite structures with certain forbidden substructures, such as triangle-free graphs, hindering further progress in the area.
We will discuss the main reasons why this is so, and how the set-theoretic method of forcing opened new pathways in this arena. We will indicate the structural properties involved in the Ramsey theory of various homogeneous structures such as the rationals, the Rado graph, the homogeneous triangle-free graph and binary relational free-amalgamation classes more generally, the generic partial order, and others, indicating similarities and differences between their Ramsey-theoretic characterizations. Ongoing work as well as cognate areas, including infinite-dimensional Ramsey theory of homogeneous structures and partition theory of uncountable structures, will also be discussed. This talk will include works of various author combinations from among Balko, Barbosa, Chodounsky, Coulson, El-Zahar, Erdos, Hajnal, Hubička, Komjáth, Konečny, Laflamme, Larson, Mašulović, Nešetril, Nguyen Van Thé, Patel, Pósa, Rödl, Sauer, Vena, Zucker, and the speaker.

14:15 - 15:00

Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 9
Moderator: Felix Otto
Sectional Speaker: Vlad Vicol

Formation and development of singularities for the compressible Euler equations

We consider the compressible Euler equations of fluid dynamics, in multiple space dimensions. In this talk we discuss our program of completely describing the formation and development of stable singularities, from smooth initial conditions. The questions we address are: given smooth initial conditions, precisely how does the first singularity arise? is the mechanism stable? how can one geometrically characterize the preshock (the boundary of the space-time set on which the solution remains smooth)? precisely how does the entropy producing shock wave instantaneously develop from the preshock? does uniqueness hold once the shock has formed? do other singularities instantaneously arise after the preshock? In this level of detail the problem was previously open even in one space dimension. We discuss a sequence of joint works with Steve Shkoller, Tristan Buckmaster, and Theodore Drivas, in which we have developed a multidimensional theory to answer the above questions.

14:15 - 15:00

Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 10
Moderator: Oleg Lepski
Sectional Speaker: Stefanie Jegelka

Theory of Graph Neural Networks: Representation and Learning

Graph Neural Networks (GNNs) are neural network architectures targeted at learning a map from graphs to a vector space. Due to their success in practice, they have become popular machine learning models for prediction tasks on nodes, graphs and configurations of points. In this talk, we summarize a selection of the emerging theoretical results on approximation and learning properties of widely used message passing GNNs and higher-order GNNs, focusing on function approximation, estimation and generalization, and extrapolation. Along the way, we touch upon various connections, including graph isomorphism, equivariant functions, local algorithms and dynamic programming.

14:15 - 15:00

Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 11
Moderator: Daniel Huybrechts
Sectional Speaker: Chi Li

Canonical Kaehler metrics and stability of algebraic varieties

We survey some recent developments in the study of canonical Kähler metrics on algebraic varieties and their relation with stability in algebraic geometry.

14:15 - 16:15

Track: Other
Type: Panel
Room: Room 13
Chair: Motoko Kotani
Chair: Edray Herber Goins
Moderator: Marie-Francoise Roy
Panelist: Carolina Araujo
Panelist: Edy Tri Baskoro
Panelist: Nira Chamberlain
Panelist: Anjum Halai
Panelist: Ekin Ozman

CWM-CoD Joint Panel Best practices towards a more diverse and inclusive mathematical community

Joint Panel organized by the IMU Committee for Women in Mathematics (CWM) and the IMU Committee on Diversity (CoD)

CWM was established in 2015 to discuss issues related to women in mathematics worldwide and has actively worked to promote international contacts between national and regional organizations for women in mathematical sciences and to study and reduce the gender gap in mathematics.
CoD was created in 2020 by the IMU EC as an Ad hoc committee to address the issues of diversity and inclusion on which worldwide attention has been increased.
Both committees believe a more diverse and inclusive mathematical community should be established because such a community would attract excellent talents with no restriction and allow various approaches to the mathematical sciences, and therefore develops sustainably. In the panel we assess the current situation and discuss challenges and possible actions for better future based on best practices to solve the issues.

Panelists, *titles*

- Carolina Araujo, IMPA, Brazil: *The role of organizations for women in mathematics*
- Edy Tri Baskoro, Institut Teknologi Bandung, Indonesia: *Challenges in Improving Quality and Equity of Mathematical Research in Indonesia*
- Nira Chamberlain, Loughborough University, United Kingdom: *The Black Heroes of Mathematics*
- Anjum Halai, Aga Khan University, Pakistan: *Language, learning and mathematics: Diversity and inclusion.*
- Ekin Oznam, Bogazici University, Turkey: *Research Collaboration Conferences for Women, WIN Example*
- Marie-Françoise Roy, Université de Rennes 1, France: *The Gender Gap in Mathematics.*

More details can be found at: https://www.mathunion.org/cwm/cwm-initiatives/best-practices-towards-more-diverse-and-inclusive-mathematical-community

15:15 - 16:00

Track: Mathematics of Computer Science
Type: Special Sectional Lecture
Room: Room 1
Moderator: Salil Vadhan
Sectional Speaker: Bernd Sturmfels

Beyond Linear Algebra

This lecture challenges its listeners to venture beyond linear algebra in designing models and in thinking about numerical algorithms for identifying solutions. We discuss recent advances in the computation of critical point equations in optimization and statistics, and we explores the role of nonlinear algebra in the study of linear PDE with constant coefficients.

15:15 - 16:00
Track: Dynamics
Type: 9. Dynamics
Room: Room 2
Moderator: Thomas Schick
Sectional Speaker: David Fisher

Rigidity and invariant measures beyond homogeneous dynamics

I will discuss two recent works and the role played in both by studying invariant measures outside the context of homogeneous dynamics while using tool from homogeneous dynamics. The two works concern, respectively, Zimmer's Conjecture and totally geodesic submanifolds of real and complex hyperbolic manifolds.

15:15 - 16:00
Track: Mathematical Physics
Type: 11. Mathematical Physics
Room: Room 3
Moderator: Herbert Spohn
Sectional Speaker: Thierry Bodineau

Convergence of a dilute gas to the fluctuating Boltzmann equation

Since the seminal work of Lanford, it is known that the empirical measure of a Newtonian dynamics associated with a hard sphere gas converges, in the low density limit, towards the solution of the Boltzmann equation (at least for a short time). In this talk, we are going to study the fluctuations of the empirical measure around the solution of the Boltzmann equation and show that for a short time, it converges to a Gaussian process: the fluctuating Boltzmann equation. Furthermore, starting from the equilibrium measure, this convergence can be derived for arbitrarily long times.

15:15 - 16:00
Track: Probability
Type: 12. Probability
Room: Room 4
Moderator: Marta Sanz-Sole
Sectional Speaker: Kavita Ramanan

Interacting stochastic processes on sparse random graphs

Large ensembles of stochastically evolving interacting particles, each of whose infinitesimal evolution depends only on its own state (or history) and the states (or histories) of neighboring particles with respect to an underlying possibly random interaction graph, describe phenomena in diverse fields including statistical physics, neuroscience, biology and engineering. I will describe recent progress on characterizing hydrodynamic limits and marginal dynamics of such stochastic processes on sparse random interaction graphs, and contrast their behavior with classically studied mean-field limits, which arise when the interaction graph is complete.

15:15 - 16:00
Track: Lie Theory and Generalizations
Type: 7. Lie Theory and Generalizations
Room: Room 5
Moderator: Angela Pasquale
Sectional Speaker: Peng Shan

On geometrical realization of centers

The center of an algebra is an important invariant. In Lie theory, the center of many representation categories admits interesting links to singular cohomology of the algebraic varieties. cohomology In this talk, we will review some examples of this kind and explain a new link between the center of small quantum groups and the cohomology of certain affine Springer fibers.

15:15 - 16:00
Track: Analysis
Type: 8. Analysis
Room: Room 6
Moderator: Marianna Csornyei
Sectional Speaker: Malabika Pramanik

Some Properties of Sparse Sets: A Survey

Sparse sets are, by definition, sets that are small, either in cardinality, measure, dimension or density. Curves, surfaces and other submanifolds are standard examples of sparse sets in Euclidean space. However, many sparse sets naturally occurring in ergodic and geometric measure theory, such as Cantor-like sets or self-similar fractals, lack the regularity of the aforementioned objects. Despite this deficiency, many sparse sets are rich in arithmetic, geometric and analytic properties that can be viewed as working substitutes for smoothness. This has led to a vibrant line of inquiry into the governing principles behind certain phenomena that are typically associated with manifolds, and that have the potential for ubiquity in far more general contexts. Structural and analytical properties of sparse sets, whether discrete or continuous, lie at the centre of many problems in harmonic analysis, fractal geometry, combinatorics and number theory. The talk will be a survey of a few such problems that the author has worked on.

15:15 - 16:00
Track: Number Theory
Type: 3. Number Theory
Room: Room 7
Moderator: Harald Helfgott
Sectional Speaker: Sarah Zerbes
Sectional Speaker: David Loeffler

Euler systems and the Bloch-Kato conjecture for automorphic Galois representations

The Bloch–Kato conjecture is a very general conjecture relating special values of L-functions to Selmer groups of Galois representations, generalising many earlier results and conjectures such as the Birch–Swinnerton-Dyer conjecture for elliptic curves. One of the most powerful tools available for attacking this conjecture is the theory of Euler systems, which are certain compatible families of cohomology classes which serve to bound the sizes of Selmer groups. In a series of recent works (variously joint with Lei, Pilloni, and Skinner), we have made new breakthroughs in the construction of Euler systems, combining the geometry of Shimura varieties with the representation theory of spherical pairs over local fields; and developed new techniques for proving explicit reciprocity laws, relating Euler systems to critical values of L-functions. We recently used these techniques to prove the Bloch–Kato conjecture in analytic rank 0 for critical values of the degree 4 L-function of GSp(4), and hence obtain new results towards the Birch–Swinnerton-Dyer conjecture for modular abelian surfaces. We will describe this result and work in progress to generalise it to a range of other automorphic L-functions.

15:15 - 16:00

Track: Logic
Type: 1. Logic
Room: Room 8
Moderator: Slawomir Solecki
Sectional Speaker: Andrew Marks

Measurable graph combinatorics

Measurable graph combinatorics is the study of combinatorial problems on infinite graphs where we impose measurability constraints on the solutions we consider. It has connections to combinatorics, ergodic theory, probability theory, descriptive set theory, and theoretical computer science. We survey some recent progress in this area, and applications to geometrical paradoxes like Tarski's circle squaring problem, and hyperfiniteness of countable Borel equivalence relations.

15:15 - 16:00

Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 9
Moderator: Felix Otto
Sectional Speaker: Mathieu Lewin

Mean-field limits for quantum systems and nonlinear Gibbs measures

A system of N (bosonic) quantum particles is described by the *linear* Schrödinger equation, a Partial Differential Equation (PDE) in $\mathbf{R}^{\{3N\}}$. In the limit $N \to \infty$ and for a proper choice of the interaction, the particles become independent and identically distributed according to a *nonlinear* PDE in $\mathbf{R}^3$. This is called "Bose-Einstein condensation". I will explain how this was proved using an abstract result about how independence arises from symmetry, the quantum de Finetti theorem. By considerably increasing the randomness in the system, non linear Gibbs measures can also appear in the same limit. Those are probability measures over an infinite dimensional space, which play a major role in different areas of mathematics.

15:15 - 16:00

Track: Numerical Analysis and Scientific Computing
Type: 15. Numerical Analysis and Scientific Computing
Room: Room 10
Moderator: Oleg Lepski
Sectional Speaker: Gang Bao

Mathematical Analysis and Numerical Methods for Inverse Scattering Problems

Inverse scattering problems arise in diverse application areas, such as geophysical prospecting, submarine detection, near-field and nano optical imaging, and medical imaging. For a given wave incident on a medium enclosed by a bounded domain, the scattering (direct) problem is to determine the scattered field or the energy distribution for the known scatterer. An inverse scattering problem is to determine the scatterer from the boundary measurements of the fields. Although significant recent progress has been made for solving the inverse problems, many challenging mathematical and computational issues remain unresolved. In particular, the severe ill-posedness has thus far limited the scope of inverse problem methods in practical applications. This talk is concerned with mathematical analysis and numerical methods for solving inverse scattering problem of broad interest. Based on multi-frequency data, effective computational and mathematical approaches will be presented for overcoming the ill-posedness of the inverse problems. A brief overview of these approaches and results will be provided. Particular attentions will be paid to inverse medium, inverse obstacle, and inverse source scattering problems. Related topics and open problems will also be discussed.

15:15 - 16:00

Track: Control Theory and Optimization
Type: 16. Control Theory and Optimization
Room: Room 11
Moderator: Daniel Huybrechts
Sectional Speaker: Marius Tucsnak

Reachable states for infinite dimensional linear systems: old and new

This talk considers linear time invariant controlled systems with infinite dimensional state space. The main results provide various characterizations of the states which can be reached at some positive time τ > 0 when the control describes an admissible set. The focus is on the case in which the system is described by heat type equations, establishing new relations with the theory of Hilbert spaces of holomorphic functions. We show that these systems can, in several cases of interest, be seen as exactly controllable ones. We explain why this quite surprising fact is compatible with the smoothing effect for parabolic partial differential equations.

15:15 - 16:00

Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 12
Moderator: Shi Jin
Sectional Speaker: Bin Yu

Interpreting Deep Neural Networks towards Trustworthiness

Recent deep learning models have achieved impressive predictive performance by learning complex functions of many variables, often at the cost of interpretability. This lecture first defines interpretable machine learning in general and introduces the agglomerative contextual decomposition (ACD) method to interpret neural networks. Extending ACD to the scientifically meaningful frequency domain, an adaptive wavelet distillation (AWD) interpretation method is developed. AWD is shown to be both outperforming deep neural networks and interpretable in two prediction problems from cosmology and cell biology. Finally, a quality-controlled data science life cycle is advocated for building any model for trustworthy interpretation and introduce a Predictability Computability Stability (PCS) framework for such a data science life cycle.

16:30 - 17:30

Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Carlos E. Kenig
Plenary Speaker: Weinan E

A Mathematical Perspective on Machine Learning

Deep learning has changed the way we do artificial intelligence (AI) and is poised to change the way we do science. At the same time, it is generally perceived to be a collection of techniques or even tricks without a solid theoretical foundation. In this talk, we will try to address three questions: What is the magic behind neural neural network-based machine learning? How can we use deep learning to solve challenging problems in science and scientific computing? Can we formulate more general and maybe mathematically more natural models of machine learning?

The main message is that (deep) neural networks provide an effective tool for approximating high dimensional functions. This allows us to attack many difficult problems that are known to suffer from the curse of dimensionality. We will discuss the theoretical progress that has been made so far along these lines, and highlight the most pressing unsolved mathematical and practical issues.

Saturday, 09. July 2022

10:15 - 11:15
Track: Plenary
Type: Special Plenary Lecture
Room: Room 1
Chair: Martin Hairer
Plenary Speaker: Kevin Buzzard

The rise of formalism in mathematics

Lecture on proof formalisation for ordinary mathematicians
Abstract:
Formalism is the art of writing down what you actually mean. Mathematics has a rich history of formalisation: Euclid, Russell–Whitehead and Bourbaki all tried it. This century Avigad, Hales and Gonthier have shown us that there is another way. Now a new generation of young people are formalising algebra, analysis, category theory, combinatorics, geometry, number theory, topology and more at Masters level and beyond, this time using a computer. Lean's mathematics library **mathlib** contains nearly a million lines of free and open source code corresponding to proofs of over 80,000 theorems such as the fundamental theorem of Galois theory, and it is growing fast. AIs trained on the library have solved IMO problems by themselves. What is happening? This is not about making sure the papers are right. This is not about making a computer program which will print out a one billion line proof of the Birch and Swinnerton-Dyer conjecture using only the axioms of mathematics. This is not about extracting the beauty from a proof and leaving only the directed acyclic graph. This is about developing computer tools which have the potential to help researchers and PhD students in new ways. Much remains to be done. I will give an overview of the area.

11:30 - 12:30
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Sylvia Serfaty
Plenary Speaker: Laure Saint-Raymond

Dynamics of dilute gases: a statistical approach

The evolution of a gas can be described by different models depending on the observation scale. A natural question, raised by Hilbert in his sixth problem, is whether these models provide consistent predictions. In particular, for dilute gases, it is expected that continuum laws of kinetic theory can be obtained directly from molecular dynamics governed by Newton's fundamental principle. In the case of hard sphere gases, Lanford showed that the Boltzmann equation emerges as the law of large numbers in the low density limit, at least for very short times. The objective of this talk is to present this limiting process, including recent results on the fluctuations.

13:15 - 14:00
Track: Geometry
Type: 5. Geometry
Room: Room 2
Moderator: Michael Hutchings
Sectional Speaker: Hiroshi Iritani

On decompositions of quantum cohomology D-modules

We discuss decompositions of quantum cohomology D-modules arising from various geometric settings. These decompositions can be related to semi-orthogonal decompositions of topological K-groups via the Gamma integral structure.

13:15 - 14:00
Track: Dynamics
Type: 9. Dynamics
Room: Room 3
Moderator: Anish Ghosh
Sectional Speaker: Miklós Abert

Groups, manifolds and graph limits

I will talk about recent notions, results and open problems in the topic.

13:15 - 14:00
Track: Number Theory
Type: 3. Number Theory
Room: Room 4
Moderator: Minhyong Kim
Sectional Speaker: Atsushi Ichino

Theta lifting and Langlands functoriality

We review various aspects of theta lifting and its role in studying Langlands functoriality. In particular, we discuss realizations of the Jacquet-Langlands correspondence and the Shimura-Waldspurger correspondence in terms of theta lifting and their arithmetic applications.

13:15 - 14:00
Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 5
Moderator: Tong Yang
Sectional Speaker: Charles Smart

Unique continuation for lattice Schrodinger operators

I will discuss unique continuation principles for solutions of Schrodinger operators on lattices and their application to Anderson localization. This will include a discussion of my joint work with Ding as well as works of Bourgain, Bukovsky-Logunov-Malinnokova-Sodin, Imbrie, Li, and Li-Zhang.

13:15 - 14:00
Track: Probability
Type: 12. Probability
Room: Room 6
Moderator: Bálint Tóth
Sectional Speaker: Dmitry Panchenko

Ultrametricity in spin glass models

I will discuss the topic of ultrametricity in the setting of spin glass models from statistical physics.

13:15 - 14:00
Track: Topology
Type: 6. Topology
Room: Room 7
Moderator: Robert Lipshitz
Sectional Speaker: Yi Liu

Surface automorphisms and virtual homological eigenvalues

I will explain my recent proof on why every pseudo-Anosov surface automorphism can be lifted to some finite cover, such that some homological eigenvalue of the lifted automorphism lies outside the complex unit circle.

13:15 - 14:00
Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 8
Moderator: Chiu-Chu Liu
Sectional Speaker: Mina Aganagic

Homological knot invariants from mirror symmetry

In '98, Khovanov showed that a link invariant known as the Jones polynomial arizes as the Euler characteristic of a homology theory. The knot categorification problem is to find a general construction of knot homology groups, and to explain their meaning: what are they homologies of? Homological mirror symmetry, formulated by Kontsevich in '94, naturally produces hosts of homological invariants. Typically though, it leads to invariants which have no particular interest outside of the problem at hand, I will explain that there is a vast new family of mirror pairs of manifolds, for which homological mirror symmetry does lead to interesting invariants and solves the knot categorification problem.

13:15 - 14:00
Track: Lie Theory and Generalizations
Type: 7. Lie Theory and Generalizations
Room: Room 9
Moderator: Angela Pasquale
Sectional Speaker: Evgeny Feigin

PBW degenerations, quiver Grassmannians, and toric varieties

We present a review on the recently discovered link between the Lie theory, the theory of quiver Grassmannians, and various degenerations of flag varieties. Our starting point is the induced Poincaré–Birkhoff–Witt filtration on the highest weight representations and the corresponding PBW degenerate flag varieties.

13:15 - 14:00

Track: Control Theory and Optimization
Type: 16. Control Theory and Optimization
Room: Room 10
Moderator: Monique Laurent
Sectional Speaker: Asu Ozdaglar

Independent Learning Dynamics for Stochastic Games: Where Game Theory meets Reinforcement Learning

Reinforcement learning (RL) has had tremendous successes in many artificial intelligence applications. Many of the forefront applications of RL involve *multiple agents*, e.g., playing chess and Go games, autonomous driving, and robotics. Unfortunately, classical RL framework is inappropriate for multi-agent learning as it assumes an agent's environment is *stationary* and does not take into account the adaptive nature of behavior. In this talk, I focus on *stochastic games* for multi-agent reinforcement learning in *dynamic* environments and develop *independent* learning dynamics for stochastic games: each agent is myopic and chooses best-response type actions to other agents' strategies independently, meaning without any coordination with her opponents. There has been limited progress on developing convergent best-response type independent learning dynamics for stochastic games. I will present our recently proposed independent learning dynamics that guarantee convergence in stochastic games, including for both zero-sum and single-controller identical-interest settings. Along the way, I will also reexamine some classical and recent results from game theory and RL literatures, to situate the conceptual contributions of our independent learning dynamics and the mathematical novelties of our analysis.

13:15 - 14:00

Track: Analysis
Type: 8. Analysis
Room: Room 11
Moderator: Ursula Molter
Sectional Speaker: Tianyi Zheng

Asymptotic behaviors of random walks on countable groups

In this talk we review some recent results on random walks on countable groups. We will mainly focus on quantitative estimates for random walks on amenable groups with connection to the geometry of the underlying group.

14:15 - 15:00

Track: Mathematics of Computer Science
Type: Special Sectional Lecture
Room: Room 1
Moderator: Yael Kalai
Sectional Speaker: David Silver

Simulation-Based Search

Planning is one of the oldest and most important problems in artificial intelligence. Simulation-based search algorithms such as AlphaZero have achieved superhuman performance in chess and Go and are now used in real-world applications from chemistry to quantum computing. In this talk we present a unified framework for understanding a wide variety of simulation-based search algorithms, including AlphaZero. We conclude by presenting recent results using these algorithms.

14:15 - 15:00
Track: Geometry
Type: 5. Geometry
Room: Room 2
Moderator: Michael Hutchings
Sectional Speaker: Danny Calegari

Sausages and butcher paper

For each $d > 1$ the *shift locus of degree d*, denoted $S\_\{d\}$*,* is the space of normalized degree d polynomials in one complex variable for which every critical point is in the attracting basin of infinity under iteration. It is a complex analytic manifold of complex dimension $d - 1$. We are able to give an explicit description of $S\_\{d\}$ as a complex of spaces over a contractible $\tilde{A}\_\{d - 2\}$ building, and to describe the pieces in two quite different ways:
(1) (combinatorial): in terms of dynamical extended laminations; or
(2) (algebraic): in terms of certain explicit 'discriminant-like' affine algebraic varieties.
From this structure one may deduce numerous facts, including that $S\_\{d\}$ has the homotopy type of a CW complex of real dimension $d - 1$; and that $S\_\{3\}$ and $S\_\{4\}$ are $K(\pi, 1)$s.
The method of proof is rather interesting in its own right. In fact, along the way we discover a new class of complex surfaces (they are complements of certain singular curves in C^2) which are homotopic to locally CAT(0) complexes; in particular they are $K(\pi, 1)$s.

14:15 - 15:00
Track: Dynamics
Type: 9. Dynamics
Room: Room 3
Moderator: Anish Ghosh
Sectional Speaker: Peter P. Varju

Self-similar sets and measures on the line

Self-similar sets and measures are central objects of interest in fractal geometry and they include many classical examples of fractals, such as the Cantor set, the Sierpiński triangle, the Koch snowflake curve and Bernoulli convolutions. We discuss the problem of determining the dimension of these objects focusing on the developments of the last four years.

14:15 - 15:00
Track: Number Theory
Type: 3. Number Theory
Room: Room 4
Moderator: Minhyong Kim
Sectional Speaker: Philipp Habegger

The Number of Rational Points on a Curve of Genus at Least Two

Let C be a smooth projective curve of genus at least 2 defined over the field of rational numbers. By the Mordell Conjecture, proved by Faltings, C has at most finitely many rational points. I will survey recent results regarding upper bounds for the number of such of rational points.

14:15 - 15:00

Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 5
Moderator: Tong Yang
Sectional Speaker: Alexandru D. Ionescu

On the global stability of shear flows and vortices

I will present our recent work on linear and nonlinear stability of shear flows and vortices among solutions of the Euler equations in two dimensions. Our main results concern nonlinear asymptotic stability of a large class of monotonic shear flows in the finite channel, nonlinear asymptotic stability of point vortices in the plane, and linear stability of smooth decreasing vortices in the plane. This is joint work with Hao Jia.

14:15 - 15:00

Track: Probability
Type: 12. Probability
Room: Room 6
Moderator: Bálint Tóth
Sectional Speaker: Patricia Gonçalves

On hydrodynamic limits of fractional PDEs from stochastic interacting particle systems

In the seventies, Frank Spitzer introduced, in the mathematics community, systems of stochastic interacting particles, whose dynamics conserves a certain number of quantities. These systems were already known in the physics and biophysics communities and they are toy models for a variety of interesting phenomena.

The goal, in the hydrodynamic limit, consists in deducing, by a scaling limit procedure, the macroscopic equations governing the space-time evolution of the conserved quantities of the system, from the underlying random motion of the microscopic system of particles.

In this talk, I will focus on the latest advances around the derivation of these limits in the case where the space-time evolution is given by a fractional PDEs and with several boundary conditions.

14:15 - 15:00

Track: Topology
Type: 6. Topology
Room: Room 7
Moderator: Robert Lipshitz
Sectional Speaker: Jennifer Hom

Homology cobordism and Heegaard Floer homology

Under the operation of connected sum, the set of three-manifolds form a monoid. Modulo an equivalence relation called homology cobordism, this monoid (of homology spheres) becomes a group. What is the structure of this group? What families of three-manifolds generate, or don't generate, this group? We give some answers to these questions using Heegaard Floer homology. This is joint work with various subsets of I. Dai, K. Hendricks, M. Stoffregen, L. Truong, and I. Zemke.

14:15 - 15:00

Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 8
Moderator: Chiu-Chu Liu
Sectional Speaker: Yuri Prokhorov

Effective results in the three-dimensional minimal model program

We give a brief review on recent developments in the three-dimensional minimal model program.

14:15 - 15:00

Track: Lie Theory and Generalizations
Type: 7. Lie Theory and Generalizations
Room: Room 9
Moderator: Angela Pasquale
Sectional Speaker: Yiannis Sakellaridis

Spherical varieties, functoriality, and quantization

View Abstract

14:15 - 15:00

Track: Control Theory and Optimization
Type: 16. Control Theory and Optimization
Room: Room 10
Moderator: Monique Laurent
Sectional Speaker: Qi Lü

Control Theory of Stochastic Distributed Parameter Systems: Some Recent Progresses

In recent years, important progresses have been made in the control theory for stochastic distributed parameter control systems. However, the theory is far from being complete. The primary difficulty is that many effective tools and methods for deterministic distributed parameter control systems do not work anymore in the stochastic setting. One has to develop new mathematical tools even for some very simple stochastic distributed parameter control systems, such as stochastic transposition method and stochastic Carleman estimate. The objectives of this talk are to provide some new results, to show some new phenomena, to explain the new difficulties and to present some new methods in this topic. We mainly focus on our works on the controllability for stochastic hyperbolic equations, and the Pontryagin-type maximum principle for controlled stochastic evolution equations as illustrative examples.

14:15 - 15:00

Track: Combinatorics
Type: 13. Combinatorics
Room: Room 11
Moderator: Ursula Molter
Sectional Speaker: Lauren K. Williams

The positive Grassmannian, the amplituhedron, and cluster algebras

The positive Grassmannian is the subset of the real Grassmannian where all Plücker coordinates are nonnegative. It has a beautiful combinatorial structure as well as connections to statistical physics, integrable systems, and scattering amplitudes. The amplituhedron is the image of the positive Grassmannian under a positive linear map. We will explain how ideas from oriented matroids, tropical geometry, and cluster algebras shed light on the structure of the positive Grassmannian and the amplituhedron.

15:30 - 16:30

Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Martin Hairer
Plenary Speaker: Scott Sheffield

What is a random surface?

We will survey the modern theory of "random surfaces" while also reviewing the rich history of the subject and presenting numerous computer illustrations and animations. There are many ways to begin, but one is to consider a finite collection of unit equilateral triangles. There are finitely many ways to glue each edge to a partner, and we obtain a random sphere-homeomorphic surface by sampling uniformly from the gluings that produce a topological sphere. As the number of triangles tends to infinity, these random surfaces (appropriately scaled) converge in law. The limit is a "canonical" sphere-homeomorphic random surface, much the way Brownian motion is a canonical random path.
Depending on how the surface space and convergence topology are specified, the limit is the Brownian sphere, the peanosphere, the pure Liouville quantum gravity sphere, the bosonic string or a certain conformal field theory. All of these objects have concise definitions, and are all in some sense equivalent, but the equivalence is highly non-trivial, building on hundreds of math and physics papers over the past half century.
More generally, the "continuum random surface embedded in d-dimensional Euclidean space" makes a kind of sense for any $d \in (-\infty, 25]$. This story can also be extended to higher genus surfaces, surfaces with boundary, and surfaces with marked points or other decoration. These constructions have deep roots in both mathematics and physics, drawing from classical graph theory, complex analysis, probability and representation theory, as well as string theory, planar statistical physics, random matrix theory and a simple model for two-dimensional quantum gravity.
We present here a colloquium-level overview of the subject, which we hope will be accessible to both newcomers and experts. We aim to answer, as simply and cleanly as possible, the fundamental question. What is a random surface?

16:45 - 17:45

Track: Plenary
Type: Special Plenary Lecture
Room: Room 1
Chair: Felix Otto
Plenary Speaker: Frans Pretorius

A Survey of Gravitational Waves

I will review the state of the field of gravitational wave astrophysics, framing the challenges, current observations, and future prospects within the context of the predictions of Einstein's theory of general relativity.

Sunday, 10. July 2022

09:00 - 10:30
Track: Mathematical Education and Popularization of Mathematics
Type: Panel
Room: Room 1
Chair: Anjum Halai
Panelist: Kyeong-Hwa Lee
Panelist: Veronica Sarungi
Panelist: K. (Ravi) Subramaniam
Panelist: Marcelo Borba

Panel 1: Balance between Education in Classroom and Remote Online Teaching

The COVID 19 pandemic in March 2020 led to closure of schools in most countries across the globe. 1.2 billion children in 186 countries were affected by school closures due to the pandemic (World Economic Forum, April 2020).

Teachers and students across the education systems had to rapidly transition to remote online teaching and learning. Consequently, there was a massive and rapid expansion in digital infrastructure, with a shift from physical in-person classrooms to virtual classrooms, with remote online teaching. For the purpose of this discussion, remote online teaching means teaching in a virtual environment, using digital tools synchronously (e.g., web-conferencing tools like Zoom). Typically, the aim is to replicate the in-person classroom experience. Online teaching refers to courses specifically designed for online education with a range of synchronous and asynchronous approaches used.

This rapid expansion of the digital infrastructure and remote online teaching opened many opportunities in education. For example, it expanded access to students marginalized due to gender, poverty, location, or other forms of exclusion. Though it must be noted that there exists a 'digital divide' as the expansion is not equitably spread. Dilemmas also arose in relation to the quality of the pedagogic process, assessment of students' learning, attainment of broader educational goals and not just academic achievement, among other.

Recognizing that virtual classrooms are likely to stay, merits and demerits of remote online teaching and learning need to be looked at. What could be a reasonable balance between remote online teaching and that in a physical in-person classroom? And at what level (primary, high school, tertiary)? This panel of highly experienced mathematics educators would lead the discussion on some of the issues noted above.

10:45 - 12:15
Track: Mathematical Education and Popularization of Mathematics
Type: Panel
Room: Room 1
Chair: Raissa Malu
Panelist: Mickael Launay
Panelist: Claudio Landim
Panelist: Sergey Rushkin

Panel 2: Innovation and new forms of popularization of mathematics

In elementary and high school, mathematics is not the most popular field among young people. Mathematicians are probably the least understood scientists. Their field is perhaps the most frightening. Yet, math is everywhere and it is so beautiful. During this panel, we will explore innovations and new forms of popularizing mathematics to make the field more inclusive, more diverse, and perhaps finally reconcile the public with the discipline.

13:15 - 14:00

Track: Mathematical Physics
Type: Special Sectional Lecture
Room: Room 1
Moderator: Bo Berndtsson
Sectional Speaker: Peter Hintz
Sectional Speaker: Gustav Holzegel

Recent Progress in General Relativity

We review recent progress in general relativity. After a brief introduction to some of the key analytical and geometric features of the Einstein equations, we focus on two main developments: the stability of black hole solutions, and the formation, structure, and dynamical stability of singularities.

13:15 - 14:00

Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 2
Moderator: Wee Teck Gan
Sectional Speaker: Bruno Klingler

Hodge theory, between algebraicity and transcendence

The Hodge theory of complex algebraic varieties is at heart a transcendental comparison of two algebraic structures. We survey the recent advances bounding this transcendence, obtained mainly through the use of o-minimal geometry.

13:15 - 14:00

Track: Analysis
Type: 8. Analysis
Room: Room 4
Moderator: Bunyamin Sari
Sectional Speaker: Cyril Houdayer

Noncommutative ergodic theory of higher rank lattices

I will survey recent results regarding the dynamics of positive definite functions and character rigidity of irreducible lattices in higher rank semisimple algebraic groups. These results have several applications to ergodic theory, topological dynamics, unitary representation theory and operator algebras. In the case of lattices in higher rank simple algebraic groups, I will explain the key operator algebraic novelty, which is a noncommutative Nevo–Zimmer theorem for actions on von Neumann algebras. I will also present a noncommutative analogue of Margulis' factor theorem and discuss its relevance regarding Connes' rigidity conjecture for group von Neumann algebras of higher rank lattices.

13:15 - 14:00

Track: Probability
Type: 12. Probability
Room: Room 5
Moderator: Claudio Landim
Sectional Speaker: Hubert Lacoin

Mixing time and cutoff for one dimensional particle systems

A fundamental result in the theory of Markov chains states that for any initial condition, the distribution at time t an irreducible continuous Markov chain on a finite state converges to the unique invariant measure when t tends to infinity. The study of mixing time for Markov chain explores some quantitative aspects of this convergence. In particular a substantial amount of work has been dedicated to the study of the *cutoff* phenomenon: an abrupt convergence to equilibrium.
In our talk we will survey recent results concerning the total-variation mixing time of the simple exclusion process on the segment (symmetric and asymmetric) and a continuum analog, the simple random walk on the simplex. We will put an emphasis on cutoff results.

13:15 - 14:00

Track: Combinatorics
Type: 13. Combinatorics
Room: Room 6
Moderator: Ehud Friedgut
Sectional Speaker: Sergey Norin

Recent progress towards Hadwiger's conjecture

In 1943 Hadwiger conjectured that every graph with no K_{t} minor is $(t-1)$ - colorable for every $t \geq 1$. Hadwiger's conjecture generalizes the Four Color Theorem and is among most studied problems in graph theory. I will survey the ideas behind recent progress towards this conjecture, which, in particular, allowed for the first asymptotic improvement since 1980s on the number of colors sufficient to color every graph with no K_{t} minor.

13:15 - 14:00

Track: Dynamics
Type: 9. Dynamics
Room: Room 7
Moderator: Helena Nussenzveig Lopes
Sectional Speaker: Romain Dujardin

Random algebraic dynamics in complex dimension 2

I will review some results obtained in the past few years on the dynamics of groups of automorphisms of real and complex projective surfaces: classification of stationary and invariant measures, orbit closures, and finite orbits. Some basic examples and open problems will also be discussed. This relies on a variety of techniques from complex and algebraic geometry, as well as and arithmetic random, holomorphic, dynamical systems.

13:15 - 14:00

Track: Topology
Type: 6. Topology
Room: Room 8
Moderator: Ulrike Tillmann
Sectional Speaker: Jacob Rasmussen

Floer homology of 3-manifolds with torus boundary

Manifolds with torus boundary have played a special role in the study of Floer homology for 3-manifolds since the earliest days of the subject. I will describe a simple geometric representation of the Floer homology of such a 3-manifold (defined jointly with Hanselman and Watson). I will explain a generalization of this theory to sutured manifolds and give applications to the topology of knots and 3-manifolds.

13:15 - 14:00

Track: Algebra
Type: 2. Algebra
Room: Room 9
Moderator: Leslie Greengard
Sectional Speaker: Amnon Neeman

Finite approximations as a tool for studying triangulated categories

A metric on a category assigns lengths to morphisms, with the triangle inequality holding. This notion goes back to a 1974 article by Lawvere. We'll begin with a quick review of some basic constructions, such as forming the Cauchy completion of a category with respect to a metric. And then will begin a string of surprising new results. It turns out that, in a *triangulated* category with a metric, there is a reasonable notion of Fourier series, and an approximable triangulated category can be thought of as a category where many objects are the limits of their Fourier expansions. And then come two types of theorems: (1) theorems providing examples, meaning showing that some category you might naturally want to look at is approximable, and (2) general structure theorems about approximable triangulated categories. And what makes it all interesting is (3) applications. These turn out to include the proof of a conjecture by Bondal and Van den Bergh, a major generalization of a theorem of Rouquier's, a short, sweet proof of Serre's GAGA theorem, and a proof of a conjecture by Antieau, Gepner and Heller.

13:15 - 14:45
Track: Mathematical Education and Popularization of Mathematics
Type: Panel
Room: Room 12
Chair: Mary Lou Zeeman
Panelist: Sergio Fajardo
Panelist: Edward Lungu
Panelist: Sally Cripps

Panel 3: Mathematical sciences to address societal challenges and issues

Panelists will address a selection of the following questions, sharing their wisdom about the role mathematical sciences can play in addressing societal challenges and issues:

• Please could you describe an example of a way you use mathematical sciences to address societal challenges and issues?
• In your sphere of work/applications, what are some specific, or overarching, societal challenges or issues that may be amenable to a mathematical approach, and can you give us some insight into what makes them amenable?
• Again, in your sphere of work/applications, what other disciplines are used together with the mathematical sciences, and can you give us insight into effective points of contact between the disciplines?
• Please could you give a brief insight into your path towards your current career? For example, perhaps you can identify a particular person or moment of inspiration? or a formative decision? Or perhaps this has been a lifelong drive?
• Thinking of the junior mathematical scientists in the audience who might be inspired to pursue a similar career, what advice do you have to help them shepherd their own education and training toward that goal?
• Finally, what advice do you have for mathematical institutions (e.g. academia, prof. societies, industry, non-profits, government, etc) to better prepare the workforce to address societal challenges, and to accelerate innovation and translation of knowledge into action.

14:15 - 15:00
Track: Geometry
Type: Special Sectional Lecture
Room: Room 1
Moderator: Bo Berndtsson
Sectional Speaker: Richard Evan Schwartz

A Survey Lecture on Billiards

I will give a survey lecture on billiards, concentrating on polygonal billiards, both rational and irrational, and also polygonal outer billiards. For some of the lecture I will focus on my own work, particularly the solution of the Moser-Neumann problem concerning the existence of unbounded orbits for outer billiards. I will illustrate my talk with colorful computer demos.

14:15 - 15:00
Track: Number Theory
Type: 3. Number Theory
Room: Room 2
Moderator: Wee Teck Gan
Sectional Speaker: Dimitris Koukoulopoulos

Rational approximations of irrational numbers

View Abstract

14:15 - 15:00
Track: Mathematics of Computer Science
Type: 14. Mathematics of Computer Science
Room: Room 3
Moderator: Jing Li
Sectional Speaker: Muli Safra

Mathematics of computation through the lens of linear equations and lattices

Mathematics of computation and, in particular, *computational complexity theory*, is a fundamental research area in the intersection of computer science and mathematics.

The area revolves around classifying computational problems as feasible or alternatively as infeasible, typically in the worst-case regime. In some related areas – and even more prominently in practice – the notion of average-case complexity is ubiquitous. Cryptography is a prime example where proving security of protocols/primitives often necessitates average case type hardness assumptions.

We take the choice herein to analyze these notions through the lens of *linear algebra*. This perspective allows us to smoothly present important future research directions, as well as propose conjectures that lay a roadmap for future progress.

The goal of this survey is to make research at the core of computation more accessible. More importantly, it gives us an opportunity to naturally state open questions regarding *lattices*; a solution to which would transform our perception of computation, not only scientifically, but also practically.

14:15 - 15:00
Track: Analysis
Type: 8. Analysis
Room: Room 4
Moderator: Bunyamin Sari
Sectional Speaker: Stuart White

Classification of simple amenable C^{∗}-algebras

C^{∗}-algebras are norm closed self-adjoint algebras of bounded operators on Hilbert space, and so arise naturally from unitary representations of groups and group actions, amongst other constructions. Large scale work of many researchers over decades has recently culminated in a definitive classification theorem for simple amenable C^{∗}-algebras of finite topological dimension.
In this talk, I'll describe this theorem: which C^{∗}-algebras are classified, and by what data? I'll discuss how this relates to the structure and classification theorems for von Neumann algebras from the 70s and 80s. I'll start out by reviewing C^{∗}-algebras. The talk will be illustrated by examples coming from group actions.

14:15 - 15:00

Track: Probability
Type: 12. Probability
Room: Room 5
Moderator: Claudio Landim
Sectional Speaker: Daniel Remenik

Integrable fluctuations in one-dimensional random growth

This talk will review some recent results on asymptotic fluctuations in the KPZ universality class, a broad collection of probabilistic models including one dimensional random growth, directed polymers and particle systems. Many of these models exhibit a remarkable degree of solvability, and explicit formulas can be derived for their transition probabilities. This extends, most prominently, to the KPZ fixed point, the scaling invariant Markov process which arises as the scaling limit of all models in the class. Using the explicit formulas for these processes it can be shown their transition probabilities satisfy classical integrable differential equations.

14:15 - 15:00

Track: Combinatorics
Type: 13. Combinatorics
Room: Room 6
Moderator: Ehud Friedgut
Sectional Speaker: Federico Ardila

The geometry of geometries: matroid theory, old and new

The theory of *matroids* or *combinatorial geometries* originated in linear algebra and graph theory, and has deep connections with many other areas, including field theory, matching theory, submodular optimization, Lie combinatorics, and total positivity. Matroids capture the combinatorial essence that these different settings share.
In recent years, the (classical, polyhedral, algebraic, and tropical) geometric roots of the field have grown much deeper, bearing new fruits. We survey some recent successes, stemming from three geometric models of a matroid: the matroid polytope, the Bergman fan, and the conormal fan.

14:15 - 15:00

Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 7
Moderator: Helena Nussenzveig Lopes
Sectional Speaker: Irene Fonseca

Phase Separation in Heterogeneous Media

A variational model in the context of the gradient theory for fluid-fluid phase transitions with small scale heterogeneities is studied. Two regimes are considered. Firstly, when the scale of the heterogeneities is of the same order of the scale governing the diffuse interface between the phases, it is shown that the interaction between homogenization and the phase transition process leads to an anisotropic interfacial energy. Bounds on the homogenized surface tension are established. Secondly, when the wells are allowed to move and display discontinuities, and when phase separation occurs at a smaller case than homogenization, the zeroth and first order Γ-limits are identified. In addition, a characterization of the large-scale limiting behavior of viscosity solutions to non-degenerate and periodic Eikonal equations in half-spaces is given.

14:15 - 15:00

Track: Topology
Type: 6. Topology
Room: Room 8
Moderator: Ulrike Tillmann
Sectional Speaker: Nathalie Wahl

Homological Stability: a tool for computations

Homological stability has shown itself to be a powerful tool for the computation of the homology of families of groups such as general linear groups, mapping class groups or automorphisms of free groups. We give an overview of this subject, illustrated by examples.

14:15 - 15:00

Track: Numerical Analysis and Scientific Computing
Type: 15. Numerical Analysis and Scientific Computing
Room: Room 9
Moderator: Leslie Greengard
Sectional Speaker: Marsha Berger

Towards Adaptive Simulations of Dispersive Tsunami Propagation

The shallow water equations (SWE) are a nonlinear hyperbolic system that models ocean waves whose wavelength is much greater than the ocean depth. These are used in computational models that predict the impact of tsunamis from earthquake sources that cross the deep ocean to at-risk coastal areas. Adaptive mesh refinement (AMR), which is part of the open source simulation code Geoclaw, allows locally variable resolution, from kilometer scale for long waves in the deep ocean to meter scales at the shore.
Dispersive Boussinesq type corrections to the SWE are important for shorter waves such as those created by landslides or asteroids impacts. These typically involve higher derivatives and require implicit methods, which complicate the use of adaptive mesh refinement . We present simulations using both the SWE and Boussinesq models, along with analytical explorations of some 1D models to help understand these simulations.

14:15 - 15:00

Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 10
Moderator: Mihai Paun
Sectional Speaker: Arend Bayer
Sectional Speaker: Emanuele Macrì

Wall-crossing in algebraic geometry

We discuss applications of Bridgeland stability conditions and wall-crossing in algebraic geometry.

14:15 - 15:00

Track: Number Theory
Type: 3. Number Theory
Room: Room 11
Moderator: Simone Warzel
Sectional Speaker: Sug Woo Shin

Points on Shimura varieties modulo primes

After surveying the problem of computing the zeta function and ell-adic cohomology of Shimura varieties in the context of the Langlands program, I will report on joint work with Mark Kisin and Yihang Zhu to establish a stabilized trace formula computing the cohomology of abelian-type Shimura varieties at primes of good reduction, building upon earlier work by Kisin. Some further directions will be discussed.

15:15 - 16:00

Track: Geometry
Type: Special Sectional Lecture
Room: Room 1
Moderator: Bo Berndtsson
Sectional Speaker: Bruce Kleiner

Developments in 3d Ricci flow since Perelman

This is a report on progress in 3d Ricci flow since Perelman's work twenty years ago.

15:15 - 16:00

Track: Number Theory
Type: 3. Number Theory
Room: Room 2
Moderator: Wee Teck Gan
Sectional Speaker: Xinwen Zhu

Arithmetic and geometric Langlands program

The Langlands program, proposed by Robert Langlands in 1960s, unifies many questions in number theory and representation theory, and has found significant applications to solving classical Diophantine equations. Its geometric version, formulated by Drinfeld and Laumon in 1980s, enlarges the scope of the Langlands philosophy and makes it contact with other subjects such as physics. Interestingly, in recent years, some ideas from the geometric theory also inspire and lead developments of the traditional arithmetic theory and related problems. I will give an impression of some of these recent developments.

15:15 - 16:00
Track: Numerical Analysis and Scientific Computing
Type: 15. Numerical Analysis and Scientific Computing
Room: Room 3
Moderator: Jing Li
Sectional Speaker: Rachel Ward

Stochastic Gradient Descent: where optimization meets machine learning

Stochastic Gradient Descent (SGD) is the de facto optimization algorithm for training neural networks in modern machine learning, thanks to its unique scalability to problem sizes where the data points, the number of data points, and the number of free parameters to optimize are on the scale of billions. On the one hand, many of the mathematical foundations for Stochastic Gradient descent were developed decades before the advent of modern deep learning, from stochastic approximation to the randomized Kaczmarz algorithm for solving linear systems. On the other hand, the omnipresence of stochastic gradient descent in modern machine learning, and the resulting importance of optimizing performance of SGD in practical settings, has motivated new algorithmic designs and mathematical breakthroughs. In this talk, we first provide a brief history for stochastic gradient descent. We then discuss recent breakthroughs in adaptive gradient variants of stochastic gradient descent, which go a long way towards addressing one of the weakest points of SGD: its sensitivity and reliance on hyperparameters, most notably, the choice of step-sizes.

15:15 - 16:00
Track: Dynamics
Type: 9. Dynamics
Room: Room 4
Moderator: Bunyamin Sari
Sectional Speaker: Mark Demers

Thermodynamic Formalism for Dispersing Billiards

Mathematical billiards are foundational models from statistical mechanics in which point particles collide elastically with fixed boundaries. For a class of finite horizon dispersing billiards, we review recent results proving the existence and uniqueness of equilibrium states for a family of geometric potentials, $-t \log J^{u} T$, $t \geq 0$. The importance of this family stems from the fact that $t = 1$ corresponds to the smooth invariant (SRB) measure, while $t = 0$ corresponds to the measure of maximal entropy. By constructing anisotropic Banach spaces adapted to the potentials, we are able to prove exponential mixing by way of a spectral gap for the associated transfer operator. Yet the spectral gap vanishes as $t \to 0$ and we discuss a possible phase transition for the billiard at $t = 0$.

15:15 - 16:00
Track: Probability
Type: 12. Probability
Room: Room 5
Moderator: Claudio Landim
Sectional Speaker: Jian Ding
Sectional Speaker: Julien Dubedat
Sectional Speaker: Ewain Gwynne

The Liouville quantum gravity metric

Liouville quantum gravity (LQG) is a canonical one-parameter family of random fractal surfaces. Recent works have shown that one can endow an LQG surface with a metric (distance function). We will discuss the construction of this metric, some of its properties, and some open problems.

15:15 - 16:00

Track: Combinatorics
Type: 13. Combinatorics
Room: Room 6
Moderator: Ehud Friedgut
Sectional Speaker: Asaf Shapira

Local-vs-Global Combinatorics

Many of the most outstanding open problems in combinatorics relate the local and the global properties of large discrete structures. The research aimed at solving these questions led to some of the most important developments in this area, as well as in related areas such as theoretical computer science, additive number theory and harmonic analysis. In this paper we discuss some of these advances and mention several open problems.

15:15 - 16:00

Track: Stochastic and Differential Modelling
Type: 18. Stochastic and Differential Modelling
Room: Room 7
Moderator: Helena Nussenzveig Lopes
Sectional Speaker: Sylvie Méléard

Multiscale eco-evolutionary models: from individuals to populations

Motivated by recent biological experiments, we emphasize the effects of small and random populations on long time population dynamics. We will quantify such effects on macroscopic approximations. The individual behaviors are described by the mean of a stochastic measure-valued process. We study different long time asymptotic behaviors depending on the assumptions on mutation size and frequency and on horizontal transmission rate. In some cases, simulations indicate that these models should exhibit surprising asymptotic behaviors such as cyclic behaviors. We explore these behaviors on a simple model where population and time sizes are on a log-scale. Explicit criteria are given to characterize the possible asymptotic behaviors. The impact of the time and size scales on macroscopic approximations is also investigated, leading to Hamilton-Jacobi equations.

15:15 - 16:00

Track: Algebra
Type: 2. Algebra
Room: Room 8
Moderator: Ulrike Tillmann
Sectional Speaker: Neena Gupta

The Zariski Cancellation Problem and related problems in Affine Algebraic Geometry

In this talk, we shall discuss recent results on the Zariski Cancellation Problem and the status of related problems on affine spaces especially the Epimorphism Problem and the Affine Fibration Problem.

15:15 - 16:00

Track: Control Theory and Optimization
Type: 16. Control Theory and Optimization
Room: Room 9
Moderator: Leslie Greengard
Sectional Speaker: Martin Burger

Modern regularization methods in inverse problems and data science

This talk discusses recent developments on variational methods, as developed for inverse problems. In a typical setup we review basic properties needed to obtain a convergent regularization scheme and further discuss the derivation of quantitative estimates respectively needed ingredients such as Bregman distances for convex variational and iterative methods. In addition to the approach developed for inverse problems we will also discuss analogous regularization in machine learning and work out some connections to the classical regularization theory. In particular we will discuss a reinterpretation of machine learning problems in the framework of regularization theory and a reinterpretation of variational methods for inverse problems in the framework of risk minimization.

15:15 - 16:00

Track: Geometry
Type: 5. Geometry
Room: Room 10
Moderator: Mihai Paun
Sectional Speaker: Robert Berman

Emergent complex geometry and the gauge/gravity duality

In this talk I will discuss an application of the probabilistic construction of Kähler-Einstein metrics on complex algebraic manifolds, using canonical random point processes, to the gauge/gravity duality in theoretical physics. This duality, introduced by Maldacena in 1998 - also known as the AdS/CFT correspondence - is a prime example of t'Hooft's holographic principle. I will explain how the classical space-time geometry - encoded by an Einstein metric on a Sasaki manifold S - emerges from a canonical quantum state in a dual supersymmetric gauge theory, in the limit when the rank N of the gauge group tends to infinity. The relation to complex algebraic geometry stems from the fact that the supersymmetry of the gauge theory is encoded by a complex algebraic variety (the vacuum moduli space) which in this case is the N-fold symmetric product of a complex algebraic affine cone over S. The talk is based on a joint work with Tristan Collins and Daniel Persson ("Emergent Sasaki-Einstein geometry and AdS/CFT", Nature Communications 2022).

15:15 - 16:00

Track: Mathematical Physics
Type: 11. Mathematical Physics
Room: Room 11
Moderator: Simone Warzel
Sectional Speaker: Michael Loss

The Kac Model: Variations on a theme

The Kac master equation provides a simple framework to understand certain aspects of systems of particles that interact through pairwise collisions. In this talk I will review the proof of the Kac gap conjecture for a gas of particles that undergo energy and momentum preserving collisions, as well as results on the entropy and information decay for a one dimensional Kac system coupled to a reservoir. If time permits, results about a quantum version will also be presented.

15:15 - 16:00
Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 12
Moderator: Weinan E
Sectional Speaker: Zico Kolter

Deep neural networks via monotone operators

Deep Equilibrium Models (DEQs) are a class of machine learning models that computes the fixed point of a single nonlinear operator in lieu of a traditional multi-layer network. Our recently proposed monotone equilibrium model (monDEQ) provides a firmer grounding for such models, by providing a parameterization that guarantees the existence and uniqueness of this fixed point. In this talk, I will highlight some of our recent work on these monDEQ models. Specifically, I will first highlight the general monDEQ framework, how it provides guarantees on fixed point uniqueness, and how it allows for efficient operator splitting methods for computing the fixed point; I will then illustrate how it enables us bound Lipchitz constant of the monDEQ models, which in turn allows us to produce generalization bounds for these architectures (non-trivial for these effectively "infinitely deep" networks); I will highlight a few different approaches to characterizing robustness of monDEQ models; and I will finish by highlighting the connections between monDEQs and mean-field inference, to illustrate how we can use these approaches to formulate Boltzman-machine-like models for which mean-field inference is guaranteed to converge to a globally optimal solution.

16:15 - 17:15
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Karen Vogtmann
Plenary Speaker: Mladen Bestvina

Groups acting on hyperbolic spaces - a survey

Much information about a discrete group can be gleaned from its action on a δ-hyperbolic space. This has been understood classically for hyperbolic groups by the work of Gromov in the 80s. More recently, it has been discovered that many groups of interest admit useful actions on hyperbolic spaces. In the talk I will outline a construction of such actions and survey some applications, with an emphasis on mapping class groups and automorphism groups of free groups.

Monday, 11. July 2022

09:00 - 10:00
Track: Plenary
Type: Panel
Room: Room 1
Chair: June Barrow-Green
Plenary Speaker: Christine Proust
Plenary Speaker: Sonja Brentjes

ICHM May Prize Lecture 1; ICHM May Prize Lecture 2

ICHM May Prize Lecture 1 (09:00-09:30)
Studying ancient mathematics, or how to make sense of a constellation of tiny details

Mathematical cuneiform sources are extremely fragmented. Thousands of pieces of clay tablets are scattered in numerous museums in the Near East, Europe and the United States or in private collections. The material history of these documents is mostly unknown due to the destruction of the ancient archives during illegal excavations and their dispersion on the antiquities market. However, countless mathematical, philological, textual and archaeological information can be extracted from these documents. Each of these clues, however tenuous, is valuable and deserves to be meticulously observed, analyzed and connected to others. My first researches were on school tablets. At first sight, there was little chance that these fragments, generally in rather poor condition, would deliver any sensational mathematical revelation. What interest could a historian have in these repetitive school drafts, generally considered to be of very low level? The reconstruction of the mathematics curriculum that was implemented in scribal schools was one of the main goals of my first studies. Understanding the way in which young scribes were trained in mathematics allowed me to penetrate some of the genuine ideas of ancient scribes concerning numbers, quantification, operations, and reasoning. In this presentation, we will move from some seemingly innocuous observations on very basic texts to the discovery of unexpectedly deep mathematical concepts.

ICHM May Prize Lecture 2 (09:30-10:00)
On the sociocultural contexts of the mathematical sciences in Islamicate societies

A main concern of my research in the last thirty years consisted in looking for sources, which would allow us to understand the conditions under which scholars engaged with the mathematical sciences in various Islamicate societies until about 1700. I will present results of these efforts adding to them new types of sources I explored only recently. My focus will be biographies, histories, dedications and colophons. I will use them to discuss the development of mathematical education, genealogies of families working in the mathematical sciences, regional differences and interactions, small-scale and large-scale projects, types of institutional sponsorship, social status and conflicts.

10:15 - 11:15
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Paolo Piccione
Plenary Speaker: Tobias Holck Colding

Geometry of PDEs

Optimal geometric structures and the evolution of shapes are governed by partial differential equations. These same types of equations come up over and over again across many diverse areas in science, engineering and mathematics.
The geometric invariance makes the equations canonical, and means that they also describe phenomena seemingly unrelated to geometry.
Often the geometry unlocks the structure of the equation and leads to fundamental tools in PDE. Conversely, analysis has played a central role in the development of geometry. Understanding the equations and their fundamental properties requires simultaneous insight into both analysis and geometry and the interplay between the two. In this talk we will discuss this principle for several fundamental equations. We start by seeing how a long-standing problem in geometry leads to optimal regularity for viscosity solutions of a degenerate elliptic PDE, then turn to using PDE to understand optimal shapes and geometric evolution.

11:30 - 12:30
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Nalini Joshi
Plenary Speaker: Igor Krichever

Algebraic-geometrical methods in the theory of integrable systems and Riemann-Schottky type problems

In 1979, Novikov conjectured the following remarkable relation between algebraic-geometry and the theory of integrable models: t*he Jacobians of smooth algebraic curves are precisely those indecomposable principally polarized abelian varieties (ppav) whose theta-functions provide solutions to the Kadomtsev-Petviashvili (KP) equation*. Novikov's conjecture was proved by T. Shiota in 1986.

The goal of this talk is to present a circle of ideas and methods which are instrumental for applications of algebraic-geometry to soliton theory, and conversely, pave the way for the solutions of some 120 years-old problems in algebraic geometry using the theory of integrable systems. Among the latter is the characterization of Jacobian varieties as ppav whose Kummer variety admits a trisecant line, and of the Prym varieties as ppav whose Kummer variety admits a pair of symmetric quadrisecants.

At the heart of this recent progress is the notion of abelian pole systems generalizing the pole systems such as Calogero-Moser system arising in the theory of elliptic solutions to the basic soliton hierarchies. We also present recent results in this direction on the characterization of Jacobians of curves with involution, which were motivated by the theory of two-dimensional integrable hierarchies with symmetries.

13:15 - 14:00

Track: Analysis
Type: Special Sectional Lecture
Room: Room 1
Moderator: Wilhelm Schlag
Sectional Speaker: Keith Ball

The probabilistic character of convex domains

Over the last two decades it has become clear that convex domains exhibit properties that we would expect of the joint densities of independent random variables. The developments have been guided by 3 conjectures made 25-30 years ago by Kannan, Lovász and Simonovits, Bourgain and myself. I will explain how these conjectures fit together and what is known.

13:15 - 14:00

Track: Mathematical Physics
Type: 11. Mathematical Physics
Room: Room 2
Moderator: Giovanni Felder
Sectional Speaker: Karol Kozlowski

Convergence of the two-point form factor series in the 1+1 dimensional Sinh-Gordon quantum field theory

The *S*-matrix bootstrap program was devised in the late 70s and mid 80s as a possible path for a fully explicit construction of numerous massive integrable quantum field theories in 1+1 dimensions. Ultimately, it allows one to express the physically pertinent observables in these models-the multi-point correlation functions- in terms of form factor series expansion. On technical grounds, the latter correspond to fully explicit series of multiple integrals in which the nth summand is given by a n-fold integral. While being formally effective from the point of view of various physical applications, so far, the question of convergence of such form factor series was essentially left open. Still, convergence results are necessary so as to reach the mathematical well-definiteness of this construction of massive integrable 1+1 dimensional quantum field theories and appear as necessary ingredients for the justification of numerous handlings that are carried out with the help of such series. In this talk, I will describe the technique I recently developed that allows one to prove the convergence of the form factor series that arise in the context of the simplest massive integrable quantum field theory in 1+1 dimensions: the Sinh-Gordon model. The proof amounts to obtaining a sufficiently sharp estimate on the leading large-n behaviour of the n-fold integral arising in this context. This appeared possible by refining some of the techniques that were fruitful in the analysis of the large-n behaviour of integrals over the spectrum of $n \times n$ random Hermitian matrices.

13:15 - 14:00

Track: Geometry
Type: 5. Geometry
Room: Room 3
Moderator: Anton Alekseev
Sectional Speaker: Robert J Young

Composing and decomposing surfaces in R^{n}

How do you build a complicated surface? How can you decompose a surface into simple pieces? Understanding how to construct an object can help you understand how to break it down. We will present some constructions and decompositions of surfaces based on uniform rectifiability and use these decompositions to study problems in geometric measure theory and metric geometry.

13:15 - 14:00

Track: Number Theory
Type: 3. Number Theory
Room: Room 4
Moderator: Wei Zhang
Sectional Speaker: Mahesh Kakde
Sectional Speaker: Samit Dasgupta

On the Brumer–Stark conjecture and refinements

Let *H* be a finite abelian *C M* extension of a totally real number field *F*. The Brumer-Stark conjecture states that an appropriately smoothed and depleted Stickelberger element attached to the extension *H/F* annihilates an associated ray class group of *H*. Over the past decades, many interesting refinements of the conjecture have been stated. In this talk we discuss our proof of the original Brumer–Stark conjecture and many of these refinements over $\mathbf{Z}[1/2]$. Further, we will discuss applications to explicit class field theory for totally real fields.

13:15 - 14:00

Track: Mathematics of Computer Science
Type: 14. Mathematics of Computer Science
Room: Room 5
Moderator: Piotr Indyk
Sectional Speaker: Jelani Nelson

Forty years of frequent items

We survey the last forty years of algorithm development for finding frequent items in data streams, a line of work which surprisingly wound up developing new tools in information theory, pseudorandomness, chaining methods for bounding suprema of stochastic processes, and spectral graph theory.

13:15 - 14:00

Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 6
Moderator: Lucia Caporaso
Sectional Speaker: Aravind Asok
Sectional Speaker: Jean Fasel

Vector bundles on algebraic varieties

We survey some recent progress in the theory of vector bundles on algebraic varieties and related questions in algebraic K-theory.

13:15 - 14:00
Track: Numerical Analysis and Scientific Computing
Type: 15. Numerical Analysis and Scientific Computing
Room: Room 7
Moderator: Alex Wilkie
Sectional Speaker: Lexing Ying

Prony's method, analytic continuation, and quantum signal processing

Prony's method is a powerful algorithm for identifying frequencies and amplitudes from equally spaced signals. In the first part of the talk, we will review the Prony's method. In the second part of the talk, we use the ideas of the Prony's method to solve two problems: (1) analytic continuation from noisy samples and (2) stable factorization of the phase factors for quantum signal processing.

13:15 - 14:00
Track: Algebra
Type: 2. Algebra
Room: Room 8
Moderator: Tomoyuki Arakawa
Sectional Speaker: Pierre-Emmanuel Caprace
Sectional Speaker: George Willis

A totally disconnected invitation to locally compact groups

This talk is devoted to topological groups that are locally compact and totally disconnected. These groups are found in many guises such as Lie groups over local fields, Kac-Moody groups, Galois groups of field extensions of finite transcendence degree, and automorphism groups of locally finite graphs. We present a selection of recent advances in the general theory that shed light on the role of simple groups, local structure, and comparisons with linear groups. The interaction of algebra and topology and the dynamics of the conjugation action are unifying themes.

13:15 - 14:00
Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 9
Moderator: Alexander Schrijver
Sectional Speaker: Bin Dong

On Mathematical Modeling in Image Reconstruction and beyond

Imaging has been playing a vital role in the development of natural sciences and engineering and has now become an essential component of our daily lives. Image reconstruction is one of the most fundamental problems in imaging. For the past three decades, we have witnessed phenomenal developments in mathematical models and algorithms in image reconstruction. In this talk, I will first review some progress of the two prevailing mathematical approaches for image reconstruction, i.e., the wavelet frame-based and PDE-based approaches. I will discuss the connections between the two approaches and the implications and impact of the connections. Moreover, I will review how the studies of the links between the two approaches have led us to a mathematical understanding of deep convolutional neural networks, which has further led to some intriguing progress in deep learning, computational imaging, and scientific computing.

13:15 - 14:00

Track: Mathematical Education and Popularization of Mathematics
Type: 19. Mathematical Education and Popularization of Mathematics
Room: Room 10
Moderator: Faiza Chellougui
Sectional Speaker: Anna Sfard

The long way from mathematics to mathematics education: How educational research may change one's vision of mathematics and of its learning and teaching

While telling the story of my own transition from mathematics to mathematics education, I explain the origins and consequences of conceptualizing mathematics as an activity of creating narratives that produce their own objects.

13:15 - 14:00

Track: Topology
Type: 6. Topology
Room: Room 11
Moderator: Andras Stipsicz
Sectional Speaker: Thomas Nikolaus

Frobenius homomorphisms in higher algebra

We will discuss instances of Frobenius homomorphisms in homotopy theory. Similar to ordinary algebra, these morphism play an important role in higher algebra and are related to various concepts in stable homotopy theory and algebraic K-theory. We also discuss the notion of perfectness, which is to say that these morphisms are equivalences, and relate this notion to the Segal conjecture, the red-shift conjecture and the classification of spaces by stable data. We also present new calculations of K-theory groups based on those ideas.

14:15 - 15:00

Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 1
Moderator: Wilhelm Schlag
Sectional Speaker: Gabriella Tarantello

On a Donaldson functional for CMC-immersions of surfaces into Hyperbolic 3-manifolds

We discuss a parametrization for the moduli space of Constant Mean Curvature (CMC) immersions of a closed surface (orientable and of genus larger than 1) into hyperbolic 3-manifolds by elements of the tangent bundle of the Teichmueller space. Such tangent bundle is identified by pairs formed by a conformal structure on the surface and a Dolbeault cohomology class of (0,1)-forms valued in the corresponding holomorphic tangent bundle. Thus, for any such pair, we establish the unique solvability of the Gauss-Codazzi equations, expressing the pullback metric and the second fundamental form of the immersion in terms of the given element of the tangent bundle. The Gauss-Codazzi equations can be viewed as the Hitchin's selfduality equations for a suitable nilpotent SL(2;C)-Higgs bundle, but also as the Euler-Lagrange equation of a suitable functional, introduced by Gonsalves-Uhlenbeck in 2007, and therefore referred as the Donaldson Functional. Thus we show that the given Donaldson functional admits a unique critical point corresponding to its global minimum. Actually, such uniqueness result extends to a more general version of the Donaldson functional and it permits to recover known results (also about minimal Lagrangian immersions) previously obtained via a Higgs-bundle approach. However, with the Donaldson functional in hand, we are able to describe the asymptotic behavior of its minimum when the co-homology classes vary according to some geometrical pursuit . For example for CMC immersions we shall let the constant of the mean curvature approach its limiting value and describe when the immersed CMC surfaces develop "branched" singularities. Similarly, we will analyze the behavior of minima along a whole ray of cohomology classes. Such an investigation is based on the detailed blow-up analysis developed over the years in the context of Liouville type equations. Here however, we encounter new difficulties as blow-up can occur at a point of "collapsing" zeros of the holomorphic quadratic differentials identified by the given cohomolgy classes.

14:15 - 15:00

Track: Numerical Analysis and Scientific Computing
Type: Special Sectional Lecture
Room: Room 2
Moderator: Giovanni Felder
Sectional Speaker: Eric Vanden-Eijnden

Enhancing Markov Chain Monte Carlo Sampling Methods with Deep Learning

Sampling high-dimensional probability distributions is a common task in computational chemistry, Bayesian inference, etc. Markov Chain Monte Carlo (MCMC) is the method of choice to perform these calculations, but it is often plagued by slow convergence properties. I will discuss how methods from deep learning (DL) can help enhance the performance of MCMC via a feedback loop in which we simultaneously use DL to learn better samplers based e.g. on generative models, and MCMC to obtain the data for the training of these models. I will illustrate these techniques via several examples, including the sampling of random fields, the calculation of reaction paths in metastable systems and the calculation of free energies and Bayes factors.

14:15 - 15:00

Track: Geometry
Type: 5. Geometry
Room: Room 3
Moderator: Anton Alekseev
Sectional Speaker: Mark Mclean

Floer Cohomology and Birational Geometry

We explain a few recent results applying Floer cohomology to topics in birational geometry. We show how one can prove part of the cohomological McKay correspondence by computing a Floer cohomology group in two different ways. After that we illustrate how Hamiltonian Floer cohomology can be used to prove that birational Calabi-Yau manifolds have the same small quantum cohomology algebras.

14:15 - 15:00

Track: Number Theory
Type: 3. Number Theory
Room: Room 4
Moderator: Wei Zhang
Sectional Speaker: Lillian B. Pierce

The hedgehog and the fox

In this talk, we will encounter an array of recent theorems, questions, and phenomena that can be profitably considered from viewpoints originating in the borderland between number theory and analysis.

14:15 - 15:00

Track: Mathematics of Computer Science
Type: 14. Mathematics of Computer Science
Room: Room 5
Moderator: Piotr Indyk
Sectional Speaker: Ola Svensson

Polyhedral Techniques in Combinatorial Optimization: Matchings and Tours

We overview recent progress on two of the most classic problems in combinatorial optimization: the matching problem and the traveling salesman problem. We focus on deterministic parallel algorithms for the perfect matching problem and the first constant-factor approximation algorithm for the asymmetric traveling salesman problem. While these questions pose seemingly different challenges, recent progress has been achieved using similar polyhedral techniques. In particular, for both problems, we will explain the use linear programming formulations, even exponential-sized ones, to extract structure from problem instances to guide the design of better algorithms.

14:15 - 15:00

Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 6
Moderator: Lucia Caporaso
Sectional Speaker: Ofer Gabber

Bounding the torsion in the l-adic cohomology of smooth projective varieties without unbounded searches

Using a Hard Lefschetz estimate and arguments with l-adic Lie groups we obtain a presumably primitive recursive bound for the torsion in the l-adic cohomologies of smooth projective varieties over finite fields, improving the algorithm of Wittenberg described by Poonen et al.

14:15 - 15:00

Track: Logic
Type: 1. Logic
Room: Room 7
Moderator: Alex Wilkie
Sectional Speaker: Gal Binyamini
Sectional Speaker: Dmitry Novikov

Tameness in geometry and arithmetic: beyond o-minimality

The theory of o-minimal structures provides a powerful framework for the study of geometrically tame structures. In the past couple of decades a deep link connecting o-minimality to algebraic and arithmetic geometry has been developing. It has been clear, however, that the axioms of o-minimality do not fully capture some algebro-arithmetic aspects of tameness that one may expect in structures arising from geometry. We propose a notion of *sharply o-minimal structures* refining the standard axioms of o-minimality, and outline through conjectures and various partial results the potential development of this theory in parallel to the standard one.

14:15 - 15:00

Track: Algebra
Type: 2. Algebra
Room: Room 8
Moderator: Tomoyuki Arakawa
Sectional Speaker: Syu Kato

The formal model of semi-infinite flag manifolds

We explain our description of the formal model of semi-infinite flag manifolds as explicit algebro-geometric objects, based on the recent developments in the representation theory of affine Lie algebras. We also discuss its consequences and perspectives.

14:15 - 15:00

Track: Combinatorics
Type: 13. Combinatorics
Room: Room 9
Moderator: Alexander Schrijver
Sectional Speaker: Julia Boettcher

Graph and hypergraph packing

Packing problems in combinatorics concern the edge disjoint embedding of a family of guest (hyper)graphs into a given host (hyper)graph. Questions of this type are intimately connected to the field of design theory, and have a variety of significant applications. The area has seen important progress in the last two decades, with a number of powerful new methods developed. Here, I will survey some major results contributing to this progress, alongside background, and some ideas concerning the methods involved.

14:15 - 15:00

Track: Mathematical Education and Popularization of Mathematics
Type: 19. Mathematical Education and Popularization of Mathematics
Room: Room 10
Moderator: Faiza Chellougui
Sectional Speaker: Clara Grima Ruiz

The hug of the scutoid

This paper is a personal account of my work in the popularization of mathematics. How I started doing math popularization, why I think it is important to do this kind of tasks, and, finally, how this work can lead to some fruitful results in pure research that, initially, seems not to be related with that work of popularization.

14:15 - 15:00

Track: Dynamics
Type: 9. Dynamics
Room: Room 11
Moderator: Andras Stipsicz
Sectional Speaker: Corinna Ulcigrai

Dynamics and 'arithmetics' of higher genus surface flows

We survey some recent advances in the study of (area-preserving) flows on surfaces, in particular on the typical dynamical, ergodic and spectral properties of smooth area preserving (or locally Hamiltonian) flows, as well as recent breakthroughs on linearization and rigidity questions in higher genus. We focus in particular on the Diophantine-type conditions which are required to prove such results, which can be thought of as a generalization of arithmetic conditions for flows on tori and circle diffeomorphisms. We will explain how these 'Diophantine-like' conditions on higher genus flows and their Poincaré sections (namely generalized interval exchange maps) can be imposed by controlling a renormalization dynamics, but are of more subtle nature and often exploit features which originate from the (non-uniform) hyperbolicity of the renormalization.

14:15 - 15:00

Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 12
Moderator: Terry Lyons
Sectional Speaker: Bernhard Schölkopf

From statistical to causal learning

We describe basic ideas underlying research to build and understand artificially intelligent systems: from symbolic approaches via statistical learning to interventional models relying on concepts of causality. Some of the hard open problems of machine learning and AI are intrinsically related to causality, and progress may require advances in our understanding of how to model and infer causality from data.

15:30 - 16:30

Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Peter Scholze
Plenary Speaker: Bhargav Bhatt

Algebraic geometry in mixed characteristic

For a fixed prime number p, we report on some recent developments in algebraic geometry (broadly construed) over p-adically complete commutative rings.

Tuesday, 12. July 2022

10:15 - 11:15
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Wendelin Werner
Plenary Speaker: Alice Guionnet

Random Matrices, Free Probability and the Enumeration of Maps

During the last century, large random matrices became a central mathematical object in many domains, including statistics, number theory, operator algebra theory, quantum physics, string theory, etc. As a consequence, the study of large random matrices has grown into a diverse and mature field, yielding answers to increasingly sophisticated questions. In this talk, I will discuss some classical results about large random matrices and emphasize their beautiful connections with the enumeration of maps and free probability.

11:30 - 12:30
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Luigi Ambrosio
Plenary Speaker: Camillo DeLellis

Regular and singular minimal surfaces

Minimal surfaces are surfaces whose area is stationary under smooth perturbations: a well known example is given by minimizers of the area among those which span a given contour and the study of their shape and properties dates back at least to the work of Lagrange in the middle of the 18th century. It is known since long that such objects are, in general, not necessarily smooth and this very fact presents immediately an intriguing challenge: what should we understand with the words "surface" and "area"? The mathematical literature has seen quite a few different approaches, all leading to concepts of "generalized minimal surfaces" which have distinctive features. A pivotal question is when and where these objects are smooth, how large the sets of their singularities can be, and which behavior they can possibly display at the singular points. In my talk I will review a selection of classical works, recent results, and future challenges.

13:15 - 14:00
Track: Number Theory
Type: Special Sectional Lecture
Room: Room 1
Moderator: Philippe Michel
Sectional Speaker: Joseph Silverman

Arithmetic Dynamics: A Survey

Arithmetic dynamics is a relatively new eld in which classical problems from number theory and algebraic geometry are reformulated in the setting of dynamical systems. Thus, for example, rational points on algebraic varieties become rational points in orbits, and torsion points on abelian varieties become points having nite orbits. In this talk I will discuss some representative problems motivating the eld of arithmetic dynamics and describe some of the progress that has been made during the past 20 years.

13:15 - 14:00

Track: Geometry
Type: 5. Geometry
Room: Room 2
Moderator: Tobias Ekholm
Sectional Speaker: Gang Liu

Kähler manifolds with curvature bounded below

This is a survey on certain Kähler manifolds with curvature bounded below. The topics include: The uniformization conjecture of Yau, as well as its related problems 2. Compactification of certain Kähler manifolds of nonnegative Ricci curvature 3. Gromov-Hausdorff limits of Kähler manifolds.

13:15 - 14:00

Track: Mathematics of Computer Science
Type: 14. Mathematics of Computer Science
Room: Room 3
Moderator: Ran Raz
Sectional Speaker: Oded Regev

The Reverse Minkowski Theorem

We will describe recent progress on "reverse Minkowski'" results on the geometry of lattices. Such results provide upper bounds on the number of short vectors a lattice can have, assuming that it does not have any sublattice of low determinant. We also briefly describe the proof ideas, and mention some open questions.
Based on joint work with Daniel Dadush and Noah Stephens-Davidowitz.

13:15 - 14:00

Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 4
Moderator: Jungkai Chen
Sectional Speaker: Alexander Efimov

On the K-theory of large triangulated categories

We will give a brief introduction to the notion of *continuous* K-theory, which is defined for a certain class of large (enhanced) triangulated categories, the so-called dualizable categories. In the case of compactly generated triangulated categories this continuous K-theory gives the usual algebraic K-theory of the category of compact objects. We will give a survey of results and conjectures on the computation of this K-theory for some dualizable categories coming from geometry and topology: categories of sheaves on locally compact Hausdorff spaces and categories of nuclear modules introduced recently by Clausen and Scholze.

13:15 - 14:00
Track: Control Theory and Optimization
Type: 16. Control Theory and Optimization
Room: Room 5
Moderator: Enrique Zuazua
Sectional Speaker: Regina Burachik

Enlargements: a bridge between maximal monotonicity and convexity

Perhaps the most important connection between maximally monotone operators and convex functions is the fact that the subdifferential of a convex function is maximally monotone. This fact connects convex functions with a proper subset of maximally monotone operators (i.e., the cyclically monotone operators). Our focus is to explore maps going in the opposite direction, namely those connecting an arbitrary maximally monotone map with convex functions. In this survey, we present results showing how enlargements of a maximally monotone operator T provide this connection. Namely, we recall how the family of enlargements is in fact in a bijective correspondence with a whole family of convex functions. Moreover, each element in either of these families univocally defines T. We also show that enlargements are not merely theoretical artifacts, but have concrete advantages and applications, since they are, in some sense, better behaved than T itself.
Enlargements provide insights into existing tools linked to convex functions. A recent example is the use of enlargements for defining a distance between two point-to-set maps, one of them being maximally monotone. We recall this new distance here, and briefly illustrate its applications in characterizing solutions of variational problems.

13:15 - 14:00
Track: Combinatorics
Type: 13. Combinatorics
Room: Room 6
Moderator: Béla Bollobás
Sectional Speaker: Allen Knutson

Schubert calculus and quiver varieties

The Littlewood-Richardson rule (1934) is a combinatorial (and in particular, manifestly positive) way to compute the structure constants of two a priori unrelated rings-with-basis: the representation ring of $GL_{k}(C)$, and the cohomology ring of the Grassmannian $Gr(k, C^{n})$. We recall a wealth of generalizations of the latter ring (changing the space, the cohomology theory, or the basis), all of which have non-manifestly-positive rules for computation, nowadays called their *Schubert calculus*. Until this century very few of these structure constants had combinatorial rules for their calculation, although many of the structure constants have been proven (ineffectively) to be nonnegative. In recent years the formal similarity of one of these rules (the Knutson-Tao "puzzle" rule for equivariant cohomology) to quantum integrable systems has been traced to the geometry of *quiver varieties*, a class among which one finds the cotangent bundles to Grassmannians. This allowed for the discovery and proof of rules for many heretofore unsolved Schubert calculus problems, and new connections to representation theory.

13:15 - 14:00
Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 7
Moderator: Nicolas Burq
Sectional Speaker: Kenji Nakanishi

Global dynamics around and away from solitons

I will talk about global behavior of general solutions for nonlinear dispersive equations, in particular about their transitions with respect to time evolution and to initial perturbation around solitons.

13:15 - 14:00
Track: Probability
Type: 12. Probability
Room: Room 8
Moderator: Takashi Kumagai
Sectional Speaker: Tadahisa Funaki

Hydrodynamic limit and stochastic PDEs related to interface motion

We consider several types of interacting particle systems at microscopic level, in which particles move performing random walks with or without creation and annihilation depending on the situation. From these systems, via the hydrodynamic space-time scaling limit or its nonlinear uctuation limit, we derive three different objects at macroscopic level: the motion by mean curvature arising in phase separation phenomena, Stefan free boundary problem describing segregation of species, and coupled KPZ equation which is a system of singular stochastic PDEs. These are all related to the problem of interface motion. The Boltzmann-Gibbs principle plays a fundamental role. We also touch the discrete Schauder estimate.

13:15 - 14:00
Track: Analysis
Type: 8. Analysis
Room: Room 9
Moderator: Toshiyuki Kobayashi
Sectional Speaker: Mikael de la Salle

Analysis with simple Lie groups and lattices

I will present a simple tool to perform analysis with simple Lie groups and their lattices, which has been applied in various contexts: non-unitary representations, operator algebras and their approximation properties, Fourier analysis, geometry of Banach spaces... The idea, which originates from the work of Vincent Lafforgue, is to first restrict to compact subgroups and then exploit how they sit inside the whole group.

13:15 - 14:00
Track: Mathematical Physics
Type: 11. Mathematical Physics
Room: Room 10
Moderator: Joerg Teschner
Sectional Speaker: Yoshiko Ogata

Classification of gapped ground state phases in quantum spin systems

Recently, classification problems of gapped ground state phases have attracted a lot of attention in quantum statistical mechanics. We explain about operator algebraic approach to these problems.

13:15 - 14:00
Track: History of Mathematics
Type: 20. History of Mathematics
Room: Room 11
Moderator: Niccolò Guicciardini
Sectional Speaker: June Barrow-Green

George Birkhoff's forgotten manuscript and his programme for dynamics

At the end of the 1920s, George Birkhoff began to draw up a programme of research on unsolved problems in dynamics, and in 1941 he presented his ideas at the 50th anniversary celebration of the University of Chicago. Soon afterwards a summary of his lecture was published. At the time of his death in 1944, he left unfinished a manuscript of a revised and extended version of his lecture. I will describe Birkhoff's work leading up to this manuscript before discussing the contents of the manuscript itself.

14:15 - 15:00
Track: Probability
Type: 12. Probability
Room: Room 1
Moderator: Philippe Michel
Sectional Speaker: Alison Etheridge

The motion of hybrid zones (and how to stop them)

Mathematical models play a fundamental role in theoretical population genetics and, in turn, population genetics provides a wealth of mathematical challenges. In this lecture we illustrate this by using a mathematical caricature of the evolution of genetic types in a spatially distributed population to demonstrate the role that the shape of the domain inhabited by a species can play in mediating the interplay between natural selection, spatial structure, and (if time permits) so-called random genetic drift (the randomness due to reproduction in a finite population).

14:15 - 15:00
Track: Geometry
Type: 5. Geometry
Room: Room 2
Moderator: Tobias Ekholm
Sectional Speaker: Iskander Taimanov

Surfaces via spinors and soliton equations

We survey the Weierstrass representation of surfaces in the three- and four-dimensional spaces, with an emphasis on its relation to the Willmore functional and describe an application of this representation to constructing a new type of solutions to the Davey-Stewartson II equation. They have regular initial data, gains one-point singularities at certain moments of time and extends to smooth solutions for the remaining times.

14:15 - 15:00
Track: Mathematics of Computer Science
Type: 14. Mathematics of Computer Science
Room: Room 3
Moderator: Ran Raz
Sectional Speaker: Thomas Vidick

Connes embedding problem, Tsirelson's problem, and MIP^{∗} = RE

The three problems referred to in the title originate in operator algebras, quantum information theory, and complexity theory respectively. Recently we established the complexity-theoretic equality MIP^{∗} = RE. This equality implies that the membership problem for certain quantum correlation sets is undecidable. Due to prior work by many others the result implies a negative answer to Tsirelson's problem (quantum information) as well as Connes' Embedding Problem (von Neumann algebras) and equivalent problems in operator algebras such as Kirchberg's QWEP (C^{∗} algebras). It leaves open the famous question about the existence of a non-hyperlinear group. In the talk I will explain the characterization MIP^{∗} = RE and motivate it by describing its connection to the study of nonlocality in quantum information, Tsirelson's problem, and operator algebras. I will mention some proof ideas, which draw from the theory of probabilistic checking in complexity theory and approximate stability in group theory. The main result is joint work with Ji, Natarajan, Wright and Yuen available as arXiv:2001.04383.

14:15 - 15:00
Track: Algebraic and Complex Geometry
Type: Special Sectional Lecture
Room: Room 4
Moderator: Jungkai Chen
Sectional Speaker: Marc Levine

Motivic Cohomology: past, present and future

I will give a brief overview of the development of motivic cohomology, its parallels with singular cohomology and its place in motivic stable homotopy theory. I will then describe some of the recent off-shoots of motivic cohomology: cycles with modulus, Chow-Witt theory, and motivic filtrations on p-adic K-theory, and conclude with some speculations on future developments.

14:15 - 15:00
Track: Control Theory and Optimization
Type: 16. Control Theory and Optimization
Room: Room 5
Moderator: Enrique Zuazua
Sectional Speaker: Coralia Cartis

Evaluation complexity of algorithms for nonconvex optimization

This talk presents an overview, as well as recent developments, regarding global rates of convergence and the worst-case evaluation (also called oracle) complexity of methods for nonconvex smooth optimization problems. We show how the popular methods of steepest descent and Newton's enjoy similar (sharp) bounds on their performance, despite the expectation that the latter would be 'fast(er)'. We argue the benefits of second-order regularization methods, which yield superior complexity bounds to first-order algorithms, and even optimal ones within a wide class of methods containing Newton's. Then we consider the advantages of having and incorporating higher- (than second-) order derivative information inside regularization frameworks, generating higher-order regularization algorithms that have better complexity, universal properties and can certify higher-order criticality of candidate solutions. Time permitting, we also discuss inexact settings where derivatives and even function evaluations may only be sufficiently accurate occasionally, but whose worst-case complexity can still be quantified. A story of robust methods emerges, with continuously-varying, often sharp and sometimes even optimal, complexity.

14:15 - 15:00

Track: Combinatorics
Type: 13. Combinatorics
Room: Room 6
Moderator: Béla Bollobás
Sectional Speaker: Ehud Friedgut

KKL's influence on me

In 1988 Kahn, Kalai and Linial published their landmark paper in which they proved a lower bound on the maximal influence of variables on a Boolean function. Their use of Fourier analysis to solve the question, and especially their introduction of a hypercontractive inequality (due to Bonami, Beckner and Gross), has shaped the field of study of Boolean functions and has had great influence on combinatorics and theoretical computer science. In this talk I will survey how my own work has been influenced by their approach, via a collection of various problems that I have studied throughout the years.

14:15 - 15:00

Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 7
Moderator: Nicolas Burq
Sectional Speaker: Alexander I. Nazarov

Variety of fractional Laplacians

We survey recent results on comparison of various fractional Laplacians.

14:15 - 15:00

Track: Numerical Analysis and Scientific Computing
Type: 15. Numerical Analysis and Scientific Computing
Room: Room 8
Moderator: Takashi Kumagai
Sectional Speaker: Gitta Kutyniok

The Mathematics of Artificial Intelligence

Artificial intelligence is currently leading to one breakthrough after the other, both in public life with, for instance, autonomous driving and speech recognition, and in the sciences in areas such as medical diagnostics or molecular dynamics. A similarly strong impact can currently be witnessed within mathematics on areas such as inverse problems and numerical analysis of partial differential equations. The goal of this lecture is to first provide an introduction into this new vibrant research area. We will then survey recent advances in two directions, namely the development of a mathematical foundation of artificial intelligence and the introduction of according novel approaches to solve inverse problems and partial differential equations. We will also discuss fundamental limitations of such methodologies, in particular, in terms of computability.

14:15 - 15:00

Track: Lie Theory and Generalizations
Type: 7. Lie Theory and Generalizations
Room: Room 9
Moderator: Toshiyuki Kobayashi
Sectional Speaker: Binyong Sun
Sectional Speaker: Chen-Bo Zhu

Theta correspondence and the orbit method

The theory of theta correspondence, initiated by R. Howe, provides a powerful method of constructing irreducible admissible representations of classical groups over local fields. For archimedean local fields, a principle of great importance is the orbit method introduced by A. A. Kirillov, and it seeks to describe irreducible unitary representations of a Lie group by its coadjoint orbits. In this lecture, we examine implications of Howe's theory for the orbit method and unitary representation theory, with a focus on a recent work of Barbasch, Ma, and the speakers on the construction and classification of special unipotent representations of real classical groups (in the sense of Arthur and Barbasch-Vogan).

14:15 - 15:00

Track: Mathematical Physics
Type: 11. Mathematical Physics
Room: Room 10
Moderator: Joerg Teschner
Sectional Speaker: Roland Bauerschmidt

Spin systems with hyperbolic symmetry

Spin systems with hyperbolic symmetry originated as simplified models for the Anderson metal–insulator transition, and were subsequently found to exactly describe probabilistic models of linearly reinforced walks and random forests. We discuss the main features of these models, recent results, relations to other models, and some of the many open questions.

14:15 - 15:00

Track: History of Mathematics
Type: 20. History of Mathematics
Room: Room 11
Moderator: Niccolò Guicciardini
Sectional Speaker: Krishnamurthi Ramasubramanian

The History and Historiography of the Discovery of Calculus in India

Couched in rich poetic verses in the Sanskrit language, the history of mathematics in India provides a fertile field for researching the evolution of mathematical thinking. During the talk, starting with snippets from the work of Āryabhaṭa (c. 499 CE) we shall try to present how certain important breakthroughs lead to the pioneering contribution of Mādhava (c. 1340) of the Kerala School, which has a more direct bearing on calculus. Towards the end, we would also like to highlight some of interesting facets in the historiography pertaining to development of calculus in India.

14:15 - 16:15

Track: Other
Type: Panel
Room: Room 12
Chair: Carlos E. Kenig
Moderator: Olga Gil Medrano
Panelist: Anjum Halai
Panelist: Marie-Francoise Roy
Panelist: Christophe Ritzenhaler
Panelist: Claudio Arezzo
Panelist: Mama Foupouagnigni
Panelist: Guillermo Cortiñas
Panelist: Edy Tri Baskoro

CDC Panel "Online cooperation in mathematics: challenges and opportunities for developing countries"

The aim of the activity is to learn about the difficulties of mathematicians and institutions across continents, in the face of maintaining international cooperation when global mobility is limited. And just as importantly, the solutions they have found to overcome these challenges. Special emphasis will be put on identifying how communication technology can be used to support mathematicians in developing countries, while recognizing the possibilities of a digital divide where technological disparities may lead to further exclusion and disadvantage.

15:15 - 16:00

Track: Combinatorics
Type: Special Sectional Lecture
Room: Room 1
Moderator: Philippe Michel
Sectional Speaker: Melanie Matchett Wood

Probability theory for random groups arising in number theory

We consider the probability theory, and in particular the moment problem and universality theorems, for random groups of the sort of that arise or are conjectured to arise in number theory, and in related situations in topology and combinatorics. The distributions of random groups that are discussed include those conjectured in the Cohen-Lenstra-Martinet heuristics to be the distributions of class groups of random number fields, as well as distributions of non-abelian generalizations, and those conjectured to be the distributions of Selmer groups of random elliptic curves. For these sorts of distributions on finite and profinite groups, we survey what is known about the moment problem and universality, give a few new results including new applications, and suggest open problems.

15:15 - 16:00

Track: Geometry
Type: 5. Geometry
Room: Room 2
Moderator: Tobias Ekholm
Sectional Speaker: Penka Georgieva

Real Gromov-Witten theory

In this talk we survey some of the recent developments in real Gromov-Witten theory. In particular, we discuss the main difficulties of the construction and important structural results.

15:15 - 16:00

Track: Mathematics of Computer Science
Type: Special Sectional Lecture
Room: Room 3
Moderator: Ran Raz
Sectional Speaker: Cynthia Dwork

The Mathematics of Privacy

Statistics "feel" private. Perhaps the intuition is that the same things would be learned from two different samples, or whether any individual opts in or opts out of a given sample. This is, after all, why the field of statistics works in the first place. Unfortunately, this intuition misses the mark under repetition: overly accurate estimates of too many statistics completely destroys privacy, a phenomenon known as the Fundamental Law of Information Reconstruction.
Differential Privacy is a mathematical definition of privacy tailored to the statistical analysis of large datasets. Differentially private algorithms have a parameter that bounds their privacy leakage, and composition theorems capture how privacy leakage accumulates over multiple analyses. In consequence, the algorithm designer can set the parameters to control cumulative privacy loss, a unique feature of the theory. In other words, differential privacy is programmable: we can build complex, privacy-preserving, analyses from simple differentially private building blocks. In many cases the bounds achieved by existing differentially private algorithms match the limits imposed by the Fundamental Law.
Differential privacy, now broadly deployed in industry and providing the confidentiality backbone for the 2020 US Decennial Census, also has several surprising applications even when privacy is not a concern. Among these are robustness in machine learning and, most notably, protection against "p-hacking" and overfitting in exploratory data analysis. After a brief explication of the definition, this talk will provide highlights of the state of the art in differentially private algorithm design.

15:15 - 16:00

Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 4
Moderator: Jungkai Chen
Sectional Speaker: Aaron Pixton

The double ramification cycle

The double ramification cycle parametrizes curves of genus g admitting maps to the projective line with specified ramification profiles over two points. I'll present a formula (proved in 2016) expressing this cycle in terms of tautological classes on the moduli space of stable curves. I will then discuss some of the applications and generalizations of this formula from the last few years.

15:15 - 16:00

Track: Control Theory and Optimization
Type: 16. Control Theory and Optimization
Room: Room 5
Moderator: Enrique Zuazua
Sectional Speaker: Yu Hong Dai

New trends in nonlinear optimization

Nonlinear optimization stems from calculus and became an independent subject due to the proposition of Karush-Kuhn-Tucker optimality conditions. The evergrowing realm of applications and the explosion in computing power is driving nonlinear optimization research in new and exciting directions. In this talk, I shall focus on some recent research trends in nonlinear optimization, mainly on first order methods, barrier augmented-Lagrangian methods, and optimization with least constraint violation.

15:15 - 16:00
Track: Stochastic and Differential Modelling
Type: 18. Stochastic and Differential Modelling
Room: Room 6
Moderator: Béla Bollobás
Sectional Speaker: Jacob Bedrossian

Lower bounds on the top Lyapunov exponent of stochastic systems

We will discuss recent progress on estimating Lyapunov exponents of stochastic models and their application to Eulerian and Lagrangian chaos in stochastic fluid mechanics. For Eulerian chaos, we discuss our recently introduced methods for obtaining strictly positive lower bounds on the top Lyapunov exponent of high-dimensional, stochastic differential equations such as the weakly-damped Lorenz-96 (L96) model or Galerkin truncations of the 2d Navier-Stokes equations. For Lagrangian chaos we discuss our earlier work on positive Lyapunov exponents and almost-sure exponential mixing of scalars by the stochastic Navier-Stokes equations. These hallmarks of chaos have long been observed, however, no mathematical proof had been made for either deterministic or stochastic forcing.

The work on Eulerian chaos combines (A) a new identity connecting the Lyapunov exponents to a Fisher information of the stationary measure of the Markov process tracking tangent directions (the so-called "projective process"); and (B) an L^1-based hypoelliptic regularity estimate to show that this Fisher information is an upper bound on some fractional regularity. For L96 and GNSE, we then further reduce the lower bound to proving the projective process satisfies Hörmander's condition and introduce a computational framework for checking this condition in certain systems. The work on Lagrangian chaos involves an adaptation of the à la Furstenberg method followed by large-deviation-type estimates to study the two-point dynamics. All of the work discussed is joint with Alex Blumenthal and Sam Punshon-Smith.

15:15 - 16:00
Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 7
Moderator: Nicolas Burq
Sectional Speaker: Semyon Dyatlov

Fractal uncertainty principle and quantum chaos

Classical/quantum correspondence tells us that for bounded times, singularities of solutions to wave/Schrödinger equations on a manifold propagate along geodesics. In this talk we go beyond this correspondence, showing results which rely on chaotic nature of classical dynamics but do not have classical counterparts, in particular:

• lower bounds on mass of high energy Laplacian eigenfunctions on negatively curved surfaces;
• observability for the Schrödinger equation on negatively curved surfaces;
• spectral gaps and exponential local energy decay of waves on convex co-compact hyperbolic surfaces.

A key new tool in the proofs is the *fractal uncertainty principle*, which states that no function can be localized close to a fractal set in both position and frequency. It is combined with a detailed understanding of classical/quantum correspondence up to the time when it fails.
This talk is based on joint works with Jean Bourgain, Long Jin, Stéphane Nonnenmacher, Joshua Zahl, and Maciej Zworski.

15:15 - 16:00

Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 8
Moderator: Takashi Kumagai
Sectional Speaker: Richard Nickl

Statistical inverse problems and PDEs: progress and challenges

Non-linear inverse problems arising with PDEs permeate many branches of data science and applied mathematics. A unified statistical and algorithmic approach to solve them arises from the Bayesian modelling paradigm joining forces with modern methodology from high-dimensional Bayesian computation via MCMC or related methods. Recent years have seen substantial progress on the mathematical understanding of such algorithms, and a rigorous theory of Bayesian inference methods in non-linear, non-convex models of this type is starting to emerge as a new discipline at the interface of statistics and PDEs. We review the main ideas, recent progress, and future challenges in the area.

15:15 - 16:00

Track: Algebra
Type: 2. Algebra
Room: Room 9
Moderator: Toshiyuki Kobayashi
Sectional Speaker: Michael Larsen

Character estimates for finite simple groups and applications

Let G be a finite simple group, χ an irreducible character of G, and g an element of G. I will discuss upper bounds, old and new, for $|\chi(g)|$ in terms of $\chi(1)$, particularly bounds of the form $\chi(1)^{\wedge}\alpha$, where $\alpha \leq 1$ depends on the size of the centralizer of g compared to $|G|$. I will also indicate some applications, such as determining when a product of conjugacy classes covers G and estimating the number of homomorphisms from a Fuchsian group to G.

15:15 - 16:00

Track: Topology
Type: 6. Topology
Room: Room 10
Moderator: Joerg Teschner
Sectional Speaker: Oscar Randal-Williams

Diffeomorphisms of discs

I will describe what is currently known, for $d \geq 5$, about the rational homotopy type of the group of diffeomorphisms of the d-disc relative to its boundary, and the closely related group of homeomorphisms of d-dimensional Euclidean space.

15:15 - 16:00

Track: History of Mathematics
Type: 20. History of Mathematics
Room: Room 11
Moderator: Niccolò Guicciardini
Sectional Speaker: Annette Imhausen

Some uses and associations of mathematics, as seen from a distant historical perspective

The talk presents the evolution of mathematics and its various uses in ancient Egypt.

16:30 - 17:30
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Carlos E. Kenig
Plenary Speaker: Kannan Soundararajan

The Distribution of Values of Zeta And L-Functions

I will survey recent progress on understanding the distribution of values of zeta and *L*-functions. In particular, I will discuss the problem of moments of $|\zeta(1/2 + it)|$ and moments of central values of *L*-functions, where the last twenty five years have seen a conjectural understanding of the asymptotics of these moments, together with progress in obtaining good upper and lower bounds in many situations.

Wednesday, 13. July 2022

09:00 - 10:00
Track: Plenary
Type: Panel
Room: Room 1
Chair: June Barrow-Green
Plenary Speaker: Brigitte Stenhouse
Plenary Speaker: François Lê

ICHM Montucla Prize Lecture 1; ICHM Montucla Prize Lecture 2

ICHM Montucla Prize Lecture 1 (09:00-09:30)
Learning by letters - the mathematical education of Mary Somerville (1780-1872)

Much is known of Mary Somerville's early life, thanks to her autobiography published posthumously in 1873. However, her account gives very few details on how an 18th-century woman from a small Scottish village was able to become an accomplished mathematician, recognised as an expert in analytical mathematics throughout Europe and North America. This is especially pertinent as Somerville lived at a time when advanced mathematical texts were often expensive, or rare, and when women were usually unable to access the universities, libraries, or learned societies where such texts could be found. Building on letter correspondence and draft solutions to puzzles published in periodicals, this talk will shine a light on Somerville's earliest studies, thereby offering a new perspective on how mathematical knowledge circulates (or not).

ICHM Montucla Prize Lecture 2 (09:30-10:00)
"Are the genre and the Geschlecht one and the same number?" An inquiry into Alfred Clebsch's Geschlecht

The genus is a fundamental notion which is well known to current mathematicians and which (among other properties) allows to classify algebraic curves and topological surfaces. Historiography usually attributes to Bernhard Riemann the merit of having brought out the notion itself in the 1851 and 1857 papers where Riemann surfaces are introduced, and credits to Alfred Clebsch its original German naming Geschlecht (ca. 1865). One aim of my talk is to show that Clebsch did not merely christened a notion that was "already there" in Riemann's works, and that his act of naming was associated with a true re-appropriation of these works into a framework of projective geometry. I will also evidence that in the 1860s and 1870s, mathematicians clearly differentiated Clebsch's and Riemann's notions, and reserved the name Geschlecht for Clebsch's; it was only around 1880 that Felix Klein began to use the same name for the two notions.

10:15 - 11:15
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Vera Serganova
Plenary Speaker: Catharina Stroppel

The beauty of braids - from knot invariants to higher categories

Via different perspectives on braids we indicate how the search for topological invariants leads to crucial developments in representation theory and to speculations on higher topological invariants and TQFTs.

11:30 - 12:30
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Gil Kalai
Plenary Speaker: Avi Wigderson

Symmetries, Computation and Math (or, can P ≠ NP be proved via gradient descent?)

This talk aims to summarize a project I was involved in during the past 6-7 years, with the hope of explaining our most complete understanding so far, as well as challenges and open problems. The main messages of this project are summarized below; I plan to describe, through examples, many of the concepts they refer to, and the evolution of ideas leading to them. No special background is assumed.
(1) The most basic tools of convex optimization in Euclidean space extend to a far more general setting of Riemannian manifolds that arise from the symmetries of non-commutative groups. We develop first-order and second-order algorithms, and analyze their performance in general. While proving convergence bounds requires heavy algebraic and analytic tools, convergence itself depends in an elegant way on natural "smoothness" parameters, in analogy with the Euclidean (commutative) case.
(2) These algorithms can give exponential improvements in run-time for solving many algorithmic problems across CS, Math and Physics. In particular, these include problems in algebra (e.g. testing rational identities in non-commutative variables), in analysis (testing the feasibility and tightness of Brascamp-Lieb inequalities), in quantum information theory (to the quantum marginals problem), in computational complexity (to derandomizing new special cases of the Polynomial Identity Testing problem) and in optimization (to testing membership in large, implicitly described polytopes).
(3) The focus on symmetries exposes old and reveals new relations between the problems above, and between analysis, algebra and algorithms. Essentially, they are all membership problems in null cones and moment polytopes of natural group actions on natural spaces. Invariant theory, which studies such group actions, plays an essential role in this development. In particular, a beautiful non-commutative duality theory (expending linear programming duality in the commutative case), and notions of geodesic convexity (extending the Euclidean one) and moment maps (extending the Euclidean gradient) are central to the algorithms and their analysis. Interestingly, most algorithms in invariant theory are symbolic/algebraic, and these new numeric/analytic algorithms proposed here often significantly improve on them.

Based on joint works with Zeyuan Allen-Zhu, Peter Burgisser, Cole Franks, Ankit Garg, Leonid Gurvits, Pavel Hrubes, Yuanzhi Li, Visu Makam, Rafael Oliveira and Michael Walter.

13:15 - 14:00
Track: Geometry
Type: 5. Geometry
Room: Room 1
Moderator: Mahan Mj
Sectional Speaker: Xin Zhou

Mean Curvature and Variational Theory

Mathematical models of soap bubbles and capillary surfaces are described by a class of prescribing mean curvature (PMC) equations. Minimal surfaces and constant mean curvature (CMC) surfaces are special classes of PMC surfaces. In variational theory, PMC surfaces are stationary points of the area functional plus a volume-related term. In this talk, we will survey recent developments of the existence theory of such surfaces, including the min-max theory for CMC/PMC surfaces and a Morse theory for area functional. In particular, we will explain our recent solution of the Multiplicity One Conjecture for minimal surfaces using the PMC min-max theory.

13:15 - 14:00

Track: Mathematical Physics
Type: 11. Mathematical Physics
Room: Room 2
Moderator: Volker Bach
Sectional Speaker: Alessandro Giuliani

Scaling limits and universality of Ising and dimer models

After having introduced the notion of universality in statistical mechanics and its importance for our comprehension of the macroscopic behavior of interacting systems, I will review recent progress in the understanding of the scaling limit of lattice critical models, including a quantitative characterization of the limiting distribution and the robustness of the limit under perturbations of the microscopic Hamiltonian. I will focus on results obtained for two classes of non-exactly-solvable two- dimensional systems: non-planar Ising models and interacting dimers. Based on joint works with Giovanni Antinucci, Rafael Greenblatt, Vieri Mastropietro, Fabio Toninelli.

13:15 - 14:00

Track: Analysis
Type: 8. Analysis
Room: Room 3
Moderator: Durvudkhan Suragan
Sectional Speaker: Benoit Collins

Weingarten calculus and its applications

A fundamental property of compact groups and compact quantum groups is the existence and uniqueness of a left and right invariant probability - the Haar measure. This is a very natural playground for classical and quantum probability, provided that it is possible to compute its moments. Weingarten calculus addresses this question in a systematic way. The purpose of this talk is to survey recent developments, describe some salient theoretical properties of Weingarten functions, as well as applications of this calculus to random matrix theory, quantum probability and algebra, mathematical physics, and operator algebras.

13:15 - 14:00

Track: Dynamics
Type: 9. Dynamics
Room: Room 4
Moderator: Michael Pevzner
Sectional Speaker: Amir Mohammadi

Finitary analysis in homogeneous spaces

Rigidity phenomena in homogeneous dynamics have been extensively studied over the past few decades with several striking results and applications. We will give an overview of recent activities pertaining to quantitative aspect of the analysis in this context; we will also highlight some applications.

13:15 - 14:00
Track: Numerical Analysis and Scientific Computing
Type: 15. Numerical Analysis and Scientific Computing
Room: Room 5
Moderator: Anna Gilbert
Sectional Speaker: Nicholas J. Higham

Numerical Stability of Algorithms at Extreme Scale and Low Precisions

As computer architectures evolve and the exascale era approaches, we are solving larger and larger problems. At the same time, much modern hardware provides floating-point arithmetic in half, single, and double precision formats, and to make the most of the hardware we need to exploit the different precisions. How large can we take the dimension n in matrix computations and still obtain solutions of acceptable accuracy? Standard rounding error bounds are proportional to $p(n)u$, with p growing at least linearly with n. We are at the stage where these rounding error bounds are not able to guarantee any accuracy or stability in the computed results for extreme-scale or low-accuracy computations. We explain how rounding error bounds with much smaller constants can be obtained. The key ideas are to exploit the use of blocked algorithms, which break the data into blocks of size b and lead to a reduction in the error constants by a factor b or more; to take account of architectural features such as extended precision registers and fused multiply–add operations; and to carry out probabilistic rounding error analysis, which provides error constants that are the square roots of those of the worst-case bounds. Combining these different considerations provides new understanding of the limits of what we can compute at extreme scale and low precision in numerical linear algebra.

13:15 - 14:00
Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 6
Moderator: Chenyang Xu
Sectional Speaker: Tamas Hausel

Enhanced mirror symmetry for Langlands dual Hitchin systems

I will survey enhanced mirror symmetry phenomena between Langlands dual Hitchin systems. Then I will discuss a coherent framework for understanding their classical limit.

13:15 - 14:00
Track: Topology
Type: 6. Topology
Room: Room 7
Moderator: Lars Hesselholt
Sectional Speaker: Guozhen Wang
Sectional Speaker: Zhouli Xu

Stable homotopy groups of spheres and motivic homotopy theory

The computation of stable homotopy groups of spheres is one the most fundamental problems in topology. It has connections to many topics in topology, such as cobordism theory and the classification of smooth structures on spheres. In this talk, we will survey some classical methods, explain their difficulty via Mahowald's Uncertainty Principles, and describe a new technique using motivic homotopy theory. This new technique yields streamlined computations through previously known range, and gives new computations through dimension 90. We will also discuss questions and conjectures for future study.

13:15 - 14:00

Track: Combinatorics
Type: 13. Combinatorics
Room: Room 8
Moderator: Gil Kalai
Sectional Speaker: Isabella Novik

Face numbers: the upper bound side of the story

What is the largest number of i-dimensional faces that a simplicial polytope of dimension d with n vertices can have? What about the largest possible number of i-dimensional faces that a triangulation of a $(d$ - 1)-sphere can have? What are the maximizers? How common or rare are they? How do the answers change if the object in question must be centrally symmetric (i.e., endowed with a free action of $Z/2Z$)? This talk will be a survey of what is known and what is still unknown in this fascinating field, with an emphasis on some recent developments.

13:15 - 14:00

Track: Logic
Type: 1. Logic
Room: Room 9
Moderator: Ulrich Kohlenbach
Sectional Speaker: Keita Yokoyama

Reverse mathematics from multiple points of view

Reverse mathematics is a program in mathematical logic that was initiated by H. Friedman in the 1970s and developed by S. Simpson and others. The aim of the program is to classify mathematical theorems by comparing them with various types of axioms, typically set-existence and induction axioms in the formal system for the natural numbers and their subsets. The strength of axioms can be measured by several different viewpoints, such as consistency strength or computability strength, which are heavily connected to various fields of mathematical logic. Recently, the field of reverse mathematics has been widely expanding with newer perspectives and techniques. In this talk, we overview the recent developments of reverse mathematics and their connections to related fields.

13:15 - 14:00

Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 10
Moderator: Gerhard Huisken
Sectional Speaker: Rupert Frank

Lieb-Thirring Inequalities: What we know and what we want to know

Lieb-Thirring inequalities are functional inequalities that generalize Sobolev inequalities and that have proved to be powerful tools in several questions from mathematical physics, PDEs and functional analysis. Recently, in the spirit of Lieb-Thirring inequalities, certain inequalities in harmonic analysis were extended to the setting of orthonormal functions. In this talk we give a gentle introduction to classical aspects of the subject, some recent progress and some open problems.

13:15 - 14:00
Track: Combinatorics
Type: Special Sectional Lecture
Room: Room 11
Moderator: Sujatha Ramdorai
Sectional Speaker: Jennifer Tour Chayes

Graphons and Graphexes as Limits and Models of Large Sparse Graphs

Graphons and graphexes are limits of graphs which allow us to model and to estimate properties of large-scale networks. They are now widely used in the machine learning of real-world networks. I start with the theory of dense graph limits, and then give two alternative approaches for limits of sparse graphs (those that occur most often in nature) -- one leading to unbounded graphons over probability spaces, and the other leading to bounded graphons and graphexes over sigma-finite measure spaces. I then recast the limits of dense graphs in terms of exchangeability and the Aldous-Hoover Theorem, and generalize this using Kallenberg's Theorem to obtain sparse graphons and graphexes as limits of subgraph samples from sparse graph sequences. This will provide a dual view of sparse graph limits as processes and random measures, an approach which allows a generalization of many of the well-known results and techniques for dense graph sequences.

14:15 - 15:00
Track: Geometry
Type: 5. Geometry
Room: Room 1
Moderator: Mahan Mj
Sectional Speaker: Lu Wang

Entropy in mean curvature flow

The entropy of a hypersurface is defined by the supremum over all Gaussian integrals with varying centers and scales, thus invariant under rigid motions and dilations. It measures geometric complexity and is motivated by the study of mean curvature flow. We will survey recent progress on conjectures of Colding—Ilmanen—Minicozzi—White concerning the sharp lower bound on entropy for hypersurfaces, as well as their extensions.

14:15 - 15:00
Track: Mathematical Physics
Type: 11. Mathematical Physics
Room: Room 2
Moderator: Volker Bach
Sectional Speaker: Jan Philip Solovej

The Ground State of Quantum Gases

I will discuss the ground state of many-body quantum gases. In particular, I will discuss the asymptotics of the ground state energy of Bose gases in the dilute limit. The main focus will be the recent proof of the celebrated two term asymptotic formula suggested by Lee, Huang, and Yang in 1957. The formula can be understood from Bogolubov's celebrated theory of superfluiditry and thus can be seen as a validation of this theory. This is joint work with Søren Fournais. I will also briefly discuss gases in dimensions one and two and related questions for fermions. For gases in dimension one this is joint work with Agerskov and Reuvers.

14:15 - 15:00
Track: Probability
Type: 12. Probability
Room: Room 3
Moderator: Durvudkhan Suragan
Sectional Speaker: Ronen Eldan

Revealing the simplicity of high-dimensional objects via pathwise analysis

A common motif in high dimensional probability and geometry is that the behavior of objects of interest is often dictated by their marginals onto a fixed number of directions. This is manifested in the fact that several classical functional inequalities are *dimension free* (i.e., have no explicit dependence on the dimension), the extremizers of those inequalities being functions or sets that only depend on a fixed number of variables. Another related example comes from statistical mechanics, where Gibbs measures can often be decomposed into a small number of "pure states" which exhibit a simple structure that only depend on a small number of directions in space.
In this talk, I will present an emerging technique that helps reveal phenomena of this nature. This technique is based on pathwise analysis: We construct a stochastic process, driven by Brownian motion, associated with a given high-dimensional object. This process allows us to associate quantities related to the object with corresponding properties of the stochastic process, thus making the former tractable via the analysis of the latter (for example, through differentiation with respect to time).
I will try to explain how this technique works and will briefly discuss several results that stem from it, including functional inequalities in Gaussian space, concentration inequalities in high-dimensional convexity, concentration of measures on the discrete hypercube, as well structure theorems which ensure decomposition of Gibbs measures into product-like components.

14:15 - 15:00
Track: Lie Theory and Generalizations
Type: 7. Lie Theory and Generalizations
Room: Room 4
Moderator: Michael Pevzner
Sectional Speaker: Joel Kamnitzer

Perfect bases in representation theory: three mountains and their springs

In order to give a combinatorial descriptions of tensor product multiplicites for semisimple groups, it is useful to find bases for representations which are compatible with the actions of Chevalley generators of the Lie algebra. There are three known examples of such bases, each of which flows from geometric or algebraic mountain. Remarkably, each mountain gives the same combinatorial shadow: the crystal $B(\infty)$ and the Mirković–Vilonen polytopes. In order to distinguish between the three bases, we introduce measures supported on these polytopes. We also report on the interaction of these bases with the cluster structure on the coordinate ring of the maximal unipotent subgroup.

14:15 - 15:00

Track: Mathematics of Computer Science
Type: 14. Mathematics of Computer Science
Room: Room 5
Moderator: Anna Gilbert
Sectional Speaker: Tali Kaufman

Nowhere to go but high: a perspective on high-dimensional expanders

"Nowhere to go but in" is a well-known statement of Osho. Osho meant to say that the answers to all our questions should be obtained by looking into ourselves. In a paraphrase to Osho's statement we say "Nowhere to go but high." This is meant to demonstrate that for various seemingly unrelated topics and questions, the only way to get significant progress is via the prism of a new philosophy (new field) called high-dimensional expansion. In this talk we give an introduction to the high-dimensional expansion philosophy, and how it has been useful recently in obtaining progress in various questions in seemingly unrelated fields.

14:15 - 15:00

Track: Statistics and Data Analysis
Type: 17. Statistics and Data Analysis
Room: Room 6
Moderator: Chenyang Xu
Sectional Speaker: Francis Bach

Gradient descent on infinitely wide neural networks: Global convergence and generalization

Many supervised machine learning methods are naturally cast as optimization problems. For prediction models which are linear in their parameters, this often leads to convex problems for which many mathematical guarantees exist. Models which are non-linear in their parameters such as neural networks lead to non-convex optimization problems for which guarantees are harder to obtain. I will consider two-layer neural networks with homogeneous activation functions where the number of hidden neurons tends to infinity, and show how qualitative convergence guarantees may be derived.

14:15 - 15:00

Track: Algebraic and Complex Geometry
Type: 4. Algebraic and Complex Geometry
Room: Room 7
Moderator: Lars Hesselholt
Sectional Speaker: Peter Zograf

Counting lattice points in moduli spaces of quadratic differentials (after a joint work with V. Delecroix, É. Goujard, and A. Zorich)

We show how to count lattice points represented by square-tiled surfaces in the moduli spaces of meromorphic quadratic differentials with simple poles on complex algebraic curves. We demonstrate the versatility of the lattice point count on three different examples, including evaluation of Masur-Veech volumes of the moduli spaces of quadratic differentials, computation of asymptotic frequencies of geodesic multicurves on hyperbolic surfaces, and asymptotic enumeration of meanders with a fixed number of minimal arcs.

14:15 - 15:00
Track: Combinatorics
Type: 13. Combinatorics
Room: Room 8
Moderator: Gil Kalai
Sectional Speaker: Mathias Schacht

Restricted extremal problems in hypergraphs

Extremal problems for 3-uniform hypergraphs concern the maximum cardinality of a set E of 3-element subsets of a given n-element set V such that for any l elements of V at least one triple is missing in E. This innocent looking problem is still open, despite a great deal of effort over the last 80 years. We consider a variant of the problem by imposing additional restrictions on the distribution of the 3-element subsets in E, which are motivated by the theory of *quasirandom hypergraphs*. These additional assumptions yield a finer control over the corresponding extremal problem. In fact, this leads to many interesting and more manageable subproblems, some of which were already considered by Erdos and Sós in the 1980ies. We discuss a unifying framework for these problems and report recent progress.

14:15 - 15:00
Track: Logic
Type: 1. Logic
Room: Room 9
Moderator: Ulrich Kohlenbach
Sectional Speaker: Dmitriy Zhuk

Constraint Satisfaction Problem: what makes the problem easy

Many combinatorial problems, such as graph coloring or solving linear equations, can be expressed as the constraint satisfaction problem for some constraint language. In the talk we first discuss a proof of a famous conjecture stating that for any constraint language the problem is either solvable in polynomial time, or NP-complete. Then we consider other variants of this problem whose complexity is still not known. For instance, we could allow both universal and existential quantifiers, or require the input or the solution to satisfy an additional condition.

14:15 - 15:00
Track: Partial Differential Equations
Type: 10. Partial Differential Equations
Room: Room 10
Moderator: Gerhard Huisken
Sectional Speaker: Zhifei Zhang

Hydrodynamic stability at high Reynolds number and Transition threshold problem

The hydrodynamic stability theory is mainly concerned with how the laminar flows become unstable and transit to turbulence at high Reynolds number. To shed some light on the transition mechanism, Trefethen et al. [Science 261(1993)] proposed the transition threshold problem. Many physical effects such as 3-D lift-up, inviscid damping, enhanced dissipation and boundary layer, play a crucial role in determining the transition threshold. In this talk, I will survey some important progress on linear inviscid damping and enhanced dissipation for shear flows. I will outline key ideas and main ingredients in our proof of transition threshold for 3-D Couette flow in a finite channel.

14:15 - 15:00
Track: Number Theory
Type: 3. Number Theory
Room: Room 11
Moderator: Sujatha Ramdorai
Sectional Speaker: Ye Tian

The arithmetic of quadratic twists of elliptic curves

We discuss the behavior of Selmer groups and L-values of elliptic curves under quadratic twists. The congruent number problem is a basic example in this topic. A brief overview of some progress towards the BSD conjecture will also be discussed.

15:30 - 16:30
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Shafi Goldwasser
Plenary Speaker: Craig B. Gentry

Homomorphic Encryption

Is it possible to delegate processing of data without giving away access to it? For example, can I query a search engine, and get a useful response, without telling the search engine what I am searching for? Can I send my encrypted financial information to an online tax service, and get back an encrypted completed tax form?

Using an "ordinary" encryption system, it is virtually impossible for someone without the secret decryption key to manipulate the underlying encrypted data in any useful way. However, some encryption systems are "homomorphic" or "malleable". In a homomorphic encryption system, the decryption function is a homomorphism that commutes with operations like addition and multiplication. This homomorphic property allows anyone to manipulate (in a meaningful way) what is encrypted, without knowing the secret key, by operating on ciphertexts.

This talk will survey basic concepts in modern cryptography and complexity theory, including how to prove the security of a system by reducing it to the (assumed) computational infeasibility of well-known mathematical problems, such as factoring large integers. And it will highlight the main ideas behind recent "fully homomorphic encryption" systems, which allow arbitrarily complex functions to be computed on data while it remains encrypted.

16:45 - 17:45
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Sanjeev Arora
Plenary Speaker: Umesh Vazirani

On the complexity of quantum many body systems

The ground state of a quantum system of n particles is the eigenvector of minimum eigenvalue of a matrix (the Hamiltonian) of dimension that scales exponentially in n. In this talk I will describe a recent body of work, inspired by concepts from quantum computation and information theory that shows that for a large class of 1D quantum systems the solution can be succinctly represented and computed in polynomial time on a classical computer.

Thursday, 14. July 2022

09:00 - 10:00
Track: Plenary
Type: Award
Room: Room 1
Chair: Carlos E. Kenig
Plenary Speaker: Nikolai Andreev

Leelavati Prize Lecture

10:15 - 10:30
Track: Plenary
Type: Award
Room: Room 1
Chair: Carlos E. Kenig

Leelavati video

13:15 - 14:15
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Carlos E. Kenig
Plenary Speaker: Larry Guth

Decoupling estimates in Fourier analysis

Decoupling is a recent development in Fourier analysis, which has applications in harmonic analysis, PDE, and number theory. We survey some applications of decoupling and some of the ideas in the proof.

14:30 - 15:30
Track: Plenary
Type: Plenary Lecture
Room: Room 1
Chair: Artur Avila
Plenary Speaker: Svetlana Jitomirskaya

Small denominators and multiplicative Jensen's formula

Small denominator problems appear in various areas of analysis, PDE, and dynamical systems, including spectral theory of quasiperiodic Schrödinger operators, non-linear Schrödinger equations, and non-linear wave equations. These problems have traditionally been approached by KAM-type constructions. We will discuss the new methods, originally developed in the spectral theory of quasiperiodic Schrödinger operators, that are both onsiderably simpler and lead to results completely unattainable through KAM techniques. For one-dimensional quasiperiodic operators, these methods have enabled precise treatment of various types of resonances and their combinations, leading to proofs of sharp (arithmetic) spectral transitions, the ten martini problem, and the discovery of universal hierarchical structures of eigenfunctions. The related theory of the dynamics of corresponding linear cocycles leads to a surprising extension of the classical Jensen's formula.

15:45 - 16:45
Track: Plenary
Type: Ceremony
Room: Room 1
Plenary Speaker: Carlos E. Kenig

Closing Remarks