5th European Congress of Mathematics
Amsterdam, The Netherlands, July 14–18, 2008

EMS Prizes and Felix Klein Prize

Citations and Abstracts of Prize Winner's Lectures

23rd June 2008

1 EMS Prizes

The EMS prizes are awarded by the European Mathematical Society in recognition of distinguished contributions in Mathematics by young researchers not older than 35 years. The prizes are presented every four years at the European Congress of Mathematics.

The EMS Prize Committee is appointed by the EMS and consists of a number of recognized mathematicians from a wide variety of fields. The prizes were first awarded in Paris in 1992, followed by Budapest in 1996, Barcelona in 2000, Stockholm in 2004. During 5ECM in Amsterdam, the prizes will be awarded on July 14, 2008. Each prize winner will receive 5,000 Euro.

The prize money has been generously made available by the Dutch Foundation Compositio Mathematica.

EMS Prize Committee

Chair: Robert Tijdeman, Leiden
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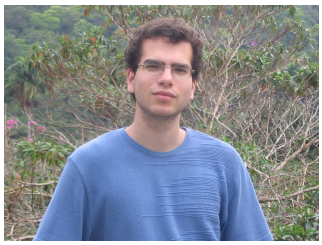
The names, citations and abstracts of the ten EMS Prize Winners are given on the next ten pages. Two of them, Artur Avila and Laure Saint-Raymond, were also selected as **invited speakers**, by the EMS Scientific Committee.



Artur Avila

Full name: Artur Avila Cordeiro de Melo, born: June 29, 1979; citizenship: Brazilian; Ph.D.: IMPA Rio de Janeiro, Brazil; presently: Clay Mathematics Institute, Paris 6, France and IMPA, Rio de Janeiro, Brazil.

Artur Avila has obtained many important results in dynamical systems, especially in the theory of iterated rational maps and the Teichmüller geodesic flow. Several of them provide the final solution to longstanding and major problems, for example: his proof with Lyubich that there are infinitely renormalizable Julia sets in the quadratic family $f(z) = z^2 + c$ with Hausdorff dimension strictly less than 2, his proof with Jitomirskaya of the "ten Martini Conjecture" of B. Simon, his proof with Viana of the Kontsevich-Zorich conjecture on symplicity of the Lyapunov spectrum for the Teichmüller geodesic flow, his proof with Forni that almost every interval exchange which does not have the combinatorics of a rotation is weakly mixing and his proof with Gouëzel and Yoccoz of exponential mixing for the Teichmüller flow. He is internationally recognized as a leader of research in these areas.

Prize Winner's Lecture **Thursday, July 17, 10:30-11:15, Room B2**

Dynamics of quasiperiodic cocycles and the spectrum of the almost Mathieu operator

Abstract: The almost Mathieu operator $H = H_{\lambda,\alpha,\theta} : \ell^2(\mathbb{Z}) \to \ell^2(\mathbb{Z})$ is given by

$$(Hu)_n = u_{n+1} + u_{n-1} + 2\lambda \cos 2\pi(\theta + n\alpha)u_n,$$

where λ (the coupling), α (the frequency) and θ (the phase) are parameters. Originally introduced and studied in the physics litterature, it turned out to also give rise to a rich mathematical theory, where algebra, analysis and dynamical systems interact. Among some key distinguishing features, we point out the presence of a remarkable symmetry (Aubry duality) between large and small couplings, and a sharp phase transition at the self-dual point $\lambda = 1$.

We stress that there is also qualitative dependence with respect to the frequency and the phase (related to their Diophantine properties), and which makes it particularly tough to achieve a description of the whole parameter space. Neverthless key natural questions (regarding the topology and measure of the spectrum, but also the nature of the spectral measures) have recently been fully addressed.

We will discuss these and related questions which focused the developments since 1980, emphasizing the connection with the dynamics of quasiperiodic cocycles which has played a fundamental role in the latest contributions.

Alexei Borodin

Born: June 25, 1975; citizenship Russian; Ph.D.: Univ. Pennsylvania, U.S.A. 2001; presently: CalTech, Pasadena, U.S.A.

Alexei Borodin has made substantial contributions to the representation theory of "big" groups, to combinatorics, interacting particle systems and random matrix theory. A key observation of Borodin and Olshanski in the representation theory of big groups is that the irreducible characters for the group are associated with stochastic point processes. Borodin found a determinantal formula for the correlation functions of the so-called generalized regular representation of the infinite symmetric group and, with Olshanski, also of the unitary group. A stunning consequence of his work is one of the first proofs of a conjecture of Baik, Deift and Johansson in Combinatorics. In later work Borodin analyzed the irreducible character associated with the generalized regular representation. Borodin and his collaborators also developed a radical new approach for analyzing totally antisymmetric simple exclusion processes. Equally remarkable is his work on isomonodromy transformations of linear systems of difference equations and his solution of a problem of Widom on the spectrum of some matrix. Borodin is a brillant mathematician.

Prize Winner's Lecture **Monday, July 14, 13:00-13:45, Room E-F**

Random surfaces in dimensions two, three, and four

Abstract: The goal of the talk is to survey recent results on various classes of random surfaces with focus on their asymptotic behavior. Examples include random partitions, driven interacting particle systems, and random tilings. No preliminary knowledge of the material will be assumed.

Ben Green

Full name: Ben Joseph Green, born: February 27, 1977; citizenship: British; Ph.D.: University of Cambridge, 2002; presently University of Cambridge, England.

Ben Green is best known for his celebrated result with Terence Tao that there exist arbitrarily long arithmetic progressions of primes. Some basic ideas for the proof can already be found in the earlier work of Green. Therein he proved that every relative dense subset of the primes contains an arithmetic progression of length 3. In another paper he improved a result of Bourgain on the sumset of two dense subsets of an interval. Where Bourgain obtained a lower bound $1/3$ in the exponent and Ruzsa an upper bound $2/3$, Green got a lower bound $1/2$. One of the essential steps in the proof of the famous result with Tao is the discovery by Green that the work of Goldston and Yildirim on short intervals between primes provided precisely the "random-like" superset of the primes that they needed. After their proof Green and Tao have continued their investigations. This has allowed them to give an asymptotic for how many progressions of length 4 there are in the primes up to N. By now Green has a string of highly impressive results.

Prize Winner's Lecture **Wednesday, July 16, 10:30-11:15, Room E-F**

Patterns of primes

Abstract: I shall talk about joint work with Terence Tao on configurations of prime numbers. In particular I shall talk about the ideas required to obtain an asymptotic for the number of 4-term arithmetic progressions of primes $p_1 < p_2 < p_3 < p_4 \leq N$. I shall also discuss progress towards a much more general result on patterns of primes.

Olga Holtz

Name: Olga V. Holtz; born: August 19, 1973; citizenship: Russian; Ph.D.: University of Wisconsin-Madison, 2000; presently: Technische Universität Berlin, Germany, and University of California-Berkeley, U.S.A.

Olga Holtz has made substantial contributions to several mathematical areas including algebra, numerical linear algebra, approximation theory, theoretical computer science and numerical analysis. Some of these are spectacular results such as the proof of the Newton inequalities for M-matrices, the fundamental work on accurately evaluating polynomials in finite arithmetic and the proof that all group theory based fast matrix multiplication methods are numerically stable. These are not only very strong results in theoretical computer science that may have a fundamental impact on computational methods of the coming years, but they also required very deep mathematical theory in the context of finite group theory. Her new work on zonotopal algebra is a substantial contribution to combinatorial commutative algebra. Olga Holtz is a mathematician who truly transcends the traditional boundaries of applied versus pure mathematics.

Prize Winner's Lecture **Monday, July 14, 13:50-14:35, Room C-D**

Complexity and stability of linear problems

Abstract: Applied mathematics relies on linearization as its main tool to solve various problems, be they ODEs, PDEs, integral equations, optimization problems, or statistical data analysis. The linearized problems are subsequently handled by numerical linear algebra algorithms, whose complexity (running time) and numerical stability (performance under computational error) are thus of importance for all applied mathematics.

The talk will offer an introduction and overview of the theoretical framework for complexity and error analysis of numerical linear algorithms. From the relevant work of Gauss to the most recent results connecting complexity and stability of matrix-matrix multiplication, this area has deep connections with pure mathematics, including group and ring theory, tensor analysis, and algebraic geometry. The intent of the speaker is to highlight these beautiful connections and to discuss future challenges.

Bo'az Klartag

Born: April 25, 1978; citizenship: Israeli; Ph.D.: Tel-Aviv University, 2004; presently: Clay Mathematics Institute, Princeton University, U.S.A.

Bo'az Klartag's main achievements are in Asymptotic Geometric Analysis. He has solved a number of long standing problems in this field. He broke the record on the minimum number of symmetrization steps of convex bodies required to transform them into near balls, thereby solving problems posed by Hadwiger and Bourgain-Lindenstrauss-Milman. He solved a slicing problem posed by Bourgain 20 years ago, exhibiting novel ideological and technical ideas. This work has a strong impact on Functional Analysis. He proved a central limit theorem for convex bodies, a beautiful result bringing, in a novel way ideas of Convex Geometry into Probability Theory. With Feffermann he solved a fundamental problem on optimal extrapolation of smooth functions. Bo'az Klartag is a surprisingly productive young mathematician who has succeeded, in a very short time, to make breakthroughs in a number of different directions of major significance in modern analysis.

Prize Winner's Lecture **Thursday, July 17, 10:30-11:15, Room C-D**

High-dimensional distributions with convexity properties

Abstract: We review recent advances in our understanding of probability measures with geometric characteristics on R^n, for large n. These advances include the central limit theorem for convex sets, according to which the uniform measure on a high-dimensional convex body has marginals that are approximately gaussian.

Alexander Kuznetsov

Born: November 1, 1973; citizenship: Russian; Ph.D.: Moscow State University, 1998; presently: Steklov Mathematical Institute, Moscow, Russia.

Kuznetsov has made fundamental contributions to birational projective geometry, representation theory, mathematical physics, homological algebra, and non-commutative geometry. A trademark of his work is the blend of his ground-breaking ideas and technical sophistication. His work on birational projective geometry includes theories of homological Lefschetz decompositions, homological projective duality and categorical resolutions of singularities. Kuznetsov boldly and innovatively combines several ideas ranging from very classical algebraic geometry such as Mori's Minimal Model Program to such hot topics as Kontsevich's Homological Mirror Symmetry Program. His techniques can be used in situations where the conventional constructions do not apply and thus extend the range of birational projective geometry considerably. Kuznetsov's work is a great source of inspiration.

Prize Winner's Lecture **Monday, July 14, 15:55-16:40, room C-D**

Derived categories and rationality of cubic fourfolds

Abstract: I will describe the structure of the derived category of coherent sheaves on a 4-dimensional cubic hypersurface and discuss an approach to the rationality problem. I will propose a conjectural criterion of rationality of a cubic fourfold in terms of its derived category and describe several examples.

Assaf Naor

Born: May 7, 1975; citizenship: Czech/Israeli; Ph.D.: Hebrew University, Jerusalem, Israel; presently Courant Institute, New York, U.S.A.

Assaf Naor has made ground-breaking contributions to three mathematical fields: functional analysis, the theory of algorithms and combinatorics. Naor is the leading architect of the modern theory of non-linear functional analysis: a theory that has taken off in recent years and has become an essential tool in mathematical computer science. Among other things, Naor and a variety of collaborators discovered an unpredicted threshold phenomenon in the non-linear Dvoretzky Theorem, found a non-linear analogue of the cotype invariant and proved a sophisticated non-linear analogue of the celebrated Maurey-Pisier Theorem. Naor's work has led to essentially optimal embeddings of finite subsets of L_1 into Hilbert space and thence, the best available polynomial time approximation algorithm to compute the sparsest cut in a network with several commodities. Assaf Naor's versatility, originality and technical power are overwhelming and his work has a profound influence on functional analysis and mathematical computer science.

Prize Winner's Lecture **Thursday, July 17, 11:20-12:05, Room C-D**

The story of the Sparsest Cut problem

Abstract: In the past decade methods from Riemannian geometry and Banach space theory have become a central tool in the design and analysis of approximation algorithms for a wide range of NP hard problems. In the reverse direction, problems and methods from theoretical computer science have recently led to solutions of long standing problems in metric geometry. This talk will illustrate the connection between these fields through the example of the Sparsest Cut problem. This problem asks for a polynomial time algorithm which computes the Cheeger constant of a given finite graph. The Sparsest Cut problem is known to be NP hard, but it is of great interest to devise efficient algorithms which compute the Cheeger constant up to a small multiplicative error. We will show how a simple linear programming formulation of this problem leads to a question on bi-Lipschitz embeddings of finite metric spaces into L_1, which has been solved by Bourgain in 1986.

We will then proceed to study a quadratic variant of this approach which leads to the best known approximation algorithm for the Sparsest Cut problem. The investigation of this "semidefinite relaxation" leads to delicate questions in metric geometry and isoperimetry, in which the geometry of the Heisenberg group plays an unexpected role.

Laure Saint-Raymond

Born: August 4, 1975, citizenship: French; Ph.D.: Paris VII, France, 2000; presently: ENS Paris, France.

Laure Saint-Raymond is well known for her outstanding results on nonlinear partial differential equations in the dynamics of gases and plasmas and also in fluid dynamics. Her most striking work concerns the study of the hydrodynamic limits of the equation of Boltzmann in the kinetic theory of gases, where she answered a question posed by Riemann within the framework of his 6th problem. Recently, in collaboration with I. Gallagher, she aims at understanding the equations of rotating fluids within the limit where the number of Rossby tends to 0. They have already obtained surprising results in this direction. At 32 years, Laure Saint-Raymond is at the origin of several outstanding and difficult results in the field of nonlinear partial differential equations of mathematical physics. She is one of the most brilliant young mathematicians in her generation.

Prize Winner's Lecture **Monday, July 14, 13:00-13:45, Room C-D**

Some results about the sixth problem of Hilbert

Abstract: The aim of this lecture is to present some mathematical results describing the transition from kinetic theory, and more precisely from the Boltzmann equation for perfect gases to hydrodynamics. Different fluid asymptotics will be investigated, starting always from solutions of the Boltzmann equation which are only assumed to satisfy the estimates coming from physics, namely some bounds on mass, energy and entropy.

We will introduce some tools for the derivation of these hydrodynamic limits. We will first comment on the entropy inequality which provides uniform a priori estimates on the distribution (depending on the scaling to be considered). We will then explain how these bounds, especially that on the entropy dissipation, allow to control the relaxation mechanism towards local thermodynamic equilibrium. We will finally study the balance between that relaxation process due to collisions, and the other important physical mechanism, namely the free transport : in viscous regimes the global structure of the scaled Boltzmann equation is actually of hypoelliptic type, and one can exhibit some regularizing effect of the free transport.

The incompressible Navier-Stokes limit is the only hydrodynamic asymptotics for which we are able to implement all these tools and for which an optimal convergence result is known. By "optimal", we mean that this convergence result holds globally in time, does not require any assumption neither on the initial velocity profile nor on the initial thermodynamic fields, and that it takes into account boundary conditions, and describes their limiting form.

The state of the art about the incompressible Euler limit is not so complete. Due to the lack of regularity estimates in inviscid regimes, the convergence results describing the incompressible Euler asymptotics of the Boltzmann equation require in particular some additional regularity assumptions on the solution to the target equations.

Agata Smoktunowicz

Born: October 12, 1973; citizenship: Polish; Ph.D.: PAN, Warsaw, Poland; presently: University of Edinburgh, Scotland and Institute of Mathematics of the Polish Academy of Sciences.

Agata Smoktunowicz has solved a number of outstanding problems in noncommutative algebra. She has made the first significant progress for decades on some fundamental problems concerning nil rings. The most spectacular of these results is the construction, over any countable field, of a simple nil algebra. This solves a famous problem of Levitsky, Jacobson and later Kaplansky from around 1970. This work is a technical tour-de-force. Other outstanding problems she has solved include an answer to a problem about polynomial rings over nil rings first asked by Amitsur in 1971, the proof of the Artin-Stafford Gap Theorem for graded domains, and the first examples of finitely generated nil, but not nilpotent algebras with polynomially bounded growth. In all her work, Smoktunowicz has introduced novel techniques and constructions and she displays a great ability to deal with long, difficult and technically demanding calculations.

Prize Winner's Lecture **Tuesday, July 15, 10:30-11:15, Room E-F**

On some open questions in noncommutative ring theory

Abstract: The aim of this talk is to analyse the diversity of some important classes of infinite-dimensional algebras with respect to their properties and their connections with other branches of mathematics. All the mentioned algebras are noncommutative and associative. The first part of the talk will focus on infinite-dimensional algebraic algebras, Golod-Schafarevich algebras, algebras with many generic relations and the Jacobson radical algebras. Some connections with combinatorial group theory and Lie algebras will be mentioned. In the middle part of the talk I will concentrate on growth properties of algebras and connections with the noncommutative algebraic geometry. In the last part of the lecture I will mention some long-standing open questions in the general ring theory, such as Kurosh problem for domains, Koethes conjecture, Anicks conjecture for quadratic algebras, Latyshevs question on finitely generated division rings and Amitsurs conjecture on finitely presented algebras. Some recent open questions on growth of algebras also will be discussed.

Cédric Villani

Born: October 5, 1973; citizenship: French; Ph.D.: ENS, Paris, France, 1998; presently: ENS Lyon, France.

Cédric Villani has contributed to the theory of non-equilibrium statistical mechanics, in particular in connection with the Boltzmann equation and the Landau equation in plasma physics. He proved the Cercignani conjecture and obtained with Desvillettes the first convergence result to a global gaussian equilibrium for the Boltzmann equation without any smallness assumption. A second component of Villani's work is at a crosspoint between probability, functional analysis, partial differential equations, differential and Riemannian geometries. With Otto he studied the link between diffusion equations, Talagrand inequalities and logarithmic Sobolev inequalities. More recently, Lott and Villani obtained a new characterization of Riemannian manifolds with bounded Ricci curvature from below, in terms of convexity of the Boltzmann entropy with respect to optimal transportation (Monge-Kantorovich-Wasserstein) metrics. By his way of looking at problems Villani has inspired many.

Prize Winner's Lecture **Monday, July 14, 15:05-15:50, Room C-D**

Optimal transport and Riemannian geometry: Monge meets Riemann

Abstract: The theory of optimal transport of measures, which has traditionally developed itself as a branch of probability theory and calculus of variations, has during the past two decades considerably expanded to reach new territories such as the theory of dynamical systems, partial differential equations, fluid mechanics and Riemannian geometry. In this talk I shall focus on recent advances about the links between optimal transport and Riemann curvature, focusing on Ricci curvature and some nonlocal variants of sectional curvature.

2 Felix Klein Prize

The Felix Klein Prize has been established by the European Mathematical Society and the endowing organization: the Institute for Industrial Mathematics in Kaiserslautern. It is awarded to a young scientist or a small group of young scientists (normally under the age of 38) for using sophisticated methods to give an outstanding solution to a concrete and difficult industrial problem, which meets with the complete satisfaction of industry. The Prize is presented every four years at the European Congresses of Mathematics. The prize committee consists of six members appointed by agreement of the EMS and the Institute for Industrial Mathematics in Kaiserslautern. The first prize was presented at 3ecm in Barcelona to David C. Dobson. During 4ecm in Stockholm, no Felix Klein Prize was awarded. The second Felix Klein Prize will be presented during 5ecm in Amsterdam to **Josselin Garnier**. It carries a monetary award of 5,000 Euros.

Felix Klein Prize Committee

Chair: Yvon Maday, Paris
Louis Bonilla, Madrid
Willi Jäger, Heidelberg
Axel Klar, Kaiserslautern
Arjen Lenstra, Lausanne
Helmut Neunzert, Kaiserslautern

Josselin Garnier

Born: June 18, 1971; citizenship: French; Ph.D.: École Polytechnique, 1996; presently: Université Paris 7.

Josselin Garnier was appointed associate Professor in Mathematics in Toulouse at the (remarkably young) age of 30, and he joined the Université Paris Diderot (Paris 7) in 2005, where he became a full professor in 2007. He is affiliated to the Laboratoire de Probabilités et Modèles Aléatoires and the Laboratoire Jacques Louis Lions. He is also a scientific consultant at the Nuclear Energy Agency (CEA), he has a number of research contracts with many teams of CEA, with the French Electric Company (EDF), and with the European Aeronautic Defence and Space company (EADS). In 2006, he has been one of the organizers (with Guillaume Bal and Didier Lucor) of the CERMRACS summer activity of SMAI that aims at promoting the collaboration between academic and industrial mathematicians on dedicated problems.

His research is at the interface of stochastics and applied analysis, and the fields of applications are mainly in optics, wave propagation and plasma physics. He is a leading scientist dealing with probabilistic aspects in the framework of partial differential equations and he has shown his ability to apply powerful theoretical tools to deal with real industrial problems.

Josselin Garnier has both an impressive academic curriculum (wave propagation in random medium where a recent breakthrough is the analysis of time reversal of the wave when the medium is randomly layered, first proof of the existence of solitons in random media with qualitative and

quantitative information, analysis of Bose-Einstein condensates...) where he has published numerous high level publications in international scientific journals both in the mathematical area and in applied physics area but he is also deeply involved in real applications (new techniques in imaging for the detection of buried objects, telecommunication for comparison of signal-to-noise ratio and signal-to-interference ratio for various protocols in wireless communication, design of the target in the Laser Mega Joule experimental device in the framework of Inertial Confinement Fusion, problems in aeronautics where for acoustic problems, electromagnetic compatibility analysis, design of antennas.... the industrial conception has to incorporate now Random modeling and uncertainty management). Finally he knows very well the state-of-the-art about most of the numerical methods in Computational Fluid Dynamics and he can provide very useful orientations for robust simulations of these problems.

Felix Klein Prize Winner's Lecture **Monday, July 14, 13:50-14:35, Room E-F**

Passive Sensor Imaging Using Cross Correlations of Noisy Signals

Abstract: In this talk we consider the problem of estimating the Green's function of the wave equation in an inhomogeneous medium. A new passive method using only ambient noise has been recently proposed. It is based on the property that the Green's function between two sensors can be estimated from the cross correlation of ambient noise recorded by the sensors. Cross correlation of noise records can be used for geophysical imaging: the cross correlation contains information about the Green's function from which the travel time can be obtained. The background propagation velocity can then be estimated from the travel times between sensors in a network covering the region of interest.

We will discuss the theoretical conditions required to observe the emergence of the Green's function between two sensors from the cross correlation of noise records. We will show that fourth-order cross correlations can also be used with auxiliary sensors in order to enhance travel time estimation in a scattering medium. We will also discuss passive sensor imaging of reflectors by suitably migrating the cross correlations. We will show that reflectors can be imaged in a scattering medium with passive sensor networks by migrating suitable fourth-order cross correlations.

The talk will survey joint work with G. Papanicolaou (Stanford) and K. Solna (UC Irvine).