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INTRODUCTION

I am very pleased to write an introduction to this brochure devoted to the prizes presented at the Opening Ceremony of the 6 ECM in Kraków, on the second of July, 2012. This gives me an exceptional opportunity to congratulate the winners for their outstanding findings and work and to express our thanks to the members of the three prize committees, for their wonderful although difficult task in making their choices among a considerable number of remarkable candidates.

Twelve prizes are awarded: ten EMS Prizes to young researchers in recognition of excellent contributions to Mathematics; the Felix Klein Prize to a young scientist for giving an outstanding solution to an industrial problem; the Otto Neugebauer in the History of Mathematics for a highly original and influential specific piece of work.

The EMS Prizes were first awarded at the 1 ECM in Paris 1992 and since then, at each ECM. Twenty years after, they are considered one of the most prestigious prizes in mathematics for young talented mathematicians. The funding for the 6 ECM EMS Prizes is generously provided by Foundation Compositio Mathematica.

The Felix Klein Prize was established by the EMS and the endowing organization the Institute for Industrial Mathematics in Kaiserslautern. It was first awarded at the 3 ECM in Barcelona 2000.

The Otto Neugebauer Prize is a tribute to the Austrian-American mathematician and historian of science who founded the review journals *Zentralblatt für Mathematik und ihre Grenzgebiete* and *Mathematical Reviews*. It was established by the EMS two years ago with the funding provided by Springer Verlag. It is awarded for the first time at the 6 ECM.

On behalf of the European Mathematical Society, I thank the sponsors of the prizes for their invaluable support to mathematics, and I wish to the prize winners every success in their future research careers.

Marta Sanz-Solé
President of the EMS

June, 2012

EMS Prize

Simon Brendle (STANFORD UNIVERSITY, USA)

For his outstanding results on geometric partial differential equations and systems of elliptic, parabolic and hyperbolic types, which have led to breakthroughs in differential geometry including the differentiable sphere theorem, the general convergence of Yamabe flow, the compactness property for solutions of the Yamabe equation, and the Min-Oo conjecture.

Simon Brendle is a Professor of Mathematics at Stanford University. He received his doctorate in 2001 under the supervision of Gerhard Huisken. He was an invited speaker at the International Congress of Mathematicians in Madrid (2006), and has held visiting professorships at ETH Zurich (2008) and Princeton University (2010). His work has focused on questions at the intersection of geometry and analysis, such as the Yamabe problem, the Ricci flow, the Sphere Theorem, and the Lawson conjecture.

Alexandrov's theorem in curved manifolds
Monday, July 2nd, 16:30, Large Hall A
A classical theorem due to A.D. Alexandrov asserts that the only embedded surfaces in Euclidean space with constant mean curvature are the round spheres. Alexandrov's theorem is closely related to the classical isoperimetric inequality, which asserts that round spheres have minimal surface area among all surfaces that enclose a given amount of volume.

It is an interesting question whether Alexandrov's theorem can be generalized to surfaces of constant mean curvature within a Riemannian manifold. In particular, if the ambient Riemannian manifold is rotationally symmetric, can one conclude that every embedded surface of constant mean curvature is a sphere of symmetry? We will give an answer to this question, and describe some unexpected links to general relativity.

EMS Prize

Emmanuel Breuillard (UNIVERSITÉ PARIS-SUD, ORSAY, FRANCE)

For his important and deep research in asymptotic group theory, in particular on the Tits alternative for linear groups and on the study of approximate subgroups, using a wealth of methods from very different areas of mathematics, which has already made a long lasting impact on combinatorics, group theory, number theory and beyond.

Emmanuel Breuillard graduated in mathematics and physics from the École Normale Superieure (Paris), then pursued graduate studies in Cambridge (UK) and Yale University (USA) where he obtained a Ph.D. in 2004. He is currently a professor of mathematics at the Université Paris-Sud, Orsay. Over the years his work has focused on various aspects of group theory and its interplay with geometry, ergodic theory, random walks, number theory and combinatorics. He was awarded the Peccot prize in 2006 by the Collège de France, and received a European Research Council grant in 2008.

Uniform spectral gaps in group theory
Monday, July 2nd, 16:30, Large Hall B
In recent years a number of new techniques were discovered in order to prove spectral gaps estimates for Cayley graphs of finite or infinite linear groups. These techniques are borrowed from many different branches of mathematics, from probability theory (random walks) to number theory (diophantine geometry) and combinatorics (approximate groups). I will give an overview of some aspects of this story and its recent developments.

EMS Prize

Alessio Figalli (UNIVERSITY OF TEXAS, AUSTIN, USA)

For his outstanding contributions to the regularity theory of optimal transport maps, to quantitative geometric and functional inequalities and to partial solutions of the Mather and Mañé conjectures in the theory of dynamical systems.

Alessio Figalli graduated in mathematics from the Scuola Normale Superiore of Pisa (2006) and he received a joint doctoral degree from the Scuola Normale Superiore of Pisa and the École Normale Supérieure of Lyon (2007). Currently he is a professor at the University of Texas at Austin. His research focuses on calculus of variations, optimal transportation, Monge-Ampère type equations and elliptic PDEs, geometric and functional inequalities, and weak Kolmogorov-Arnold-Moser (KAM) theory. He has received several prizes, including the Giuseppe Borgia Prize of the Accademia Nazionale dei Lincei (2008), the Faculty Fellowship of the Harrington Society (2009), and the Peccot-Vimont Prize from the Collège de France (2011).

Stability in functional inequalities and applications
Monday, July 2nd, 16:30, Medium Hall A
Geometric and functional inequalities play a crucial role in several problems arising in the calculus of variations, partial differential equations, geometry, etc. More recently, there has been a growing interest in studying the stability for such inequalities. The basic question one wants to address is the following: suppose we have a functional inequality for which minimizers are known. Can we prove, in some quantitative way, that if a function 'almost attains the equality' then it is close (in some suitable sense) to one of the minimizers? In recent years there have been several results in this direction, showing sharp stability results for the Euclidean/anisotropic isoperimetric inequality, the Brunn-Minkowski inequality on convex sets, the Gaussian isoperimetric inequality, Sobolev and Gagliardo-Nirenberg inequalities, etc. The aim of this talk is to review some of these result and show some applications.

EMS Prize

Adrian Ioana (UNIVERSITY OF CALIFORNIA SAN DIEGO, USA)

For his impressive and deep work in the field of operator algebras and their connections to ergodic theory and group theory, and in particular for solving several important open problems in deformation and rigidity theory, among them a long standing conjecture of Connes concerning von Neumann algebras with no outer automorphisms.

Adrian Ioana received a Ph.D. from the University of California, Los Angeles in 2007, for work under the supervision of Sorin Popa. He spent a subsequent year as a Taussky-Todd Instructor at the California Institute of Technology where he taught a graduate course on Functional Analysis. Currently he is an assistant professor at the University of California, San Diego. He was awarded a Clay Research Fellowship at UCLA for 2008–2011. His research topics include von Neumann algebras and ergodic theory.

Classification and rigidity for von Neumann algebras
Wednesday, July 4th, 17:00, Large Hall A
I will survey recent progress made on the classification of von Neumann algebras arising from countable groups and their actions on the probability spaces. In particular, I will present the first results which provide classes of (superrigid) groups and actions that can be entirely reconstructed from their von Neumann algebras.

EMS Prize

Mathieu Lewin (CNRS & UNIVERSITY OF CERGY-PONTOISE, FRANCE)

For his ground breaking work in rigorous aspects of quantum chemistry, mean field approximations to relativistic quantum field theory and statistical mechanics.

Mathieu Lewin studied mathematics at the École Normale Supérieure (Cachan), before moving to the university of Paris-Dauphine where he received Ph.D. in 2004. He currently holds a full-time CNRS research position at the University of Cergy-Pontoise, near Paris. His research focuses on applications of variational and spectral methods to models from quantum mechanics. Recently, he was awarded a starting grant from the European Research Council.

A nonlinear variational problem in relativistic quantum mechanics
Wednesday, July 4th, 17:00, Large Hall B

In a heavy atom, the core electrons move much faster than the ones of the outer shells. Relativistic effects are then important and the Dirac equation must be used. The Dirac operator is a differential operator of order one, whose spectrum is unbounded both from above and from below. Variational problems based on the Dirac operator are difficult to deal with, because of the lack of control on the energy functional.

In this talk I will present existence results for a rather unconventional variational problem based on the Dirac operator. In this model, the energy is a bounded-below nonlinear function of an operator of infinite rank. Minimizers have odd decay properties at infinity, which are related to charge renormalization.

This is a review of joint works with Philippe Gravejat (École Polytechnique, France), Christian Hainzl (Univ. Tübingen, Germany), Éric Séré (Univ. de Paris-Dauphine).

EMS Prize

Ciprian Manolescu (UNIVERSITY OF CALIFORNIA, LOS ANGELES, USA)

For his deep and highly influential work on Floer theory, successfully combining techniques from gauge theory, symplectic geometry, algebraic topology, dynamical systems and algebraic geometry to study low-dimensional manifolds, and in particular for his key role in the development of combinatorial Floer theory.

Ciprian Manolescu studied mathematics at Harvard University; he received his Ph.D. in 2004 for work under the supervision of Peter B. Kronheimer. In 2004–2005 he was a Veblen Research Instructor at Princeton University. He next worked for three years at Columbia University, and since 2008 he has been an associate professor at the University of California, Los Angeles. In 2001 he received the Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student. He was a recipient of the Clay Research Fellowship from 2004 till 2008.

Combinatorial Heegaard – Floer Theory
Monday, July 2nd, 16:30, Medium Hall B
We review the use of grid diagrams in the development of the combinatorial Heegaard Floer theory. We describe a construction of the combinatorial knot Floer complex, and the resulting algorithm for unknot detection. We also explain how grid diagrams can be used to show that the Heegaard– Floer invariants of 3-manifolds and 4-manifolds are algorithmically computable. This talk is based on joint work with Peter Ozsváth, Sucharit Sarkar, Zoltán Szabó, and Dylan Thurston.

EMS Prize

Grégory Miermont (UNIVERSITÉ DE PARIS-SUD, FRANCE)

For his outstanding work on scaling limits of random structures such as trees and random planar maps, and his highly innovative insight in the treatment of random metrics.

Grégory Miermont received his education at École Normale Supérieure in Paris in 1998–2002. He was awarded a Ph.D. in 2003 for a thesis supervised by Jean Bertoin. He also spent a year at Berkeley in 2001–2002, working under the supervision of David Aldous and Jim Pitman. Miermont held a CNRS researcher position in 2004–09, first in Orsay and then in Paris (Université Pierre et Marie Curie and the École Normale Supérieure). Since 2009 he has been a professor at the Université Paris-Sud 11 (Orsay). In 2011–2012 he has been granted leave from his home institution to take up a visiting professorship at the University of British Columbia (Vancouver).

Random maps and continuum random 2-dimensional geometries
Wednesday, July 4th, 17:00, Medium Hall A
A map is a gluing of a finite number of polygons, forming a connected orientable topological surface. It can be interpreted as assigning this surface a discrete geometry, and the theoretical physics literature in the 80–90's argued that random maps are an appropriate discrete model for the theory of 2-dimensional quantum gravity, which involves ill-defined integrals over all metrics on a given surface. The idea is to replace these integrals by finite sums, for instance over all triangulation of the sphere with a large number of faces, hoping that such triangulations approximate a limiting "continuum random surface".

In the recent years, much progress has been made in the mathematical understanding of the latter problem. In particular, it is now known that many natural models of random planar maps, for which the faces degrees remain small, admit a universal scaling limit, the *Brownian map*.

Other models, favorizing large faces, also admit a one-parameter family of scaling limits, called *stable maps*. The latter are believed to describe the asymptotic geometry of random maps carrying statistical physics models, as has now been established in some important cases (including the so-called rigid $O(n)$ model on quadrangulations).

EMS Prize

Sophie Morel (HARVARD UNIVERSITY, USA)

For her deep and original work in arithmetic geometry and automorphic forms, in particular the study of Shimura varieties, bringing new and unexpected ideas to this field.

Sophie Morel studied mathematics at the École Normale Supérieure in Paris, before obtaining a Ph.D. at the Université Paris-Sud for work under the supervision of Gerard Laumon. In 2006, she was awarded a post-doctoral position at the Institute for Advanced Study in Princeton, where she remained until 2009 (and was a member till 2011.) She also won a research fellowship from the Clay Mathematics Institute. Since December 2009, she has been a professor at Harvard University.

The organizers of 6 ECM regret that Professor Morel will not attend the Congress.

EMS Prize

Tom Sanders (UNIVERSITY OF OXFORD, UNITED KINGDOM)

For his fundamental results in additive combinatorics and harmonic analysis, which combine in a masterful way deep known techniques with the invention of new methods to achieve spectacular applications.

Tom Sanders studied mathematics in Cambridge (UK); he received a Ph.D. in 2007 for work under the supervision of William T. Gowers. In the academic year 2007–2008 he was a member of the Institute for Advanced Study at Princeton. From 2006 to 2011 he was a Fellow under Title I at Christ's College, Cambridge, and since October of 2011 he has been a Royal Society University Research Fellow at the University of Oxford. In 2011 he received the Adams Prize awarded by the Faculty of Mathematics at the University of Cambridge and St. John's College.

Approximate groups

Wednesday, July 4th, 17:00, Medium Hall A

Our aim is to discuss the structure of subsets of Abelian groups which behave 'a bit like' cosets (of subgroups). One version of 'a bit like' can be arrived at by relaxing the usual characterisation of cosets: a subset S of an Abelian group is a coset if for every three elements $x, y, z \in S$ we have $x + y - z \in S$. What happens if this is not true 100% of the time but is true, say, 1% of the time? It turns out that this is a situation which comes up quite a lot, and one possible answer is called Freĭman's theorem. We shall discuss it and some recent related quantitative advances.

EMS Prize

Corinna Ulcigrai (UNIVERSITY OF BRISTOL, UK)

For advancing our understanding of dynamical systems and the mathematical characterisations of chaos, and especially for solving a long-standing fundamental question on the mixing property for locally Hamiltonian surface flows.

Corinna Ulcigrai obtained a degree in mathematics from the Scuola Normale Superiore in Pisa (2002) and received her Ph.D. at Princeton University (2007) for work under the supervision of Y. G. Sinai. In 2007–2008 she was a postdoc at the Mathematical Sciences Research Institute in Berkeley and at the Institute for Advanced Studies in Princeton. Since August 2007 she has been a Lecturer and a Research Councils UK Fellow at the University of Bristol.

Shearing and mixing in parabolic flows
Wednesday, July 2nd, 16:00, Small Hall A
Parabolic flows are dynamical systems in which nearby trajectories diverge with polynomial speed. A classical example is the horocycle flow on a surface of constant negative curvature. Other important classes of examples are smooth area-preserving flows on surfaces, whose study is connected with Teichmueller dynamics, and Heisenberg nilflows. We will survey some of the chaotic properties of these flows, focusing in particular on mixing, and we will explain the shearing mechanism which is responsible for mixing in parabolic dynamics. This is based on some of our previous work (in the case of area preserving flows) and recent joint work with Avila-Forni (for time-changes of Heisenberg nilflows) and Forni (for time-changes of horocycle flows).

Otto Neugebauer Prize

Jan P. Hogendijk (UTRECHT UNIVERSITY, NL)

Prof. Jan Hogendijk's professional career has been devoted to the history of ancient and medieval mathematics. Although he received his doctorate from the University of Utrecht, much of the work for his thesis was carried out in the department Otto Neugebauer founded, the Department of the History of Mathematics at Brown University. For almost thirty years since then Professor Hogendijk has illuminated how Greek mathematics was absorbed in the medieval Arabic world, how mathematics developed in medieval Islam, and how it was eventually transmitted to Europe. He has presented this work in a long series of courses, lectures and outstanding publications in Dutch, English, Persian, French, Arabic, and German, where he has discussed scientific production in algebra, arithmetic, geometry, trigonometry, astronomy, geography, astrology, and architecture.

His analysis also embraces the scientific traditions of the Babylonian, Greek, Indian, Persian, Eastern and Western Arabic, and Latin civilizations. His work is mainly based on previously unexplored manuscripts and primary sources. For example, he has brought to light a major work, composed by the king of Zaragosa in the 11th century, that was previously known to scholars only by its title. His research has revealed essential information that has became decisive for an exact comprehension of the evolution of mathematics. However, the highly specialized contents of his writings are balanced by his precise yet friendly style that provides the reader with a striking understanding of the advances in the different mathematical traditions. For all of these reasons the jury is unanimous in recommending that Prof. Hogendijk receive the Neugebauer Prize.

Jan P. Hogendijk obtained his Ph.D. at Utrecht University in 1983 with a dissertation on an unpublished Arabic treatise on conic sections by Ibn al-Haytham (ca.~965-1041). He was a member of the History of Mathematics Department at Brown University, RI, USA (1983-1985), the Institut f\"ur Geschichte der Naturwissenschaften at the J.W. Goethe Universit\"at in Frankfurt am Main (1985-1986), the Mathematics Department at Leiden University (2004-2009), and the Mathematics Department of Utrecht University (1986-present), where he is now a full professor of the history of mathematics. He is also an adjunct professor at the Department of Mathematical Sciences of King Fahd University of Petroleum and Minerals in Dhahran (Saudi Arabia). His research is in the history of ancient and medieval mathematical sciences, especially in Islamic civilization, and in the history of mathematics in the Netherlands between 1580 and 1850.

Mathematicians and decorative geometric tilings in the medieval Islamic world

Monday, July 2nd, 15:00, Large Hall A

Although many medieval Islamic mosques and palaces are adorned with geometric tilings, such tilings are hardly ever mentioned in medieval texts on geometry in Arabic or Persian. An exception is a Persian text of 40 pages with brief descriptions of tilings, which will be edited (with translation and commentary) in the near future by a research team. The text includes approximate solutions of problems which cannot be solved exactly by ruler and compass. The text may have been written for craftsmen with only little mathematical training in the way of Euclid's Elements. We will discuss some of the constructions in the text, and then comment on the relationship between craftsmen and 'scholarly' mathematicians in the medieval Islamic world.

Felix Klein Prize

Emmanuel Trélat (UNIVERSITÉ PIERRE ET MARIE CURIE, PARIS, FRANCE)

Emmanuel Trélat combines truly impressive and beautiful contributions in fine fundamental mathematics to understand and solve new problems in control of PDE's and ODE's (continuous, discrete and mixed problems), and above all for his studies on singular trajectories, with remarkable numerical methods and algorithms able to provide solutions to many industrial problems in real time, with substantial impact especially in the area of astronautics. He is certainly an example of a "success researcher" in the field of mathematics for industry, illustrating that it is possible to be highly recognized in mathematics and working on real problems, with end-product in the form of software that is really useful in industry.

Emmanuel Trélat obtained his Ph.D. at the University of Bourgogne in 2000. Currently he is a full professor at the University Pierre et Marie Curie (Paris~6), France, and a member of the Institut Universitaire de France since 2011. He was previously professor at the University of Orléans, France (2006–2011), and associate professor at the University of Paris-Sud, Orsay, France (2001–2006). He is also an external member of the GECO team at INRIA Saclay. He has a number of research contracts with EADS Astrium, with the CNES and the CEA. He was one of the founding members of the OPALE (Optimization Applied to European Launchers, 2005–2009) set up by CNES, EADS, INRIA, ONERA and several universities, to promote collaboration between academics and industrials on aerospace control problems. He is the editor in chief of *Acta Applicandae Mathematicae* and an associate editor of several other journals. His research field is control theory in finite and infinite dimensions. His main contributions are on the role of singular trajectories in control theory, in relation to other fields like sub-Riemannian geometry, PDE modelling or tomography.

Optimal control theory and some applications to aerospace problem

Monday, July 2nd, 15:00, Large Hall B

We first shortly report on some classical techniques of nonlinear optimal control such as the Pontryagin Maximum Principle and the conjugate point theory, and on their numerical implementation. We illustrate these issues with problems coming from aerospace applications such as the orbit transfer problem which is taken as a motivating example. Such problems are encountered in a longstanding collaboration with the European space industry EADS Astrium.

On this kind of nonacademic problem it is shown that the knowledge Past Prize Winners 15 resulting from the maximum principle is insufficient for solving adequately the problem, in particular due to the difficulty of initializing the shooting method, which is an approach for solving the boundary value problem resulting from the application of the maximum principle. On the orbit transfer problem we show how the shooting method can be successfully combined with a numerical continuation method in order to improve significantly its performances.

We comment on assumptions ensuring the feasibility of continuation or homotopy methods, which consist of deforming continuously a problem towards a simpler one, and then of solving a series of parametrized problems to end up with the solution of the initial problem. Finally, in view of designing low cost interplanetary space missions, we show how optimal control can be also combined with dynamical system theory, which allows to put in evidence nice properties of the celestial dynamics around Lagrange points that are of great interest for mission design.

PAST PRIZE WINNERS

1 ECM, Paris 1992

THE EMS PRIZE WINNERS

Richard Borcherds *(United Kingdom)* Fields Medal 1998
Jens Franke *(Germany)*
Alexander Goncharov *(Russia)*
Maxim Kontsevitch *(Russia)* Fields Medal 1998
François Labourie *(France)*
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Stefan Müller *(Germany)*
Vladimir Šverák *(Czechoslovakia)*
Gábor Tardos *(Hungary)*
Claire Voisin *(France)*.

2 ECM, Budapest 1996

THE EMS PRIZE WINNERS

Alexis Bonnet *(France)*
William Timothy Gowers *(United Kingdom)* Fields Medal 1998
Annette Huber *(Germany)*
Aise Johan de Jong *(Netherlands)*
Dmitrij Kramkow *(Russia)*
Jiři Matoušek *(Czech Republic)*
Loc Merel *(France)*
Grigori Perelman *(Russia)* Fields Medal 2006 (not accepted)
Ricardo Perez-Marco *(Spain / France)*
Leonid Polterovich *(Israel)*.

3 ECM, Barcelona 2000

THE EMS PRIZE WINNERS

Seymon Alesker *(Israel)*
Rafaël Cerf *(France)*
Dennis Gaitsgory *(USA)*
Emmanuel Grenier *(France)*

Dominic Joyce *(United Kingdom)*
Vincent Lafforque *(France)* Fields Medal 2002
Michael McQuillan *(United Kingdom)*
Stefan Nemirovski *(Russia)*
Paul Seidel *(France)*
Wendelin Werner *(France)* Fields Medal 2006

FELIX KLEIN PRIZE
David C. Dobson *(USA)*

4 ECM Stockholm

THE EMS PRIZE WINNERS
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Stefano Bianchini *(Italy)*
Paul Biran *(Israel)*
Elon Lindenstrauss *(Israel)* Fields Medal 2010
Andrei Okounkov *(Russia)* Fields Medal 2006
Sylvia Serfaty *(France)*
Stanislav Smirnov *(Russia)* Fields Medal 2010
Xavier Tolsa *(Spain)*
Warwick Tucker *(Australia/Sweden)*
Otmar Venjakob *(Germany)*.

5ECM Amsterdam

THE EMS PRIZE WINNERS
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Alexei Borodin *(Russia)*
Ben Green *(United Kingdom)*
Olga Holtz *(Russia)*
Bo'az Klartag *(Israel)*
Alexander Kuznetsov *(Russia)*
Assaf Naor *(Czech Republik/Israel)*
Laure Saint-Raymond *(France)*
Agata Smoktunowicz *(Poland)*
Cédric Villani *(France)*, Fields Medal 2010

FELIX KLEIN PRIZE
Josselin Garnier *(France)*

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