CENTRE DE RECHERCHES MATHÉMATIQUES

Le Bulletin

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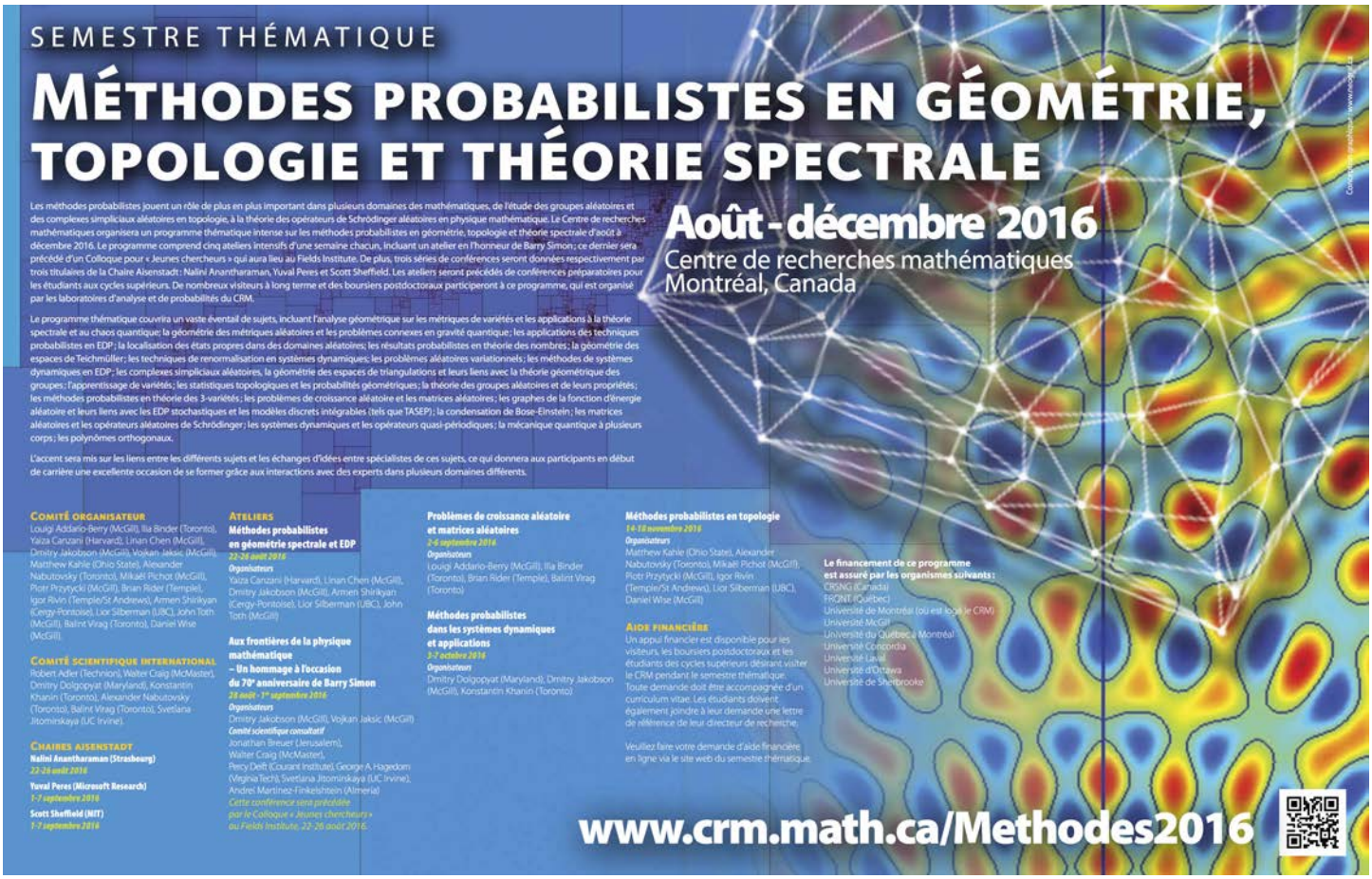
Thematic Semester

Probabilistic Methods in Geometry, Topology and Spectral Theory

August — December 2016

Probabilistic methods have played an increasingly important role in many areas of mathematics, from the study of random groups and random simplicial complexes in topology, to the theory of random Schrödinger operators in mathematical physics. The Centre de recherches mathématiques will organize an intensive Thematic Program on Probabilistic Methods in Geometry, Topology and Mathematical Physics during the period of August – December 2016. The program will be comprised of five intensive week-long workshops, including a workshop in honour of Barry Simon; the latter will be preceded by a Young Researchers Symposium held at the Fields Institute. In addition, there will be lecture series by three Aisenstadt Chair holders: Nalini Anantharaman, Yuval Peres, and Scott Sheffield. The workshops will be preceded by preparatory lectures for advanced graduate students. Numerous long-term visitors and postdoctoral researchers will participate in the program, hosted by the CRM Laboratories in Analysis and Probability.

The thematic program will cover a broad range of topics, including geometric analysis on manifolds of metrics and applications to spectral theory and quantum chaos; geometry of random metrics and related problems in quantum gravity; applications of probabilistic techniques in PDE; eigenstate localization in random domains; probabilistic results in number theory; geometry of Teichmüller spaces; renormalization



methods in dynamical systems; random variational problems; dynamical systems methods in PDE; random simplicial complexes and geometry of spaces of triangulations and connections to geometric group theory, manifold learning, topological statistics, and geometric probability; theory of random groups and their properties; probabilistic methods in 3-manifold theory; random growth problems and random matrices; random energy landscapes and their connections to stochastic PDEs and to integrable discrete models (such as TASEP); Bose – Einstein condensation; random matrices and random Schrödinger operators; dynamical systems and quasi-periodic operators; many-body quantum mechanics; orthogonal polynomials.

There will be an emphasis on interconnections and cross-fertilization of ideas between these topics, giving junior participants an excellent opportunity to learn from, and interact with, experts in several different fields.

ORGANIZING COMMITTEE

Louigi Addario-Berry, Linan Chen, Dmitry Jakobson, Vojkan Jakšić, Mikaël Pichot, Piotr Przytycki, John Toth & Daniel Wise (McGill); Ilia Binder, Alexander Nabutovsky & Balint Virag (Toronto); Yaiza Canzani (Harvard); Matthew Kahle (Ohio State); Brian Rider (Temple); Igor Rivin (Temple/St Andrews); Armen Shirikyan (Cergy-Pontoise); Lior Silberman (UBC)

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AISENSTADT CHAIRS

Nalini Anantharaman, Strasbourg (August 22 – 26, 2016); Yuval Peres, Microsoft Research (September 1 – 7, 2016); Scott Sheffield, MIT (September 1 – 7, 2016)

WORKSHOPS

Probabilistic Methods in Spectral Geometry and PDE

August 22 – 26, 2016

Organizers: Yaiza Canzani (Harvard); Linan Chen, Dmitry Jakobson & John Toth (McGill); Armen Shirikyan (Cergy-Pontoise); Lior Silberman (UBC)

Frontiers in Mathematical Physics — Conference in Honour of Barry Simon's 70th Birthday

August 28 – September 1, 2016

Organizers: Dmitry Jakobson & Vojkan Jakšić (McGill)
Scientific Advisory Committee: Jonathan Breuer (Hebrew); Walter Craig (McMaster); Percy Deift (Courant Institute); George A. Hagedorn (Virginia Tech); Svetlana Jitomirskaya (UC Irvine); Andrei Martinez-Finkelshtein (Almeria)

This conference will be preceded by a five-day Young Researchers Symposium, to be held at Fields Institute, August 22 – 26, 2016.

Random Growth Problems and Random Matrices

September 2 – 6, 2016

Organizers: Louigi Addario-Berry (McGill); Ilia Binder & Balint Virag (Toronto); Brian Rider (Temple)

Probabilistic Methods in Dynamical Systems and Applications

October 3 – 7, 2016

Organizers: Dmitry Dolgopyat (Maryland); Dmitry Jakobson (McGill); Konstantin Khanin (Toronto)

Probabilistic Methods in Topology

November 14 – 18, 2016

Organizers: Matthew Kahle (Ohio State); Alexander Nabutovsky (Toronto); Mikaël Pichot, Piotr Przytycki & Daniel Wise (McGill); Igor Rivin (Temple/St Andrews); Lior Silberman (UBC)

FINANCIAL SUPPORT

Support is available for visitors, postdoctoral fellows and graduate students wishing to attend the various events. All requests must be accompanied by a CV. Furthermore, graduate students are asked to send a letter of recommendation from their research supervisor.

Please apply online on the thematic semester website: www.crm.math.ca/Methods2016

SPONSORS

This thematic program is funded by the following organizations: NSERC (Canada), FRQNT (Québec), Université de Montréal (where the CRM is located), McGill University, UQAM, Concordia University, Université Laval, University of Ottawa, Université de Sherbrooke.

2016 CRM Nirenberg Lectures in Geometric Analysis

Gunther Uhlmann (Washington & Hong Kong)

Pengfei Guan & Dmitry Jakobson (McGill); Iosif Polterovich (Montréal); Alina Stancu (Concordia)

Gunther Uhlmann

The annual lecture series in geometric analysis in honour of Louis Nirenberg was inaugurated by the CRM in 2014. The 2016 CRM Nirenberg lectures were delivered by Professor Gunther Uhlmann over the period March 18 – 22, 2016. Professor Uhlmann is the Walker Family Endowed Professor of Mathematics at the University of Washington and IAS Si Yuan Professor at the Hong Kong University of Science and Technology. He is a world leader in the field of geometric analysis, and is particularly well known for his fundamental contributions to the study of inverse problems. His outstanding research achievements include major breakthroughs on Calderón's inverse problem, and the boundary rigidity problem, as well as the mathematics of invisibility cloaking. He has received many awards and honours, such as the Guggenheim fellowship in 2001, the 2011 Bôcher Memorial Prize of the AMS and the 2011 Ralph E. Kleinman Prize of the SIAM. He is a member of the American Academy of Arts and Sciences and the Finnish Academy of Science and Letters.

The three lectures by Professor Uhlmann focussed on some recent developments in the field of inverse problems. The first lecture, with the intriguing title *Harry Potter's Cloak via Transformation Optics*, was delivered to a packed audience. As one could guess from the title, the topic was invisibility and the mathematical foundations of cloaking. This subject is closely related to Calderón's inverse problem in electrical impedance tomography (EIT) in which the conductivity of a domain is inferred from the Dirichlet-to-Neumann map, or the voltage-to-current map, on its boundary. The speaker described his breathtaking results with Greenleaf and Lassas on nonuniqueness for EIT and cloaking, illustrated by a beautiful example of a "blow-up" of a point into a ball-shaped cloak. In a joint work with Greenleaf, Kurylev and Lassas, the approach was extended to other types of cloaking, such as the cloaking for Maxwell's equations and approximate quantum cloaking. Some exciting applications of these mathematical ideas were presented, notably, to optics, medical imaging and metamaterials. The speaker has also indicated a number of further applications that may become possible in the future.

The second lecture took the audience on a *Journey to the Center of the Earth*. Professor Uhlmann introduced an inverse problem arising from global seismology: the question is to determine the sound speed or index of refraction of a medium by measuring the travel times of waves going through the medium. It can be reformulated as a boundary rigidity problem in geometric analysis. Examples indicate that certain conditions are needed for this type of rigidity to hold. One possible condition is that the Riemannian manifold is *simple*, that is, it has a strictly convex boundary and the exponential map is a diffeomorphism at each point. It was conjectured by Michel in 1981 that simple manifolds are boundary rigid, i.e. that the distance function between the points on the boundary uniquely determines the Riemannian metric up to an isometry which is the identity on the boundary. After reviewing some earlier results, Professor Uhlmann presented his groundbreaking work with Pestov in which they proved the conjecture in dimension two. In higher dimensions, the conjecture is known to be true for a generic set of simple metrics, due to a result by Stefanov and Uhlmann. After a brief discussion of the lens rigidity problem, the speaker moved on to the boundary rigidity with partial data. He described some important recent developments on the subject, mainly due to Stefanov, Vasy and himself. This has led to a discussion of the so-called "foliation condition," which turned out to be a natural generalization of the classical condition for nonradial speeds introduced by Herglotz and Wieckert-Zoeppritz. The proofs of these results involved some novel ideas and powerful techniques ranging from integral geometry to scattering theory.

The final lecture was entitled *Seeing Through Space-Time*. Professor Uhlmann started by discussing the inverse problems for scalar nonlinear hyperbolic equations. He explained how the nonlinear term could be of help, which is somewhat counter-intuitive. After that, the speaker presented the inverse problems for the Einstein equation with a time-dependent metric on a 4-dimensional globally hyperbolic Lorentzian manifold. He described some recent results on inverse problems in space-time in which the aim is to determine the topology and the metric of the space-time using passive measurements (jointly with Kurylev and Lassas), as well as inverse problems for nonlinear wave equations (jointly with Kurylev and Lassas, and jointly with Lassas and Wang). The main idea of the proofs is to explore the singularities of solutions via a sophisticated study of the interaction between waves. At the end of the lecture, Professor Uhlmann described his most recent results on an inverse problem for the Einstein scalar field equations, which are of importance in general relativity.

The lecture series generated a lot of interest among the members of the Montréal mathematical community. In particular, many students and postdocs were present. As in the previous years, we had the pleasure and honour to have Professor Louis Nirenberg in attendance.

Nikita Nekrasov (Stony Brook University), Aisenstadt Chair

September 14 – 18, 2015

Alexander Maloney, McGill University

Nikita Nekrasov

Nikita Nekrasov visited the CRM from September 14 – 18, 2015, to give four lectures as part of the 2015 Aisenstadt Chair lecture series. Nekrasov was one of two Aisenstadt Chair holders hosted as part of the thematic semester on *AdS/CFT, Holography and Integrability.*

A professor at the Simons Center for Geometry and Physics at the Stony Brook University, Nekrasov is regarded as one of the leading experts on mathematical aspects of quantum field theory. Nekrasov received his Ph.D. in 1996 from Princeton University, where he studied under the supervision of David Gross. He then joined the society of fellows at Harvard University as a junior fellow, after which he spent two years as a Dicke fellow at Princeton University. Nekrasov joined the faculty of the Institut des Hautes Études Scientifiques in Bures-sur-Yvette, France, before moving in 2013 to his current position at the Simons Center. Nekrasov's work has been honoured by several awards, including the Jacques Herbrand Prize, the Herman Weyl Prize and the Compositio Prize.

Nekrasov's work has centred on the theory of supersymmetric gauge theories; these theories share many of the important features of the quantum field theories that describe the fundamental interactions of matter, yet possess enough symmetry that exact computations are possible. A typical quantum field theory computation can be performed only perturbatively, in a regime where the theory possesses a coupling constant which can be tuned to be small; corrections can then be computed either using Feynmann diagrams or instanton techniques. Nekrasov's signature contributions have often involved the computation of quantum field theory observables precisely at all values of the coupling constant. In particular, in defining a quantum field theory one can in principle formulate the dynamics in terms of a functional integral over a continuous space of field variables. Nekrasov has shown that in many cases these function integrals can be computed precisely, using a technique known as *localisation* where the a-priori infinite-dimensional integral is reduced to a finite-dimensional matrix integral.

Nekrasov's primary interest lies in Yang – Mills theories with $\mathcal{N} = 2$ supersymmetry, where the dynamics at low energies can be captured by the Seiberg – Witten prepotential. Among other things, Nekrasov has clarified the mathematical structure contained within the Seiberg – Witten prepotential, which is related to the Donaldson invariants of four-manifolds as well as to Gromov – Witten theory. Nekrasov has pioneered the use of various deformations of quantum gauge theories as a tool for solvability. For example, by putting the theory in a noncommutative space, where the algebra of functions is modified so that coordinates do not commute:

$$[x^i, x^j] = i\theta^{ij},$$

the theory can be rendered solvable. Similarly, Nekrasov has pioneered the use of the Ω deformation, where the theory is considered on a particular curved background and deformed in such a way that the supersymmetry is preserved. Notable in Nekrasov's work is the relationship between these Yang – Mills invariants and integrability and combinatorics, where — for example — Yang – Mills partition functions are related to statistical ensembles of random partitions.

Nekrasov gave a general lecture, *Gauge Theories and Integrable Systems*, which introduced the general notion of integrability in Yang – Mills theory and described several examples. This was accompanied by a set of four technical lectures entitled the *BPS/CFT Correspondence* I – IV which outlined Nekrasov's recent work relating the quantum field theories in four dimensions to two-dimensional conformal field theories. In particular, topological invariants of instanton moduli spaces in four dimensions are related to the space of conformal blocks in two-dimensional conformal field theories. Nekrasov's "BPS/CFT" programme unifies observations which have been made by various authors over the past decade — including the celebrated AGT conjecture — and develops new techniques for the computation of field theory partition functions.

In memoriam

Fedor Soloviev

Fedor Soloviev

It is with great sadness that we announce the passing of Dr. Fedor Soloviev on March 24, 2016, after a battle with cancer since 2012.

Dr. Soloviev was a Fields – CRM postdoctoral fellow at the Fields Institute and at the CRM since 2013. He was also a postdoctoral fellow, lecturer, and seminar organizer at the University of Toronto since receiving his Ph.D. (Mathematics) from New York University in May 2010. His area of research was classical integrable systems.

Bertrand Eynard (CEA Saclay), Aisenstadt Chair

September 28 – November 6, 2015

John Harnad (Concordia)

Bertrand Eynard

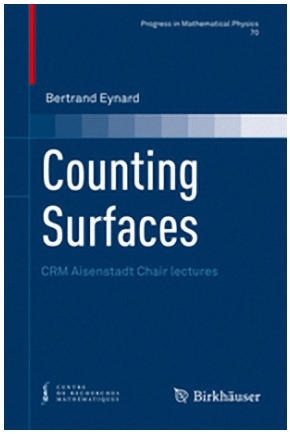
A key part of the 2015 CRM Thematic semester on AdS/CFT, Holography and Integrability, was the Aisenstadt Chair lecture series given by Bertrand Eynard (IPhT, CEA Saclay). This consisted of three lectures, the first relating to the general theme of "Topological Recursion," an area in which he has been a leading pioneer, the second and the third on the general theme of "CFT Amplitudes and Hitchin Systems." These were supplemented by two intensive series of minicourses developing the same topics in greater detail.

Bertrand Eynard is a member of the Institut de Physique Théorique, CEA Saclay. A leading innovator in a number of currently active fields of mathematical physics, including random matrices, conformal field theory, quantum gravity, string theory, graphical enumeration and combinatorics, random geometry and integrable systems, he has become known over the past decade as the driving force behind the exciting unifying development that goes under the name "Topological Recursion." This forms one of the two main topics of his 2015 Aisenstadt Chair lecture series.

He is recognized worldwide for his contributions and is a frequent invited speaker at major international meetings, including an invited talk at the 2014 ICM in Seoul, South Korea and invited plenary talks at the series of biannual String-Math conferences (most recently, in Edmonton, 2014) and the StatPhys24 conference (Cairns, Australia, 2010).

Since the founding of the CRM's Mathematical Physics Laboratory (PhysMath), Bertrand Eynard has been a valuable long-term visiting member (2001 – 2003), subsequently an external member, and a frequent collaborator with several of its regular members (M. Bertola, J. Harnad, J. Hurtubise, D. Korotkin). Throughout this time he also has been a key member of the joint FQRNT research team on Random Matrices, Moduli Spaces and Integrable Systems.

Topological recursion is an ubiquitous and universal recursive relationship between various enumerative/geometric/topological invariants associated with Riemann surfaces and their moduli, links, knots and other basic low dimensional topological invariants of current interest. Numerous applications are known in various domains of mathematics and physics, including: volumes of moduli spaces, coefficients of asymptotic expansions in random matrix theory, Hurwitz numbers, Jones polynomials, Gromov – Witten invariants, and many other combinatorial objects, all mysteriously satisfying the same recursion relations. Moreover, these relations are effective: they allow an actual computation of the invariants involved. The theory has by now been axiomatized into a definition of "new invariants" of curves. The first Aisenstadt Chair lecture, entitled *Topological recursion* (Oct. 2, 2015) introduced the notion of topological recursion, listed its properties and illustrated it with several beautiful examples. The subsequent two lectures, *CFT amplitudes and Hitchin systems* (Oct. 9 & 23, 2015) introduced a systematic construction of CFT amplitudes from an arbitrary Hitchin system, and explained the relationship between CFT conformal blocks and tau functions of integrable systems, as well as showing how the Liouville theory 4-point function is related to Painlevé VI tau function.



These Aisenstadt Chair lectures were supplemented by two intensive series of minicourses further elaborating on the topics involved. The first (Sept. 29 – Oct. 15, 2015) gave a detailed introduction to topological recursion, treating numerous examples and explaining the general formalism. The material presented forms the basis of a monograph *Counting Surfaces* published by Springer.

The first lecture dealt with two main introductory examples: Hurwitz numbers and Mirzakhani's recursion. The next gave an introduction to the general theory underlying the notion of topological recursion, introducing the associated spectral curves, both classical and quantum, and recalling some basic algebraic geometry of plane curves. The third detailed the main features of the diagrammatic computation, and introduced the notions of symplectic invariance, modular invariance, singular limits and form-cycle duality. The fourth introduced tau functions, Baker – Akhiezer functions and the Sato relations, connecting them to topological recursion. The final lecture tied together the previous constructs, relating the tau function to generating functions for the various enumerative and topological invariants associated to Riemann surfaces and their moduli spaces.

The second minicourse (Oct. 21 – Nov. 3, 2015) *Integrable Systems, Random Matrices, Hitchin Systems and CFTs* placed

(*continued on page 6*)

Moduli Spaces, Integrable Systems, and Topological Recursions
January 9 – 13, 2016

Organizers: Dmitry Korotkin (Concordia University), Jacques Hurtubise (McGill University)

The computation and enumeration of invariants of moduli spaces took a sudden turn with the conjecture of Witten that they could be combined into a formal series that solved the KdV hierarchy. This conjecture, subsequently proven by Kontsevich, was motivated by considerations of quantum gravity. It was followed by a series of developments in the same direction, notably in the computation of invariants for Hurwitz spaces and for Gromov – Witten invariants, for example in the work of Okounkov and Pandharipande, tying Gromov – Witten theory to the 2-Toda hierarchy. Kontsevich's proof involved a detour through the theory of random matrices, and subsequently Eynard and Orantin proposed a vast generalization of the technique, with a wide variety of implications. The questions have physical motivations, and the subject has advanced with the rapid mixture of calculation and heuristic reasoning which characterizes theoretical physics; mathematicians have in many but not all cases provided proof, and, it is hoped, some understanding.

Thus a first piece of the puzzle is the theory of moduli spaces. The moduli spaces of interest are mainly associated with complex algebraic curves: moduli spaces of (pointed) curves, moduli spaces of meromorphic functions on curves (Hurwitz spaces and spaces of admissible covers) and, more generally, moduli spaces of stable maps. A second part of the puzzle, brought to the fore by Chekhov, Eynard and Orantin, has its origin in the theory of random matrices; invariants are combined into generating series from which can be computed directly a single spectral curve, by what has come to be known as the topological or Eynard – Orantin recursion. A third theme comes with the theory of Frobenius manifolds, which were introduced around 1990 by Dubrovin as a geometrization of quantum cohomology that originated from Witten – Dijkgraaf – Verlinde – Verlinde (WDVV) associativity equation in topological field theories. The quantities associated to the Frobenius manifolds are computable in terms of the topological recursion.

The theory of integrable systems seems to lie at the heart of the subject, providing a thematic link. It is fair to say, though, that the way in which it happens is still ill-understood. Indeed, so far, it is more the tools, computational devices, and actual functions that appear, rather than flows and conserved quantities.

The workshop covered all these themes, and contributed greatly to completing the picture. Thus, Hurwitz numbers of many sorts are now seen to have a computation in terms of a family of spectral curves; the same goes for the Gromov – Witten invariants of toric Calabi – Yau manifolds, where the spectral curve is in effect the mirror. The theme of topological recursion is extending its remit to knot invariants and Chern – Simons theories. Likewise, one now has a clear idea of which spectral curves correspond to Frobenius manifolds. From the integrable systems side, the ties between the topological recursion and WKB approximations for either Schrödinger operators or Hitchin systems are gradually becoming clearer. The workshop was a veritable hotbed of ideas and discussions, with lively scientific discussion not only during the talks but also between them and well into the evening afterwards. The CRM staff was in its usual efficient and pleasant form, and helped make the event a scientific success for its participants.

Bertrand Eynard

(*continued from page 5*)

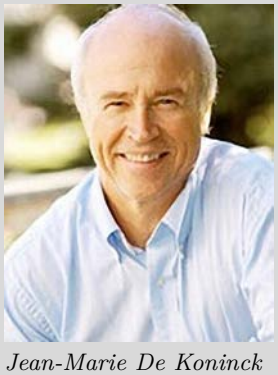
the study of conformal field amplitudes in the context of integrable systems, most notably, Hitchin systems, and the spectral theory of random matrices.

The first lecture introduced the Lax formalism, isospectral systems, algebro-geometric solutions, and Baker – Akhiezer functions, expressed in terms of prime forms and theta functions corresponding to the associated invariant spectral curves. The next lecture focused on partition functions for random matrices, spectral correlation functions and orthogonal polynomials as illustrations of solutions to integrable hierarchies. The ODEs and recursion relations satisfied by the corresponding orthogonal polynomials were shown to be isospectral or isomonodromic systems for an associated Lax matrix and meromorphic covariant derivative. The partition function and various spectral correlators were interpreted as tau functions of the associated integrable hierarchy. The last two lectures of the series dealt in greater detail with the Liouville theory 4-point function and its relation to the Painlevé VI tau function.

In January, Prof. Eynard returned to the CRM to give the opening talk of the last workshop of the thematic semester, *Moduli Spaces, Integrable Systems, and Topological Recursions*.

Prix

Jean-Marie De Koninck



Jean-Marie De Koninck

Jean-Marie De Koninck (Laval) a reçu le prix commémoratif Margaret Sinclair pour 2016 en reconnaissance de son travail de promotion des mathématiques.

Le prix commémoratif Margaret Sinclair souligne l'innovation et l'excellence dans l'enseignement des mathématiques au niveau élémentaire, secondaire, collégial et universitaire.

2014 CAP – CRM Prize in Mathematical Physics

Lecture by Mark Van Raamsdonk (UBC)

Gravity and Entanglement

Robert Brandenberger (McGill)

Mark Van Raamsdonk

Professor Mark Van Raamsdonk is the 2014 winner of the CAP – CRM Prize in Mathematical Physics for his highly original, influential contributions to several areas of theoretical physics, including string theory, quantum field theory, and quantum gravity.

Mark Van Raamsdonk is a theoretical physicist whose work, as the CAP – CRM citation states, lies in the field of string theory and quantum gravity. Through his work, he attempts to answer some of the grandest open question, in theoretical physics: What is space? What is time? How did our universe begin? How will it end? What is inside a black hole? Throughout his career, he has made many novel contributions applying string theory to other areas of physics, from nuclear matter at high densities to properties of black holes.

Mark received his B.Sc. degree from the University of British Columbia in 1995. For his graduate work he moved to Princeton University where he obtained his Ph.D. in 2000 under the supervision of Professor Washington Taylor. After two postdoctoral years at Stanford University he joined the faculty of UBC in 2002, where he has rapidly risen to the rank of Full Professor.

Already as a Ph.D. student Mark co-authored papers which were to become classics in the field. In particular, in his most highly cited paper he and his co-authors discovered an intriguing mixing of high energy and low energy effects in a class of noncommutative quantum field theories. Other pioneering and highly cited work which Mark did while still a Ph.D. student involved the study of multiple D-branes (nonperturbative objects which arise in superstring theory) in weakly curved background space-times.

As a postdoctoral fellow at Stanford Mark turned to other topics in quantum field theory and string theory. He wrote many influential papers on M-theory, a candidate for nonperturbative superstring theory. Maybe the most impressive contribution from Mark's postdoctoral years is the proof of confinement in a class of four-dimensional quantum field theories.

After taking up his faculty position at UBC, Mark has continued to produce outstanding research. He has a steady stream of highly cited papers on string theory and quantum field theory, including applications to condensed matter physics and cosmology. He has established productive collaborations with leading international researchers in string theory in the United States, England and India, he has written papers with faculty colleagues at UBC, he has attracted excellent postdoctoral fellows to UBC, and he has successfully trained a number of good Ph.D. students. He has helped make UBC one of the leading centres of research in formal quantum field theory and string theory in North America. He has organized workshops on forefront topics at UBC which participants rave about.

In recent years, Mark's attention has turned to the connections between quantum entanglement and gravitation. With a paper entitled *Building up spacetime with quantum entanglement*, he won first prize in the Gravity Research Foundation essay award competition of 2010. In this paper, Mark argues that the emergence of classically connected space-times is intimately related to the quantum entanglement of degrees of freedom in a nonperturbative description of quantum gravity. This essay is based on a single author paper which Mark put out a year earlier, and has spawned a huge amount of interest in the field.

Mark's Prize lecture at the CRM on March 27, 2015 was a beautiful description of this work. Mark's work on gravity and entanglement is very deep and touches on some of the most important unsolved problems in fundamental physics. Our classical description of space-time appears to be in conflict with the need for quantum mechanics to describe the nongravitational forces of nature. This is the driving force behind our search for a quantum theory of gravity. Traditional ways to quantize gravity have run into road blocks or technical difficulties. Since the pioneering work of Maldacena in 1999, the hope has arisen that certain gravitational theories are dual to nongravitational theories which live in one lower space-time dimension. Since the dual nongravitational theories can be quantized, it is thus possible to study certain quantum aspects of gravity. In his recent work, Mark goes one important step forwards and presents a framework for the emergence of a classical space-time from quantum building blocks.

Mark's research excellence has been recognized by a Sloan Foundation Research Fellowship and by a Canada Research Chair. He is also one of the principal investigators on a large Simons Foundation team research project involving leading experts on string theory and quantum information from across the world. We wish to congratulate Mark on his research achievements and on winning the 2014 CAP – CRM Prize for Mathematical Physics.

Grande Conférence publique du CRM

Systèmes et contrôle : enjeux et réussites

Enrique Zuazua (Universidad Autónoma de Madrid)

Christiane Rousseau (Montréal)

Enrique Zuazua

Le 29 janvier dernier, le CRM recevait Enrique Zuazua de la Universidad Autónoma de Madrid. Ce dernier a relevé avec brio le défi de donner une grande conférence publique en français sur le thème *Systèmes et contrôle : enjeux et réussites*.

Selon le conférencier, qui a cité Aristote, le désir d'automatisation remonte à très loin : « Si les navettes tissaient toutes seules ; si l'archet jouait tout seul de la cithare, les employeurs se passeraient d'ouvriers et les maîtres, d'esclaves. » Le premier exemple de contrôle présenté, celui de la réduction du bruit, a permis de montrer la différence entre le contrôle passif et les boucles de rétroaction.

La conférence a ensuite fait un détour vers le calcul des variations avec, comme motivation, la quête par Leonhard Euler de principes d'optimisation pour expliquer les lois de l'univers. Des exemples ont illustré le propos : le problème isopérimétrique de la reine Dido, les géodésiques sur une surface, les bulles de savon et le problème de Plateau, le principe de Fermat en optique, ainsi que le transport optimal. Comment trouver numériquement un minimum : le conférencier a présenté deux méthodes d'esprit tout à fait différent : la méthode du gradient est efficace lorsque la fonction ou fonctionnelle à minimiser est suffisamment régulière, alors qu'on préfère une méthode de Montecarlo quand la structure de la fonctionnelle est très complexe.

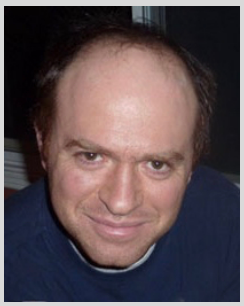
Le cœur de la conférence a porté sur la contrôlabilité : c'est la cybernétique introduite par Ampère au XIX^{e} siècle et que Norbert Wiener décrit comme *the science of control and communication in animals and machines*, anticipant que, dans le futur, on voudrait que les machines imitent les humains. Le propos a été illustré par l'exemple d'un bras de robot, n'ayant que 3 doigts en opposition au pouce, parce que chaque doigt additionnel ajoute énormément à la complexité de la conception. Peut-on contrôler l'état de n composantes avec seulement m contrôles, lorsque $n \gg m$? Le théorème de Kálmán (1958) donne des conditions nécessaires et suffisantes pour que ce soit le cas. Ainsi, dans une auto, on a 4 degrés de liberté, soit la position de son centre de gravité, son orientation et l'orientation des roues motrices. Pourtant, deux contrôles suffisent, soit le volant et le mouvement d'avancer, comme l'ont illustré plusieurs vidéos de chauffeurs particulièrement doués.

Enrique Zuazua est ensuite passé à la description des mathématiques impliquées dans la conception optimale d'un avion, soit la mécanique des fluides pour simuler l'écoulement de l'air le long d'un avion, et l'optimisation de la forme par itérations successives en minimisant la fonctionnelle coût. Il a expliqué dans les équations de Navier – Stokes l'importance du terme de viscosité qui permet aux oiseaux de voler et les grands défis que posent la solution de ces équations aux mathématiciens.

La conférence s'est terminée sur les perspectives et nombreuses applications de la théorie du contrôle en mécanique, médecine, électronique, chimie, économie et finance. Les réseaux qui nous entourent sont de plus en plus complexes et distribués, posant ainsi de nouveaux défis aux mathématiciens. De nouveaux outils sont nécessaires : la combinatoire et la théorie des graphes, le forage de données et le Big data, l'apprentissage statistique, tandis que des algorithmes computationnels de plus en plus raffinés voient le jour. Le public a quitté la salle, charmé, tout autant que l'organisatrice.

Prix

Daniel T. Wise



Daniel T. Wise

Daniel T. Wise (McGill) est le lauréat 2016 des prix CRM – Fields – PIMS et Jeffrey – Williams. M. Wise est généralement reconnu comme l'un des meilleurs théoriciens des groupes géométriques dans le monde, et le meilleur de sa génération. Ses travaux ont des répercussions profondes non seulement en théorie des groupes géométriques, mais aussi en raison de leur rôle clé dans la résolution de problèmes jamais encore résolus en théorie des variétés à 3 dimensions.

Le prix CRM – Fields – PIMS souligne des réalisations exceptionnelles en sciences mathématiques.

Le prix Jeffery – Williams de la SMC rend hommage aux mathématiciens qui se sont distingués par l'excellence de leur contribution à la recherche mathématique.

In memoriam

S. Twareque Ali (1942 – 2016)

S. Twareque Ali

A Book of Verses underneath the Bough,
A Jug of Wine, a Loaf of Bread – and Thou
Beside me singing in the Wilderness –
Oh, Wilderness were Paradise enow!
(The Rubáyát of Omar Khayyám, Quatrain XII,
English transl. E. FitzGerald, 5th ed., 1889)

It is with great sorrow that we communicate the passing of Syed Twareque Ali, a long-time member of the CRM, Professor at Concordia University, eminent researcher in mathematical physics, good friend and valued colleague. The following is a collection of personal recollections by some of his closest friends and collaborators, who had the privilege of sharing thoughts and experiences with him over many years, and an overview of his career and his scientific contributions.

Personal recollections

Jean-Pierre Antoine (Louvain-la-Neuve)

I started to collaborate with Twareque in 1989, on the topic of coherent states. He was originally referred to me because of difficulties encountered in the decomposition of a phase space representation of the Poincaré group. The solution to this was quickly found, just replacing a bounded Hilbert space operator by an unbounded one, and this began a wonderful collaboration that continued till the sadly unexpected, premature end of his life. In the following year, Jean-Pierre Gazeau joined us and thus started our triangular collaboration that led to eleven joint papers and two joint books.

Twareque travelled a lot; we kept meeting each other all over the world, until the most recent times. We often attended the same meetings, in addition to visiting each other at our home universities, including being respective invited professors. To name a few of the places we travelled together, there were Québec, Germany (Clausthal), Poland (Białowieża), Cuba, France, Italy, Bangladesh (Dhaka), China (Tianjin), India (Bangalore), and many others.

Working with Twareque was always a rewarding experience. Even if his papers were sometimes dense and compact, his clean, polished mathematical style was always a pleasure to read, and all his papers have a luminous clarity. His nonscientific writings have the same quality, including his poetry; I remember a memorable poem composed by him in Białowieża! His talks were always extremely clear and pedagogically well thought out, and his ideas were often thought-provoking.

Altogether I feel fortunate to have been able to work with him for so long, and so surely do all his other collaborators. Everyone will remember his characteristic whole-hearted laughter, inviting everyone to share his great and subtle sense of humour, and enjoyment of the moment, and of life.

Jean-Pierre Gazeau (Paris-Diderot)

I met Twareque through Jean-Pierre Antoine at the end of the 1980s, and we started a long and fruitful collaboration, which continued to the last. It was always extremely pleasant to work with him because of his intelligence and extreme tolerance for the ideas advanced by others. Open mindedness was one of his great qualities. We still had new projects planned, and I had planned to come to Montréal this May to develop one of these with his recent Master's student Das. I believe it was my mention of Twareque's name to Anatol Odzijewicz in '91 that led to his subsequent strong and constant involvement in the organization of the Białowieża series, with so many excellent remembrances.

Gerald Goldin (Rutgers)

Twareque Ali and I met in Clausthal, Germany during the 1980s, invited by Heinz-Dietrich Doebner to the Arnold Sommerfeld Institute. Each summer from 1992 to 2015, nearly without exception, we would see each other at the Workshop on Geometric Methods in Physics in Białowieża, Poland. With our spouses we toured Beijing and visited the Great Wall of China after the Group Theory Colloquium in Tianjin in 2012 (where he was honoured on the occasion of his 70th birthday). We shared family weddings and other events. Twareque was not only a colleague and collaborator, but a close personal friend, an intimate confidant. He was someone with whom one could discuss the meaning of life's joys and disappointments without self-consciousness.

With his serious expression, his black hair and beard only lately streaked with grey, he looked thoughtful and wise — but his eyes twinkled, and he loved to laugh. He knew how to live life, to find humour in its seriousness. He would quote poetry extensively from memory, in Bengali, Italian, German,

and of course English. He loved Omar Khayyam's Rubáyát, in the Edward FitzGerald translations. And his laughter always restored balance. He was especially fond of the novel *Small World* by David Lodge, which satirizes the sometimes pretentious academic scene we both knew so well. We imagined we could recognize Lodge's characters in people we knew, including (of course) ourselves.

And Twareque was a deep thinker. He believed deeply in peace, and gave generously of himself to the less-privileged in the world. For him, the truths of science were part of the ever-unattainable beauty for which he yearned, for which all of us yearn. He sought scientific truths through mathematics, especially an understanding of the mysteries of quantum mechanics. Influenced deeply by his teacher Gérard Emch, he in turn inspired numerous students and colleagues. Though Twareque has gone now, his inspiration, gentleness, and humanity will live on for many generations.

John Harnad (Concordia)

Twareque was a cherished friend, a unique and wonderful human being, a highly esteemed researcher and valued colleague. We shared many things over nearly four decades of friendship. All who knew Twareque could appreciate his abundance of wisdom, humour, generosity, kindness, tolerance, and enduring, simple goodness of nature.

Science and friendship were both very important to him. He had a large network of colleagues and friends around the globe with whom he kept in touch in his many travels, and shared his enjoyment of life, and his fascination with the variety and richness of all he encountered. He saw something positive everywhere, and had a genuine love of different cultures, personalities and environments, finding something of value to enjoy and celebrate everywhere he went and in all things he did.

It was characteristic of Twareque to be constantly on the move, travelling around the world, visiting friends and family, attending scientific conferences, sharing his thoughts and experiences generously with others, while always further augmenting his vast store of knowledge, his awareness of things of beauty, and the poetry and richness of life.

Sharing his laughter, good humour and enjoyment of the diverse environments he relished and the friendships he formed helped lift everyone's spirits. The wide scope of his knowledge, not only of science, but the broad range of human experience, things of learning and of beauty, poetry, art, diverse cultures and languages, together with the benefits of humour, combined to give him a unique perspective on life. We all benefitted from his positive spirit, his learning, and his appreciation of the variety and richness of life.

In addition to his scientific work, he worked relentlessly, discretely, unobtrusively, in helping others in need; this was simply second nature to him, an essential ingredient in his life. Whether those who came to Canada to continue their lives, or remained in his home country of Bangladesh, or in Cuba, or elsewhere, where circumstances made their lives much more difficult than here, he was always helping those facing the challenges of life. He made it his ongoing mission to assist students, colleagues and others in overcoming the obstacles they faced and making possible the fullest use of their abilities. Throughout the many crises that occurred in his country of origin, he remained a lifelong, devoted, generous source of help to those who needed it.

I had the good fortune of sharing and enjoying his friendship, his company and good nature for many years, occasionally on travels, at various events and places around the world, as well as at home. It was both uplifting and cheering to be with him. I greatly benefitted from the generous gift of his friendship, his wisdom, his kindness and his enjoyment and celebration of life. Twareque was a unique, kind and good human being, an irreplaceable friend and highly valued colleague. He will be sorely missed.

Mourad Ismail (Central Florida)

I first met Twareque Ali when we both arrived in Toronto in the fall of 1975 to start a one-year postdoctoral fellowship. We shared an office and taught two different sections of a calculus class concurrently. Twareque had such a nice personality that we became friends very quickly and this led eventually to a lifelong friendship.

In those early days, it seemed that our research interests were far apart, but later Twareque and I met at various conferences and exchanged ideas about our work. Fast forwarding thirty-five years, when I visited Montréal in the summer of 2011, Twareque told me about coherent states and proposed a very interesting question involving orthogonal polynomials. We then began a very enjoyable and fruitful working collaboration on this problem. He also invited me to give a talk at a special session he was organizing at a meeting on Group Theoretical methods in Physics in Tianjin, China. At first, I was hesitant, but Twareque insisted that it would be worthwhile to attend. In the end, it turned out to be one of the most productive meetings I ever attended. Thanks to Twareque, working on this topic led to a goldmine of new research results relating our overlapping interests in orthogonal polynomials and coherent states, including two joint papers on the subject.

Twareque will live in my memory for the rest of my life, as a friend, collaborator, and a very caring and wonderful human being.

Anna Krasowska (Vanier College) and **Renata Deptula** (John Abbott College)

Twareque Ali was our Ph.D. supervisor at Concordia University; we came to know him as "Dr. Ali." He will forever remain in our hearts as Dr. Ali, and this is the way we remember him, a fatherly figure. He had a far deeper impact in our lives than the role of supervisor.

He was always a very patient, encouraging teacher and so generous with his time. He understood so well all the needs and challenges of students in a foreign land, undoubtedly because this had been his experience more than once in his own life. Our meetings, while mostly filled with discussions about

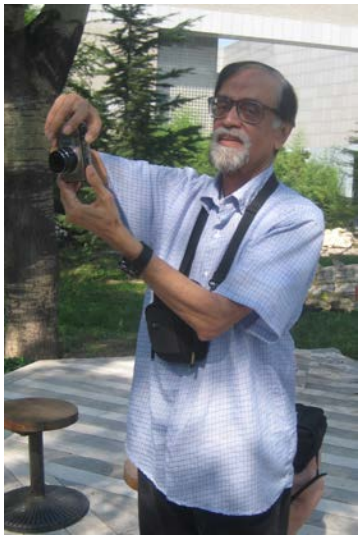
wavelets or Wigner functions, always had time reserved to talk about our new experiences in Montréal. If anything in our lives became too complicated it was a clear sign we needed to talk to Dr. Ali. Every meeting with him provided a big dose of encouragement and new energy, never accompanied with any criticism or judgment.

All his students knew how fond he was of visiting new places, meeting new people, establishing new friendships. And as it was with everything else, whatever he cherished, he shared: whether we travelled to Cuba, Mexico or Germany we felt part of a big family, because we were students of Dr. Ali.

It has been a great privilege to have known Dr. Ali. He will always be an inspiration to us as a wonderful teacher and a virtuous person.

Reinaldo Rodriguez Ramos (Havana)

Twareque Ali's contributions to the scientific development of the Faculty of Mathematics and Computer Science at the University of Havana went well beyond the co-organization of conference series. Since 1998, he began collaborating with the faculty, encouraging the participation of teachers in research and in the development of the research on wavelets and its various applications. He provided further ongoing help to the University and the Faculty of Mathematics and Computer Science by organizing donations of computer equipment and bringing international experts to deliver specialized courses and share their knowledge and experience with the Cuban community of mathematicians. In 2009, the University of Havana honoured him with the special award of Invited Professor of the University of Havana.



He was a man of great human sensitivity, and a deep thinker who could often come up with the best solution to any problem. He was also a cherished special friend of my family. We regret the loss of a great friend and a great man of science.

Overview of Twareque Ali's scientific contributions and career

Nitya kaaler utshab taba
Bishyer-i-dipaalika
Aami shudhu tar-i-mateer pradeep
Jaalao tahaar shikhaa (Tagore)
(English transl.: "Thine is an eternal celebration… A cosmic Festival of Lights!… Therein I am a mere flicker of a wicker lamp… O kindle its flame, (my Master!).")

Twareque Ali's life and career included a range of contrasting experiences. Born a citizen of the British Empire, he acquired a succession of three further nationalities: Pakistani in 1947, Bangladeshi in 1971, and finally Canadian.

After completing his M.Sc. in Dhaka, Bangladesh in 1966, and a Ph.D. in 1973 in Rochester, USA under the supervision of G. Emch, he occupied positions successively at ICTP (Trieste, Italy), Univ. of Toronto, Univ. of Prince Edward Island, and TU Clausthal (Germany), before settling down, in 1981, in Montréal, first as Assistant Professor (1981 – 1983) in the Department of Mathematics and Statistics, Concordia University, then Associate Professor (1983 – 1990) and finally Full Professor (as of 1990).

Twareque Ali was a world-recognized leader in at least three domains of current research in mathematical physics: quantization methods, coherent states and wavelet analysis; he managed to build important bridges between these, as well as publishing a large number of ground breaking research articles and widely appreciated monographs on these subjects.

He was a member of the Mathematical Physics Laboratory of the Centre de recherches mathématiques since its inception in 2001, and contributed actively to its range of scientific activities. He was also Concordia's representative to the ISM for many years, before becoming ISM Director in 2003. Over the years, he was an invited professor at many foreign universities throughout the world and was in constant demand as an invited speaker at international conferences.

His main scientific interests can be aptly summarized by the key words that represent his favourite topics: phase space, quantization, positive operator valued measures, reproducing kernels, coherent states. He began a close and fruitful collaboration in the late 1980s with two of his principal co-authors — Jean-Pierre Antoine and Jean-Pierre Gazeau — that continued throughout his lifetime. As described in the personal recollections above, it is on the last of these topics that they collaborated for the first time and this continued up to the present day. Along the way, eleven papers were jointly written (plus four with JPA alone and ten with JPG), three books edited (the Białowieża conference proceedings), two research monographs [2, 3] were co-authored, and a recent special volume co-edited, together with F. Bagarello [1]. Throughout these years, Twareque relentlessly sought to instill mathematical rigour in the field of coherent states, something he felt was needed, but too often missing in some of the published literature on quantum optics.

More specifically, in the 1970s and 1980s, he devoted much of his attention to measurement problems in (fuzzy) phase space and stochastic, Galilean and Einsteinian; quantum mechanics. This was partly in joint work with E. Prugovecki in Toronto (which led to a memorable and lasting dispute with Gerald Kaiser), G. Emch in Rochester and H.-D. Doebner in Clausthal. His 1984 *Stochastic Localization, Quantum Mechanics on Phase Space and Quantum Space-Time* was a pedagogical landmark for the domain. He then gradually focused on coherent states for the Galilei and the Poincaré groups and other semi-direct product groups. One of his first works in this direction was with S. De Bièvre. A notable result of [2] was the extension of square integrability of group representations to homogeneous spaces and the introduction of continuous frames in Hilbert spaces, the key to many applications, including wavelets.

One of his best known joint papers with Antoine and Gazeau was the 1993 Annals of Physics *Continuous frames in Hilbert space*. Twareque subsequently began to be interested in quantization methods, mostly Berezin or coherent states quantization, and in the mathematics of signal processing. In the last few years, his focus of interest included noncommutative quantum mechanics, quaternionic Hilbert spaces and complex orthogonal polynomials, on which a further productive collaboration began with his old friend from Toronto days, Mourad Ismail. (See M. I.'s personal recollections above.)

Travelling widely and frequently in his professional life, he always managed to combine these travels with a keen appreciation for the cultural and human milieu in which he found himself.

Another important part of Twareque's working life was the organization of scientific meetings on topics generally related to his research interests. Two series of conferences are notable. First, the Białowieża Workshops on Geometric Methods in Physics, spearheaded by their charismatic founder and chief organizer, Anatol Odzijewicz. These take place annually in a region of Poland bordering on Belarus that is famous for its local culture and natural beauty, the wild forests, bison, and local artisanal crafts. The workshops are characterized also by the abundance of good food (as well as vodka), good spirits and active participation of several Russian mathematicians of the highest caliber. From the XIth meeting, in 1992, onward, Twareque was instrumental in transforming what was earlier a small local workshop into a full-fledged international event, which is still going strong. (The last edition was Nr. XXXIV, in June, 2015.)

A further remarkable achievement was the series of workshops in Havana, Cuba, organized jointly by Concordia University and the Universidad de La Habana, in which the leading spirit was Twareque's longtime friend Reinaldo Rodriguez Ramos. As member of the Organizing Committee and founder of the Workshops I – XII held in the Faculty of Mathematics and Computer Science at La Habana from 1998 to date, Twareque was one of the driving forces of the meetings. He succeeded in attracting a number of distinguished participants of international standing to those beautiful surroundings and almost single-handedly arranged for the publication of the proceedings. Through the Department of Mathematics and Statistics and the Center for International Academic Cooperation at Concordia University, he contributed valuably to the development of international cooperation and scientific collaboration with the Universidad de La Habana.

More recently Twareque also became a faithful participant and contributor at the school and workshops on mathematical physics (COPROMAPH) organized in Cotonou, Bénin, by Norbert Hounkonnou.

Throughout his career Twareque was deeply devoted to the teaching and supervision of students, both undergraduate and graduate, and was greatly appreciated by all his students for his patience, insight and generous help. Chairman of the graduate studies committee at Concordia's Department of Mathematics and Statistics for many years, nine Doctoral degrees were completed under his supervision or co-supervision and an equal number of Master's degrees. He was also, from 2003 till 2006, Director of the Institut des sciences mathématiques (ISM), the inter-university consortium responsible for coordinating graduate studies at Québec universities. During his term as Director, he contributed much to the enhancement of both the quality of graduate education in mathematics at Québec universities and the level of its support. He helped enhance the ISM outreach to schools and CEGEPs, as well as to improve and advance the rationalization of pedagogical resources, the level of cooperation between different university groups, and the recruitment of high quality students from overseas.

All his scientific colleagues and collaborators would agree that Twareque had a very deep and subtle understanding of Quantum Physics, both in its foundations and its working mathematical tools. It was extremely pleasant to interact and work with him, not just because of his intelligence, original insights and innovative contributions, but also his modesty, consideration and generous interest in the ideas advanced by others. Open-mindedness was one of his greatest qualities.

[1] S.T. Ali, J.-P. Antoine, F. Bagarello, and J.-P. Gazeau, eds. *J. Phys. A: Math. Theor.* 45.24 (2012): *Special Issue on Coherent States*: *Mathematical and Physical Aspects.*

[2] S.T. Ali, J.-P. Antoine, and J.-P. Gazeau. *Coherent States, Wavelets and Their Generalizations.* 2nd ed. Theoretical and Mathematical Physics, volume. New York: Springer, 2014.

[3] J.-P. Antoine, R. Murenzi, P. Vandergheynst, and S.T. Ali. *Two-Dimensional Wavelets and their Relatives.* Cambridge: Cambridge Univ. Press, 2004.

Grande Conférence publique du CRM

The Art and Science of Systems Involving Too Many Unknowns

Emmanuel Candès (Stanford University)

Christian Genest and David A. Stephens (McGill)

Emmanuel Candès

On October 29, 2015, a public lecture on *The Art and Science of Systems Involving Too Many Unknowns* was given at the CRM by Professor Emmanuel Candès, holder of the Barnum – Simons Chair in Mathematics and Statistics at Stanford University. Born in Paris, France, where he received most of his education, Professor Candès has consistently earned high acclaim for his groundbreaking contributions to compressed sensing, an area of research and emerging technology that largely grew out of his joint work with Justin Romberg and Terence Tao over the past 15 years [1–3].

Compressed sensing [4] is a signal processing technique for efficiently acquiring and reconstructing a signal by solving underdetermined linear systems of equations. In his hour-long presentation, Professor Candès motivated and illustrated some of his research on the subject by drawing mainly from diagnostic medicine, with an emphasis on medical magnetic resonance imaging, where the need for rapid and yet high-quality image reconstruction is paramount. He stressed, however, that compressed sensing finds applications in many other areas, including circuit design, optics, photography, holography, and facial recognition. As a further illustration of this general methodology, he discussed the 2006 – 2009 Netflix Prize open competition, whose ultimate goal was to predict user ratings for films as accurately as possible, based only on previous ratings without any other information about the users or films.

Compressed sensing is based on the principle that, through optimization, the sparsity of a signal can be exploited to recover it from far fewer observations than prescribed by the famous Nyquist – Shannon theorem. In the canonical two-dimensional imaging example, measurements y are made at various locations (k_1, k_2) in the spectral domain, the required image f lies in the spatial domain, and the two objects are related through the identity

$$y(k_1, k_2) = \iint f(x_1, x_2) K(k_1, k_2, x_1, x_2)\, \mathrm{d}x_1\, \mathrm{d}x_2,$$

where K stands for a Fourier kernel. The main challenge is to reconstruct f at as high a resolution as possible when only a sketch of the Fourier transform is available, i.e. on the basis of a few observations from the spectrum. Minimizing data collection in the spectral domain is practically relevant, e.g. in the context of magnetic resonance imaging where taking measurements is potentially time consuming and invasive or unpleasant for the patient.

Professor Candès explained that under a discrete approximation, the problem of reconstructing an image f from indirect measurements $y \in \mathbb{R}^m$ reduces, for a known $m \times n$ matrix A, to the solution $x \in \mathbb{R}^n$ of a linear system of equations $y = Ax$ given by the discrete (inverse) Fourier transform of the observed data. This system is underdetermined when $m < n$, i.e. when data collection has low resolution. However, a unique solution can be found by imposing that x has as many zero entries as possible, provided that the measurement matrix A satisfies minimal conditions, in particular if it contains a sufficient amount of "randomness" and "incoherence."

In practice, the search for the sparse (or compressed) solution is computationally intractable, as it is an NP-hard problem. Luckily, it turns out that under broad and realistic conditions, equivalent sparse solutions can be obtained by instead imposing ℓ_1 constraints, thereby converting the optimization problem into a convex programming issue. As Professor Candès showed, the resulting sparse reconstruction is extremely effective.

In the last third of his talk, Professor Candès went on to demonstrate how these principles could be generalized to other forms of underdetermined systems using alternative constrained solutions and low-rank decompositions. The unifying theme was again the framing of a mathematically and computationally intractable problem in a tractable, convex optimization setting.

The "Grande Conférence" by Professor Candès attracted a large audience and aroused much interest among mathematicians, statisticians, and the general public alike. It was a privilege to have him visit Montréal and the CRM for a few days. A video of his talk (in French) can be found at www.crm.math.ca/Candes/, and a related lecture (in English) given by Professor Candès at the 2014 International Congress of Mathematicians in Seoul, South Korea, is available on YouTube (www.youtube.com/watch?v=W-b4aDGsbJk). See also [5] for a popular introduction to compressed sensing.

[1] E.J. Candès and J.K. Romberg. "Sparsity and incoherence in compressive sampling". *Inverse Problems* 23:3 (2007), 969–985.

[2] E.J. Candès, J.K. Romberg, and T. Tao. "Stable signal recovery from incomplete and inaccurate measurements". *Comm. Pure Appl. Math.* 59:8 (2006), 1207–1223.

(*continued on page 14*)

Prix CRM – SSC

Matías Salibián-Barrera (UBC)

La détection de courbes aberrantes

Éric Marchand (Sherbrooke)

Matías Salibián-Barrera, professeur titulaire de l'Université de la Colombie-Britannique et 17e lauréat du prix CRM – SSC, était à Montréal le 11 février dernier pour présenter des travaux de recherche récents. C'est en reconnaissance de ses contributions fondamentales à la statistique robuste et à des algorithmes innovants que Matías s'est vu décerner ce prix prestigieux.

L'exposé du professeur Salibián-Barrera (disponible sur le site WEB du CRM) a brillamment abordé des perspectives aussi diverses que les défis de la modélisation en statistique et de l'identification de données aberrantes, l'analyse de données fonctionnelles (ADF) traitant de l'analyse d'échantillons de courbes et de surfaces, l'analyse en composantes principales en ADF et l'utilisation de méthodes robustes pour estimer ces composantes principales. Le tout fut illustré par une analyse de courbes (journalières) de concentration d'ozone à Richmond (C.B.) pour les mois d'août de 2004 à 2012.

L'évolution de la statistique robuste émane du souci que les modèles avec lesquels on travaille sous-estiment la variabilité sous-jacente ou encore la complexité des données. Elle cherche à développer des méthodes d'inférence moins sensibles à des données atypiques ou non représentatives du modèle. Matías Salibián-Barrera a aussi relevé la pertinence accrue d'aborder de telles méthodes robustes, ainsi que des distributions de mélange, dans des contextes actuels où les données deviennent d'une part plus faciles à obtenir et plus volumineuses, mais d'autre part sont assujetties à des sources de plus en plus hétérogènes.

En analyse de données fonctionnelles (voir par exemple l'ouvrage de Jim Ramsay et de Bernard Silverman), chaque observation — dont la concentration d'ozone sur une période de 24 heures — est une courbe ou une surface. L'identification de données aberrantes ou atypiques est alors plus complexe que pour le cas de données vectorielles car l'évaluation de la proximité de deux courbes par une distance usuelle telle la distance L^2 ne tient pas compte d'une différence de forme.

Et de telles différences peuvent être très significatives pour des courbes. Matías Salibián-Barrera a abordé de telles difficultés et a passé en revue la notion de profondeur pour des données vectorielles (due à John Tukey), ainsi que de telles mesures pour des données fonctionnelles et permettant d'identifier des courbes atypiques.

L'exposé s'est alors tourné vers l'analyse en composantes principales (ACP) en ADF et la recherche d'une bonne approximation pour des données fonctionnelles (typiquement en dimension infinie) par des objets en plus basse dimension. Une technique pour contourner cette difficulté fait intervenir la représentation de Karhunen – Loève en termes d'éléments de la base orthonormale associée aux valeurs propres d'un opérateur induit par la fonction d'autocovariance. Par contre, cette approche requiert l'existence de seconds moments et des méthodes alternatives robustes sont alors d'intérêt.

Matías Salibián-Barrera

Abordant des aspects de modélisation probabiliste, Matías Salibián-Barrera a introduit la notion de courbes elliptiques et d'une représentation-clé faisant intervenir des mélanges de lois normales, telles que présentées dans un article conjoint avec Graciela Boente et David Tyler (*Journal of Multivariate Analysis*, 2014). Matías a alors enchaîné avec la présentation d'une nouvelle méthode (G. Boente et M. Salibián-Barrera, *Journal of the American Statistical Association*, 2015) robuste pour l'analyse en composantes principales de données fonctionnelles. Il a présenté des propriétés d'optimalité, dont la convergence, il a exposé des défis au niveau de la mise en œuvre de l'algorithme et il a conclu par une évaluation et une illustration de la méthode proposée sur les données de concentration.

Emmanuel Candès

(*continued from page* 13)

[3] E.J. Candès and T. Tao. "The power of convex relaxation: Near-optimal matrix completion". *IEEE Trans. Inform. Theory* 56:5 (2010), 2053–2080.

[4] D.L. Donoho. "Compressed sensing". *IEEE Trans. Inform. Theory* 52:4 (2006), 1289–1306.

[5] D. Mackenzie. "Compressed sensing makes every pixel count". *What's Happening in the Mathematical Sciences, Volume* 7. Providence, RI: Amer. Math. Soc., 2009, 114–127.

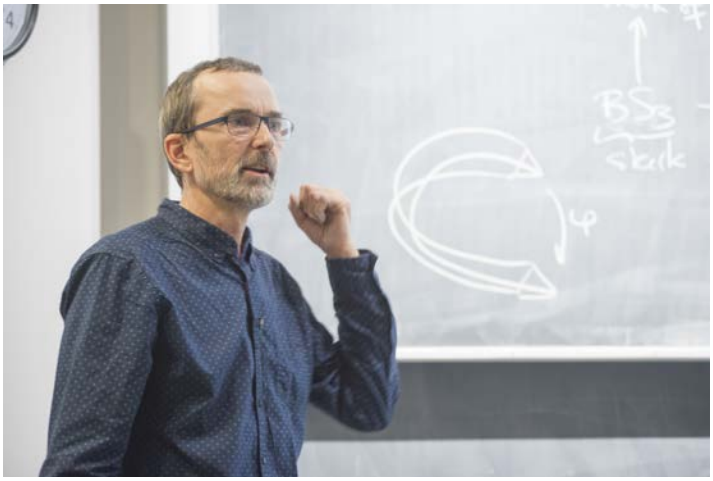
2015 CRM – Fields – PIMS Prize

Lecture by Kai Behrend (UBC)

Algebraic Stacks and the Inertia Operator

Jacques Hurtubise (McGill)

What does the space of all curves look like? How about the space of all algebraic subvarieties of projective space? The question of how to describe and classify such objects has preoccupied algebraic geometers for more than a century, and has seen a variety of approaches. Tied to this question is of course that of deciding which objects in our category are the same; one is typically quotienting out some group of equivalences. In the late nineteenth century, a lot of effort went into describing invariant theory — one looks for functions on a set of objects invariant under the action of the group. Mumford, in the 1960s, gave more geometric meaning to this by describing which geometric objects were actually described by the invariants — the so-called stable ones.



Kai Behrend

It turns out, however, than in a few crucial applications, these stable objects are not enough — the function theory misses some objects, and has trouble handling families. This brought on, already in the 1960s, the theory of stacks. In some sense, stacks are tautological — one simply takes all families, and all equivalences and maps between families, and tries not to get lost in all the arrows. The difficulty, of course, is in describing the actual properties of such a creature; for example, what is its cohomology?

There are applications: for example, the theory of Gromov – Witten classes of a complex manifold. One considers the set of maps of curves into a complex manifold, and integrates certain naturally defined forms over this set, to get numbers, which should be invariants. But are they? How does one integrate them? And the Gromov – Witten are only some of the invariants, many inspired by ideas from theoretical physics, that have appeared over the last few years, and involve similar basic issues of definition.

Kai Behrend's work has given us many answers to these types of questions, for example in developing the fundamental cycle over which one performs the integrals. He has, along with his collaborators, built up the theory of these stacks and other related objects, not only in the algebraic category, but also in the related area of symplectic geometry, where similar invariants can be found, easy to posit, but hard to define in a rigorous fashion. His work has been fundamental in understanding these invariants, and for this he was quite rightly awarded the 2015 CRM – Fields – PIMS Prize.

It was therefore with great pleasure that the Montréal mathematical community went to hear him lecture on some of the basic ideas underlying stacks, illustrated by a very simple example, that of families of triangles in the plane. In essence, while equivalence classes of triangles are well known, one can already see some of the subtleties which occur when considering families. In the end, this justifies, if not for triangles at least for the more elaborate cases involved in defining invariants, the development of a remarkable and elaborate machine. And more, a machine which gives answers.

Prix

Louigi Addario-Berry

Louigi Addario-Berry

Le directeur adjoint aux programmes scientifiques du CRM, Louigi Addario-Berry (McGill) est le lauréat 2016 du prix Coxeter – James pour sa contribution exceptionnelle à la recherche mathématique. Louigi Addario-Berry s'intéresse aux interconnexions entre la probabilité et la combinatoire. « Le professeur Addario-Berry s'est taillé une place comme leader de sa génération dans le domaine des probabilités discrètes », a commenté un évaluateur.

Le prix Coxeter – James de la SMC a été créé en 1978 afin de souligner la contribution exceptionnelle de jeunes mathématiciens qui se sont démarqués dans le domaine de la recherche en mathématique.

Appel à propositions

Le CRM émet un appel à propositions concernant des activités scientifiques de haut niveau en sciences mathématiques. Lors du choix de notre programme scientifique, notre priorité est de soutenir des activités de grande qualité scientifique qui présentent de passionnantes nouvelles directions de recherche à la communauté du CRM tout entière.

Programmes thématiques

Ils sont le fondement des activités du CRM. Généralement les programmes thématiques sont d'une durée allant de 4 mois à un an. Ils englobent des ateliers, des conférences, des mini-cours ou des écoles, ainsi que des séjours prolongés au CRM, de chercheurs venant d'ailleurs.

Programme général

Le CRM appuie également des activités de courte durée qui ne sont pas associées au programme thématique. Elles comprennent des ateliers, des conférences, des groupes de recherche, et des activités de formation telles que les écoles ou les mini-cours soutenues par des chercheurs invités.

Calendrier

Programmes thématiques

Nous sollicitons présentement des lettres d'intention en vue des programmes thématiques qui se tiendront au cours de la période de juillet 2019 à juin 2020. Les lettres d'intention devraient inclure l'information suivante :

- Le titre du programme.
- Le nom et les coordonnées des organisateurs.
- Une description scientifique de l'événement, incluant les principales activités de recherche et de formation.
- Une liste provisoire des principaux participants invités et leur rôle éventuel dans le cadre du programme.
- Un calendrier des activités proposées.

Les lettres d'intention devraient être transmises au plus tard le **1er octobre 2016**.

Programme général

Nous sollicitons présentement les propositions pour des activités de courte durée qui auront lieu au cours de la période commençant en juillet 2017 et se terminant en juin 2018. La date limite pour soumettre des propositions d'activités qui se tiendront en 2017 est le **1er octobre 2016**. La date limite pour soumettre des propositions d'activités qui se tiendront en 2018 est le **1er avril 2017**.

Conditions

Toutes les activités doivent être d'un intérêt scientifique manifeste et pertinentes pour les domaines de recherches du CRM. L'argumentaire doit être détaillé dans la proposition.

Le CRM reconnaît la sous-représentation systématique de groupes dans la communauté de chercheurs en sciences mathématiques et compte sur les organisateurs pour aborder cette question, à la fois dans la proposition et dans la planification.

Généralement, le CRM ne finance pas les événements qui se répètent. Il est notamment peu probable que les conférences récurrentes reçoivent un appui.

Pour de plus amples informations

De l'information supplémentaire sur les conditions des propositions est disponible à crm.math.ca/Propositions.

Les propositions doivent être envoyées au CRM par courriel à projet@crm.umontreal.ca.

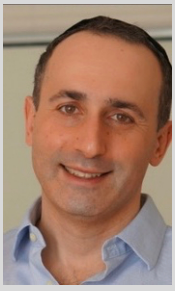
Simons Fellows

Adrian Iovita et Adam Oberman

Adrian Iovita

Deux membres du CRM, Adrian Iovita (Concordia) et Adam Oberman (McGill) viennent d'être nommés « Simons Fellows » en mathématiques par la Simons Foundation. Les 37 *fellows* choisis en mathématiques pour 2016 (dont trois provenant d'universités canadiennes) sont d'éminents mathématiciens à différents stades de leurs carrières respectives.

Les *fellows* reçoivent des fonds leur assurant, pendant quelques mois ou un semestre, une tâche réduite d'enseignement et de services à la collectivité. Cette réduction de tâche stimule la créativité et la productivité des professeurs qui reçoivent cet honneur.



Adam Oberman

Call for Proposals

The CRM invites proposals for scientific activities of high calibre in the mathematical sciences. When choosing our scientific programming, our priority is to support activities of top scientific quality and which introduce exciting new research directions to the entire CRM community.

Thematic programs

These are a cornerstone of the CRM activities. Thematic programs typically have a duration of between four months and one year. They include workshops, conferences, short courses or schools, and extended visits to the CRM by researchers from other locations.

General program

The CRM also supports shorter activities not associated with a thematic program. These include workshops, conferences, research in groups, and training activities such as schools or short courses by visiting scholars.

Timeframe

Thematic programs

We are currently inviting letters of intent (LOIs) for thematic programs to take place in the period July 2019 – June 2020. LOIs should include the following information:

- The title of the program.
- Names and contact information for the organizers.
- A scientific description of the event, including the major research and training activities.
- A tentative list of the principal invited participants and their proposed role within the thematic program.
- A proposed timeline of activities.

LOIs should be received by **October 1, 2016**.

General program

We are currently inviting proposals for shorter activities to take place in the period July 2017 – June 2018. For activities taking place in 2017, the deadline for proposals is **October 1, 2016**. For activities taking place in 2018, the deadline for proposals is **April 1, 2017**.

Requirements

All activities should be of clear scientific interest and relevance to the research areas of the CRM. The case for this should be explicitly made in the proposal.

The CRM recognizes that there are systematically underrepresented groups within the mathematical sciences research community, and expects organizers to actively address this fact, both in their proposal and throughout the planning process.

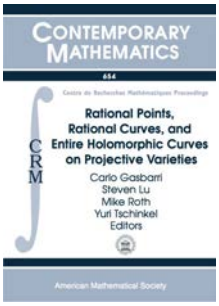
The CRM typically does not fund repeat events. In particular, recurring conferences are unlikely to be offered support.

Further information

Additional information on requirements for proposals can be found at crm.math.ca/Proposals.

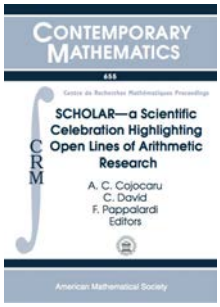
Proposals should be sent to the CRM by email at proposal@crm.umontreal.ca.

AMS – CRM Publications



This volume contains papers from the Short Thematic Program on Rational Points, Rational Curves, and Entire Holomorphic Curves and Algebraic Varieties, held from June 3 – 28, 2013, at the CRM.

The program was dedicated to the study of subtle interconnections between geometric and arithmetic properties of higher-dimensional algebraic varieties. The main areas of the program were, among others, proving density of rational points in Zariski or analytic topology on special varieties, understanding global geometric properties of rationally connected varieties, as well as connections between geometry and algebraic dynamics exploring new geometric techniques in Diophantine approximation.



M. Ram Murty has had a profound impact on the development of number theory throughout the world. To honour his mathematical legacy, a conference focusing on new research directions in number theory inspired by his most significant achievements was held from October 15 – 17, 2013, at the CRM.

This proceedings volume is representative of the broad spectrum of topics that were addressed at the conference, such as elliptic curves, function field arithmetic, Galois representations, L-functions, modular forms and automorphic forms, sieve methods, and transcendental number theory.

Positive Grassmannians: Applications to Integrable Systems and Super Yang – Mills Scattering Amplitudes

July 27 — 31, 2015

Organizers: Marco Bertola (Concordia and SISSA), Michael Gekhtman (Notre-Dame), John Harnad (Concordia)

The workshop was organized within the framework of the thematic semester "AdS/CFT, Holography, Integrability." The theory of Grassmannians and their positive substructures has been developed by mathematicians without a particular application to physics in mind; on the other hand, in the past years, theoretical physicists have recognized that certain computations they performed laboriously by hand can be framed in that theory. The encounter is thus one of those serendipitous situations in science, like the development of non-Euclidean geometries (a purely mathematical topic, at the time of their invention without any "real" application) and later on general relativity.

The main goal of the workshop was therefore bringing together mathematicians and theoretical physicists who have been lately discovering that the tools developed in the study of positive Grassmannians prove useful in seemingly unrelated fields such as computation of scattering amplitudes, soliton interactions, discovery of new discrete integrable models, mirror symmetry, parameterizations of rings of invariants, etc.

Each session of the workshop was loosely tied to a unifying theme, although none of these topics were isolated within a general flow of the workshop. These included

- Integrable maps generated by cluster mutations (Glick, Pylyavskyy, Shapiro, Kenyon)
- Combinatorics of positive Grassmannians with applications to geometry and analysis (Farber, Muller, Neitzke, H. Williams, L. Williams)
- Scattering amplitudes, on-shell diagrams and the amplituhedron (Arkani-Hamed, Franco, Thomas, Trnka)
- Cluster structures in Poisson geometry and invariant theory (Fomin, Gekhtman)
- Solitons and positive Grassmannians (Abenda, Kodama)
- Conformal field theory and quantum cluster algebras (Di Francesco, Kedem, Marshakov)
- Twistor theory (Mason)
- Cluster combinatorics (Garver, Musiker)

The scope of presentations ranged from analyzing a particular illustrative example, to reporting on progress on a long-term research program, to providing a broad overview of future directions of research. For example, Shapiro and Kenyon presented two different approaches to the construction of discrete integrable systems associated with toric quivers — one relying on rational boundary measurement matrices arising from directed networks on a cylinder, another based on dimer configurations constructed from Newton polytopes of algebraic curves. These talks were complemented by Glick's report on a new rich family of discrete maps that can be analyzed via either of these approaches and by Pylyavskyy's account of conjectures on integrability of certain compositions of cluster mutations associated with bipartite quivers, complete with supporting examples.

Similarly, lectures of Arkani-Hamed and Thomas presented complementary perspectives on the definition and properties of the amplituhedron, one motivated by theoretical physics, another geometric and combinatorial in nature. Franco and Trnka provided a fascinating array of concrete examples and conjectures arising in the study of the amplituhedron.

New exciting applications of the combinatorics of plabic networks in a disc — to the mirror duality and to Legendrian knots — were outlined in talks by L. Williams and H. Williams, while Fomin described how more complicated networks (possibly on higher genus surfaces) provide novel insights into the classical theory of invariants. He concluded with a list of concrete conjectures that will be certain to attract a lot of interest.

The success of the goal of bridging together, developing a common language and striking interactions between the abstract mathematical community on the one hand, and the theoretical physics community on the other, was evident. With sixty registered participants, the talks were well attended and were followed by active discussions during breaks between the talks, and in the afternoon. We list these examples as evidence of the successful and scientifically significant event that the workshop proved to be.

Particularly enlightening was the panel discussion: a panel of experts (Gekhtman, Harnad, Kodama, Mason, Trnka, L. Williams), representing the main themes of the workshop, invited the audience to a discussion of questions and problems inspired by workshop, often striving at creating an effective translation dictionary between the two communities.

The organizers are investigating the possibility of publishing proceedings of the workshop in a special issue of *Journal of Physics* A: *Mathematical and General*.

Le Bulletin du CRM
Volume 22, N° 1
Printemps 2016

Le *Bulletin du CRM* est une lettre d'information à contenu scientifique, faisant le point sur les actualités du Centre de recherches mathématiques (CRM).

ISSN 1492-7659

Le Centre de recherches mathématiques a vu le jour en 1969. Actuellement dirigé par Luc Vinet, il a pour objectif de servir de centre national pour la recherche fondamentale en mathématiques et leurs applications. Le personnel scientifique du CRM regroupe plus d'une centaine de membres réguliers et de boursiers postdoctoraux. De plus, le CRM accueille chaque année entre mille et mille cinq cents chercheurs du monde entier.

Le CRM coordonne des cours de cycles supérieurs et joue un rôle prépondérant (en collaboration avec l'ISM) dans la formation de jeunes chercheurs. On retrouve partout dans le monde de nombreux chercheurs ayant eu l'occasion de parfaire leur formation en recherche au CRM. Le Centre est un lieu privilégié de rencontres où tous les membres bénéficient de nombreux échanges et collaborations scientifiques.

Le CRM tient à remercier ses divers partenaires pour leur appui financier à sa mission : le Conseil de recherches en sciences naturelles et en génie du Canada, le Fonds de recherche du Québec – Nature et technologies, la National Science Foundation, l'Université de Montréal, l'Université du Québec à Montréal, l'Université McGill, l'Université Concordia, l'Université Laval, l'Université d'Ottawa, l'Université de Sherbrooke, le réseau Mitacs, ainsi que les fonds de dotation André-Aisenstadt et Serge-Bissonnette.

Directeur : Luc Vinet

Directrice d'édition : *Galia Dafni*
Conception : *André Montpetit*

Centre de recherches mathématiques
Université de Montréal
C.P. 6128, succ. Centre-ville
Montréal, QC H3C 3J7

Téléphone : 514.343.7501
Courriel : CRM@CRM.UMontréal.CA

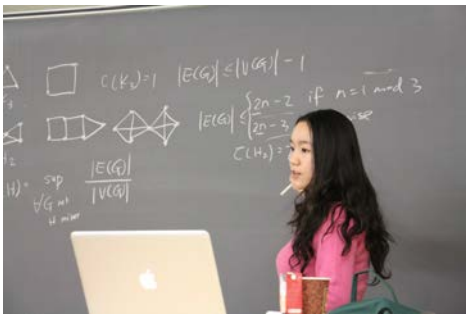
Le Bulletin est disponible à :
crm.math.ca/docs/docBul_fr.shtml.

Séminaires Universitaires en Mathématiques à Montréal

Alexis Langlois-Rémillard, président de l'édition 2016 des SUMM

Ce sont près de 130 étudiantes et étudiants en mathématiques, en physique, en statistique et en informatique du Québec et de l'Ontario qui se sont rassemblés en janvier dernier à l'occasion de la septième édition des *Séminaires Universitaires en Mathématiques à Montréal*. Grâce à l'accueil généreux du département de mathématiques de l'Université du Québec à Montréal et de l'ISM, les participants et participantes du colloque ont échangé pendant une fin de semaine des idées, communiqué des problèmes mathématiques et présenté leurs résultats de recherche, le tout dans une atmosphère conviviale. Ce fut l'occasion pour plusieurs de rencontrer ou de revoir leurs collègues provenant de diverses universités de la métropole et de l'étranger. De constater autant de cohésion au sein de la communauté mathématique étudiante est pour nous fort réjouissant.

Dix-neuf conférences étudiantes sur une palette variée de sujets ont ainsi été données en anglais et en français, en plus des traditionnelles conférences plénières. Cette année, ce sont les professeurs Christian Genest de McGill, Franco Saliola de l'UQAM, Dimiter Dryanov de Concordia ainsi que la professeure Marlène Frigon de l'Université de Montréal qui ont eu la parole lors de la fin de semaine.



Conférence étudiante Photo : *Gida Hussani*

Cette année, l'événement était subventionné et soutenu par les départements de mathématiques et de statistique des universités montréalaises, par le service à la vie étudiante et la faculté des sciences de l'UQAM, par l'ISM, le STUDC, Waterloo Maplesoft ainsi que les nombreuses associations étudiantes de mathématiques et de statistique de la métropole.

CRM Summer School on Spectral Theory and Applications
Université Laval, July 4 – 14, 2016

The goal of the 2016 CRM Summer School in Quebec City is to prepare students for research involving spectral theory. The school will give an overview of a selection of topics from spectral theory, interpreted in a broad sense. It will cover topics from pure and applied mathematics, each of which will be presented in a 5-hour mini-course by a leading expert. These lectures will be complemented by supervised computer labs and exercise sessions. At the end of the school, invited speakers will give specialized talks. This rich subject intertwines several sub-disciplines of mathematics, and it will be especially beneficial to students. The subject is also very timely, as spectral theory is witnessing major progress both in its mathematical sub-disciplines and in its applications to technology and science in general.

The school is intended for advanced undergraduate and beginning graduate students. As such, the prerequisites will be kept at a minimum. Students will be housed on campus in the university dormitories.

For more information, or to submit an application, please see the webpage of the summer school: www.crm.math.ca/2016/Quebec16/

Mot du directeur

Merci ! Thank you!

We never say that enough. If you are reading these lines it is because you have an interest in the CRM, and you may be sure that we appreciate it. Thank you.

Si vous avez des textes à lire dans ce *Bulletin*, c'est que des collègues ont pris du temps pour les écrire, c'est qu'il y a eu des événements scientifiques excitants, des chercheurs qui sont venus de partout pour y participer, des organisateurs qui ont conçu et réalisé ces activités, des membres de comités bénévoles qui ont apporté leur assistance, etc. Je les en remercie tous. Merci aussi au grand public qui participe aux grandes conférences que l'on organise pour lui.

If the *Bulletin* offers interesting reading material, it is due to industrial partners teaming up with our researchers, lab directors orchestrating our 13 research units, and the presence in their midst of fantastic graduate students, postdocs and faculty that keep making scientific advances. We applaude all of them. This *Bulletin* is in front of you also because the CRM has a creative executive team and above all a remarkable staff composed of dedicated and professional people who are making it all happen. This is not taken for granted. Nothing would occur of course without the financial support from our funding agencies, our partner universities and the tax payers. We are very grateful.

From January onward, the CRM has transitioned from an extremely successful ensemble of activities organized around the AdS/CFT correspondance to a programming focusing on computational mathematics in emerging applications. As usual the diversity of events past or future is inspiring. I hope you will enjoy learning about these many facets of the CRM in the various articles of this *Bulletin*. J'espère que cela aura pour effet de soutenir votre intérêt et de vous encourager à maintenir votre implication dans cet institut qui est le vôtre.

Le CRM est une grande famille accueillante et « tricotée serré » qui cherche toujours à s'agrandir et à intégrer d'autres membres. Comme toute famille, le CRM partage les joies et les succès des uns mais aussi les peines que la vie amène. Nous nous réjouissons énormément de la reconnaissance dont plusieurs membres du CRM ont été l'objet récemment, mentionnons le prix Coxeter – James de la SMC à Louigi Addario-Berry, les prix CRM – Fields – PIMS et Jeffrey – Williams à Dani Wise et les Simons fellowships à Adrian Iovita et Adam Oberman. Si besoin était, cela témoigne de l'immense talent des chercheurs que le CRM regroupe.

The CRM was much saddened however by the recent loss of three members who were all intimately part of the fabrics of the CRM: Jacques St-Pierre who was the first Director of the CRM, Twareque Ali, our much esteemed colleague from the Mathematical Physics Lab, and Fedor Soloviev, a postdoctoral fellow in that same lab. We mourn them and will have them in mind as we move forward, always celebrating the human spirit. Merci Jacques, thank you Twareque, thank you Fedor. Ils sont le CRM et vous l'êtes aussi.

Luc Vinet

In memoriam

Jacques St-Pierre

Jacques St-Pierre

M. Jacques St-Pierre, premier directeur du Centre de recherches mathématiques, s'est éteint le 29 mars 2016 à l'âge de 95 ans.

À la fin des années 60, Roger Gaudry, Maurice L'Abbé et Jacques St-Pierre jetaient les bases du CRM pour créer le prototype du modèle qui est aujourd'hui prévalent. On ne peut que s'émerveiller de la force visionnaire de ces fondateurs. Jacques St-Pierre aura été le premier directeur du CRM ; c'est à lui que l'on doit la mise en place des structures administratives qui ont si bien servi le centre.

Springer – CRM Publications

CRM Short Courses

The CRM is happy to announce the recent launch of a new series of publications with Springer.

The volumes in the CRM Short Courses series have a primarily instructional aim, focusing on presenting topics of current interest to readers ranging from graduate students to experienced researchers in the mathematical sciences. Each text is aimed at bringing the reader to the forefront of research in a particular area or field, and can consist of one or several courses with a unified theme. The inclusion of exercises, while welcome, is not strictly required. Publications are largely but not exclusively, based on schools, instructional workshops and lecture series hosted by, or affiliated with, the Centre de recherches mathématiques (CRM). Special emphasis is given to the quality of exposition and pedagogical value of each text.

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