CENTRE DE RECHERCHES MATHÉMATIQUES

Annual Report

2011
2012

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2011 2012

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Presenting the Annual Report 2011–2012

It is a pleasure to present the CRM annual report for 2011-2012. Our two themes for the year, Quantum Information on one hand and Geometric Analysis and Spectral Theory on the other, are among the most important research areas in the mathematical sciences. As is now the tradition at the CRM, the Centre welcomed world-renowned experts in both themes, including the Aisenstadt Chairholders: John Preskill, Renato Renner, László Erdős, Elon Lindenstrauss, and Richard M. Schoen. Apart from the lectures by these Chairholders, the thematic semester on Quantum Information featured one summer school, two conferences, and four workshops, while the thematic semester on Geometric Analysis and Spectral Theory featured six workshops. In 2011-2012 the CRM also had a substantial general program, since it organized or supported 14 events (schools, conferences, or workshops), in particular two very important summer schools (the Summer School on Non-Equilibrium Statistical Mechanics and the Séminaire de Mathématiques Supérieures on Metric Measure Spaces) and the International Workshop on the Perspectives on High-Dimensional Data Analysis II. The multidisciplinary and industrial program of the CRM in 2011-2012 included a conference on statistics (Statistics 2011 Canada), a workshop on the climate problem, and the Fourth Montréal Industrial Problem Solving Workshop.

The CRM is also proud of the outstanding researchers who were awarded its four prizes this year: Stevo Todorčević from the University of Toronto (CRM–Fields–PIMS Prize 2012), Marco Gualtieri from the University of Toronto and Young-Heon Kim from the University of British Columbia (both awarded the André-Aisenstadt Prize 2012), Luc Vinet from the Université de Montréal (CAP–CRM Prize 2012), and Changbao Wu from the University of Waterloo (CRM–SSC Prize 2012).

For several years now the CRM has had international agreements, in particular with the ALGANT consortium of the European Union and the Tata Institute of Fundamental Research in India. The year 2011 was a milestone in the development of international relations at the CRM, since the CNRS (the institution responsible for research in France) established an Unité Mixte Internationale (UMI) at the CRM. This UMI, one of only 30 UMIs (in all subjects) around the world, is led by Laurent Habsieger (CNRS) and the CRM director. It supports visits of French mathematicians to the CRM and vice versa, thus ensuring the creation or strengthening of links between the two countries.

The activities of the CRM are supported by the Government of Canada through NSERC, the Government of Québec through FRQNT, the Government of the United States through the National Science Foundation (NSF), the Mprime network, and its partner universities: the Université de Montréal, McGill University, the Université du Québec à Montréal, Concordia University, the Université Laval, the Université de Sherbrooke, and the University of Ottawa. On behalf of the CRM I extend my warmest thanks to all of these institutions, which have helped the CRM attain the status of a world-class research centre in the mathematical sciences.

François Lalonde, Director
Centre de recherches mathématiques (CRM)

Thematic Program

Thematic Programs of the Year 2011–2012 "Quantum Information" and "Geometric Analysis and Spectral Theory"

Quantum Information

Quantum information science is an interdisciplinary field lying at the boundary of mathematics, computer science and physics. The main goal of the field is to understand the fundamental nature of information in a quantum mechanical world while simultaneously trying to exploit that understanding for technological gain. Montréal has been an important centre for quantum information research from the beginning; twenty-five years ago, Gilles Brassard, a local researcher, invented the first protocol for exchanging secret keys exploiting quantum mechanics. About fifteen years ago, Brassard, Claude Crépeau and collaborators discovered the famous quantum teleportation protocol following a workshop here in Montréal.

The Fall 2011 thematic semester on quantum information was notable not just for the variety and success of its activities, but also for its judicious application of creative chronology. Fall 2011 officially began in June with the 11th Canadian Summer School on Quantum Information and ended when Montréal hosted the 2012 edition of the prestigious Quantum Information Conference in December 2011. In between, there was a student-only conference designed to provide young researchers with a supportive environment in which to present their research, in addition to four workshops exploring quantum information from the point of view of computer science, many-body physics, communication theory, and the foundations of quantum mechanics. Renato Renner of ETH Zürich and John Preskill of Caltech together spent about five weeks in Québec as the two Aisenstadt chairs, delivering seven brilliant and well-attended distinguished lectures.

The semester also benefited from the heroically industrious participation of Charles Bennett, Aram Harrow and Steve Flammia, the three schismatic popes of the Quantum Pontiff blog (http://dabacon.org/pontiff). Together, they produced live transcripts for several of the thematic semester's workshops and conferences. Readers interested in browsing the bloggers' capsule summaries of the talks can follow the links provided below.

The scientific committee of the semester included the following researchers: Alexandre Blais (Sherbrooke), Gilles Brassard (Montréal), Claude Crépeau (McGill), Guillaume Duclos-Cianci (Sherbrooke), Christopher Fuchs (Perimeter Inst.), Patrick Hayden (McGill), Aram Harrow (Washington), Peter Høyer (Calgary), Olivier Landon-Cardinal (Sherbrooke), Michel Pioro-Ladrière (Sherbrooke), David Poulin (Sherbrooke), Bertrand Reulet (Sherbrooke), Louis Salvail (Montréal), and Alain Tapp (Montréal).

Geometric Analysis and Spectral Theory

The 2012 Spring Semester focused on various topics in geometric analysis, spectral theory, partial differential equations, and mathematical physics, including: geometric PDE, spectral geometry, probabilistic methods in geometry and analysis, quantum many-body systems, and geometry and dynamics of fluids. The goal of the semester was to highlight some remarkable recent developments and to foster collaboration between researchers working in these diverse and yet interrelated areas of mathematics. The semester featured six workshops, respectively on convexity and asymptotic geometric analysis, geometric PDE, the geometry and dynamics of fluid, quantum many-body systems, the geometry of eigenvalues and eigenfunctions, and manifolds of metrics and probabilistic methods in geometry and analysis.

The scientific committee of the semester included the following researchers: Galia Dafni (Concordia), Pengfei Guan (McGill), Dmitry Jakobson (McGill), Vojkan Jakšić (McGill), Niky Kamran (McGill), Sergei Kuksin (École Polytechnique), Iosif Polterovich (Montréal), Stephen Preston (CU-Boulder), Robert Seiringer (McGill), Alexander Shnirelman (Concordia), Alina Stancu (Concordia), John Toth (McGill), and Steve Zelditch (Northwestern).

Aisenstadt Chairholders in 2011–2012
John Preskill, Renato Renner, László Erdős, Elon Lindenstrauss, and Richard M. Schoen

John Preskill and Renato Renner were the Aisenstadt chairholders for the semester on quantum information. László Erdős, Elon Linderstrauss, and Richard M. Schoen were the Aisenstadt chairholders for the semester on geometric analysis and spectral theory.

John Preskill

by Patrick Hayden (McGill University)

John Preskill is the Richard P. Feynman Professor of Theoretical Physics at Caltech and began his career working at the intersection of particle physics and cosmology. Early on, he observed that incorporating grand unified theories of elementary particles into cosmology predicts the widespread production of superheavy magnetic monopoles, which is in sharp conflict with observation. Resolving the conflict ultimately led to the theory of the inflationary universe.

Inspired by Peter Shor's landmark factoring paper in the mid-1990s, Preskill became interested in whether quantum computers could ever be stabilized against imperfections and environmental noise. With his student Daniel Gottesman and others, Preskill made the profound discovery that once the noise is pushed below a certain threshold value, quantum computations can be scaled up indefinitely. Contrary to expectation, longer and larger computations do not require appreciably more precise apparatus. In the absence of the threshold theorem, quantum computation would have been a theoretical curiosity without any prospect of ever becoming an engineering reality. With the theorem in hand (if not always understood), armies of experimentalists are now trying to build viable quantum computers. Over the past fifteen years, Preskill has relentlessly pursued improvements to the theory of quantum fault-tolerance. By simplifying the reasoning, improving the underlying computational building blocks, and introducing more realistic models of the noise, he, as much as anyone, has helped close the gap between what experimentalists can achieve and the noise thresholds required for fault tolerance.

In another celebrated result, Preskill joined forces with Peter Shor to give a proof of the security of quantum key distribution. The goal in key distribution is for two parties to expand a very short secret into an arbitrarily long one, which can then be used as cryptographic fuel for secure encryption and many other tasks. Information-theoretically secure key distribution is impossible without invoking the laws of quantum mechanics, but in the 1980s Bennett and Brassard showed how to exploit quantum mechanics to make it work. Real-world complications like noise and loss confound their protocol and analysis, however. Université de Montréal Ph.D. student Dominic Myers found a way around those problems, but his argument was uncommonly difficult to follow and, hence, underappreciated. Preskill and Shor found a conceptually simple proof by relating the security of real-life key distribution protocols to the success of currently science-fictional entanglement distillation protocols. In cryptography, vulnerabilities stem just as often from subtle implicit assumptions as from failures of abstract reasoning, so the transparent simplicity of the Shor–Preskill proof greatly amplified its impact.

In addition to being a leading researcher, Preskill has been a prolific mentor to young scientists. He has supervised more than 40 Ph.D. students over the years, an impressive fraction of whom are now leading researchers themselves. His lecture notes on quantum computation form one of the standard references on the subject. In 2000 he founded the Institute for Quantum Information (IQI) at Caltech, which for many years was the undisputed theoretical hub of the subject. (Today it is just the disputed hub.) Many of Canada's leading young researchers in quantum information spent time as postdoctoral fellows at the IQI, including Andrew Childs (Waterloo), Debbie Leung (Waterloo), Ashwin Nayak (Waterloo), David Poulin (Sherbrooke), and Robert Raussendorf (UBC). (I was lucky to spend three years there myself.)

As the Aisenstadt chair, Preskill delivered a series of four lectures: a public lecture, physics colloquia at McGill and Sherbrooke, as well as a research talk in the Codes, Geometry and Random Structures workshop. The public lecture, entitled "Putting weirdness to work: quantum information science," gave a high-level introduction to quantum algorithms, key distribution and fault-tolerance, ending with a report on the current experimental state of the art. The physics collo-

quia were devoted to "Battling decoherence: the fault-tolerant quantum computer." In each, Preskill managed to explain the crucial ideas behind quantum fault-tolerance in just under an hour. Starting with an explanation of how quantum error correcting codes can be used to correct continuous families of errors, he then showed how to compute with encoded qubits, ultimately building to the recursive error-suppression of full fault-tolerant quantum computation. To analyze the recursive construction, he used a particularly versatile and robust version of the threshold argument that he found with Gottesman and Aliferis in 2005. The talk ended with a quick introduction to topological quantum computation, in which the inherent stability of the topological degrees of freedom thought to be present in certain exotic materials could eliminate (or at least mitigate) the need for active quantum error correction.

Preskill's contribution to the Codes, Geometry and Random Structures workshop was a remarkable hybrid of nonlinear quantum electronics and quantum error correction to which he gave the title "Protected gates for superconducting qubits." Over the past few years, experiments building qubits out of the macroscopic degrees of freedom of superconducting circuits have made tremendous strides. The decoherence time of such qubits, for example, has been extended by several orders of magnitude. Preskill's objective was to find a way to engineer superconducting qubits that would be intrinsically fault-tolerant, just as excitations in materials with topological order are thought to be. Remarkably, he, Peter Brooks, and Alexei Kitaev showed that there is a quantum error correcting code lurking inside the previously proposed superconducting "0–π" qubit. More importantly, logic gates can be fault-tolerantly applied to the encoded qubits using nothing more exotic than a tunable Josephson coupling between an LC oscillator and the qubits in question. This work arguably increases from two to three the number of known paradigms for achieving fault-tolerant quantum computation. More importantly, it hints that there are probably others awaiting invention.

Renato Renner

by Patrick Hayden (McGill University)

Despite having only received his Ph.D. in 2005, Renato Renner has already had a tremendous impact on quantum information theory and its applications to both quantum cryptography and statistical physics. Recipient of medals for the best diploma and Ph.D. theses at ETH Zürich, as well as a dissertation prize from the Association for Computing Machinery, his alma mater quickly hired him as an assistant professor in their Institute for Theoretical Physics in 2007.

The ideas and techniques introduced in Renner's Ph.D. thesis have spread like wildfire through the community of quantum information researchers. Shannon's entropy plays a central role in information theory and the von Neumann entropy an analogous role in quantum information theory. When studying optimal compression rates or communication capacities, however, the Shannon and von Neumann entropies provide the right answers only when the systems being studied have a great deal of independence in their constituents. When communicating over channels with internal memory states or trying to analyze the eavesdropping strategies of a malicious adversary, the standard entropies prove to be clumsy and often inadequate tools. In his thesis, Renner introduced the quantum min-entropy and developed a formalism for analyzing it. This new entropy reduces to the von Neumann entropy in the appropriate limit of many identical and independent quantum states, but is universally applicable. The thesis then proceeded to give a new proof of the security of quantum key distribution sufficiently general to encompass most of the known protocols. More importantly, the proof yielded quantitative bounds on the security of the protocols for finite length keys; previous arguments were only valid in the limit of infinite key lengths.

Since completing his thesis, Renner has been astonishingly productive, having written over 90 articles at last count, including an amazing 21 last year, during which he was also graciously fulfilling his duties as Aisenstadt chair. That work has now comprehensively reformulated quantum information theory in the universal min-entropy formalism. One benefit of the formalism is that the theory applies without modification to real physical systems, in which the independence assumptions justifying the use of the von Neumann entropy are often violated. In a beautiful recent Nature paper, Renner and his collaborators showed that the conditional min-entropy is proportional to the amount of work required to erase the contents of one quantum memory register without modifying another. Providing an interesting twist on the second law of thermodynamics, the fact that the conditional min-entropy

is negative for some entangled quantum states means that erasing information can sometimes produce work rather than consuming it.

Renner gave a series of three Aisenstadt lectures: a public lecture and two scientific talks, one each in the Quantum Computer Science and Quantum Many-Body Physics workshops. The public lecture addressed the question: "What does quantum cryptography tell us about quantum physics?" Renner started by observing that Aisenstadt, like himself, had obtained a doctorate in Zürich and then somewhat later become involved with the CRM. While Renner's supervisor was the very eminent cryptographer Ueli Maurer, Aisenstadt worked for none other than Albert Einstein. Since Renner's talk would be devoted to consequences of cryptography for the completeness of quantum mechanics, the latter a subject of great concern to the great man himself, it seemed an auspicious beginning.

John Bell's great discovery in the 1960s was that quantum mechanics made predictions incompatible with *local realism*, the paired assumptions that signals can't propagate faster than light and that objects have well-defined states prior to being measured. Experiments have since confirmed Bell's predictions, requiring that either locality or realism be false. These developments were generally thought to refute Einstein's view that a more complete theory of physics would ultimately replace quantum mechanics. However, while Bell's result ruled out a wholesale replacement of quantum mechanics by a local realistic theory, it isn't widely appreciated that the possibility of a more complete theory of physics remained open. In his talk, Renner presented joint work with Roger Colbeck (Perimeter) that finally lays that possibility to rest. Half the challenge was formulating a clear mathematical question, but they ultimately proved a more formal version of the following statement:

Theorem. *Assume that measurement statistics are correctly predicted by quantum theory and that measurement settings can be chosen freely. Then there cannot exist any extended theory that provides additional information about the outcomes of quantum measurements.*

Not surprisingly, the formalization of "providing additional information" involves Renner's beloved quantum conditional entropies. The proof of the theorem was both ingenious and elementary, allowing him to present it in its entirety during the public lecture. The connection to cryptography is that the argument was by contradiction, making use of an experiment inspired by previously proposed quantum key distribution protocols. For his talk in the Quantum Computer Science workshop, Renner spoke about "Free randomness amplification," another project with Roger Colbeck. The mathematical concept of free randomness is actually a way of formalizing, through the use of random variables located in spacetime, the words "chosen freely" used in the theorem above. In his lecture, he showed how a weak source of free randomness could be processed and upgraded into a form sufficiently good to be used in the theorem or in cryptographic applications. Crucially, the argument doesn't assume the validity of quantum mechanics, just the impossibility of signalling faster than light. Finally, changing gears somewhat, Renner devoted his final lecture, in the Quantum Information in Many-Body Physics workshop, to "An information-theoretic view on thermalization." The talk sketched some of the implications of our rapidly advancing understanding of quantum information for thermodynamics, including the remarkable discovery mentioned earlier in this article that work can sometimes be extracted when erasing parts of entangled quantum states.

László Erdős

In the week of March 19, Professor László Erdős was visiting the CRM as Aisenstadt chair. L. Erdős is Chair of Applied Mathematics and Numerics at the Ludwig-Maximilians-Universität München, Germany. He has made substantial contributions to the analysis of large quantum systems, in particular concerning the derivation of effective kinetic equations in certain scaling limits. His recent research has led to spectacular new results in the theory of random matrices, which was the topic of his Aisenstadt lectures.

L. Erdős gave three lectures during his visit. The first one, which was suitable for a general audience, was entitled "Universality of spectral statistics of random matrices." It contained a description of the recent proof of the celebrated Wigner–Gaudin–Mehta–Dyson conjecture, which was obtained by L. Erdős in collaboration with Benjamin Schlein, Horng-Tzer Yau and Jun Yin. This conjecture asserts that the local eigenvalue statistics of a random matrix with independent entries depend only on the symmetry class of the random matrix and is independent of the detailed structure of the matrix ensemble. In particular, it is the same as for the Gaussian ensembles, where the eigenvalue distribution

can be calculated explicitly. L. Erdős presented a nice overview of the history of this subject, and explained the key steps involved in their proof.

His subsequent talk ("The local version of Wigner's semicircle law and Dyson's Brownian motion") contained some of the details of the proof. In particular, L. Erdős explained the notion of Dyson Brownian motion and how it can be used in combination with a local version of Wigner's semicircle law to prove universality for arbitrary Wigner matrices. Finally, in the third talk by L. Erdős ("Quantum diffusion and random band matrices"), the problem of localization vs. diffusion for random band matrices was discussed. Random band matrices can be viewed as intermediate between completely random matrices and random Schrödinger operators, where the randomness is only in the diagonal. There is a precise conjecture on the critical band width separating the regimes of localization and delocalization, respectively, and L. Erdős and his collaborators have recently made substantial progress towards a proof of this conjecture.

Elon Lindenstrauss

Professor Elon Lindenstrauss from Hebrew University of Jerusalem delivered a series of three Aisenstadt lectures from June 4 to June 7, 2012, during the Workshop on Geometry of Eigenvalues and Eigenfunctions. Professor Lindenstrauss is a world leader in Ergodic Theory and Dynamical Systems. His contributions include the proof of the Arithmetic Quantum Unique Ergodicity conjecture of Rudnick and Sarnak, work on the Littlewood conjecture, and study of distributions of periodic torus orbits in some arithmetic spaces. He was awarded the Fields Medal in 2010. Professor Lindenstrauss has received numerous other prizes, including the Clay Fellowship, the 2003 Salem Prize, the 2004 European Mathematical Society Prize, the 2008 Michael Bruno Memorial Award, and the 2009 Erdős and Fermat Prizes.

In the lectures, Professor Lindenstrauss discussed his proof of the Quantum Unique Ergodicity conjecture and related work, which concerns asymptotic distribution of eigenfunctions of the Laplacian on a Riemannian manifold in the semiclassical limit. Asymptotic behaviour of eigenfunctions is one example of the relationship between classical dynamics of systems and their quantum behaviour. The Quantum Unique Ergodicity Conjecture of Rudnick and Sarnak states that if the manifold has negative sectional curvature (which implies that the classical dynamics is uniformly hyperbolic, hence "chaotic"), the eigenfunctions of the Laplacian should become equidistributed in the semiclassical limit.

In the first lecture (titled "Entropy and Quantum Unique Ergodicity"), Professor Lindenstrauss gave an overview of ergodic flows, the Kolmogorov–Sinai entropy of ergodic measures, the Ledrappier–Young entropy formula, and the Bowen–Margulis theorem on equidistribution of periodic orbits. He then reviewed Shnirelman's Quantum Ergodicity theorem and the Quantum Unique Ergodicity conjecture, and he discussed recent results due to Anantharaman, Nonnenmacher, and Koch that hold for general negatively curved surfaces.

The second and third lectures were devoted to Quantum Unique Ergodicity on finite area arithmetic hyperbolic surfaces. Such surfaces possess a lot of symmetry, provided by the Hecke operators. Joint eigenfunctions of the Laplacian and those operators are called Hecke–Maass automorphic forms. They play an important role in modern analytic number theory. One can use Hecke operators to get much more information about Hecke–Maass forms than about general eigenfunctions. Lindenstrauss surveyed recent results about these eigenfunctions (and the closely related class of holomorphic forms) using both number theoretic and dynamical techniques developed by himself (some of them together with Bourgain), Silberman and Venkatesh, Holowinsky and Soundararajan.

Professor Lindenstrauss also presented his recent joint work with S. Brooks, which relates the study of eigenfunctions and quasi modes on arithmetic surfaces to the study of eigenfunctions of the discrete Laplacian on finite graphs.

Richard M. Schoen

Professor Richard Schoen delivered a series of three Aisenstadt lectures from February 27 to March 2, 2012. Professor Schoen is Anne T. and Robert M. Bass Professor of Mathematics at Stanford University. He is a world leader in the field of geometric analysis. His many outstanding research achievements include the proof of the positive mass conjecture in General Relativity (with Shing-Tung Yau), the solution of the Yamabe problem, and the proof of the differentiable sphere theorem (with Simon Brendle). He has been awarded

the Bôcher Memorial Prize, the MacArthur Fellowship, and the Guggenheim Fellowship. He is a member of the National Academy of Sciences and the American Academy of Arts and Sciences.

The three lectures by Professor Schoen focused on some recent developments in geometric analysis. His first lecture was on "The geometry of positive curvature." He started with a beautiful survey of Riemannian manifolds of positive curvature, summarizing what is known and what is conjectured. He then presented the recent breakthrough on the quarter pinching theorem, which was proved by S. Brendle and himself. This landmark result was achieved through a powerful analysis of the Ricci flow, one of the most important techniques in geometric analysis, together with geodesic and minimal surface techniques. This result provides deep insight into the geometry of manifolds with positive curvature and represents another major advance in mathematics after Perelman's proof of the Poincaré conjecture.

In the second lecture, Professor Schoen described his recent work with A. Fraser concerning an extremal problem for the first Steklov eigenvalue on surfaces with boundary. This question is closely related to the investigation of extremal metrics for the first eigenvalue of the Laplacian on compact closed surfaces. In both Laplace and Steklov cases, extremal eigenvalue problems are linked to the study of minimal surfaces. For closed surfaces these are minimal surfaces in spheres, while for surfaces with boundary one obtains minimal surfaces in a ball satisfying some natural boundary condition. A detailed description was given for extremal surfaces for the first Steklov eigenvalue in the genus zero case.

The final lecture was concerned with a new mean curvature proof of the space-time positive mass theorem. The original Schoen–Yau mean curvature proof of the general positive mass theorem gave the positivity of energy. In a recent joint work with M. Eichmair, L. Huang, and D. Lee, a direct proof was given of the timelike character of the total energy momentum vector using the marginally outer trapped surface (MOTS) equation. They also improved the density theorems for initial data sets satisfying the dominant energy condition.

Aisenstadt Chair

The Aisenstadt chair was endowed by Montréal philanthropist Dr. André Aisenstadt. Under its auspices, one or more distinguished mathematicians are invited each year for a period of at least one week, ideally one or two months. During their stay the lecturers present a series of lectures on a specialized topic. They are also invited to prepare a monograph (see the chapter on publications in the present report for a list of these monographs). At the request of Dr. Aisenstadt, the first lecture given by an Aisenstadt chairholder should be accessible to a wide audience. Previous holders of the Aisenstadt chair are: Marc Kac, Eduardo Zarantonello, Robert Hermann, Marcos Moshinsky, Sybren de Groot, Donald Knuth, Jacques-Louis Lions, R. Tyrrell Rockafellar, Yuval Ne'eman, Gian-Carlo Rota, Laurent Schwartz, Gérard Debreu, Philip Holmes, Ronald Graham, Robert Langlands, Yuri Manin, Jerrold Marsden, Dan Voiculescu, James Arthur, Eugene B. Dynkin, David P. Ruelle, Robert Bryant, Blaine Lawson, Yves Meyer, Ioannis Karatzas, László Babai, Efim I. Zelmanov, Peter Hall, Sir David Cox, Frans Oort, Joel S. Feldman, Roman Jackiw, Duong H. Phong, Michael S. Waterman, Arthur T. Winfree, Edward Frenkel, Laurent Lafforgue, George Lusztig, László Lovász, Endre Szemerédi, Peter Sarnak, Shing-Tung Yau, Thomas Yizhao Hou, Andrew J. Majda, Manjul Bhargava, K. Soundararajan, Terence Tao, Noga Alon, Paul Seymour, Richard Stanley, John J. Tyson, John Rinzel, Gerhard Huisken, Jean-Christophe Yoccoz, Wendelin Werner, Andrei Okounkov, Svante Janson, Craig Tracy, Stéphane Mallat, Claude Le Bris, Akshay Venkatesh, Yuri Gurevich, Angus Macintyre, Alexander Razborov, James Robins.

Activities of the Thematic Semesters

11th Canadian Summer School on Quantum Information

June 6–15, 2011, Jouvence

Sponsored by the CRM, the Université de Sherbrooke, EPIQ, CIFAR, INTRIQ, Mitacs, the Perimeter Institute for Theoretical Physics, and QuantumWorks

Main Organizer: David Poulin (Sherbrooke)

Co-organizers:

Alexandre Blais (Sherbrooke), Michel Pioro-Ladrière (Sherbrooke), Bertrand Reulet (Sherbrooke)

Speakers:
Patrice Bertet (CEA/Saclay), Gilles Brassard (Montréal), Carlton M. Caves (Albuquerque), Andrew Childs (Waterloo), Daniel Gottesman (Perimeter Inst.), Kurt Jacobs (UMass Boston), Michele Mosca (Waterloo), Jason Petta (Princeton), Robert Raussendorf (UBC), Renato Renner (ETH Zürich), Norbert Schuch (Caltech), Graeme Smith (IBM Res.)

Number of participants: 112

Over the past decade, the Canadian Summer School on Quantum Information has developed into a venerable institution as the go-to summer destination for young people interested in pursuing research in the area. The School has rotated through Calgary, Montréal, Toronto, Waterloo, and Vancouver over the years, so bringing it back to the Montréal area was the perfect way to kick off the thematic semester. This 11th edition was organized by Université de Sherbrooke professors David Poulin, Alexandre Blais, Michel Pioro-Ladrière, and Bertrand Reulet. More than 90 students attended, representing 37 universities in 21 countries. Those international students were treated not just to challenging courses, but to a quintessentially Canadian lakeside setting at the idyllic Centre de villégiature Jouvence in Québec's Parc national du Mont-Orford. The quiet setting allowed the students, ranging from the M.Sc. to the postdoctoral level, to focus on their intense program of twelve mini-courses, offered by as many world-renowned researchers. The wide-ranging list of topics (given below) introduced the students to the interdisciplinary scope of quantum information science.

- Patrice Bertet, *Superconducting qubits*
- Gilles Brassard, *Communication complexity*
- Carlton M. Caves, *High precision measurements*
- Andrew Childs, *Quantum algorithms*
- Daniel Gottesman, *Quantum error correction*
- Kurt Jacobs, *Decoherence*
- Michele Mosca, *Quantum algorithms*
- Jason Petta, *Spin qubits in quantum dots*
- Robert Raussendorf, *Topological fault-tolerance*
- Renato Renner, *Quantum cryptography*
- Norbert Schuch, *Quantum many-body physics*
- Graeme Smith, *Quantum channels and capacities*

The organizers also took the innovative step of making the summer school a formal graduate-level course at the Université de Sherbrooke. Students received three credits for successful completion of the school, which for the first time included a challenging final exam assembled from questions supplied by the lecturers. The organizers noted the positive effects of the looming final exam on the students' focus and work ethic. The next edition of the school will take place in Waterloo in the summer of 2012.

8th Canadian Student Conference on Quantum Information

June 16–17, 2011, Jouvence

Sponsored by the CRM, the Université de Sherbrooke, EPIQ, CIFAR, INTRIQ, Mitacs, the Perimeter Institute for Theoretical Physics, and QuantumWorks

Organizers:
Guillaume Duclos-Cianci (Sherbrooke), Olivier Landon-Cardinal (Sherbrooke)

Speakers:
Khulud Almutairi (Calgary), Félix Beaudoin (Sherbrooke), Ran Hee Choi (Calgary), Julien Camirand-Lemyre (Sherbrooke), Sergey Filippov (MIPT), Kent Fisher (Waterloo), Jan Florjanczyk (McGill), Jose Raul Gonzalez Alonso (Southern California), Paweł Mazurek (Gdańsk), Leonardo A. Pachon (Toronto), Kyungdeock Park (Waterloo), Sarah Plosker (Guelph), Anna Przysiężna (Gdańsk), Cyril Stark (ETH Zürich), Xiaoya Judy Wang (McGill), Marco Zaopo (Pavia), Lucy Liuxuan Zhang (Toronto)

The student conference was held in Jouvence immediately after the summer school, making it convenient to participate in both. The conference has also become something of a tradition, organized and attended exclusively by students, free from the intimidating interference of their graduate supervisors. This year, the organizers were Université de Sherbrooke Ph.D. students Guillaume Duclos-Cianci and Olivier Landon-Cardinal. The conference fulfills a real need since traditional conferences usually provide very few opportunities for exposure to junior researchers. At the student conference, every participant had the opportunity to present his or her work as either a talk or a poster. Speakers were strongly encouraged to make their presentations accessible. In the end, 70 students participated, from countries as diverse as Colombia, Korea, India, Italy, Switzerland, Poland, Russia, and the United States.

Workshop on Quantum Computer Science

October 4–7, 2011, CRM

Organizers:
Peter Høyer (Calgary), Alain Tapp (Montréal)

Speakers:
Aleksandr Arkhipov (MIT), Gilles Brassard (Montréal), Harry Buhrman (CWI & Amsterdam), Andrew Childs (Waterloo), Matthias Christandl (ETH Zürich), Richard Cleve (Waterloo), Andrew Drucker (MIT), Daniel Gottesman (Perimeter Inst.), Peter Høyer, Marc Kaplan (Montréal), Elham Kashefi (Edinburgh), Sophie Laplante (Paris-Sud), Debby Leung (Waterloo), Michele Mosca (Waterloo), Ashwin Nayak (Waterloo), David Poulin (Sherbrooke), Oded Regev (ÉNS), Ben Reichardt (Waterloo), Renato Renner (ETH Zürich), Wim van Dam (UC Santa Barabara), John Watrous (Waterloo)

Number of participants: 45

The promise of a quantum computer is not that it will run more quickly than a traditional computer. Indeed, it is quite likely that the individual logic gates of any real quantum computer will be slower than the gates in their classical counterparts. Instead, quantum computers have the potential to reduce the scaling of running time with problem size. Most famously, Peter Shor discovered in the 1990s that a quantum computer could factor integers in an amount of time polynomial in the number of digits of the integer, even though there is no known algorithm for traditional "classical" computers capable of doing so. Quantum computer science includes the design of quantum algorithms and the related classification of problems according to the quantum mechanical resources required to solve them, known as quantum complexity theory.

The workshop, organized by Alain Tapp and Peter Høyer, brought together 45 researchers interested in various aspects of quantum computer science, broadly interpreted. Participants presented new algorithms, such as Matthias Christandl's quasipolynomial time algorithm for testing quantum separability, and refined our understanding of quantum complexity classes, as in Andrew Ducker's study of quantum computation with non-standard sources of "advice." The talks made surprising connections to physics as well. Daniel Gottesman explained why finding the ground state energy of even translationally invariant one-dimensional systems can be computationally intractable while Alex Arkipov explained how optical experiments in the near future should be capable of performing calculations thought to be intractable for traditional computers.

Harry Buhrman supplied one of the highlights of the workshop when he gave an experimental demonstration of "garden hose complexity," an idea he and his co-authors introduced to prove no-go theorems in the area of position-based cryptography. Pumping water through a network of pipes hung from his torso, Harry calculated the value of a function by determining which of his feet got more heavily splashed by the apparatus.

Workshop on Quantum Information in Quantum Many-Body Physics

October 18–21, 2011, CRM

Organizer: David Poulin (Sherbrooke)

Speakers:
Héctor Bombin (Perimeter Inst.), Sergey Bravyi (IBM Res.), Courtney Brell (Sydney), Winton Brown (Sherbrooke), Olivier Buerschaper (Perimeter Inst.), Philippe Corboz (ETH Zürich), Andrew Darmawan (Sydney), Guillaume Duclos-Cianci (Sherbrooke), Jutho Haegeman (Gent), Alioscia Hamma (Perimeter Inst.), Stephen Inglis (Waterloo), Ann Kallin (Waterloo), Roger Melko (Waterloo), Spiros Michalakis (Caltech), Anne E. B. Nielsen (MPI Quantenoptik), Tobias Osborne (Hannover), Renato Renner (ETH Zürich), Norbert Schuch (Caltech), David Sénéchal (Sherbrooke), Barbara Terhal (RWTH Aachen), André-Marie Tremblay (Sherbrooke), Matthias Troyer (ETH Zürich), Maarten van den Nest (MPI Quantenoptik), Frank Verstraete (Wien), Guifre Vidal (Perimeter Inst.), Tzu-Chieh Wei (Stony Brook), Johannes Wilms (Wien)

Number of participants: 42

Many recent developments in the theory of quantum information have led to important insights and applications in condensed matter physics. For instance, the theory of entanglement has shed new light on the density matrix renormalization and the real space renormalization numerical methods, culminating in a deeper understanding of the strengths of the methods and applications to a wider class of problems including critical systems and systems in more than one spatial dimension. Similarly, the theory of quantum error correction has led to new theoretical models of interacting particles that exhibit topological order, an exotic phase of matter in which excitations can have non-Abelian statistics. Moreover, the study of information propagation in a system of interacting particles was used to prove the existence of an entanglement entropy area law in the ground state of systems with local interactions. The problem of finding ground states of a system composed of interacting particles was proven to be

complete for the complexity class QMA, the quantum analogue of NP. These are just a few examples illustrating the connections between quantum information and condensed matter physics.

The workshop, organized by David Poulin, brought together experts from both domains to discuss the latest results and new directions. A major emphasis was the study of numerical techniques for the simulation of many-body quantum systems on today's "classical" computers. More traditional techniques like quantum Monte Carlo and mean field approximation were compared to new quantum information-inspired algorithms like multiscale entanglement renormalization and matrix product states. Another theme was the understanding of the nature of topological order. Sergey Bravyi of IBM Research described an exotic three-dimensional lattice system that would store quantum mechanical information robustly in topological degrees of freedom without the need for additional error correction, a first step towards building a "quantum hard drive." Meanwhile, Spiros Michalakis of Caltech explained his proof that topological order ensures that an energy gap between the ground and excited states is robust against weak perturbations for so-called frustration-free Hamiltonians.

Steve Flammia of the Quantum Pontiff blog produced an amazingly detailed transcript of the workshop's talks at http://tinyurl.com/7ags843.

Workshop on Quantum Information: Codes, Geometry and Random Structures

October 24–26, 2011, CRM

Organizers:
Patrick Hayden (McGill), Aram Harrow (Washington)
Speakers:
Robin Blume-Kohout (Los Alamos Natl. Lab.), Fernando Brandão (UF Minas Gerais), Matthias Christandl (ETH Zürich), Frédéric Dupuis (ETH Zürich), Omar Fawzi (McGill), Marius Junge (UI Urbana-Champaign), Yi-Kai Liu (NIST), Ashley Montanaro (Cambridge), John Preskill (Caltech), Joseph M. Renes (ETH Zürich), Mary-Beth Ruskai (Tufts), Pranab K. Sen (Tata Inst.), Graeme Smith (IBM Res.), Jean-Pierre Tillich (INRIA Rocquencourt), Michael Walter (ETH Zürich), Mark Wilde (McGill), Jürg Wullschleger (Montréal), Deping Ye (Memorial)
Number of participants: 36

One of the primary concerns of quantum information theory is the design of codes for achieving communication in noisy environments, often while simultaneously achieving cryptographic objectives. The probabilistic method is often used to prove the existence of good codes and may even play a role in more explicit and efficient constructions. At the same time, many basic quantum-information-theoretic tasks have natural geometric interpretations that link them to a range of other application areas such as compressed sensing and approximation algorithms through shared underlying mathematics. This workshop, organized by Patrick Hayden and Aram Harrow, provided a forum for participants to present the latest developments in the theory of quantum communication while highlighting the range of mathematical techniques used in the area, including representation theory, asymptotic geometric analysis, random matrix theory, and operator theory.

One of the most exciting talks of the workshop also happened to be the first, by Fernando Brandão. Random unitary transformations play a role in quantum information theory analogous to that of random functions in traditional information theory. Brandão explained how to prove that composing small random unitary gates generates approximate polynomial unitary designs, which are the analogs of k-wise independent random variables. The talk blended elements from condensed matter theory, Markov chains, and computer science. Later the same day, Marius Junge explained how Shannon's information theory can be naturally re-expressed using the language of Banach spaces. The translation then lifts to the quantum, converting basic questions about quantum information theory into analogous problems in the theory of operator spaces. For some questions, notably about how badly communication above a channel's maximum capacity must fail, this translation is quite fruitful. Participants also reported remarkable progress on the design of practical error correcting codes for communicating over quantum media. Jean-Pierre Tillich explained how to build quantum turbo codes that are excellent at reducing if not completely eliminating errors, while Joseph Renes and Mark Wilde presented their respective approaches to quantum polar coding. A highlight of the workshop was an hour-long moderated discussion. While the participants objected somewhat to the organizers' semi-facetious invitation to identify the areas of quantum information research that had proved

to be dead ends, the resulting spirited conversation confirmed that the field as a whole is vibrant and full of interesting research problems.

Simultaneously wearing his organizer's cap and his pope's mitre, Aram Harrow managed to produce a lucid summary of the talks for the Quantum Pontiff blog at http://tinyurl.com/897qxsu.

Workshop on Quantum Foundations in the Light of Quantum Information III

December 6–9, 2011, CRM

Organizers:
Gilles Brassard (Montréal), Christopher Fuchs (Perimeter Inst.)

Speakers:
D. Marcus Appleby (Perimeter Inst.), Somshubhro Bandyopadhyay (Bose Inst.), Howard Barnum (New Mexico), Caslav Brukner (Wien), Jeffrey Bub (Maryland), Giulio Chiribella (Perimeter Inst.), Man-Duen Choi (Toronto), Giacomo Mauro D'Ariano (Pavia), Lucien Hardy (Perimeter Inst.), Jan-Åke Larsson (Linköping), Markus P. Müller (Perimeter Inst.), Paolo Perinotti (Pavia), John A. Smolin (IBM Res.), Robert Spekkens (Perimeter Inst.), Michael D. Westmoreland (Denison)

Number of participants: 37

This was the third CRM workshop with this title, the first having been held in 2000, and the second (which was also a Commune) in 2002. All were organized with great flair by Gilles Brassard and Christopher Fuchs. A main goal was "to explain quantum-mechanical phenomena as inevitable consequences of information-theoretic considerations, and to derive as much of quantum mechanics as possible from this perspective." This project has proved intellectually compelling, spawning a resurgence of interest in the axiomatic exploration of mathematically represented physical theories, fed by an infusion of fresh ideas involving composite systems, information processing, and probabilistic inference, and using mathematical tools such as category theory (physical processes as morphisms) and ordered linear spaces (for representing states and measurements by compendia of probabilities).

To an extent, QFLQI III celebrated and reviewed the enormous advances that have been made since the early CRM workshops, in no small part catalyzed by them. For example, while the story is not finished, we know much more now about the "Fuchs–Brassard conjecture": that the possibility of tamper-evident secret key distribution, combined with the impossibility of bit commitment, might go a long way toward characterising quantum theory. But to an even greater extent the workshop showcased, and furthered, exciting work that is very recent or still in progress, underlining the continued vibrancy of this line of research. A major theme that emerged was the desire to integrate information-based and axiomatic approaches to quantum theory with spacetime physics, a project that is less advanced than the informational and axiomatic understanding of quantum-information-style "Alice 'n Bob" quantum theory, but clearly a focus of current activity. Some of the formal presentations are described below, but a crucial component of the workshop's success was the ample time for informal interaction, during which a lot of serious mathematics and physics was done and new collaborations were initiated, many involving student and postdoc participants.

Sharpening a seminal 2000 result of Lucien Hardy, Markus Müller, working with Lluis Masanes, showed that finite-dimensional quantum theory is characterized, among finite-dimensional convex theories allowing all measurements consistent with the state space, by requiring: (1) that states of composite systems are determined by the statistics and correlations of measurements on their parts ("local tomography"); (2) that continuously reversible dynamics can take any extremal ("pure") state to any other; and (3) that each system or subsystem for which the largest set of perfectly distinguishable states has a given size (the system's "information capacity") is isomorphic to every other system with that information capacity. With Cozmin Ududec, he showed that if reversible dynamics can take any pair of perfectly distinguishable states to any other such pair, then the system has a self-dual unnormalized state space, a very strong condition, satisfied by quantum theory and physically interesting because of its connections to time-reversal symmetry and other important properties.

The Pavia group of Chiribella, D'Ariano, and Perinotti reviewed their derivation of quantum theory from assumptions including local tomography and the existence, for every mixed state of a system A, of a "purification": a state on a composite of A with another system, having the original state as its marginal A state, unique up to reversible transformations on the additional system, showing that given their assumptions

There is One Church of the Larger Convex State Space and *It is the Church of the Larger Hilbert Space*. (Quantum information theorists have practiced the CLHS's rite of purification daily since ancient times.) But most of their presentations aimed to meld this operational approach with spacetime physics, with D'Ariano deriving discrete Dirac-like equations on a lattice of qubits in an approach somewhat reminiscent of the work of Feynman and Jacobson, but aimed at interpreting mass and propagation speed informationally, and Chiribella and Perinotti investigating probabilistic theories where the causal structure is not fixed ahead of time. Rob Spekkens also emphasized the need to formulate quantum theory in a causally neutral way, as a theory of Bayesian inference. Howard Barnum talked about the possibility of abandoning local tomography, and thereby being able to make composites of systems whose cones of measurements are homogeneous and self-dual, as well as some information-processing notions (purification, and Schrödinger's notion of "steering" an ensemble) that imply homogeneity. Michael Westmoreland discussed the fascinating quantum-like mathematical phenomena that arise when one tries to do something like quantum theory with Z_2 instead of the complex numbers as the scalars. After some wise remarks on the nature of language and its relevance to physics, Marcus Appleby reviewed work on a beautifully simple question of pure mathematics that has seen an enormous amount of interest and effort in quantum information and foundations: Does there exist, in n-dimensional complex space with a sesquilinear inner product, an equiangular set of n^2 lines? We leave this as an exercise for the reader.

15th Conference on Quantum Information Processing — QIP 2012

December 12–16, 2011, UQAM

Sponsored by the CRM, INTRIQ, the Institute for Quantum Computing, Sandia National Laboratories, the National Science Foundation (NSF), the Université de Montréal, ID Quantique (IDQ), Tourisme Montréal, and the Perimeter Institute for Theoretical Physics

Program Committee:

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Local Organizers:

Kassem Kalach (Montréal), Marc Kaplan (Montréal), Magalie Lascar (Montréal), Louis Salvail (Chair), Benno Salwey (Montréal), Dave Touchette (Montréal)

Plenary Speakers:

Itai Arad (Hebrew), Aleksandrs Belovs (Latvia), Sergey Bravyi (IBM Res.), Eric Chitambar (Toronto), Markus Greiner (Harvard), Jeongwan Haah (Caltech), Sandu Popescu (Bristol), Jérémie Roland (ULB)

Other Speakers:

Salman Beigi (IPM), Fernando Brandão (UF Minas Gerais), Gilles Brassard (Montréal), Jop Briet (CWI), Josh Cadney (Bristol), André Chailloux (UC Berkeley), Matthias Christandl (ETH Zürich), Richard E. Cleve (Waterloo), Toby Cubitt (Complutense), Nilanjana Datta (Cambridge), Runyao Duan (UT Sydney), Guillaume Duclos-Cianci (Sherbrooke), Rodrigo Gallego (ICFO), Sevag Gharibian (Waterloo), Esther Hänggi (NU Singapore; CQT), Robert Koenig (IBM Res.), Andrew Landahl (Sandia Natl. Labs.), Olivier Landon-Cardinal (Sherbrooke), François Le Gall (Tokyo), Troy Lee (CQT), Spyridon Michalakis (Caltech), Rajat Mittal (Waterloo), Abel Molina (Waterloo), Ashwin Nayak (Waterloo), Joseph M. Renes (ETH Zürich), Miklos Santha (Paris Diderot; CNRS), Or Sattath (Hebrew), Norbert Schuch (Caltech), Martin Schwarz (Wien), Rolando Somma (Los Alamos Natl. Lab.), Florian Speelman (CWI), Mark Wilde (McGill), Xiaodi Wu (Michigan), Jon Yard (Los Alamos Natl. Lab.)

Number of participants: 257

The final event of the semester was also the largest. Quantum Information Processing (QIP) 2012, which took place at UQAM's Cœur des Sciences, had 257 registered participants from around the world. QIP is the leading conference on quantum algorithms, communication, and complexity. Each year, a small handful of researchers who have made outstanding breakthroughs are invited to speak at QIP. The remaining

speaking slots are filled through a competitive selection process. Since there are no proceedings, participants are free to submit work being published elsewhere, ensuring that nearly all of the year's best results get presented at QIP. Before 2012, the most recent incarnations of the conference took place in Singapore, Zürich, New Mexico, and New Delhi. Further excavation of its history, however, reveals that the year 2000 incarnation of QIP was also hosted by the CRM in Montréal. This was the first time QIP had ever returned to the same city. That the quantum information community was so enthusiastic about returning to Montréal is in no small part due to the exceptional support the CRM has provided over the years!

The conference's eight plenary speakers were a microcosm of the field as a whole, providing echoes of the highlights of the semester's workshops. Sergey Bravyi and Jeongwan Haah spoke about three-dimensional topological quantum memories and their stability against thermal noise. Itai Arad explained how to prove an area law for one-dimensional frustration-free quantum systems that is exponentially stronger than those previously known. Aleksandrs Belovs explained new characterizations of quantum query complexity, while Jérémie Roland presented a powerful new quantum algorithmic tool called quantum rejection sampling. Meanwhile, Eric Chitambar disposed of a longstanding problem in quantum information theory by showing that the set of local operations with classical communication (LOCC) is not closed. Sandu Popescu treated the audience to a beautiful discussion in the foundations of thermodynamics about how to construct the smallest possible thermal machines. Finally Markus Greiner brought everyone back to reality by describing his experiments on lattices of ultracold atoms, which would have sounded like science fiction not very long ago.

The Quantum Pontiff bloggers, of course, covered the whole conference. Their report can be found at http://dabacon.org/pontiff/?p=5865. QIP 2013 will take place at Tsinghua University in Beijing.

Workshop on Convexity and Asymptotic Geometric Analysis

April 16–20, 2012, CRM

Partly funded by the National Science Foundation (NSF)

Organizers:
Monika Ludwig (NYU-Poly; TU Wien), Vitali Milman (Tel Aviv), Alina Stancu (Concordia)

Speakers:
Judit Abardia (Frankfurt am Main), Semyon Alesker (Tel Aviv), David Alonso Gutiérrez (Alberta), Andreas Bernig (Frankfurt am Main), Andrea Colesanti (Firenze), Dmitry Faifman (Tel Aviv), Joseph Fu (Georgia), Maria Hernandez Cifre (Murcia), Dan Klain (UMass Lowell), Alexander Koldobsky (Missouri), Alexander Litvak (Alberta), Mohammad Najafi Ivaki (Concordia), Grigoris Paouris (Texas A&M), Peter Pivavorov (Texas A&M), Liran Rotem (Tel Aviv), Dmitry Ryabogin (Kent State), Eugenia Saorín Gómez (Magdeburg), Matthias Schulte (Case Western Reserve), Carsten Schütt (Kiel), Alexander Segal (Tel Aviv), Thomas Wannerer (ETH Zürich), Elisabeth Werner (Case Western Reserve), Jie Xiao (Memorial), Vlad Yaskin (Alberta), Deping Ye (Memorial), Artem Zvavitch (Kent State)

Number of participants: 43

This workshop included talks that were as diverse as the field itself, a result of the rapid developments seen in the area in recent years. Moreover, almost a third of the speakers were very young researchers: graduate students or postdocs within 3 years of their thesis completion, giving a measure of renewed interest and intense current activity in new and classical challenges of the field.

One of the directions emphasized in this meeting was the complexity of duality. The classical duality for convex bodies is reflected in the space of convex functions as two other types of dualities whose properties are just being understood. New results were the subject of talks by Liran Rotem and Alexander Segal. One should note that duality of convex bodies is also at the core of Mahler's conjecture, an old outstanding problem in the field, on which progress was reported by Artem Zvavitch and Grigoris Paouris, each in a different context.

The topics of area measures and their connection to PDEs, affine differential geometry, and Hermitian integral geometry were touched upon by Mohammad Najafi Ivaki and Thomas Wannerer (respectively). Further connections to quantum information theory (Elisabeth Werner), containment problems (Dan Klain), and geometric, isoperimetric-type, inequalities (David Alonso Gutiérrez) were also presented.

Another direction of research emphasized at the meeting was probabilistic in nature. One of the 2011 E. W. R Steacie Memorial Fellowship's recipients,

Alexander Litvak, delivered a lecture on estimates on norms of random matrices with applications in convex geometry, computational geometry, and compressive sensing theory. Different other probabilistic aspects were addressed by Carsten Schutt and Peter Pivovarov. The latter presented novel distributional inequalities for the volume of random convex sets.

Finally, in an exciting direction, the theory of valuation now opens a new road to algebraic integral geometry (Andreas Bernig), while classical problems of extending continuously valuations from subspaces of convex compact sets to the whole space are seeing solutions (Semyon Alesker).

Overall, the atmosphere was very enthusiastic, filled with discussions, and many of the talks were attended by local people outside the field. The special CRM–ISM colloquium of the two-time ICM speaker, Vitali Milman, was integrated within the workshop's program and added to the visibility of the meeting.

Workshop on Geometric PDE

April 23–27, 2012, CRM

Organizers:
Pengfei Guan (McGill), Niky Kamran (McGill), Alina Stancu (Concordia)
Speakers:
Vestislav Apostolov (UQAM), Maria Buzano (Oxford), Ailana Fraser (UBC), Jixiang Fu (Fudan), Bo Guan (Ohio State), Tom Ilmanen (ETH Zürich), Spiro Karigiannis (Waterloo), Marcus Khuri (Stony Brook), Junfang Li (Alabama at Birmingham), Qun Li (Wright State), Lei Ni (UC San Diego), Natasa Sesum (Pennsylvania), Joel Spruck (Johns Hopkins), Valentino Tosatti (Columbia), Cristina Trombetti (Federico II), Gantumur Tsogtgerel (McGill), McKenzie Y. Wang (McMaster), Mu-Tao Wang (Columbia), Ben Weinkove (UC San Diego), Steve Zelditch (Northwestern), Ahmed Zeriahi (Paul Sabatier)
Number of participants: 36

The goal of this workshop was to bring together researchers working in geometry and PDEs, with the objective of reviewing important recent results in the field and highlighting new research trends. The lectures were anchored around several subthemes of current interest.

• *Geometric flows in Riemannian and Hermitian geometry*: These topics were covered in the lectures by Ben Weinkove, Natasa Sesum, Junfang Li, McKenzie Wang, Tom Illmanen and Maria Buzano. The increasingly important role played by torsion in non-Kähler Hermitian geometry and the emergence of the Chern–Ricci flow as a new model for flows on complex surfaces, the recent advances in the study of singularity formation for the mean curvature flow of surfaces using new ideas from geometric measure theory, ancient solutions to the Yamabe flow and the explicit construction of Ricci flows on manifolds with large isometry groups were highlighted throughout these lectures.

• *Extremal Kähler and other special metrics*: These formed the substance of the lectures by Vesti Apostolov, Jixiang Fu, Valentino Tosatti, Ailana Fraser and Spiro Karigiannis. Recent developments on the explicit construction of extremal Kähler metrics on toric orbifolds, Hermitian Yang–Mills metrics on stable vector bundles, collapsing of Calabi–Yau manifolds, extremal eigenvalue problems for surfaces with boundary, and G_2 structures were at the heart of this set of lectures.

• *PDE problems in connection with the Monge–Ampère equation, the Yamabe problem, and General Relativity*: These were dealt with in the lectures by Bo Guan, Joel Spruck, Steve Zelditch, Mu Tao Wang, Lei Ni, Marcus Khuri, Ahmed Zeriahi, and Gantumur Tsogtgerel. Many important advances and new perspectives were covered in the lectures. Again, torsion in Hermitian geometry occupied a prominent place in the talks concerned with the Monge–Ampère equation, as well as the analysis of the initial value problem in connection to the geodesic equation on the set of Kähler metrics. From the General Relativity perspective, the central role was played by the initial value problem with various geometric assumptions on the initial data sets, as well as the important problem of defining of quasi-local mass and momentum for isolated systems.

The workshop was very successful in bringing together some of the strongest researchers active today in geometric analysis. Many fruitful scientific discussions and exchanges took place during the workshop, during and between the lectures, making this a memorable scientific event.

Workshop on Geometry and Dynamics of Fluid

May 21–25, 2012, CRM

Organizers:
Sergei Kuksin (École Polytechnique), Stephen Preston (CU-Boulder), Alexander Shnirelman (Concordia)
Speakers:
Emanuele Caglioti (La Sapienza), Dongho Chae (Chung-Ang), Alexey Cheskidov (UI Chicago), Diego Córdoba (ICMAT), Walter Craig (McMaster), Sergey Denissov (Wisconsin–Madison), David Ebin (Stony Brook), Susan Friedlander (Southern California), François Gay-Balmaz (ÉNS), John D. Gibbon (Imperial Coll.), Boris Khesin (Toronto), Anna Mazzucato (Penn State), Gerard Misiolek (Notre Dame), Clément Mouhot (Cambridge), Tudor Ratiu (EPFL), Filippo Santambrogio (Paris-Sud), Roman Shvydkoy (UI Chicago), Vladimir Sverak (Minnesota), Feride Tiglay (Fields), Vladimir Tseitline (ÉNS), Vlad Vicol (Chicago), Cornelia Vizman (Vest din Timişoara), Xinwei Yu (Alberta)
Number of participants: 33
The workshop featured 25 speakers, who gave 40-minute talks on various topics related to fluid mechanics. The goal of the workshop was to get experts in disparate areas of fluid mechanics interested in each other's work, and our compressed format of short talks made it easy for people to attend many of them.

The topics our speakers focused on broadly included (i) long-time behaviour of two-dimensional fluids, (ii) aspects of the diffeomorphism group geometry, (iii) one- and two-dimensional model systems for fluids, (iv) aspects of turbulence in three-dimensional fluids, and (v) weak solutions of the Euler equations.

(i) Emanuele Caglioti and Clément Mouhot spoke on various aspects of the long-time behaviour of solutions of the 2D Euler equation. Although global existence for sufficiently smooth solutions of 2D Euler has been known for many years, there are still poorly understood phenomena such as the seeming existence of attractors and the energy cascade. Caglioti explained aspects of attractors in a weak-damping limit, and Mouhot described a rigorous approach to Landau damping.

(ii) David Ebin, Francois Gay-Balmaz, Feride Tiglay, Cornelia Vizman, and Vladimir Zeitlin spoke on global differential-geometric aspects of the Euler and related equations, which follow the Arnold approach to fluid mechanics via Riemannian geometry of the diffeomorphism group. Ebin described the geometry of quantomorphism groups, Gay-Balmaz spoke on liquid crystal equations, Tiglay spoke about geometric aspects of some integrable 1D equations, Vizman described dual pair structures for generalized Camassa–Holm equations, and Zeitlin discussed finite-dimensional Lie algebra structures to approximate fluid and geostrophic equations.

(iii) Diego Cordoba, Walter Craig, Susan Friedlander, Boris Khesin, Filippo Santambrogio, Vlad Vicol, and Xinwei Yu all spoke about various one- and two-dimensional PDEs that share structures with the 3D Euler or Navier–Stokes equations. Friedlander and Vicol spoke about different aspects of active-scalar equations such as the surface-quasi-geostrophic equation. Yu spoke about some generalizations of the two-dimensional magnetohydrodynamic equations. Craig and Khesin spoke about vortex filament and vortex membrane equations, which model fluids for which vorticity is concentrated on singular sets. Cordoba spoke on free-boundary problems describing interfaces between two ideal irrotational fluids. Santambrogio described a crowd-flow model that relates to optimal transport and generalized flows of fluid.

(iv) Alexey Cheskidov, John D. Gibbon, Roman Shvydkoy, and Vladimir Sverak spoke about aspects of turbulence and blowup in the 3D Euler and Navier–Stokes equations. Cheskidov and Gibbon addressed intermittency in the Navier–Stokes equations (i.e., large deviations from the mean in vorticity) and its possible relation to blowup. Shvydkoy discussed nonexistence of self-similar blowup solutions of the Euler equation, while Sverak discussed self-similar solutions of the Navier–Stokes equation.

(v) Finally, Anna Mazzucato, Gerard Misiolek, and Sergey Denisov spoke on aspects of weak solutions of Euler and Navier–Stokes equations. Mazzucato described results on the dissipation of enstrophy in weak solutions of the 2D Euler equation with unbounded vorticity. Misiolek described the failure of well-posedness in the Hadamard sense for 2D Euler, constructing examples for which the dependence on initial conditions is continuous but not uniformly continuous. Denisov gave sharp results on the dynamics of vortex patches that collapse into each other asymptotically, as well as estimates on the growth of Sobolev norms for smooth 2D Euler solutions.

The workshop featured a lively mix of talks together with some social events such as a reception, a walking tour of Old Montréal, and a free banquet in order to foster discussion and collaboration. The diversity of

speakers (by age, gender, location, and field) was a primary goal of the organizers. Graduate students were actively supported and encouraged to attend all events. Attendees expressed great appreciation for the organization and the facilities of the CRM, and we believe we fostered several useful collaborations that will develop in the future.

Workshop on Quantum Many-Body Systems

May 28–June 1, 2012, CRM

Organizers:
Vojkan Jakšić (McGill), Robert Seiringer (McGill)
Speakers:
Michael Aizenman (Princeton), Jan Derezinski (Warsaw), Rupert L. Frank (Princeton), Alessandro Giuliani (Roma Tre), Christian Hainzl (Tübingen), Victor Ivrii (Toronto), Israel Klich (Virginia), Edwin Langmann (KTH), Mathieu Lewin (Cergy-Pontoise), Elliott H. Lieb (Princeton), Vieri Mastropietro (Tor Vergata), Bruno Nachtergaele (UC Davis), Heinz Siedentop (München), Israel Michael Sigal (Toronto), Robert Sims (Arizona), Jan Philip Solovej (Copenhagen), Daniel Ueltschi (Warwick), Simone Warzel (TU München), Jakob Yngvason (Wien), Valentin Zagrebnov (Aix-Marseille)
Number of participants: 30

This workshop consisted of 20 one-hour lectures by the participating experts. The unifying theme of the workshop was the mathematical analysis of models in quantum mechanics describing a large number of mutually interacting particles. The topics covered concerned the renormalization group analysis of lattice models in condensed matter physics, including graphene, the interaction of matter with radiation, effects of impurities (i.e., randomness) on interacting particle systems, semiclassical analysis of atoms and molecules, and the characterization of possible phases occurring in ground states in low-dimensional spin systems.

Four lectures were scheduled each day of the week, two in the morning and two in the afternoon. This schedule left plenty of time for discussions among the participants before and after the lectures. These discussions have led to new ideas, interesting open problems, and new research directions that will be pursued in the future. The excellent facilities and pleasant atmosphere at the CRM have contributed to the success of the workshop, and many participants have expressed their interest in returning to the CRM in the near future for similar events.

The workshop started on Monday with a talk by Elliott Lieb, in which he explained entanglement in quantum systems and ways to quantify it using entropy inequalities. The second morning talk, by Heinz Siedentop, concerned a model of a graphene quantum dot, for which spectral properties were investigated. Graphene was also the topic of the first afternoon talk by Vieri Mastropietro, who presented a proof of universal conductivity using rigorous renormalization group techniques. The final talk on Monday was given by Alessandro Giuliani, and discussed the scaling limit of correlation functions in nonintegrable Ising models.

Mathieu Lewin gave the first talk on Tuesday, in which he explained how to obtain the Pekar model for a polaron as a macroscopic limit of a microscopic polaron model. The Scott correction in different models of atoms and molecules was the topic of the second talk, given by Jan Philip Solovej. Rupert Frank's talk in the afternoon concerned ground state properties of multipolaron systems, in particular the question of stability and binding. The last talk on Tuesday was given by Michael Sigal, in which he discussed Rayleigh scattering and the propagation speed of photons in phonons in simple quantum field models.

The effects of randomness on quantum systems were the topic of the first three talks on Wednesday. The session started with a talk by Michael Aizenman on phase transitions in quantum and classical spin systems subject to random external fields. It was followed by Simone Warzel's talk on the Bose–Hubbard model. Jakob Yngvason gave the first talk in the afternoon, explaining the effects of random impurities on one-dimensional Bose–Einstein condensates, described by the Lieb–Liniger model. The second afternoon talk was given by Victor Ivrii, explaining the asymptotics of the ground state energy for heavy atoms and molecules.

In the first talk on Thursday, Bruno Nachtergaele explained the classification of ground state phases in gapped one-dimensional quantum systems. The second talk by Robert Sims contained results on dynamical localization for the random XY spin chain. Israel Klich gave the first afternoon talk on Thursday, explaining entanglement in systems of matter coupled to radiation. Finally, Valentin Zagrebnov closed the ses-

sion with a talk on his results on a model of a leaky photon cavity pumped by an atomic beam.

Friday was the last day of the workshop, and it started with a talk by Jan Derezinski on the joint energy-momentum spectrum of homogeneous Fermi gases. The second talk, by Daniel Ueltschi, investigated the nature of correlations in quantum Heisenberg models. Luttinger-type models of correlated fermions in higher dimensions were the topic of the first afternoon talk, given by Edwin Langmann. The final talk of the workshop was given by Christian Hainzl, explaining the microscopic derivation of the Ginzburg–Landau model from the microscopic Bardeen–Cooper–Schrieffer theory.

Workshop on Geometry of Eigenvalues and Eigenfunctions

June 4–8, 2012, CRM

Organizers:
Dmitry Jakobson (McGill), Iosif Polterovich (Montréal)
Speakers:
Ram Band (Bristol), Alex Barnett (Dartmouth Coll.), Rafael D. Benguria (PUC), Shimon Brooks (Stony Brook), Almut Burchard (Toronto), Yaiza Canzani (McGill), Hans Christianson (UNC—Chapel Hill), Suresh Eswarathasan (McGill), Alexandre Girouard (Neuchâtel), Victor Guillemin (MIT), Victor Ivrii (Toronto), Christopher Judge (IU Bloomington), Achim Kempf (Waterloo), Vladimir Kozlov (Linköping), Eveline Legendre (Paul Sabatier), Elon Lindenstrauss (Hebrew), Dan Mangoubi (Hebrew), Alexei V. Penskoi (Moscow SU; IU Moscow), Peter A. Perry (Kentucky), Yiannis Petridis (Univ. Coll. London), Grigori Rozenblioum (Chalmers UT), Yuri Safarov (King's Coll. London), Alexander Strohmaier (Loughborough), Steve Zelditch (Northwestern)
Number of participants: 49

The workshop brought together the leading researchers and young mathematicians working in various areas of geometric spectral theory. Many problems in the field are motivated by questions originating in the study of real life phenomena: quantum-mechanical effects, vibration of membranes and plates, oscillations of fluids, etc. The conference continued a series of related meetings at the CRM, including workshops on Spectrum and Dynamics and Mathematical Aspects of Quantum Chaos in 2008, as well as workshops on Spectral Geometry, Semiclassical Theory of Eigenfunctions and PDEs (CRM/Fields), and Spectral Theory and Automorphic Forms in 2004.

One of the main highlights of the meeting was a series of Aisenstadt lectures on quantum unique ergodicity by Elon Lindenstrauss. Quantum ergodicity and properties of eigenfunctions in the semiclassical limit were among the central themes of the workshop. Related topics were discussed in the talks by Suresh Eswarathasan, Hans Christianson, Shimon Brooks, Yiannis Petridis, and Yaiza Canzani. A survey talk by Victor Ivrii focused on the asymptotic distribution of eigenvalues and remainder estimates in Weyl's law. Dan Mangoubi presented a new proof, not involving "hard analysis," of the celebrated Donnelly–Fefferman estimate on the growth of high-energy eigenfunctions. In the talk on symbolic calculus of Fourier integral operators, Yuri Safarov developed an analytic machine that could be used to study quantum ergodicity for branching billiards.

The talks by Alexandre Girouard, Vladimir Kozlov, Alexei Penskoi, Eveline Legendre, and Christopher Judge were concerned with the properties of eigenvalues of the Laplacian and other elliptic operators on Riemannian manifolds and Euclidean domains. Many important subjects were discussed, including extremal problems for eigenvalues on surfaces, estimates on the eigenvalues of Dirichlet-to-Neumann operators, domain dependence of Dirichlet eigenvalues, Kähler metrics with simple Laplace spectrum, and existence of embedded eigenvalues in the continuous spectrum for hyperbolic triangles. Almut Burchard presented some recent results on Steiner symmetrization of compact sets. Steiner symmetrization is a powerful technique in geometric analysis that is used, in particular, to prove sharp isoperimetric inequalities for eigenvalues.

Several talks, including the ones by Rafael Benguria, Peter Perry, and Achim Kempf, emphasized the links between spectral theory and mathematical physics. The talks by Ram Band and Grigori Rozenblioum focused on the properties of eigenvalues and eigenfunctions of the Laplace and Schrödinger operators on combinatorial and quantum graphs.

Recent advances in computational spectral theory were presented by Alex Strohmaier and Alex Barnett. In particular, a new efficient method for numerical computation of Dirichlet eigenvalues of planar domains was presented, as well as a fast algorithm for

calculating eigenvalues and spectral zeta functions on Riemannian surfaces with explicitly controlled error estimates.

The workshop also featured a stimulating session on open problems. A number of interesting questions were proposed by Victor Ivrii, Rafael Benguria, Alexandre Girouard, and Dmitry Jakobson.

Workshop on Manifolds of Metrics and Probabilistic Methods in Geometry and Analysis

July 2–6, 2012, CRM

Organizers:
Dmitry Jakobson (McGill), Semyon Klevtsov (ULB), Steve Zelditch (Northwestern)

Speakers:
Robert Adler (Technion), Robert Berman (Chalmers UT; Gothenburg), Nicolas Burq (Paris-Sud), Yaiza Canzani (McGill), Linan Chen (McGill), Brian Clarke (Stanford), François David (CEA/Saclay), Bertrand Duplantier (CEA/Saclay), Frank Ferrari (ULB), Boris Hanin (Northwestern), Dmitry Jakobson, Semyon Klevtsov, Nikolai G. Makarov (Caltech), Liam McAllister (Cornell), Liviu Nicolaescu (Notre Dame), Raphaël Ponge (Seoul NU), Yanir A. Rubinstein (Stanford), Scott Sheffield (MIT), Bernard Shiffman (Johns Hopkins), Lior Silberman (UBC), Song Sun (Imperial Coll.), Igor Wigman (Cardiff), Steve Zelditch

Number of participants: 31

The workshop brought together mathematicians and physicists working on questions related to random geometry in a broad sense. The organizers hope that this conference will spur rapid development in the new area of rigorous approaches to random metrics, inspired by the physics research in this subject within the last 30 years.

Morning sessions during the first two days of the workshop were devoted to lectures on 2d quantum gravity and the physical definition of random metrics. Frank Ferrari started on Monday with the introduction to the seminal 1981 work of Polyakov on Liouville 2d gravity. Further developments in Liouville gravity during the 80's and 90's were reviewed in two lectures by Francois David on Monday and Tuesday. Finally, Bertrand Duplantier gave an introductory lecture on his ground-breaking 2008 work with Scott Sheffield, where a random two-dimensional volume form was mathematically defined and KPZ relations were proved using the DDK's GFF approach.

Monday afternoon talks were devoted to the geometry of the space of Riemannian metrics. Brian Clarke introduced the L^2 (or Ebin) distance on the space of Riemannian metrics, discussed the construction of its completion, and showed that the resulting metric space has nonpositive curvature. Sun surveyed the work on the metric geometry of the space of Kähler metrics, and its importance in the study of canonical metrics in Kähler geometry, in particular of constant scalar curvature metrics. Yanir Rubinstein gave a survey on different aspects (PDEs, Hamiltonian dynamics, geometric flows, convex geometry, geometric quantization, metric geometry) of the geometry of the infinite-dimensional space of Kähler metrics.

Bertrand Duplantier started his morning talk on Wednesday July 4th, by congratulating the audience on the discovery of the Higgs particle, announced on that very day. After that François David talked on a new (physical) derivation of the KPZ relation using the replica trick. Liam McAllister reviewed recent advances in the problem of counting metastable vacua in the string theory landscape, due to the creative application of random matrix model methods. Wednesday's afternoon session was devoted to novel approaches to random metrics. Semyon Klevtsov talked on a novel definition of random metric on a Kähler manifold, which arises as the scaling limit of random matrix ensembles of Bergman metrics and its relation to stability in Kähler geometry. In Robert Berman's talk Kähler–Einstein metrics "emerge" in the large N limit of certain random point processes, giving rise to a new notion of stability. Physical applications of Aubin–Yau and Mabuchi action functionals in Kähler geometry, possibly leading to the extensions of the Polyakov's Liouville model of quantum gravity, were explained by Frank Ferrari on Friday. The Tuesday talk by Scott Sheffield described Imaginary Liouville Quantum Gravity and its implications.

A possible extension of results obtained by Duplantier and Sheffield in dimension two to higher dimensions was outlined on Friday. Raphaël Ponge gave an overview of Fefferman's program and conformally invariant differential operators (including the Yamabe and the Paneitz operators). He also presented a computation of the logarithmic singularities of the Green functions of the conformal powers of the Laplacian. Linan Chen outlined a construction of random mea-

sures in dimension four (inspired by the construction of Duplantier and Sheffield in dimension two), and described an approach to derive a KPZ-type relation for spherical averages of those measures.

Several talks at the conference were devoted to the properties of random functions, random sections of holomorphic line bundles, and related problems. On Tuesday, Bernard Shiffman discussed critical points of random sections of holomorphic line bundles. Boris Khanin discussed his recent results on correlations and nearest neighbour spacings between zeros and critical points of random polynomials. Nikolai Makarov discussed distribution of eigenvalues for random normal matrix ensembles, near the boundary and near some singular points in the bulk.

On Thursday, Robert Adler discussed some results in random algebraic topology, including the persistence homology of the sublevel sets of Gaussian processes over manifolds, and limit theorems for the Betti numbers of random complexes built over random point processes. Liviu Nicolaescu described his results on critical values of random functions on a given compact Riemann manifold, given as a random Fourier series involving the eigenfunction of the Laplacian. Igor Wigman described his results on nodal length fluctuations for random Gaussian Laplace eigenfunctions on the torus ("arithmetic random waves").

Nicolas Burq gave a talk on probabilistic Sobolev embeddings, showing that, from a PDE point of view, randomly chosen functions may behave much more nicely than what the deterministic theory would predict. On Friday, Yaiza Canzani described recent results on the distribution of perturbations of propagated Schrödinger eigenfunctions, establishing asymptotics for their moments under certain admissibility conditions (which involve the geometry of the space of metrics on Riemannian manifolds).

Several talks at the conference were also devoted to the geometry of manifolds of metrics. In addition to the talks describing the geometry of spaces of Kähler metrics, and the talk of Brian Clarke on the L^2 distance, Lior Silberman described how the $\mathrm{CAT}(0)$ property of the manifold of Riemannian metrics can be used to show that random groups with strong fixed-point properties have no nontrivial smooth volume-preserving actions on compact manifolds, via the associated action on the space of metrics. Finally, Dmitry Jakobson described how one can define Gaussian measures on manifolds of metrics with the fixed volume form, and use them to compute the moment-generating function for the Ebin distance to the reference metric.

Past Thematic Programs

The Centre de recherches mathématiques has organized thematic activities every year since 1993. From 1987 to 1992, the CRM organized various types of activities, including special semesters, concentration periods, and thematic activities. Here is a list of the main activities organized by the CRM since 1987.

January–June 2011 Statistics

July–December 2010 Geometric, Combinatorial and Computational Group Theory

January–April 2010 Number Theory as Experimental and Applied Science

August–December 2009 Mathematical Problems in Imaging Science

2008–2009 Joint CRM-PIMS Program: Challenges and Perspectives in Probability

2008–2009 Probabilistic Methods in Mathematical Physics

January–June 2008 Dynamical Systems and Evolution Equations

June–December 2007 Applied Dynamical Systems

January–June 2007 Recent Advances in Combinatorics

June–December 2006 Combinatorial Optimization

2005–2006 Analysis in Number Theory

2004–2005 The Mathematics of Stochastic and Multiscale Modelling

2003–2004 Geometric and Spectral Analysis

2002–2003 Mathematics in Computer Science

2001–2002 Groups and Geometry

2000–2001 Mathematical Methods in Biology and Medicine

1999–2000 Mathematical Physics

1998–1999 Number Theory and Arithmetic Geometry

1997–1998 Statistics

1996–1997 Combinatorics and Group Theory

1995–1996 Applied and Numerical Analysis

1994–1995 Geometry and Topology

1993–1994 Dynamical Systems and Applications

1992 Probability and Stochastic Control (special semester)

1991–1992 Automorphic Forms in Number Theory

1991 Operator Algebras (special semester)

1990 Nonlinear PDEs and Applications (concentration period)

1988 Shimura Varieties (special semester)

1987 Quantum Field Theory (special semester)

1987–1988 Fractals: Theory and Application

1987 Structural Rigidity (special semester)

General Program

The CRM's general program funds a wide variety of scientific events, both on the premises of the CRM and elsewhere in Canada. Whether it be for specialized workshops attended by a small number of researchers or large meetings attended by hundreds of participants, the general program promotes research in the mathematical sciences at all levels. The program is quite flexible, allowing projects to be considered as they arise. *The reports are presented in the language in which they were submitted.*

CRM activities

Workshop on Moving Frames in Geometry

June 13–17, 2011, CRM

Organizers:
Niky Kamran (McGill), Abraham Smith (McGill), Francis Valiquette (McGill)
Keynote Speakers:
Robert Bryant (UC Berkeley), Andreas Cap (Wien), Jeanne N. Clelland (CU-Boulder), Mark Fels (Utah State), Peter Olver (Minnesota), Keti Tenenblat (Brasília)
Other Speakers:
Stephen Anco (Brock), Andrea Dziubek (SUNY IT), Daniel Fox (CC Philadelphia), Tania Goncalves (Kent), Thomas Ivey (Coll. Charleston), Nabil Kahouadji (McGill), Irina Kogan (North Carolina State), Gloria Mari Beffa (Wisconsin–Madison), Thomas Mettler (UC Berkeley), Robert Milson (Dalhousie), Peter J. Olver (Minnesota), Juha Pohjanpelto (Oregon State), Colleen Robles (Texas A&M), Konrad Schöbel (Jena), Ekaterina Shemyakova (Western Ontario), Roman Smirnov (Dalhousie), Chuu-Lian Terng (UC Irvine), Dennis The (Texas A&M), Robert Thompson (Minnesota), Peter John Vassiliou (Canberra), Igor Zelenko (Texas A&M)
Number of participants: 49

Brought to maturity by Elie Cartan, the method of moving frames has been in the mathematical landscape for more than a century. From the Frenet–Serret frame to Cartan's "repère mobile" and beyond, moving- frame techniques have proven indispensable in the study of symmetries, invariants, and other intrinsic properties of geometrical objects. Explicit applications of moving-frame techniques range from classical differential geometry to integrable systems, and on toward control theory and computer vision.

The objective of this workshop was to discuss recent applications and theoretical advances of these techniques. Several particular topics were covered dealing with contemporary applications of both Cartan's equivalence method and equivariant moving frames in geometry and analysis, such as the geometry of differential equations and conservation laws, geometric submanifold flows, and classification problems in differential and algebraic geometry. Each topic began with a one-hour general overview of the subject given by one of the primary speakers. It was followed by more traditional contributed research talks of 30 to 45 minutes. The breadth of the list of topics covered in this talk was quite remarkable. The discussion sessions scheduled in the workshop were particularly stimulating and fruitful and helped to chart the course for future developments in this very active field of geometry.

CRM Special Lecture "What is the Shape of Inner Space?" by Shing-Tung Yau

June 20, 2011, CRM

In this public lecture, Professor Yau spoke about how mathematics and physics can come together to the benefit of both fields, particularly in the case of Calabi–Yau spaces and string theory–our leading attempt to explain the universe to date. He discussed his personal introduction to geometry, as well as a bit of the history of geometry. Thus Professor Yau gave his audience a sense of how mathematicians think and approach the world and conveyed the realization that mathematics does not have to be a wholly abstract discipline, disconnected from everyday phenomena, but is instead crucial to our understanding of the physical world.

Professor Yau's work has impacted both mathematics and physics. Calabi–Yau manifolds are among the "standard toolkit" for string theorists today. He has made fundamental contributions at the interface between geometry and theoretical physics. His proof of the positive energy theorem in general relativity demonstrated sixty years after its discovery that Einstein's theory is consistent and stable. His proof of the Calabi conjecture allowed physicists using Calabi–Yau compactification to show that string theory is a viable candidate for a unified theory of nature. Shing-Tung

Yau is Professor of Mathematics at Harvard University. His fundamental contributions to research have been recognized by the Fields Medal, the Crafoord Prize, the National Medal of Science, and the Wolf Prize. He is also a member of the National Academy of Sciences of the United States.

Complex Analysis and Potential Theory A Conference in Honour of Paul M. Gauthier and Kohur GowriSankaran

June 20–23, 2011, CRM

Sponsored by the Mathematical Analysis Laboratory, the Canada Research Chair in Spectral Theory and Complex Analysis, the Département de mathématiques et statistique of the Université de Montréal, and the Department of Mathematics and Statistics of McGill University

Organizers:

André Boivin (Western Ontario), Javad Mashreghi (Laval)

Speakers:

Hiroaki Aikawa (Hokkaido), Victor Anandam (Madras), Nadya Askaripour (Calgary), Dominique Bakry (Paul Sabatier), Lucian Beznea (Simion Stoilow), Maritza Branker (Niagara), Alexander Brudnyi (Calgary), Debraj Chakrabarti (Tata Inst.), Fausto Di Biase (G. D'Annunzio), David Drasin (Purdue), Driss Drissi (Kuwait), Peter L. Duren (Michigan), Roman Dwilewicz (Missouri UST), Konstantin Fedorovskiy (Moscow STU), Alastair Fletcher (Warwick), Richard Fournier (Dawson; Montréal), Stephen Gardiner (UC Dublin), Wolfhard Hansen (Bielefeld), Tsubasa Itoh (Hokkaido), Sebti Kerbal (Sultan Qaboos), Dmitry Khavinson (South Florida), Nikolai G. Makarov (Caltech), Jane McDougall (Colorado Coll.), Yoshihiro Mizuta (Hiroshima), Jürgen Müller (Trier), Vassili Nestoridis (Athens), Ivan Netuka (Charles), Markus Niess (KU Eichstätt-Ingolstadt), Anthony G. O. O'Farrell (NU Ireland), Petr Paramonov (Moscow SU), Thomas J. Ransford (Laval), Murali Rao (Florida), Dominic Rochon (UQTR), Azimbay Sadullaev (NU Uzbekistan), Nageswari Shanmugalingam (Cincinnati), David Singman (George Mason), Manfred Stoll (South Carolina), Nikolai Tarkhanov (Potsdam), Jie Xiao (Memorial), Eduardo Santillan Zeron (Cinvestav), Ruhan Zhao (Coll. Brockport, SUNY)

Number of participants: 49

This four–day international conference gathered more than 50 mathematicians from 15 countries and its program consisted of 24 invited presentations and 14 contributed talks. The lectures, given by some of the leaders in their respective fields, covered a large range of topics: Geometric Function Theory; Approximation Theory; Operator Theory; Function Spaces; Classical, Abstract, and Probabilistic Potential Theory; Pluripotential Theory; Harmonic Analysis; Orthogonal Polynomials; Complex Dynamics; and other topics. The conference proceedings, containing more than 20 refereed articles, were published in the CRM Proceedings & Lecture Notes Series. The proceedings are a mixture of original research and expository articles.

The conference was honouring the important contributions to mathematics and the mathematical community of two influential analysts from Montréal: Professor K. N. GowriSankaran (McGill University) and Professor Paul M. Gauthier (Université de Montréal). Each of them has had a long and distinguished career in Montréal, extending over four decades. The conference brought together specialists, young researchers, and graduate students in both Complex Analysis and Potential Theory; it fostered exchanges of ideas and techniques and cooperation to find new research perspectives.

Summer School on Non-Equilibrium Statistical Mechanics

July 1–29, 2011, CRM

Sponsored by the Agence Nationale de la Recherche (ANR), the CNRS, the CRM, NSERC, McGill University, and the Université de Cergy-Pontoise

Organizers:

Laurent Bruneau (Université de Cergy-Pontoise), Vojkan Jakšić (McGill University), Roberto Livi (Università degli Studi di Firenze), Claude-Alain Pillet (Université du Sud Toulon-Var), Robert Seiringer (McGill University)

Number of participants: 59

The summer school on *Non-Equilibrium Statistical Mechanics* took place at the CRM in July 2011 and was the second part of the joint CRM–Université de Cergy-Pontoise semester on *Frontiers in Mathematical Physics*. The first part of the joint semester was held at the Université de Cergy-Pontoise in the month of May. The May program included two eighteen-hour mini-courses titled *Dynamics and statistics on lattices and networks* and *Non-equilibrium quantum statistical mechanics*, given, respectively, by Roberto Livi and Vojkan Jakšić; a one-day seminar (*Dynamics in spa-*

tially extended systems) held on May 6 (the speakers were H. Chaté, CEA/Saclay; J. Kurchan, ESPCI ParisTech; A. Pikovsky, Potsdam; A. Politi, Firenze); and a two-day workshop (*Frontiers in Mathematical Physics*) held on May 26–27 (the speakers were M. Aizenman, Princeton; S. De Bièvre, Lille 1; V. Jakšić, McGill; A. Joye, Joseph Fourier; A. Klein, UC Irvine; F. Klopp, Paris 13; C.-A. Pillet, Toulon; R. Seiringer, McGill; and S. Warzel, TU München). These activities were followed by an intense four-week program held in Montréal in July, and described below. The joint semester was initiated and enthusiastically supported by F. Germinet, vice-president of the Université de Cergy-Pontoise. The organizers were L. Bruneau, V. Jakšić, R. Livi, C.-A. Pillet, and R. Seiringer.

The July program included a fifteen-hour course by J. Derezinski (Warsaw) titled *A mathematical introduction to quantum electrodynamics*, and twelve three-hour mini-courses listed below.

- L. Bruneau (Cergy-Pontoise) *Repeated Interaction Quantum Systems*. I.
- B. Derrida (ÉNS) *Density and current fluctuations in non-equilibrium diffusive systems*.
- G.-M. Graf (ETH Zürich) *Adiabatic evolution and dephasing*.
- A Joye (Joseph Fourier) *Repeated interaction quantum systems*. II.
- I. Klich (Virginia) *Entanglement in many body systems*.
- E. Lieb (Princeton) *The Polaron*.
- C. Liverani (Tor Vergata) *Fourier law from a dynamical systems point of view*.
- R. Livi (Firenze) *Heat transport in low-dimensional systems*.
- J. Møller (Aarhus) *Pauli–Fierz systems at zero and positive temperature*.
- C.-A. Pillet (Toulon) *Open systems*.
- R. Seiler (TU Berlin) *Typicality in classical and quantum information theory*.
- R. Seiringer (McGill) *Cold quantum gases and Bose-Einstein condensation*.

The program also included twenty-four 45-minute talks given by Y. Avron (Technion), S. Bachmann (UC Davis), J.-M. Barbaroux (Toulon), H. Cornean (Aalborg), S. De Bièvre (Lille 1), W. De Roeck (Heidelberg), M. Fraas (Technion), F. Germinet (Cergy-Pontoise), P. Grech (ETH Zürich), F. Hiai (Tohoku), S. Kuksin (École Polytechnique), E. Livi (Firenze), M. Merkli (Memorial), B. Nachtergaele (UC Davis), Y. Ogata (Tokyo), A. Panati (Toulon), Y. Pautrat (Paris-Dauphine), D. Ruelle (IHÉS), A. Shirikyan (Cergy-Pontoise), D. Taj (Toulon), L. Thomas (Virginia), M. Westrich (Aarhus), J. Yngvason (Wien), and V. Zagrebnov (Méditerranée).

A selection of articles based on the courses will be published in a special issue of the *Journal of Mathematical Physics* devoted to the summer school. We are also happy to acknowledge, with special thanks to B. Nachtergaele, the financial contribution of the American Institute of Physics/*Journal of Mathematical Physics* toward the organization of the summer school. The summer school and the entire joint semester were a considerable success. In spite of the intensity of the program, there was plenty of time for discussions and forging of new scientific collaborations. A very friendly and relaxed atmosphere was combined with one of the most pleasant springs/summers Paris/Montréal had in a long time.

SMS 2011 Summer School
Metric Measure Spaces: Geometric and Analytic Aspects

June 27–July 8, 2011, Université de Montréal
Sponsored by the CRM, the Fields, PIMS, the ISM, the Mathematical Sciences Research Institute (MSRI), the Université de Montréal (Département de mathématiques et de statistique), Concordia, and the CMS

Organizers:
Galia Dafni (Concordia), Robert McCann (Toronto), Alina Stancu (Concordia)
Number of participants: 60

The 50th edition of the Séminaire de mathématiques supérieures (SMS) took place from June 27 to July 8, 2011, on the campus of the Université de Montréal. This university has supported the summer school, which has acquired international renown, for over 50 years, often in collaboration with NATO. For the first time this year, a new funding structure was initiated by the SMS Director, Octav Cornea, and the school was supported by the Canadian mathematical community, as well as at the North American level. This is reflected in the list of sponsors of the SMS 2011 Summer School, given above.

In recent decades, metric measure spaces have emerged as a fruitful source of mathematical questions in their own right, and as indispensable tools for addressing classical problems in geometry, topology,

dynamical systems, and partial differential equations. The summer school was designed to lead young scientists to the research frontier concerning the analysis and geometry of metric measure spaces, by exposing them to a series of mini-courses featuring leading researchers who highlighted both the state-of-the-art and some of the exciting challenges that remain. The selection of funded participants from the pool of nearly 140 applicants, many of them highly qualified, was difficult. In the end, with over 60 participants, mostly graduate students, coming from 13 countries in Africa, Asia, Europe, and North America, this 50th edition of the Séminaire de mathématiques supérieures was a resounding success.

There were 13 four-hour minicourses given by international experts in their fields:

- L. Ambrosio (Scuola Normale Superiore di Pisa): *Calculus in metric measure spaces with Ricci curvature bounded from below*;
- M. Barlow (University of British Columbia): *Heat equation on some fractal metric spaces*;
- T. Coulhon (Université de Cergy-Pontoise): *Heat kernel estimates, Sobolev type inequalities and Riesz transform on non-compact Riemannian manifolds*;
- G. David (Université Paris-Sud): *Regularity results for minimal sets*;
- P. Hajłasz (University of Pittsburgh): *Sobolev mappings into metric spaces*;
- V. Kapovitch (University of Toronto): *Fundamental groups of manifolds with lower Ricci curvature bounds*;
- Y.-H. Kim (University of British Columbia): *Ma–Trudinger–Wang curvature and regularity of optimal transport*;
- P. Koskela (University of Jyväskylä): *Quasiconformal mappings and function spaces*;
- R. McCann (University of Toronto): *Optimal Transportation*;
- E. Milman (Technion–Israel Institute of Technology): *Isoperimetric, functional and concentration inequalities*;
- Y. Ollivier (CNRS; Université Paris-Sud): *Discrete Ricci curvature with applications*;
- F. Otto (Max-Planck-Institut für Mathematik in den Naturwissenschaften): *Burgers' equation as a gradient flow on two-phase Wasserstein space*; and
- K. T. Sturm (Universität Bonn): *Ricci bounds for metric measure spaces and geometric analysis.*

The abstracts and some lecture notes can be found on the SMS website, http://dms.umontreal.ca/~sms/Metric11/index_e.php. In addition, the proceedings of the summer school will be collected in a volume to be published in the CRM Proceedings and Lecture Notes series.

The mini-courses came under three general themes, with certain talks providing links between them. The first and perhaps most prevalent was the use of techniques from optimal transportation to define geometric notions on metric measure spaces, in particular the notion of lower curvature bounds. Yann Ollivier began the school with a beautiful series of lectures introducing a definition of discrete Ricci curvature on metric spaces, based on the idea of comparing the (average transportation) distance between balls to the distance between their centers. Ollivier's talks were complemented on the one hand by Vitali Kapovitch's lectures, emphasizing the Riemannian geometry point of view, and on the other by Robert McCann's lectures on optimal transportation.

In a carefully prepared series of talks aimed at an audience consisting in part of non-geometers, Kapovitch described the consequences of curvature bounds on Riemannian manifolds, comparing in particular Ricci curvature versus sectional curvature, and metric analogs in Alexandrov spaces, and emphasizing the importance of splitting theorems. The highlights of the course were the results of Kapovitch and Wilking on the finitely generated fundamental group of manifolds with Ricci curvature bounded from below. McCann's mini-course provided students with insight into the techniques and applications of optimal transportation, starting with the classical transportation problem of Monge and Kantorovich and progressing to the recent theorems concerning smoothness of optimal maps by Ma, Trudinger, Wang, and Loeper. Along the way there were excursions into two-player zero sum games, convex duality and linear programming, fully nonlinear partial differential equations, the economics of optimal pricing, and connections with minimal Lagrangian submanifolds in semi-Riemannian geometry.

This theme was taken up in the second week by Karl-Theodor Sturm, who spoke about the celebrated curvature-dimension condition for metric measure spaces, originating in his work and that of Lott–Villani (with ideas tracing back to the work of McCann). He introduced a variant of this condition, the so-called "reduced curvature-dimension condition," which has the

local-to-global property. The mini-course concluded with a detailed exposition of the relevant notions and results in the setting of Finsler spaces. The discussion of optimal transportation started by McCann continued with a series of talks by Young-Heon Kim on Ma–Trudinger–Wang curvature and regularity of optimal transport. In this theory, the non-negativity of certain sectional curvatures of a metric induced by the transportation cost turns out to be necessary and sufficient for the smoothness of optimal maps. Focusing his talks in the Riemannian setting, Kim outlined the state-of-the art through a series of examples and counterexamples, building up to his recent joint work on Hölder continuity of optimal maps between not-necessarily-smooth distributions of mass.

The course by Felix Otto illustrated further uses of notions coming from optimal transportation, in particular the Wasserstein distance, arising in partial differential equations from applied mathematics modelling dissipative mixing of immiscible fluids. Here he revisited his classical bound on the nonlinear mixing rate. This appears uncontrolled in the linearized regime due to the Rayleigh–Taylor instability, which predicts that thin fingers of fluid grow faster, with the thinnest fingers growing arbitrarily fast. More than a decade ago, Otto coarse-grained the dynamics, to show that the average fluid density as a function of its height obeys a Burgers' type equation that predicts mixing at a bounded rate. In a recent preprint with Gigli, he showed that this dynamics actually represents a gradient flow in a metric space setting, which picks out the unique entropy solution to the scalar conservation law, as explained in his lectures.

The second theme of the summer school, roughly coming under the "analytic aspects"of metric spaces, concerned notions of differentiability on metric measure spaces and the corresponding function spaces. This theme started in the first week with the parallel series of lectures by Piotr Hajłasz and Pekka Koskela. Without relying on much background from the audience, Hajłasz succeeded in introducing students to the fascinating and sometimes surprising world of Sobolev mappings between manifolds, from manifolds into metric spaces, and between metric spaces, in which basic facts such as approximation by smooth or Lipschitz functions cannot be taken for granted, and may depend on topological properties involving homotopy groups (in the case of manifolds). Koskela's dynamic lectures exposed the audience to questions from the theory of quasi-conformal mappings in the context of (Ahlfors regular) metric-measure spaces, covering in detail the regularity of QC maps, the notion of quasi-symmetry, and the function spaces preserved under these maps. In addition to Sobolev spaces (using the definition given by Hajłasz), recent work by Koskela, Yang, and Zhou was described, showing that certain appropriately defined Besov and Triebel–Lizorkin spaces are preserved.

The two themes described above came together in the mini-course by Luigi Ambrosio in the school's second week. Ambrosio reviewed and compared various notions of weak gradients and Sobolev spaces in metric measure spaces, such as upper gradients (due to Heinonen and Koskela), absolute continuity on lines (a definition by Levi extended to metric measure spaces by Shanmugalingam), and Cheeger's energy, and showed the identification of weak gradients using optimal transportation techniques, without relying on doubling or Poincaré assumptions. These exciting results (joint work of Ambrosio with Gigli and Savaré) used a gradient flow based on the Wasserstein distance and the curvature-dimension conditions of Lott–Sturm–Villani.

The final theme could be described as functional and geometric inequalities. The mini-course of Ollivier concluded with results on concentration of measure and the Brunn–Minkowski inequality for the discrete hypercube (the latter joint work with Villani), part of the body of work for which he was awarded the 2011 CNRS bronze medal. The course of Emanuel Milman, spanning the two weeks, described the relations between isoperimetric inequalities, concentration of measure, and functional inequalities such as Poincaré, Sobolev, and log-Sobolev. While isoperimetric inequalities imply Sobolev type inequalities, and it is known from work of Gromov–V. Milman that, in any metric space, the Poincaré inequality implies exponential concentration, the reverse implications do not hold in general. It was thus an impressive result that in the case of a Riemannian manifold with density having lower bounds on the Bakry–Émery tensor, E. Milman showed that concentration inequalities imply isoperimetric inequalities. A main ingredient of his proof is a result of Frank Morgan, well known in geometric measure theory. The latter topic was featured in the lectures by Guy David. Starting with the famous Plateau problem in higher dimensions (not yet solved) as an illustration, David's course discussed the structure of minimizers to functionals on currents with a given lower dimen-

sional rectifiable current as boundary. The focus was now on the lack of smoothness, and minimizers in the sense of Almgren, concluding with the proof of Jean Taylor's theorem that characterizes them.

The relations between various inequalities was also the subject of the course by Thierry Coulhon in the second week. Again working in the Riemannian context, but this time on a non-compact manifold with volume doubling, Coulhon discussed the implications of various heat kernel estimates to L^p boundedness of Riesz transforms, an important question that relates back to the second theme since it concerns the compatibility of various definitions of weak derivatives (i.e., the weak gradient and the square-root of the Laplacian) and the corresponding Sobolev spaces. An example was given of a fractal-like manifold where local and global bounds differ. Heat kernel estimates, and in particular this type of discrepancy between local and global behaviour, also played a prominent role in the lectures by Martin Barlow, where Gaussian bounds were shown to be equivalent to a parabolic Harnack inequality on the one hand, and doubling and Poincaré on the other. These inequalities (or their failure) were discussed in detail for the Sierpinski carpet.

All talks were of an exceptionally high quality. Moreover, many of the speakers attended the other minicourses and this generated interesting interactions. Students too posed questions to the speakers, ranging from elementary to very knowledgeable, and continued the discussions between the talks and during the lunch breaks and social activities. Despite the full schedule, there was a lot of enthusiasm among participants until the very last lecture, and a subsequent survey conducted by PIMS demonstrated high rates of satisfaction. Just as two of the speakers, Robert McCann and Young-Heon Kim, recounted positive memories of past SMS summer schools they attended as students, it is hoped that the 2011 SMS will remain memorable for its participants, and some of them will even return as future speakers.

17th International Conference on Difference Equations and Applications (ICDEA)

July 24–29, 2011, UQTR

Sponsored by the International Society of Difference Equations, the CRM, the UQTR, the Département de mathématiques et informatique and the Department de physique of UQTR, and the Association générale des étudiants de l'UQTR

Organizer: Adel F. Antippa (UQTR)

Main speakers:

Göran Högnäs (Åbo Akademi), Anna Mazzucato (Penn State), Stefan Siegmund (TU Dresden), Petr Stehlík (West Bohemia), Aleksandr N. Sharkovsky (Mathematics Inst., ASU), Erik Van Vleck (Kansas), Pavel Winternitz (Montréal)

Number of participants: 48

C'est sur le campus de l'Université du Québec à Trois-Rivières que s'est déroulé pour la première fois au Canada le congrès annuel de la Société internationale des équations aux différences finies (ISDE). Au cours du congrès, marqué par la contribution d'éminents chercheurs et professeurs en provenance de 14 pays, une cérémonie a été organisée pour la remise du prix Bernd Aulbach au P^{r} Aleksandr N. Sharkovsky. Ce prix a été décerné pour la toute première fois par l'International Society of Difference Equations (ISDE). En plus des activités scientifiques, les participants du congrès ont été invités au salon du maire de Trois-Rivières ainsi qu'à une réception organisée par le recteur de l'Université du Québec à Trois-Rivières, M. André Paradis.

Complex Analytic and Algebraic Trends in the Geometry of Varieties

August 15–17, 2011, UQAM

Organizers:

Karol Palka (UQAM), Peter Russell (McGill), Steven Shin-Yi Lu (UQAM)

Speakers:

V. Charette (Sherbrooke), D. Daigle (Ottawa), F. Donzelli (Ottawa), B. Gilligan (Regina), R. Gurjar (Tata Inst.), Sh. Kaliman (Miami), M. Koras (Warsaw), A. Maharana (IISER Mohali), K. Masuda (Kwansei Gakuin), M. Miyanishi (Kwansei Gakuin), L. Moser-Jauslin (Bourgogne), A. Sathaye (Kentucky), J. Winkelmann (Bochum), D.-Q. Zhang (NU Singapore), Y. Zong (Toronto)

Number of participants: 23

The conference was organized to take advantage of the presence in Montreal during August 2011 of three postdoctoral fellows (F. Donzelli, A. Maharana, K. Palka) and several long-term visitors (R. Gurjar, M. Koras, K. Masuda, M. Miyanishi, A. Sathaye, J. Winkelmann, D.-Q Zhang) specializing in complex analytic and algebraic geometry. Several research projects resultig from this collaboration are ongoing.

There were 15 presentations of 50 minutes each. If one looks for a common denominator for a majority of the talks, one will find it in the study of group actions, including infinitesimal ones, on varieties, in one of a manifold of incarnations of this subject. The talks of Zhang and Gilligan dealt with compact Kähler manifolds, the first with the study of the dynamics of automorphisms from the view point of the minimal model program and the second with the existence of (local) Kähler structure on homogeneous spaces and tube neighborhoods of CR-solvmanifolds.

The talks of Miyanishi, Masuda, Daigle, and Moser-Jauslin dealt with automorphisms of affine varieties. Miyanishi characterized derivations D on a factorial affine threefold Spec A that are locally nilpotent (and hence come from a $\mathbf{G_a}$-action) in terms of the fibration $\mathrm{Spec}(A) \to \mathrm{Spec}(\mathrm{Ker}\, D)$. Masuda proved structure theorems for affine domains that have an *algebraic* derivation, a notion that generalizes local nilpotency and corresponds to actions of more general algebraic groups. Daigle described a general construction of normal affine surfaces that admit a non-trivial $\mathbf{G_a}$-action and have trivial canonical class (as, for instance, hypersurfaces in $\mathbb{A}^3$). Moser-Jauslin described the construction of families of contractible (hence diffeomorphic to $\mathbb{C}^3$) smooth hypersurfaces in $\mathbb{C}^4$ with pairwise non-isomorphic members. A key tool here is the use of the Makar-Limanov invariant (the intersection of the kernels of all locally nilpotent derivations) of these threefolds.

Kaliman gave a survey of the present state of Andersen–Lempert theory, that is the study of the density properties of the Lie algebra generated by completely integrable vector fields in the space of all holomorphic vector fields on a Stein manifold. This and the analogous question of algebraic density on an affine variety are very active areas of research at present, in particular in connection with the study of *flexible* varieties. (A smooth point on a variety is flexible if the tangent space is generated by the tangents at the points of orbits of $\mathbf{G_a}$-actions.) Donzelli in his talk studied the connection between flexibility and the Makar-Limanov and related Derksen invariants in the case of affine surfaces. The talk of Charette was on real 3-manifolds. She described 3-manifold quotients of Euclidian 3-space by non solvable groups of affine transformations (discovered by Margulis) and discussed recent results on the deformation spaces of such groups.

The talks of Gurjar and Maharana dealt with aspects of the classical subject of cyclic multiple planes, that is cyclic ramified covers of the complex plane $\mathbb{C}^2$. Gurjar described a common approach to multiple planes and branched covers of the n-sphere based on Smith's theory of finite group actions on simplicial complexes. This gives in particular a new proof of Zariski's result on the irregularity of a multiple plane. Maharana gave a classification in terms of the ramification locus of the multiple planes that have logarithmic Kodaira dimension less than 2. Koras described the almost completed classification of closed embeddings of $\mathbb{C}^*$ in $\mathbb{C}^2$. Fairly sophisticated results in the theory of open surfaces, in particular the logarithmic BMY-inequality, are used.

Sathaye in his talk raised, and largely solved, an elementary question on extensions of a field k: If t is a root of an irreducible polynomial $f(x)$ over k, when is $k(t) = k\big(f'(t)\big)$? The question arose in connection with the Jacobian problem. Winkelmann's talk dealt with the relation between the Diophantine behaviour of a variety X defined over a number field K and the properties of the complex manifold $X(\mathbb{C})$, in particular an analogy between infinite sets of integral points over a finite extension of K and holomorphic curves. He showed that these objects have similar lifting properties with respect to principal bundles. The subject of Zong's talk was the monodromy of torsion points of abelian varieties and the Mumford–Tate conjecture. He outlined a proof of a theorem of Serre on big monodromy of torsion points.

Combinatorial Algebra Meets Algebraic Combinatorics

January 20–22, 2012, UQAM

Sponsored by the CRM, LaCIM, and the Canada Research Chair in Combinatorial Algebra and Mathematical Computer Science

Organizers:

François Bergeron (UQAM), Johanne Patoine (UQAM),

Franco Saliola (UQAM), Luis Serrano (UQAM), Jérôme Tremblay (UQAM)

Speakers:

Ali Alilooee (Dalhousie), Federico Ardila (San Francisco State), Elizabeth Beazley (Williams Coll.), Chris Berg (UQAM), Zhi Chen (York), Emma Connon (Dalhousie), Federico Galetto (Northeastern), Christophe Hohlweg (UQAM), Anthony Iarrobino (Northeastern), Ilias Kotsireas (Wilfrid Laurier), Alejandro Morales (MIT), Rosa Orellana (Dartmouth Coll.), Kevin Purbhoo (Waterloo), Yong-Su Shin (Sungshin WU), Christian Stump (UQAM), Hugh Thomas (New Brunswick), Greg Warrington (Vermont), Nathan Williams (Minnesota)

Number of participants: 45

Le but de cette rencontre était de faire le point sur les progrès récents concernant plusieurs questions ouvertes à l'intersection de la combinatoire, de l'algèbre commutative, et de la géométrie algébrique. Parmi les faits marquants, mentionnons des descriptions explicites: (1) de constantes de structures pour des anneaux de cohomologie de variétés de drapeaux et de grassmaniennes, (2) de résolutions linéaires équivariantes d'idéaux de monômes, (3) de la "structure" de systèmes de racines pour des groupes de Coxeter infinis, (4) de la structures de certaines algèbres amassées.

Voici la liste des conférences.

- The graded Betti numbers of the path ideal of a cycle (A. Alilooee).
- Power ideals of hyperplane arrangements (F. Ardila).
- Quantum cohomology and the poset of Newton polygons (E. Beazley).
- Expansions of k-Schur functions in the affine nil Coxeter algebra (C. Berg).
- A Plethysm formula on the induced linear character from $U_n(\mathbb{F}_q)$ into $\mathrm{GL}_n(\mathbb{F}_q)$ (Z. Chen).
- Generalizing Fröberg's theorem on ideals with linear resolutions (E. Connon).
- Free resolutions of orbit closures for representations with finitely many orbits (F. Galetto).
- Asymptotical behaviour of roots of Coxeter groups (C. Hohlweg).
- Bound on the Jordan type of a nilpotent matrix commuting with a given matrix (T. Iarrobino).
- New results on D-optimal matrices (I. Kotsireas).
- Flow polytopes and the Kostant partition function for signed graphs (A. Morales).
- On a diagram centralizer algebra (R. Orellana).
- A tale of two staircases (K. Purbhoo).
- Gorenstein sequences of socle degree 4 and 5 and Artinian Level algebras of codimension 3 (Y. S. Shin).
- A new combinatorial approach to cluster algebras of finite types (C. Stump).
- Canonically positive bases in the cluster algebra associated to an annulus (H. Thomas).
- On using quasisymmetric functions to determine Schur expansions (G. Warrington).
- Young's lattice and the cyclic sieving phenomenon (N. Williams).

SUMM 2012
Seminars in Undergraduate Mathematics in Montréal

January 21–22, 2012, Université de Montréal

Organizers:

Jean-François Arbour (UQAM), Geoffroy Bergeron (Montréal), Vincent Gélinas (Concordia), Kevin Gervais (Montréal), Andréanne Lapointe (Montréal), Vincent Létourneau (Montréal), Daniel Lévesque (Montréal), Michael Snarski (McGill)

Speakers (professors):

Steven Boyer (UQAM), Henri Darmon (McGill), Chantal David (Concordia), Paul Gauthier (Montréal)

Speakers (students): Jean-François Arbour, Léo Belzile, Nicolas Bouchard, David Boulet, Philippe Charron, Gabriel Gaudreault, Vincent Gélinas, Kevin Gervais, Bruno Joyal, Jamie Klassen, Andréanne Lapointe, Alex Lavoie, Vincent Létourneau, Daniel Lévesque, Frédéric Quesnel, Jifeng Shen, Nicolas Simard, Michael Snarski, David Thibodeau

Number of participants: 90

Le Séminaire universitaire de mathématiques à Montréal (SUMM) est un évènement organisé annuellement par des étudiants de premier cycle en mathématiques et ayant lieu dans l'une des quatre universités montréalaises. Il est né en 2009 de l'initiative d'étudiantes de McGill et sa première édition a eu lieu à l'UQAM au mois de février 2010. L'objectif de ce séminaire est de permettre aux étudiants de se rencontrer dans le but d'échanger sur différents domaines des mathématiques, tant fondamentales qu'appliquées. Les exposés sont donnés par des étudiants et des professeurs (invités) des quatre universités montréalaises (voir le site http://summ.math.uqam.ca/). Le séminaire de 2012 a attiré un grand nombre de participants : en effet beaucoup d'étudiants qui n'avaient pas rempli le formulaire du CRM ont participé au séminaire. En 2012 les sujets couverts allaient de la théorie des nombres et

de la théorie des nœuds (sujets abordés par les professeurs invités) à la théorie des représentations, la théorie des groupes, la théorie des jeux, les algèbres amassées, l'axiome du choix et la logique.

69th Algebra Day

April 14, 2012, Ottawa
Sponsored by the CRM, the University of Ottawa, and Carleton University

Organizer: Erhard Neher (Ottawa)
Speakers:
Alex Hoffnung (Ottawa), José Malagón López (Ottawa), Holger Petersson (FU Hagen), Zinovy Reichstein (UBC), Elizabeth Dan-Cohen (Louisiana State)
The Algebra Day, which has a long tradition, enables algebraists to meet in order to share their latest work. In 2012 H. Petersson spoke about *Moufang sets and the problem of commuting U-operators in Jordan algebras*; J. Malagón López about *Exponents and formal group rings*; A. Hoffnung about *Hecke algebras and cohomology*; Z. Reichstein about *Simplifying polynomials by Tschirnhaus transformations: old and new*; and E. Dan-Cohen about *A Koszul category of representations of finitary Lie algebras.*

Geometry and Physics — GAP 2012

May 5–7, 2012, Waterloo & Perimeter Inst.
Sponsored by the CRM, the Department of Mathematics of the University of Toronto, the Faculty of Mathematics of the University of Waterloo, the Faculty of Science of McMaster University, the Fields Institute for Research in Mathematical Sciences, and the Perimeter Institute for Theoretical Physics.

Organizers:
Marco Gualtieri (Toronto), Spiro Karigiannis (Waterloo), Ruxandra Moraru (Waterloo), Rob Myers (Perimeter Inst.), Pedro Vieira (Perimeter Inst.), McKenzie Wang (McMaster)
Principal Speakers:
David Baraglia (ANU), Robert Bryant (UC Berkeley), Gil Cavalcanti (Utrecht), Mark Haskins (Imperial Coll.), Jacques Hurtubise (McGill), Boris Khesin (Toronto; IAS), Dmitry Korotkin (Concordia), Martin Kruczenski (Purdue), Naichung Conan Leung (Chinese U Hong Kong), Chuu-Lian Terng (UC Irvine), Gang Tian (Princeton; Peking), Barton Zwiebach (MIT)
Local Postdocs:
Michael Bailey (UQAM), Ronan Conlon (McMaster), Răzvan Gurau (Perimeter Inst.), David Kubiznak (Perimeter Inst.), Steve Rayan (Toronto), Amit Sever (Perimeter Inst.), Aaron Smith (Waterloo)
Number of participants: 75
The "Geometry And Physics" conference has been held each year since 2009, with the goal of bringing together researchers working at the interface between mathematics and physics, fostering the exchange of innovative ideas, and exposing participants to new developments which may accelerate their research. An important secondary aim is to increase further Canada's presence and visibility in geometry within the international mathematical community. Each year, the conference focuses on three distinct themes in geometry and physics as well as the connections between them. This results in an interesting diversity of talks, and is a distinguishing feature of the conference which we aim to maintain.

The GAP 2012 conference witnessed several striking breakthroughs in all three of the chosen theme areas: generalized geometry, integrable systems, and special holonomy. The following are some of the highlights which made GAP 2012 such a success. In the theme of generalized geometry, Barton Zwiebach unveiled a new notion of Riemann tensor in the double field formalism, which has implications for the study of generalized metrics, and posed several open problems of interest to mathematicians and physicists. David Baraglia succeeded in extending the formalism of variation of Hodge structure, so crucial in mirror symmetry, to generalized complex manifolds. Also Michael Bailey presented his recent thesis results, which complete the local classification of generalized complex manifolds. Finally Gang Tian outlined his recent research programme, in which he applies the B-field renormalization group flow to generalized Kähler manifolds.

In integrable systems, much excitement centred around the recent explicit computations of scattering amplitudes and Wilson loops in terms of minimal surface areas, which in turn may be expressed in terms of integrable systems such as the Hitchin system. This work, exemplified by the talks of Amit Sever and Martin Kruczenski, generated intense discussions among the assembled experts in integrable systems. In another direction, Boris Khesin described his beautiful recent work with Fedor Soloviev, which uncovers a great number of new discrete integrable systems with con-

tinuum limit given by a specialization of the KdV hierarchy.

In the field of special holonomy, Mark Haskins announced his spectacular recent achievement in the construction of new compact G2 manifolds with known diffeomorphism type, as well as compact G2 manifolds containing calibrated submanifolds. This represents a major development in a field tightly linked to M-theory and string compactifications. In a remarkably energetic presentation, Ronan Conlon described an important enhancement to the famous result of Tian and Yau proving the existence of asymptotically conical Calabi-Yau manifolds, which extends our understanding of noncompact Calabi-Yau manifolds, also crucial in the study of string compactifications. Tian, who was in attendance, seemed to approve. Finally, in a tour-de-force performance, Robert Bryant produced explicit resolutions of the canonical coassociative cone in 7 dimensions, making use of an unexpected integrability hidden in the ring of SO(3)-invariant polynomials in dimension 7, settling a thirty-year-old question in the study of calibrated geometry.

The Bellairs Workshop in Number Theory 2012

May 6–12, 2012, Bellairs Research Institute (Barbados)
Sponsored by CICMA

Organizers:
Henri Darmon (McGill), Eyal Z. Goren (McGill)
Keynote speaker: Minhyong Kim (Oxford)
Evening speakers:
Jennifer Balakrishnan (Harvard), Amnon Besser (Ben Gurion), Bryden Cais (Arizona), Henri Darmon (McGill), Romyar Sharifi (Arizona)
Number of participants: 29

The purpose of the workshop was to present aspects of the algebraic theory of the pro-unipotent fundamental group and its arithmetic applications to diophantine questions, following Minhyong Kim's progam to study rational points on varieties through anabelian descent and Chabauty-type techniques. The lectures aimed to be accessible to non-experts and newcomers to the subject, including graduate students, although some background in number theory and algebraic geometry was assumed.

A series of five two-hour lectures were delivered in the mornings by Minhyong Kim, supplemented by lectures from attending experts in the evenings. The morning lectures were extremely successful, with many questions and lively participation from the audience, so that the planned two-hour sessions often lasted three hours or more. The more specialised evening lectures were also well received overall.

The Bellairs Institute provides a unique environment for scientific interaction, and the afternoons were set aside for informal discussions, allowing many of the participants to make progress on various collaborative research projects.

SAGE Days at CRM

May 5–11, 2012, CRM

Organizers:
Srecko Brlek (UQAM), Sébastien Labbé (UQAM), Franco Saliola (UQAM)
Main speakers:
Meinolf Geck (Aberdeen), Viviane Pons (Marne-la-Vallée), Derek Ruths (McGill), Anne Schilling (UC Davis), Øyvind Solberg (NTNU), Nicolas M. Thiéry (Paris-Sud), Doron Zeilberger (Rutgers)
Number of participants: 58

In early May 2012, the CRM hosted Sage Days 38. The audience included researchers of all levels, from undergraduates embarking on summer research projects to established researchers, as well as university and CEGEP educators. The goal of the workshop was twofold: to provide a gentle introduction to Sage for newcomers, and to develop and implement algorithms for mathematics research. All participants were encouraged to come equipped with their own research problems that could benefit from some computational experimentation.

We designed the schedule of the workshop with these goals in mind. We had a rigid schedule for the first few days of the week and an evolving schedule for the last two days. Almost all of the presentations were scheduled for the morning sessions. The afternoon sessions were dedicated to follow-up discussions, work on tutorial exercises (for new users), and coding sprints (for developers). We ended every day with a "status report" where participants would describe their progress.

Since one of the workshop goals was to provide a gentle introduction to Sage, there was a strong emphasis on tutorials. This made the workshop very popular, and we had a great turnout (58 participants). It seems that there is a large appetite for workshops that introduce new research tools! We had seven one-hour tu-

torials throughout the week, led by various Sage developers: "Using the Sage notebook and navigating the help system," F. Saliola; "Calculus and Linear Algebra in Sage," F. Saliola; "Programming in Python and Sage," F. Hivert; "Contributing to Sage," A. Schilling; "Introduction to Cython," S. Labbé; "Cython," F. Hivert; and "Introduction to the Sage category theory framework," N. M. Thiéry.

The tutorials offered practical experience for the participants: relevant notions were introduced and then exercises were assigned to the participants. In addition to the presentations and tutorials on Sage, there were several mathematical presentations. These began by acquainting the audience with the relevant mathematics and then described some of the computational aspects of the theory, together with relevant software packages. Note that some of this software is independent of Sage, and that these talks also served as a means to establish communication between the developers of the different software packages.

At the end of the week we sent out a questionnaire asking for comments on the week. We asked for comments on the schedule, and whether the tutorials and presentations were adapted to the participants' needs as beginners, users, or developers of Sage. The responses were very positive. There was some criticism of the pace of the tutorials as a few participants felt the tutorials were a "bit rushed." Nonetheless they expressed gratitude for the scheduled free time, which they used to review the tutorials and work on the exercises. Some participants went from user to developer over the course of the week, making their very first contributions to Sage. Several participants emphasized that they liked the daily status reports, that it was a good motivator, a good way to see what the other participants where working on during the week, and a good way to observe the progress made over the week.

We feel that the workshop was very successful. New users left emboldened with new skills that they can build upon in the future. The workshop resulted in several contributions to Sage, from the fixing of bugs to the development of new functionalities, and it established communication between different software projects. Many research publications will be appearing as new tools and algorithms are developed. We look forward to these developments.

2012 Montréal–Toronto Workshop in Number Theory
"Cycles on Kuga Fibre Varieties"

May 28–29, 2012, CRM

Sponsored by the CRM, the Fields Institute for Research in Mathematical Sciences, and CICMA

Organizers:

Eyal Z. Goren (McGill), Stephen S. Kudla (Toronto)

Speakers:

Zavosh Amir-Khosravi (Toronto), Dylan Attwell-Duval (McGill), Henri Darmon (McGill), Andrew Fiori (McGill), Eyal Goren, Stephen Kudla, Kartik Prasanna (University of Michigan at Ann Arbor), Siddarth Sankaran (Universität Bonn), Brian Smithling (Johns Hopkins University), Patrick Walls (Toronto), Ying Zong (Toronto)

Number of participants: 25

This workshop was dedicated to the study of Kuga fibre varieties and their applications, in particular to the Hodge conjecture, the construction of points on elliptic curves and the Griffiths groups, and higher weight versions of Gross–Zagier theory. These recent, and very recent, developments are due to Abdulali, Bertolini–Darmon–Prassana, and Mellit. The program included, besides background material aimed mostly at graduate students and junior researchers, several expositions devoted to these emerging directions. Kartik Prasanna presented new work with Darmon, some of it completed the night before (!), and so we are happy to have instigated new research contributions.

As before, the workshop was a resounding success, evident at the level of talks, the participants' engagement and commitment, and the pleasant and cooperative atmosphere surrounding the whole 2-day activity. In addition, during the workshop, through the questions of the audience and discussions, interesting new research directions have emerged. Hopefully these will be taken up by some of the participants.

The Montréal–Toronto workshops, the fourth of which has just been concluded, are gaining reputation as a fine collaborative initiative between the number theory groups in Montréal and in Toronto, and one of the successful collaborative programs between the CRM in Montréal and the Fields Institute in Toronto.

International Workshop
Perspectives on High-Dimensional Data Analysis II

May 30 – June 1, 2012, CRM

Organizers:
S. Ejaz Ahmed (Brock & Windsor, Chair), Abbas Khalili (McGill), David Stephens (McGill), Éric Marchand (Sherbrooke), Peter X. K. Song (Michigan), Ji Zhu (Michigan)

Speakers:
Jeongyoun Ahn (Georgia), Shojaeddin Chenouri (Waterloo), Michael Daniels (Florida), Guoqing Diao (George Mason), Lee Dicker (Rutgers), Kjell Doksum (Wisconsin–Madison), Yingying Fan (Southern California), Yang Feng (Columbia), Xiaoli Gao (Oakland), Yulia Gel (Waterloo), Zhigeng Geng (Wisconsin–Madison), Ali Ghodsi (Waterloo), Md Shakhawat Hossain (Winnipeg), Xiaoming Huo (Georgia Tech), Timothy D. Johnson (Michigan), Frank Konietschke (Göttingen), Shingchang Samuel Kou (Harvard), Hannes Leeb (Wien), Hua Liang (Rochester), Yufeng Liu (UNC—Chapel Hill), Jinchi Lv (Southern California), Shuangge Ma (Yale), Bin Nan (Michigan), Debashis Paul (UC Davis), Benedikt M. Pötscher (Wien), Ruslan Salakhutdinov (Toronto), Ali Shojaie (Washington), Nozer D. Singpurwalla (George Washington), Peter X. Song (Michigan), Lu Tian (Stanford), Joseph S. Verducci (Ohio State), Anand Vidyashankar (George Mason), Peng Wang (Bowling Green State), Yichao Wu (North Carolina State)

Number of participants: 55

This workshop went very smoothly and was a huge success. Besides domestic participants, it attracted many international participants from the USA and some European countries. At the end of the workshop, many participants indicated their interest in taking part in a future workshop of a similar nature, in order to discuss research progress in these areas. This workshop fulfilled the agenda of promoting research activities in the area of high-dimensional data analysis and created a rather focused venue for participants to discuss and exchange research ideas via presentations and informal discussions (following the presentations). The list of speakers at the workshop was really impressive, and most of the talks were based on unpublished and on-going work. There was a significant proportion of Canadian speakers, who had been given this opportunity to develop future collaborations among them and with researchers from other countries. The two keynote lectures were of the highest quality and we now summarize each of them.

The topic of the first keynote lecture (by Samuel Kou) was protein folding. Essentially all the biological functions in our bodies are carried out by proteins. The specific function of a protein is in turn determined by its 3D structure. Since it is quite time-consuming and expensive to conduct laboratory experiments to obtain a protein's 3D structure, it is very desirable to be able to compute the 3D structure of a protein out of its amino acid sequence. This problem, known as protein folding, is a long-standing one in biology, dating back to Anfisen's ground-breaking (Nobel prize) work in the 1950s. The difficulty of protein folding is twofold: first, we do not have a good energy function that can accurately capture the interactions between the different parts of the protein, due to our lack of detailed scientific understanding; second, even with a perfect energy function, it is still extremely difficult to obtain the 3D structure because the energy function has a huge number of local minima, which can easily prevent a search algorithm from finding a global optimum. Efficient algorithms that can explore the vast space of all possible conformations (3D structures) are critical.

In Samuel Kou's lecture, a new Markov Chain Monte Carlo algorithm for exploring the conformation space of a protein, Fragment Regrowth via Energy-guided Sequential Sampling (FRESS), is introduced. The key ingredient of FRESS is to delete a randomly selected fragment of varying length from the current conformation and then regrow the deleted fragment (in each iteration of the algorithm). This regrowth of the fragment is carried out by energy-guided importance sampling so that conformations with lower energies have higher probabilities of being sampled. In particular, the fragment regrowth is done one backbone atom at a time through sequential Monte Carlo. This sequential scheme allows FRESS to avoid being trapped at local minima in the conformation space. To utilize the information from known protein structures, the sequential placement of the backbone atoms is guided by the existing 3D structures in the PDB (protein databank) so that the bond angles and torsion angles frequently appearing in the existing protein structures have a higher probability of being sampled. It is demonstrated in the talk that for about 700 test proteins, the FRESS algorithm is able to fold them into a conformation within 5 RMSD (root mean squared distance) of the true structure (within 5 RMSD is considered a gold standard).

The topic of the second keynote lecture (by Kjell Doksum) was high-dimensional data analysis and biomedical genomics. A highly relevant concern in statistics is how to deal with the high-dimensional data that have become so prevalent in recent experiments and studies. These types of data occur in genomics, astronomy, and finance as well as other fields. Thus it is not unusual that the numbers of variables to be considered are in the hundreds of thousands while the sample size is at most three thousand. The classical statistical techniques are designed for the case where the number of variables is less than the sample size, so new methods are now required. In Kjell Doksum's talk, he discussed a set of approaches based on Principal Component Analysis (PCA). In this approach, when investigating the association between a variable and a response, the other variables are replaced by their first k principal components, where k is at most ten. In this way the dimension is reduced to ten or less. The hope is that the first k principal components capture the relevant information, in the sense that they can be used to remove any confounding effects. Kjell Doksum gave a result showing when this approach provides non spurious tests of association between a variable and a response. He also reviewed methods based on PCA and compared them with a new proposed nonparametric approach. This talk opens many new research problems in a host of applications.

In addition to the keynote lectures, 31 invited talks were presented by influential researchers on various aspects of High-dimensional Data Analysis and were well received by the audience. Most presentations were followed with insightful comments and interesting discussions. A poster session was also organized during a reception in order to showcase the recent work of graduate students. This was also well attended. Participants had active exchanges of ideas and in-depth discussions on current research activities and future research directions.

Colloquium Series

The CRM, together with the Institut des sciences mathématiques (the Québec universities graduate mathematics consortium), runs two Montréal colloquium series, one in mathematics and the other in statistics (the latter jointly with GERAD, an operations research centre located in the André-Aisenstadt building). During the academic year, these series offer survey talks on topics of current interest by distinguished mathematicians and statisticians.

CRM–ISM Mathematics Colloquium

In 2011–2012 the colloquium coordinators were Iosif Polterovich (Montréal) and Jean-Christophe Nave (McGill).

September 9, 2011
Fedor Nazarov (Kent State)
Non-trivial convex bodies with maximal sections of constant volume

September 15, 2011
Joseph Silverman (Brown)
Number theory and dynamical systems: a survey

September 16, 2011
Paul Biran (ETH Zürich)
Symplectic topology in the large — from Morse to Floer and beyond

September 23, 2011
Jayce Getz (McGill)
On Langlands functoriality

September 30, 2011
Jean-Pierre Serre (Collège de France)
Variation with p of the number of solutions mod p *of a system of polynomial equations*

October 21, 2011
Sergey Norin (McGill)
Divisors on graphs

November 4, 2011
Leonid Chekhov (Steklov Inst.)
Teichmüller spaces of Riemann surfaces with holes and algebras of geodesic functions

November 11, 2011
Bun Wong (UC Riverside)
Domains with non-compact automorphism groups

November 18, 2011
Michael Levitin (Reading)
Tricks in spectral theory

November 25, 2011
Alex Furman (UI Chicago)
Groups with good pedigrees, or superrigidity revisited

December 2, 2011
Gerda de Vries (Alberta)
Formation of animal groups: the importance of communication

December 9, 2011
Gilbert Strang (MIT)
Balanced splitting methods / infinite matrices

December 16, 2011
Alan Huckleberry (Bochum)
Disordered bosons: a complex geometric viewpoint

January 13, 2012
Louis-Pierre Arguin (Montréal)
Probability and statistical physics of disordered systems

January 20, 2012
Jason Starr (Stony Brook)
Rational curves and rational points

January 27, 2012
Alex Eskin (Chicago)
Rational billiards and the $\mathrm{SL}(2,\mathbb{R})$ *action on moduli space*

February 3, 2012
Vadim Kaimanovich (Ottawa)
Equivalence relations, random graphs and stochastic homogenization

February 10, 2012
Ludmil Katzarkov (Miami)
On the Shafarevich conjecture

February 17, 2012
Olga Kharlampovich (McGill)
Definable subsets in free and torsion free hyperbolic groups

March 9, 2012
Philip Candelas (Oxford)
Periods of Calabi–Yau manifolds in physics and number theory

March 23, 2012
Steven Johnson (MIT)
On the limits of invisibility

March 30, 2012
Dmitri Burago (Penn State)
Boundary rigidity and minimal surfaces: a survey

April 19, 2012
Vitali Milman (Tel Aviv)
The reasons behind some classical constructions in analysis

April 20, 2012
Mikaël Pichot (McGill)
Discrete groups of intermediate rank

CRM–ISM–GERAD Statistics Colloquium

In 2010–2011 the organizing team of the Statistics Colloquium included Jean-François Angers (Montréal), Mylène Bédard (Montréal), Simon Guillotte (UQAM), Abbas Khalili (McGill), Johanna Nešlehova (McGill), Lea Popovic (Concordia), and Arusharka Sen (Concordia). Note that in most cases, two seminars were scheduled on the same date.

September 9, 2011
Aurelie Labbe (McGill)
An integrated hierarchical Bayesian model for multivariate expression-quantitative trait locus (eQTL) genetic mapping

Edward Susko (Dalhousie)
Properties of Bayesian posteriors and bootstrap support in phylogenetic inference

October 14, 2011
Debbie Dupuis (HEC Montréal)
Modeling non-stationary extremes: the case of heat waves

Richard A. Davis (Colorado State)
Estimating extremal dependence in time series via the extremogram

November 11, 2011
Hélène Guérin (Rennes 1)
An ergodic variant of the telegraph process for a toy model of bacterial chemotaxis

Ana-Maria Staicu (Toronto)
Skewed functional processes and their applications

December 9, 2011
Giles Hooker (Cornell)
Detecting evolution in experimental ecology: diagnostics for missing state variables

January 13, 2012
Yulei He (Harvard)
Bayesian approaches to evidence synthesis in clinical practice guideline development

February 10, 2012
Jochen Blath (TU Berlin)
Longterm properties of the symbiotic branching model

Winfried Stute (Gießen)
Principal component analysis of the Poisson process

March 9, 2012
Mori Jamshidian (CSU Fullerton)
Using tests of homoscedasticity to test missing completely at random

Hugh Chipman (Acadia)
Sequential optimization of a computer model and other "active learning" problems

April 13, 2012
Longhai Li (Saskatchewan)
High-dimensional feature selection using hierarchical Bayesian logistic regression with heavy-tailed priors

Sunil Rao (Miami)
Best predictive estimation for linear mixed models with applications to small area estimation

Multidisciplinary and Industrial Program

The main vehicles for the CRM's efforts in this area are the research networks to which it belongs, principally Mprime, a national network focusing on the mathematics of information technology and complex systems, and the National Institute for Complex Data Structures (NICDS). *The reports are presented in the language in which they were submitted.*

Activities of the Multidisciplinary and Industrial Program

Statistics 2011 Canada
IMST 2011 – FIM XX

July 1–4, 2011, Concordia
Sponsored by Concordia University, the Forum for Interdisciplinary Mathematics, the CRM, the SSC, and Georgia State

Local Organizing Committee (Concordia):
Yogendra P. Chaubey (Chair), Simon Bacon, Satyaveer Chauhan, Patrice Gailliardetz, Jose Garrido, Nikolay Gospodinov, Cody Hyndman, Jochen Jaeger, Tak Mak, Danielle Morin, Fassil Nebebe (Co-chair), Lea Popovic, Arusharka Sen, Debaraj Sen, Mahesh Sharma, Murari Singh, Wei Sun, Robert Weladji
International Advisory Committee:
Bovas Abraham (Waterloo), David Brillinger (UC Berkeley), M. C. Jones (Open), Rob Kass (Carnegie Mellon), Govind S. Mudholkar (Rochester), J. N. K. Rao (Carleton), Nancy Reid (Toronto), Louis-Paul Rivest (Laval), Pranab K. Sen (UNC—Chapel Hill), G. P. H. Styan (McGill), Rob Tibshirani (Stanford)
Plenary Speakers:
Richard Cook (Waterloo), Narsingh Deo (Central Florida), Jean-Marie Dufour (McGill), Christian Genest (McGill), M. C. Jones, Robert Kass, Govind S. Mudholkar, J. Sunil Rao (Miami), Pranab K. Sen

In July 2011 the Department of Mathematics and Statistics of Concordia University, the Department of Decision Sciences & MIS of the same university, and the Forum for Interdisciplinary Mathematics (FIM) hosted a joint conference, "Statistics 2011 Canada: 5th Canadian Conference in Applied Statistics," together with the 20th conference of the Forum for Interdisciplinary Mathematics. The title of the joint conference was "Interdisciplinary Mathematical & Statistical Techniques."

In keeping with the long tradition of decennial conferences since 1971, this conference was dedicated to all areas of mathematical and statistical sciences. In addition to traditional theoretical/applied areas, interdisciplinary research was encouraged and promoted. Historically these meetings have focused on the following areas of scholarship: applied and theoretical statistics, Bayesian statistics, bioinformatics, biostatistics, combinatorics, computer and information sciences, design of experiments, ergodic theory, functional analysis, graph theory, multivariate analysis, number theory, partial differential equations, and topology.

The conference featured contributed and invited paper sessions and poster presentations, along with a special inaugurating lecture to honour Professor T. D. Dwivedi (who has been a driving force behind the previous conferences in this series), sponsored by an endowment from the Dwivedi family and the Faculty of Arts and Science of Concordia University.

The conference was a large-scale one, with 9 plenary talks, 50 invited sessions and 14 contributed sessions. The talks by Richard Cook, Rob Kass, and Christian Genest were among the highlights of the plenary sessions. The invited sessions spanned a wide spectrum of topics, such as data mining, forest fire modelling, cryptography, functional data analysis, mathematical finance, survival analysis, to name only a few. Our report will focus on two invited sessions, one that was organized and chaired by Lajmi Lakhal Chaieb and another that was organized and chaired by Arusharka Sen.

The one organized by Lajmi Lakhal Chaieb and entitled "Recent Advances in Survival Analysis (I34)" featured three speakers: Prof. Adin-Cristian Andrei, Dr. Auguste Gaddah, and Prof. Eleanor Pullenayegum. A.-C. Andrei's talk was entitled "A semiparametric model for recurrent events." In it he presented a regression model for gap-time. Typically gap-times are subject to dependent censoring. The proposed inference methodology was based on Jackknife and illustrated with a real data set on cystic fibrosis where he investigated the effect of covariates on gap-times between repeated pulmonary exacerbations. A. Gaddah's talk was entitled "Random censorship single-index quantile regression model." In it he considered the estimation of the conditional quantile from randomly right-censored survival data. The proposed methodology is based on an iterative algorithm to estimate jointly the link function and the re-

gression parameter. A simulation study and a practical data set analysis concluded this interesting talk. E. Pullenayegum's talk was entitled "Longitudinal data subject to censoring and intermittent measurement." In it she extended Diggle et al.'s analysis of increments to the case of irregular follow-up. The proposed methodology is based on combining binning with weighting, imputation, and multiple imputation.

In the session "Survival Analysis (I50)," organized by Arusharka Sen, there were also three speakers: Prof. Lajmi Lakhal Chaieb, Dr. Yassir Rabhi, and Prof. Winfried Stute, but Dr. Rabhi was absent. L. Lakhal Chaieb's talk was entitled "On the association between failure times in the presence of dependent censoring: A sensitivity study" and he presented a framework for modelling bivariate survival-time data under dependent censoring using copulas. A sensitivity study was carried out on the copula parameter and illustrated with simulated as well as real twin-registry data-sets. W. Stute's talk was entitled "Nonparametric regression for consecutive survival data under truncation and censorship effects" and he constructed a nonparametric regression estimator for times between consecutive events observed on a patient. The problem is complicated because of the truncation of the first and the censoring of the second variable; it requires a modification of both the Lynden-Bell and Kaplan-Meier estimators. Both sessions were reasonably well attended and the speakers drew a lot of questions from the audience.

Fourth Montréal Industrial Problem Solving Workshop

August 15–19, 2011, CRM
Sponsored by CRM and Mprime

Organizers:
Fabian Bastin (Montréal), Eliot Fried (McGill), Michel Gendreau (Polytechnique Montréal), Huaxiong Huang (York), Odile Marcotte (CRM; UQAM), Dominique Orban (Polytechnique Montréal), Sylvain Perron (HEC Montréal), Jean-Marc Rousseau (CIRANO; rcm_2; chair), Louis-Martin Rousseau (Polytechnique Montréal), Luc Vinet (Montréal)

Participating researchers:
Fabian Bastin, C. Sean Bohun (UOIT), Stephen Y. Chen (York), Ellis Cumberbatch (Claremont Graduate), Michel Denault (HEC Montréal), Alistair Fitt (Oxford Brookes), Michel Gendreau, Huaxiong Huang, Claude Le Bris (ÉNPC), Christian Léger (Montréal), Emmanuel Lorin de la Grandmaison (Carleton), Apala Majumdar (Oxford), Odile Marcotte, Beatriz Murrieta Cortes (Tecnologico de Monterrey), Aaron Newman (Dalhousie), Dominique Orban, Jean-François Plante (HEC Montréal), Mason Porter (Oxford), Christopher Prior (Oxford), Mary Pugh (Toronto), Jean-Pierre Raynauld (Montréal), Tim Reis (Oxford), Suzanne Shontz (Penn State), Rex Westbrook (Calgary)

Industrial representatives:
Gilles Boesch and Michel Carreau (Énergies renouvelables, Hatch), Alain Cournoyer (Institut national d'optique), Ozgur Gurtuna (Turquoise Technology Solutions Inc.), Arnaud Lina (Matrox Electronic Systems), Mario L. Morfin Ramírez (York & Acculogic), Vincent Zalzal (Matrox Electronic Systems)

Number of participants: 24 researchers, 7 industrial representatives, and 26 students and postdoctoral fellows

The Fourth Montreal IPSW was attended by 57 participants, who worked on six problems proposed by five companies: Acculogic, Hatch, Institut national d'optique (INO), Matrox Electronic Systems, and Turquoise Technology Solutions Inc. Note that Acculogic is based in Markham (Ontario) and INO in Quebec City. Two of the problems, i.e., those supplied by INO, required the use of tools from what one might call "applied continuous mathematics" (in particular differential equations). These problems dealt with the optimization of the temporal shape of laser pulses and the modelling of CO2 polishing of glass, respectively. The teams working on the INO problems benefited greatly from the expertise of researchers from Oxford, Paris, and Ontario (among others).

Two companies (Acculogic and Matrox Electronic Systems) provided problems related to computer vision. Acculogic manufactures systems for testing Electronic Circuit Boards (ECBs) and those systems must be able to "see" the points where the tests will be carried out. The goal of the team was to propose methods for improving the testing rate of the systems, i.e., minimizing the number of tests that cannot be carried out because the points have not been located properly. Matrox Electronic Systems proposed a very nice mathematical problem arising in computer vision: given a curve in the plane and a number of points (denoted by N), how can one select N points on the curve so that the points are spaced in a regular fashion? This problem appealed to many participants and the team members studied it from different angles.

Finally the workshop included two problems related to renewable energies. The problem supplied by Hatch dealt with the assessment of the uncertainty in the measurement of a wind resource. This problem is of the utmost importance in the field of wind power, since the companies that design wind farms must be able to predict the energy output of such farms. On the other hand, Turquoise Technology Solutions Inc. proposed to study the behaviour of a portfolio of renewable energy investments (especially solar energy investments). This topic is more relevant than ever because if one can show that the output of multiple renewable energy investments is reliable, then the electricity systems operators may agree to integrate renewable energy into existing grids.

As was the case for the first three Montreal IPSWs, the atmosphere at the workshop was friendly and relaxed. The rooms where the teams worked were all located on the first floor of the André-Aisenstadt building, and the wonderful logistical support of the CRM was appreciated by all the participants. The reader may find more details on the workshop web site (http://www.crm.umontreal.ca/probindustriels2011/index_e.shtml).

Workshop on Balance, Boundaries and Mixing in the Climate Problem

September 28–30, 2011, CRM
Sponsored by CRM and Mprime

Organizers:
Peter Bartello (McGill), K. Shafer Smith (NYU), David Straub (McGill)

Speakers:
Rafail V. Abramov (UI Chicago), Farid Ait Chaalal (McGill), Gualtiero Badin (Boston), Erich Becker (Rostock), Alexander Bihlo (Montréal), Eric A. D'Asaro (Washington), Baylor Fox-Kemper (CU-Boulder), Nicolas Grisouard (NYU), Ian Groom (NYU), Igor Kamenkovich (Miami), Patrice Klein (Ifremer), Amala Mahadevan (WHOI), James C. McWilliams (UC Los Angeles), Sonajit Mukherjee (UMass Dartmouth), Balasubramanya T. Nadiga (Los Alamos Natl. Lab.), Keith Ngan (Met Office), Sanjiv Ramachandran (UMass Dartmouth), Gjergj Smailekaj (IAMS), Amit Tandon (UMass Dartmouth), Leif Thomas (Stanford), Vladimir Tseitline (ÉNS), Geoffrey K. Vallis (Princeton), Jacques Vanneste (Edinburgh), Jena Vinod (CIET), Jinho Wang (WHOI), Stephanie Waterman (Imperial Coll.)

Number of participants: 44

In recent years there has been a shift of emphasis in research on balanced dynamics. Whereas early research was strongly motivated by NWP and focused on the construction and analysis of balanced models, following the important work of Lorenz, Warn, Ford, Vanneste, and others, the concept of a "fuzzy slow manifold" has become widely accepted; thus research has been more concerned with imbalance (generation and interactions with the balanced flow) rather than balance per se. This is especially the case in oceanography, where there is still uncertainty concerning the closing of the energy budget.

This meeting primarily dealt with the modelling of submesoscale oceanographic flows, where Rossby and Froude numbers are O(1) and lengthscales of O(1 km). Here, by contrast with the (mesoscale) eddy-permitting models that are customarily used in GCMs, small-scale eddies and gravity-wave generation are ubiquitous; simulations are typically done in domains with dimensions of O(100 km) and grid spacings of O(25 m). Talks discussed modelling strategies, instability mechanisms (inertial instability in particular), geostrophic turbulence phenomenology, and applications. The breakdown of balance received most attention, but there were a few talks on balanced small-scale phenomena in the vicinity of boundaries, i.e., surface quasi-geostrophic-like dynamics. Mixing was discussed specifically in only a few presentations, but it was implicit in most of the oceanographic talks: by contrast with atmospheric scientists, who tend to view gravity waves as a means for transporting (pseudo)momentum, oceanographers are interested in gravity waves on account of their (diapycnal) mixing properties.

Although this was not the intention of the organizers, there was very little representation from atmospheric scientists (just 2 presentations). This probably reflects a cultural difference: NWP, which is strongly synoptic-scale-centric, has been hugely influential in the development of dynamical meteorology. The oceanographical talks were eye-opening for many participants, inasmuch as they started from different premises, ones that are closer to the modern view of geophysical fluid dynamics. Jim McWilliams' joke about meteorologists and their concern with balanced dynamics went down very well with the audience; nonetheless, it would have been nice if there had been some representation of work from the perspective of large-scale balanced dy-

namics. Below we summarize the most interesting presentations.

V. Zeitlin talked about inertial instability in 2-layer rotating shallow water. In the first part of the talk he reviewed the classical linear stabilitiy criterion and reminded the audience that inertial instability is often called symmetric instability in the case of the along-front $k = 0$ modes. The numerical simulations, for a barotropic Bickley jet with different densities in the two layers, were designed to elucidate the connection between inertial instability and baroclinic instability. For small Ro, the linear analysis is recovered and the barotropic mode is the most unstable mode; for large Ro, the most unstable mode becomes baroclinic. Moreover, the baroclinic instability for $k = 0$ can be identified with the symmetric inertial instability.

J. McWilliams discussed a number of theoretical ideas in the context of the California undercurrent, a separating boundary current. The generation of unbalanced motion represents one way in which the energy budget of the ocean may be closed and the tendency for (barotropic) energy to be cascaded to large scales via geostrophic turbulence counteracted. Numerical simulations showed generation of mesoscale and submesoscale eddies where the undercurrent separated from the shore due to the bottom topography.

P. Klein reviewed recent work on the impact of submesoscales on larger oceanic scales. Observations suggest that eddies are ubiquitous on submescoscales, but until recently they were assumed to have no effect on larger scales. Following work on surface quasigeostrophy, the talk focused on the impact of surface dynamics on submesoscale eddies at depth. Generally SQG works well, suggesting that the ageostrophic motion is weak, departures being related to the presence of ageostrophic instability and spontaneous gravity-wave emission. The quantification of the imbalance caught the participants' attention: it is estimated that the energy in internal gravity waves is 5 orders of magnitude smaller than that in balanced modes. At the surface small-scale ageostrophic motion can lead to departures from SQG, i.e., to vortex asymmetry and modification of the eddy forcing.

E. Becker gave a very interesting talk on numerical simulations of the atmospheric energy spectrum in a mechanistic model in which heating rates are prescribed. The numerical simulations were carried out at T330 in the horizontal with two vertical grids, L100 (with approximately 250 m grid spacing in the middle atmosphere) and L30 (with dz $\sim$ 1km). A -5/3 mesoscale spectrum could be obtained only in a few special cases: unphysical hyperdiffusion, anisotropic subgrid (Smagorinsky) model, and the finer vertical grid. A detailed analysis of the spectral fluxes in the upper troposphere indicated that fluxes due to horizontal advection and adiabatic convergence are comparable, which is consistent with Lindborg's work on stratified turbulence. Although the tuning of the Smagorinsky scheme seemed a little contrived, the sensitivity of the mesoscale dynamics to physical parameterization would seem to hold more generally.

J. Vanneste spoke mostly about gravity-wave generation in shear flows. The first half of his talk was a review of work on the breakdown of balance and exponential asymptotics. The second half dealt mostly with a specific problem, a 2-d SQG-like model that has been modified to account for the exponentially-small radiation of gravity waves. An important point was that the solution for the stream function, which is obtained by matching to the far field, must contain an exponentially increasing component as well as an exponentially decaying one. In previous work on SQG this has not always been done.

B. Nadiga gave a very interesting talk on energy fluxes in geostrophic turbulence. The starting point was recent work by Scott and Wang claiming, in contrast to the well-known picture due to Salmon, that there is an inverse cascade of baroclinic energy. This was investigated using the Princeton Ocean Model and LES-type diagnostics, yielding energy fluxes across scales. The main message was that the situation is more complicated than Scott and Wang implied. While Salmon's picture generally holds, an inverse baroclinic cascade can be induced by basin geometry (the so-called beta-flux) and topographic interactions.

I. Grooms spoke about weakly stratified rotating turbulence. Although the title is suggestive of rotation-dominated, large-scale PG or SG dynamics, he only considered the wave modes defined by normal modes. The claim, which is completely standard, is that these fast modes, which are obtained from a linear stability analysis (strictly valid only for Rossby and Froude numbers going to 0), include a balanced component. He demonstrated this by looking at various linear measures of imbalance, e.g., the mismatch between the Coriolis, buoyancy, and pressure-gradient terms, for

Boussinesq as well as limit equations for rotating convection.

L. Thomas discussed the relevance of symmetric instability as a possible mechanism for the transfer of energy from balanced to unbalanced modes. In particular, he analyzed a simple model including stratification and strain. Most of us were surprised at the attention devoted to symmetric instability and imbalance; there wasn't much interest in the subject several years ago. Recent observations, however, indicate that this mechanism may be relevant to the ocean. E. d'Asaro showed Lagrangian-float observations of shallow fronts. The main result was that there is evidence of symmetric instability where there is negative PV and, furthermore, that models do not exhibit glaring inconsistencies with this.

G. Vallis gave two talks for the price of one. In the first half, he examined the contribution of realistic bottom topography to the kinetic energy budget, more specifically, to avoiding inertial runaway; the tentative conclusion is that the resulting unbalanced flow may be small. In the second half, he examined an idealized model of the meridional overturning circulation and compared it to GCM simulations. Finally A. Bihlo presented a poster on invariant parameterization schemes. The idea was to use Lie-group methods, in particular the differential invariants, to derive parameterization schemes that respect the continuous symmetries; it was illustrated with an application to the barotropic vorticity equation.

CRM Prizes

The CRM created and administers, either alone or jointly, four of the eight major national prizes in the mathematical sciences, namely: the CRM–Fields–PIMS Prize, the Prize for Theoretical Physics awarded in collaboration with the Canadian Association of Physicists (CAP), the Prize for young researchers in Statistics awarded jointly with the Statistical Society of Canada (SSC), and the CRM André-Aisenstadt Prize awarded to rising young Canadian stars, selected by the International Scientific Advisory Committee of the CRM. The CRM has invested enormously in time, effort, and its own resources in order to propel leading Canadian scientists into the spotlight, giving them international recognition when they most need it.

CRM–Fields–PIMS Prize 2012 Awarded to Stevo Todorcevic

Professor Todorcevic obtained his Ph.D. in 1979 in Belgrade and currently holds a Canada Research Chair at the University of Toronto. His contributions to set theory made him a world leader in this topic with a particular impact on combinatorial set theory and its connections with topology and analysis.

Stevo Todorcevic

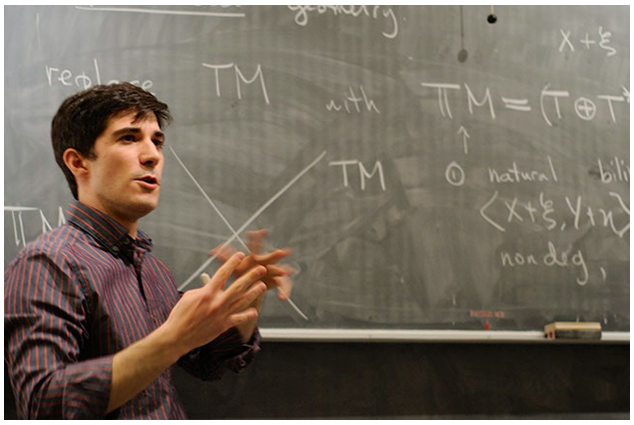
His work is recognized for its striking originality and technical brilliance. He was an invited speaker at the 1998 ICM in Berlin for his work on ρ- functions. He made major contributions to the study of S- and L-spaces in topology, proved a remarkable classification theorem for transitive relations on the first uncountable ordinal, and made a deep study of compact subsets of the Baire class 1 functions, thus continuing work of Bourgain, Fremlin, Talagrand, and others in Banach space theory. Together with P. Larson he completed the solution of Katetov's old compact spaces metrization problem. Among the most striking recent accomplishments of Todorcevic (and co-authors) are major contributions to the von Neumann and Maharam problems on Boolean algebras, the theory of non-separable Banach spaces, including the solution of an old problem of Davis and Johnson, the solution of a long-standing problem of Laver, and the development of a duality theory relating finite Ramsey theory and topological dynamics. For a detailed description of Dr. Todorcevic's scientific contributions, we refer the reader to the article by Claude Laflamme (Calgary) in the Spring 2012 issue of Le Bulletin du CRM.

The CRM–Fields–PIMS Prize

This prize was established in 1994 as the CRM–Fields Prize to recognize exceptional research in the mathematical sciences. In 2005 PIMS became an equal partner in the awarding of the prize and its name was changed to the CRM–Fields–PIMS Prize. A committee appointed by the three institutes chooses the recipient. The previous recipients of the prize are H. S. M. (Donald) Coxeter (1995), George A. Elliott (1996), James Arthur (1997), Robert V. Moody (1998), Stephen A. Cook (1999), Israel Michael Sigal (2000), William T. Tutte (2001), John B. Friedlander (2002), John McKay (2003), Edwin Perkins (2003), Donald A. Dawson (2004), David Boyd (2005), Nicole Tomczak-Jaegermann (2006), Joel S. Feldman (2007), Allan Borodin (2008), Martin Barlow (2009), Gordon Slade (2010), Marc Lewis (2011).

André-Aisenstadt Prize 2012 Awarded to Marco Gualtieri and Young-Heon Kim

In 2012 the André-Aisenstadt Prize was jointly awarded to Marco Gualtieri and Young-Heon Kim.



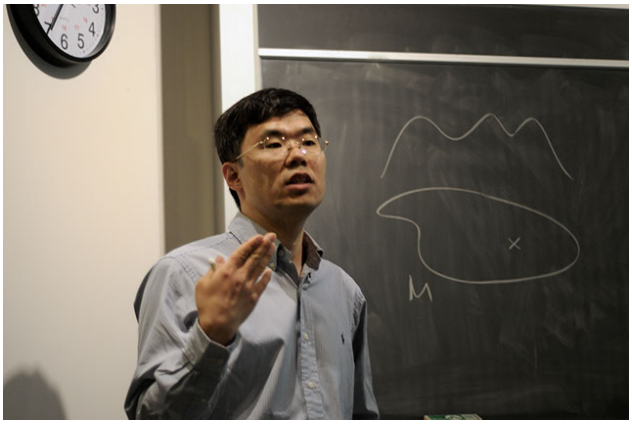
Marco Gualtieri

Dr. Gualtieri obtained a bachelor's degree in science at McGill University in 1999 and his Ph.D. from Oxford University in 2004 under the supervision of Nigel J. Hitchin. He was awarded the Lichnerowicz Prize in Poisson geometry in 2010 and joined the University of Toronto in 2008. Prior to that appointment Professor Gualtieri had held postdoctoral positions at MSRI (Berkeley), the Fields Institute (Toronto), and MIT. His area of research is differential geometry and he has made essential contributions to the development of generalized complex geometry, an active area of research at the interface of complex geometry and symplectic geometry.

More specifically, Marco Gualtieri's research focuses on the geometry of generalized complex structures, a fairly recent and active area of mathematics pioneered by Nigel Hitchin in the 2000s, which provides a novel and unified approach to symplectic and complex geometry. Applications to mathematical physics (string theory and mirror symmetry) and noncommutative geometry are at the forefront of current developments in this vibrant domain.

In this vein, Marco Gualtieri's Ph.D. thesis provides the first systematic study of generalized complex geometry, and introduces a number of new notions of fundamental importance, such as the Kuranishi theory for generalized complex structures and the generalized Kähler geometry. His foundational work has been the source of inspiration for many related studies. Currently, Google Scholar lists 535 citations to this work and one part of it has recently appeared in the *Annals of Mathematics*. More recently Marco Gualtieri has studied D-branes in generalized complex manifolds and their relation to noncommutative geometry, as well as further generalizations of classical geometries. At the age of 32, he was awarded the prestigious André Lichnerowicz Prize (shared with Xiang Tang) at the IMPA in Rio de Janeiro. He also won an Early Research Award of the Ontario Government for the period 2010–2015.

Dr. Young-Heon Kim obtained his bachelor's degree in mathematics at the Pohang University of Science and Technology and a Master's degree at the Korea Advanced Institute of Science and Technology in South Korea. In 2005 he was awarded a Ph.D. from Northwestern University (under the supervision of Ezra Getzler). He joined the mathematics department of the University of British Columbia in 2008. His specialty is in analysis and his most important contributions concern the fast developing topic of optimal transportation. Dr. Kim received a Sloan Fellowship in 2012. For a detailed description of Dr. Kim's scientific contributions, we refer the reader to the article by Robert McCann (Toronto) in the Spring 2012 issue of *Le Bulletin du CRM*.



Young-Heon Kim

The André-Aisenstadt Prize

Created in 1991, the André-Aisenstadt Mathematics Prize is intended to recognize and reward research achievements in pure and applied mathematics by talented young Canadian mathematicians. This prize consists of a $3,000 award and a medal. The recipient is chosen by the International Scientific Advisory Committee of the CRM. At the time of consideration, can-

didates must be Canadian citizens or permanent residents of Canada, and no more than seven years from their Ph.D.

The previous recipients of the André-Aisenstadt Prize are Niky Kamran (1992), Ian Putnam (1993), Michael Ward (1995), Nigel Higson (1995), Adrian S. Lewis (1996), Lisa Jeffrey (1997), Henri Darmon (1997), Boris Khesin (1998), John Toth (1999), Changfeng Gui (2000), Eckhard Meinrenken (2001), Jinyi Chen (2002), Alexander Brudnyi (2003), Vinayak Vatsal (2004), Ravi Vakil (2005), Iosif Polterovich (2006), Tai-Peng Tsai (2006), Alexander E. Holroyd (2007), Gregory G. Smith (2007), József Solymosi (2008), Jonathan Taylor (2008), Valentin Blomer (2009), Omer Angel (2010), Joel Kamnitzer (2011).

The CAP–CRM Prize 2012 Awarded to Luc Vinet

The 2012 CAP–CRM Prize in Theoretical and Mathematical Physics was awarded to Luc Vinet, Université de Montréal, for his outstanding and continued contributions to mathematical physics, mainly based on the study of symmetries, algebraic structures, and special functions.

Luc Vinet

Luc Vinet is one of Canada's leading mathematical and theoretical physicists, who has made outstanding contributions in numerous areas. The unifying feature of his research is the innovative use of group-theoretical and algebraic methods, the emphasis on exact solutions of physical problems, and the originality of his approach. He has made important contributions that have had great impact on both physics and mathematics. His early remarkable work was on gauge field theories, in particular on exact invariant solutions of Yang-Mills equations in Minkowski space. Also early in his career he identified the symmetries and supersymmetries of magnetic monopole systems. He explored various algebraic structures that can be used to describe symmetries in different physical problems. These go well beyond standard Lie groups and algebras. They include polynomial, quantum, and super- and para-super-algebras. He is very well known for his influential work on quantum many-body problems and for his application of this work to a proof of the long-standing Macdonald conjecture on properties of multivariate orthogonal polynomials. His contributions to the symmetry theory of difference and q-difference equations are truly pioneering.

Remarkably, Vinet's scientific career was not interrupted by his heavy administrative duties as director of the Centre de recherches mathématiques, then provost of McGill University, and finally rector of the Université de Montréal. He continued to publish highly innovative work during his administrative tenure and is now going through a new burst of creativity. Quite recently, in 2011, he has discovered new families of orthogonal polynomials, associated with reflections. These have already found many applications. In the context of quantum information theory, he has shown how spin chains can be used to design perfect quantum wires. Dr. Vinet gave a prize lecture entitled *Fils quantiques, polynômes orthogonaux et approximation diophantienne* at the CRM on October 5, 2012.

The CAP–CRM Prize

The Centre de recherches mathématiques (CRM) and the Canadian Association of Physicists (CAP) created in 1995, on the occasion of the 50th anniversary of the CAP, a joint prize for recognizing exceptional achievements in theoretical and mathematical physics. The prize consists of a $2,000 award and a medal.

The previous recipients of the prize are Werner Israel (1995), William G. Unruh (1996), Ian Affleck (1997), J. Richard Bond (1998), David J. Rowe (1999), Gordon W. Semenoff (2000), André-Marie Tremblay (2001), Pavel Winternitz (2002), Matthew Choptuik (2003), Jiří Patera (2004), Robert Myers (2005), John Harnad (2006), Joel S. Feldman (2007), Richard Cleve (2008), Hong Guo (2009), Clifford Burgess (2010), Robert Brandenberger (2011).

The CRM–SSC Prize 2012 Awarded to Changbao Wu

Changbao Wu

Professor Changbao Wu, from the Department of Statistics and Actuarial Science at the University of Waterloo, is the 2012 winner of the CRM–SSC Prize. This prize highlights Professor Wu's outstanding contributions to survey sampling and his exceptional mentoring of graduate students. Professor Wu also distinguished himself with extended service to his institution, the SSC, and several scholarly journals. The author or co-author of over 30 scientific articles, Wu has carried out fundamental work on calibration methods; in particular, he showed how to construct optimal estimators of various finite-population parameters by exploiting auxiliary information efficiently through a model-calibration approach. The general framework he developed for model-assisted calibration methods stimulated much research. More recently, Wu has focused his interest on empirical likelihood methods for survey data. He is one of the leading developers of pseudo-empirical likelihood techniques and the efficient computational algorithms he developed in this context are widely used.

Throughout the years, Changbao Wu also seized many opportunities to get his hands dirty with data. For example, he gained first-hand experience with fishery abundance survey design and analysis. He also played a key role in the Chinese leg of the International Tobacco Control Policy Evaluation Project. In recognition of his leadership role in survey sampling, he was invited to serve as Associate Editor for *Biometrika*, the *Journal of Nonparametric Statistics*, *Survey Methodology*, *The Australian and New Zealand Journal of Statistics*, and of course *The Canadian Journal of Statistics*. Advisor or co-advisor of three Ph.D. students and more than 10 M.Math. students at the University of Waterloo, Wu is also appreciated for his community contributions. He served on numerous committees at his institution and within the SSC; among others, he was President of the Survey Methods Section in 2005 –2006.

Born in 1963, Wu was raised in a small village in the Chinese province of Anhui. After the Cultural Revolution, he was able to study mathematics at Anhui Laodong University. He graduated in 1982 and was hired as a faculty member at the Anhui Institute of Education, a training centre for high school teachers; the institution later became Hefei Normal University. At the beginning of his career, Wu was younger than most of his students. He was recognized as an energetic and passionate teacher and completed an M.Sc. diploma in Mathematical Statistics at East China Normal University in 1986. Nine years later, he left his job to pursue doctoral studies in statistics in Canada. He completed his Ph.D. at Simon Fraser University in 1999. His thesis, entitled "The effective use of complete auxiliary information from survey data," was written under the supervision of the late Randy Sitter. Since 1999, he has held a position at the University of Waterloo, where he is now a Full Professor.

The CRM–SSC Prize

The SSC, founded in 1977, is dedicated to the promotion of excellence in statistical research and practice. The prestigious CRM–SSC Prize, jointly sponsored by the SSC and the CRM, is given each year to a Canadian statistician in recognition of outstanding contributions to the discipline during the recipient's first 15 years after earning a doctorate.

Changbao Wu is the fourteenth recipient of the CRM–SSC Prize. The previous winners of the award are Christian Genest (1999), Robert J. Tibshirani (2000), Colleen D. Cutler (2001), Larry A. Wasserman (2002), Charmaine B. Dean (2003), Randy Sitter (2004), Jiahua Chen (2005), Jeffrey Rosenthal (2006), Richard Cook (2007), Paul Gustafson (2008), Hugh Chipman (2009), Grace Y. Yi (2010), Edward Susko (2011).

The CRM Outreach Program

The CRM is eager to fulfill the public's desire for understanding the latest developments in the mathematical sciences. To this end, the CRM initiated in the spring of 2006 a series of lectures called the *Grandes Conférences du CRM*, which feature outstanding lecturers able to convey the beauty and power of mathematical research to a wide audience. The *Grandes Conférences du CRM* are now well established and there were three lectures geared towards a general audience in 2011–2012: a lecture by Professor Gerda de Vries on December 1st, 2011, a lecture by Professor Moshe Y. Vardi on February 16, 2012, and a lecture by Professor Daniel Pauly on May 11, 2012. The three lectures took place at the Université de Montréal. The reader will find summaries of these lectures below. Each Grande Conférence attracted hundreds of people of all ages, and was followed by a "vin d'honneur" that enabled the participants to ask questions, reconnect with friends and colleagues, and meet people interested in mathematics and science in general.

In 2011–2012 the *Grandes Conférences* program was under the stewardship of Christiane Rousseau and Yvan Saint-Aubin, professors at the Département de mathématiques et de statistique of the Université de Montréal.

The language of life: When mathematics speaks to biology
Gerda de Vries (University of Alberta)
by Michael C. Mackey (McGill University)

Last December 1, Montréal mathematicians were given the chance to hear Professor Gerda de Vries of the University of Alberta (http://www.math.ualberta.ca/~devries/) speak on "The language of life: When mathematics speaks to biology." A member of the Alberta Centre for Mathematical Biology (http://www.math.ualberta.ca/~mathbio/), Professor de Vries, President of the Society for Mathematical Biology and an acclaimed teacher, researcher, and lecturer led all of us on a breath-taking tour of just a few of the fascinating areas currently occupying the attention of biomathematicians.


Gerda de Vries

The starting point for the talk was a reminder that mathematical biology is not a new discipline in mathematics, but rather has a long and rich history. She noted that Leonhard Euler was led, in part, to his study of incompressible fluid flow by his interest in blood flow in arteries, and that Daniel Bernoulli had major interests in promoting vaccination for smallpox based on his analysis of morbidity and mortality data using mathematical models. Using the example of Bernoulli as a spring-board, she then moved into recent considerations about the spread of the avian flu virus, SARS, the H1N1 virus, and the West Nile virus, showing how simple considerations derived from epidemiological models allow public health policy makers to decide between various strategies.

From there she turned to a discussion of the formation of patterns in biology (think zebra stripes and giraffe spots) using the framework of Alan Turing's seminal paper of 1952 to explain simply how reaction-diffusion systems can generate spatio-temporal patterns. These problems are, of course, areas of active research in many centres around the world even today, in fields as diverse as the formation of patterns in embryogenesis and the formation of spatial structures in animal populations. These same questions also occur in the context of the formation of animal group patterns, i.e., in the swarming behaviour of fish and insects.

In the hour that Professor de Vries had she could hardly scratch the surface of what modern mathematical biology is all about. Currently, any area of biology that one cares to name (ranging from molecular biology through organ physiology to clinical medicine and ecological situations) has an active and vibrant component of mathematicians working hand in hand with experimentalists to make more sense of the data collected either in the laboratory, the clinic, or the field, and to offer hypotheses that can be tested and are based on realistic mathematical models of the phenomena of interest. When I first started out as a young researcher in this field 40 plus years ago, reading a few journals and going to the bi-annual Gordon Conference on Theoretical Biology sufficed to keep one up-to-date with what was happening. Nowadays there are literally scores

of journals devoted to various aspects of mathematical biology, a large number of conferences, and summer/winter schools that one can attend to be brought up to speed.

As is the case with many mathematicians, Professor de Vries is a multidimensional person with wide ranging interests not only in mathematics and biology but also in the fine arts. She is an accomplished quilter (see http://www.telusplanet.net/public/gdevries/) and gives wonderful lectures on the mathematics in her quilts that are just as fascinating as her "Grande Conférence" lecture.

From Aristotle to the Pentium
Moshe Y. Vardi (Rice University)

by Benoit Larose (Concordia University and Champlain College)

Moshe Y. Vardi

On February 16, 2012, the CRM had the privilege of hosting the lecture of Professor Moshe Y. Vardi of Rice University entitled "From Aristotle to the Pentium." Moshe Y. Vardi is the George Professor in Computational Engineering and Director of the Ken Kennedy Institute for Information Technology at Rice University. He chaired the Computer Science Department at Rice University from January 1994 till June 2002. Prior to joining Rice in 1993, he was at the IBM Almaden Research Center, where he managed the Mathematics and Related Computer Science Department. His research interests include database systems, computational-complexity theory, multi-agent systems, and design specification and verification. Vardi received his Ph.D. from the Hebrew University of Jerusalem in 1981. He is the author and co-author of about 400 articles, two books, and is the editor of several collections.

Vardi is the recipient of numerous awards, including three IBM Outstanding Innovation Awards, the 2000 Gödel Prize, the 2005 ACM Kanellakis Award for Theory and Practice, the 2006 LICS Test-of-Time Award, the 2008 ACM PODS Mendelzon Test-of-Time Award, the 2008 ACM SIGMOD Codd Innovations Award, the 2008 Blaise Pascal Medal for Computer Science by the European Academy of Sciences, the 2008 ACM Presidential Award, the 2010 CRA Distinguished Service Award, the 2010 ACM Outstanding Contribution Award, and the 2011 IEEE Computer Society Harry H. Goode Award. He holds honorary doctorates from the Universität des Saarlandes, Germany, and the Université d'Orléans, France. Vardi is an editor of several international journals, and Editor-in-Chief of the Communications of the ACM. He is a Guggenheim Fellow, as well as a Fellow of the ACM, the American Association for the Advancement of Science, the Association for the Advancement of Artificial Intelligence, and the IEEE. He was elected a member of the US National Academy of Engineering, the American Academy of Arts and Science, the European Academy of Sciences, and the Academia Europaea.

M. Vardi's lecture consisted of a broadly accessible historical outline of the connection between formal logic and computer science. We were treated to a bird's eye view of the last 2500 years, from Epimenides' Liar's Paradox to the Pentium chip, interleaved with amusing and insightful quotes from such logicians as Aristotle and Lewis Carroll. Using Leibniz's unfulfilled dream of mechanizing reasoning as a recurring theme, Professor Vardi took us through a humorous and fascinating tour of the history of formal logic, visiting such characters as Ramon Llull, George Boole and Charles Peirce. We eventually returned to Euclid, whose great text has been in use for over 2000 years, in a discussion of what Wigner referred to as mathematics' unreasonable effectiveness, the notion of mathematical proof, and the consequences of the attempt by mathematicians of the late 19th and early 20th century to clarify this concept. This thread was followed, from Frege's introduction of first-order logic, via the discovery of Russell's paradox and Russell and Whitehead's *Principia Mathematica*, to the fall, at the hands of Gödel, Church, and Turing, of Hilbert's program to consolidate the foundations of mathematics. Professor Vardi argued that it is precisely out of this quest that computer science was born; by the early 50s, computers were being built around the world, based on von Neumann's ideas, thus fulfilling

Leibniz's dream: "from reasoning, to patterns of reasoning, to logic, to computers, to computers that reason." M. Vardi closed the lecture with a moving quote from C. Papadimitriou on the sad fate of so many logicians such as Boole, Cantor, Frege, Gödel, and Turing, and a remarkably prescient quote from Leibniz on the advent of the modern computer.

The talk was a hit with the audience, and in fact members of the public were overheard saying that Moshe Vardi's lecture was the best of the "Grande Conférences" series. The lecture was followed by a reception in the hall of the Jean-Coutu building, where the participants had the opportunity to exchange ideas with the speaker.

Major trends in world fisheries and their effects on ecosystems
Daniel Pauly (University of British Columbia)

Daniel Pauly

Since the end of the second World War, the spread of industrial fisheries has led to increases in catches and also successive crashes, which began to affect global catches in the 1970s, and intensified in the 1980s and 1990s. In response, the industrialized countries of the Northern Hemisphere redeployed their fishing effort in the waters of developing countries, and beyond into the Southern Hemisphere, all the way to Antarctica. This geographic expansion has now been completed and global catches, which peaked in the late 1980s, are now declining, while the damage to marine ecosystems and biodiversity continues to increase and the effects of global warming are starting to be felt in numerous fisheries. Daniel Pauly's lecture, delivered in French, illustrated these trends, discussed their implications, and proposed some remedies.

Daniel Pauly was born in France and completed his Ph.D. in the biology of fisheries at the University of Kiel (Germany) in 1979. After spending many years at the International Center for Living Aquatic Resources Management in Manila (Philippines), he became a professor at the UBC Fisheries Centre, of which he was the director from 2003 to 2008. He is a Fellow of the Royal Society of Canada and has been awarded many prizes, including the Award of Excellence of the American Fisheries Society in 2004, the International Cosmos Prize in 2005, the Excellence in Ecology Prize in 2007, and the Ramon Margalef Prize in Ecology in 2008. Four universities have awarded Daniel Pauly an honorary doctorate, including the Université de Montréal (in 2007).

CRM Partnerships

The CRM is strongly committed to its national mission and takes measures to ensure that as many Canadian scientists as possible benefit from its activities and become involved in their planning. For instance, it appoints to its International Scientific Advisory Committee eminent Canadian scientists from various parts of the country; it is present in all important forums where the future directions of the Canadian mathematical sciences are discussed; it urges its organizers to ensure that Canadian specialists are included in their activities; it organizes and supports scientific events across the country; it collaborates with Canadian institutes, societies, and associations. A specific budget is set aside each year for the participation of Canadian graduate students in its programs. The CRM is the only national institute that operates in the two official languages of Canada and it is highly visible on the international scene. In keeping with its national role, it coordinates its activities with the Fields Institute for Research in Mathematical Sciences, the Pacific Institute for the Mathematical Sciences (PIMS), the Mprime Network, the Canadian Mathematical Society (CMS), the Canadian Applied and Industrial Mathematics Society (CAIMS), the Statistical Society of Canada (SSC), the Canadian Association of Physicists (CAP), as well as other societies and institutes abroad.

CRM Partners

The Fields Institute for Research in Mathematical Sciences and the Pacific Institute for the Mathematical Sciences

Since the early 1990s two other research institutes have joined the CRM on the Canadian scene: Toronto's Fields Institute for Research in Mathematical Sciences and the Pacific Institute for the Mathematical Sciences (PIMS). As well as coordinating their scientific activities, the three institutes have worked closely on a variety of initiatives, the most important of which is the Mprime Network. The three institutes are also involved in other initiatives, such as the CRM–Fields–PIMS Prize awarded in recognition of outstanding accomplishments in the mathematical sciences in Canada. It was created in 1994 as the CRM–Fields Prize and became the CRM–Fields–PIMS Prize in 2006. The administrative responsibility for this prize rotates between the three institutes.

National and International Collaborations

The CRM collaborates with research centres in the Montréal area, especially the Groupe d'études et de recherche en analyse des décisions (GERAD). The CRM, the ISM, and GERAD jointly organize a weekly statistics colloquium (see the section General Program). The CRM is a partner of the Banff International Research Station (BIRS).

The researchers belonging to the CRM or a CRM laboratory enjoy close collaborations with French colleagues, in particular CNRS and INRIA researchers. In July 2011 some CRM members and researchers from the Université de Cergy-Pontoise organized the Summer School on Non-equilibrium Statistical Mechanics (see the section General Program). Also in 2011 an Unité Mixte Internationale (UMI) of the CNRS was established at the CRM. There are only 30 UMIs (in all subjects) around the world. Laurent Habsieger (CNRS) and the CRM director are the codirectors of the UMI. The UMI supports visits of French mathematicians to members of the CRM and vice versa. In 2012 the French researchers Claude-Alain Pillet and Pierre Ille visited the UMI located at the CRM. Louigi Addario-Berry, a professor at McGill and a member of the UMI, visited some French colleagues in 2012. For more information we refer the reader to www.crm.umontreal.ca/UMI/.

The CRM has signed agreements with the European Union. For instance, in 2006 the CRM and the ISM signed an agreement with the ALGANT consortium (where ALGANT stands for Algebra, Geometry, Number Theory) to further the exchange of graduate students. In 2010 the CRM was one of the 12 partners to sign an agreement with SISSA (an Italian centre) to promote exchanges of visiting researchers specializing in mathematical physics. SISSA (International School for Advanced Studies, in English) is based in Trieste and is a university dedicated to the training of graduate students.

The CRM has signed two agreements with the Tata Institute of Fundamental Research (TIFR), a prestigious research centre in India. The scope of the first agreement was applied mathematics and it was signed in 2006 between the CRM and the TIFR Centre for Applicable Mathematics in Bangalore. The scope of the second agreement was pure mathematics and was signed in 2011 between the CRM and the Mumbai TIFR.

In its publishing activities, the CRM is continuing its partnership with the American Mathematical Society (AMS), in particular through its two series of joint publications, the CRM Monograph Series and the CRM Proceedings & Lecture Notes. A CRM Series in Mathematical Physics is published by Springer. The CRM has exchange agreements with the Fields Institute, PIMS, MSRI, the Institute for Mathematics and its Applications (University of Minnesota), École normale supérieure (France), the Isaac Newton Institute, the Institut des Hautes Études Scientifiques (France), and BIRS.

Associations and Professional Societies

The CRM maintains close ties with the different professional societies in the mathematical sciences: CMS, CAIMS, SSC, and CAP . The president of the CMS is an ex-officio member of the CRM International Scientific Advisory Committee. The CRM has also supported financially certain initiatives of the CMS, such as the mathematical camps. Together with the other institutes, the CRM organizes or sponsors special sessions at the CMS, CAIMS, and SSC meetings. The CRM awards a prize each year jointly with the SSC; similarly, it awards a prize each year with the CAP in mathematical and theoretical physics.

The Mprime Network

The Mprime Network (www.mprime.ca) is the only Network of Centres of Excellence for the mathematical sciences, bringing together academia, industry, and the public sector to develop cutting-edge mathematical tools vital to our knowledge-based economy. Known as Mitacs (Mathematics of Information Technology and Complex Systems) from 1999 to 2011, it is a pan-Canadian network whose creation was proposed by the three Canadian mathematical sciences institutes (the CRM, the Fields Institute for Research in Mathematical Sciences, and PIMS). The organization now called Mitacs is not focused solely on mathematics but on the development of the next generation of innovators with vital scientific and business skills (see www.mitacs.ca).

The purpose of the Mitacs and then Mprime Networks was to lead Canada's effort in the generation, application, and commercialization of new mathematical tools and methodologies within a world-class research program. In order to do so, Mprime initiated and fostered linkages with industrial, governmental, and not-for-profit organizations. Mprime research focuses on five key sectors of the economy: biomedical and health sector; environment and natural resources; information processing; risk and finance; and communication, networks, and security.

Mprime also extends financial support to some events organized by the CRM and other institutions. For instance, in 2011–2012, Mprime was the principal source of support for the Fourth Montreal Industrial Problem Solving Workshop (see the section on the CRM multidisciplinary and industrial program).

Atlantic Association for Research in the Mathematical Sciences (AARMS)

AARMS was founded in March 1996 at a time when the National Network for Research in the Mathematical Sciences was being discussed and planned. AARMS exists to encourage and advance research in all mathematical sciences (including statistics and computer science) in the Atlantic region. In addition AARMS acts as a regional voice in discussions of the mathematical sciences on a national level. Since its inception, AARMS has played an important role in the research activities in the Atlantic region, sponsoring or co-sponsoring numerous meetings and workshops. In the summer of 2002, AARMS initiated an annual Summer School for graduate students and promising undergraduates. AARMS is grateful to Canada's three mathematical institutes (the CRM, the Fields Institute for Research in Mathematical Sciences, and PIMS), as well as to the member universities, for providing funding for its activities. Its member universities are Acadia University, Cape Breton University, Dalhousie University, Memorial University of Newfoundland, Mount Allison University, St. Francis Xavier University, Saint Mary's University, the Université de Moncton, the University of New Brunswick, and the University of Prince Edward Island. Finally AARMS receives some financial support from the provinces of New Brunswick and Nova Scotia. One can find information on the activities of AARMS at the following web site: http://www.aarms.math.ca.

Academic Partners

The activities of the CRM rest on a solid basis of cooperation with regional universities, in particular the

Montréal universities, and most particularly the Université de Montréal, whose support for the CRM has been unfailing. The Université de Montréal releases five of its faculty members to work at the CRM each year, and the support of these faculty members is an essential asset for the CRM's scientific activities. There is in addition a regular program of teaching releases for the other Montréal universities, bringing the equivalent of another two positions to the CRM each year. On an ad-hoc basis linked to the thematic program, the CRM has also been arranging the release of research personnel from nearby universities such as Laval, Sherbrooke, Queen's, and Ottawa. The partnerships of the CRM with the other research institutes in the Montréal area have been very profitable.

With the financial support of the Université de Montréal, McGill University, the Université du Québec à Montréal, Concordia University, and Université Laval, as well as grants from NSERC and the Fonds de recherche du Québec – Nature et technologies (FRQNT), the CRM finances the activities of its nine laboratories, which collectively represent the most active branches of the mathematical sciences. These laboratories are the perfect illustration of scientific vitality and serve to feed the national and international scientific programs of the CRM. The reader may refer to the section Research Laboratories for a description of the activities of each of these laboratories.

Association with the University of Ottawa

In 2003, the Department of Mathematics and Statistics of the University of Ottawa became a member of the CRM. In partnership with the University of Ottawa, the CRM cofinances the CRM–University of Ottawa Distinguished Lecture Series, postdoctoral fellowships, and teaching releases so that University of Ottawa faculty members can undertake research with colleagues in the CRM's laboratories or participate in the scientific activities of the CRM.

CRM–University of Ottawa Distinguished Lecture Series

The series features talks by prominent mathematicians from Canada and abroad on topics at the forefront of today's mathematical research. In 2011–2012 there were two such talks at the University of Ottawa.

Entropy rigidity for non-positively curved compact manifolds, by François Ledrappier (University of Notre Dame), on February 10, 2012

The Transverse Geometry of Tiling Spaces, by Jean Bellissard (Georgia Institute of Technology), on April 13, 2012

Network for Computing and Mathematical Modeling (ncm_2)

The CRM is one of the founding members of the Network for Computing and Mathematical Modeling (ncm_2), a network created by several research centres in order to respond to the needs of industry in fields related to computing and mathematical modelling. The research of the network focuses on five major themes: risk management, information processing, imaging and parallel computing, transport and telecommunications, and health and electronic commerce. The ncm_2 was founded by the CRM, the Centre de recherche en calcul appliqué (CERCA), the Center for Interuniversity Research and Analysis on Organizations (CIRANO), the Centre for Research on Transportation (CRT), the Computer Research Institute of Montréal (CRIM), and the Institut national de la recherche scientifique – Télécommunications (INRS-Télécom). At the present time the following centres are members of the ncm_2: CIRANO, CRM, CIRRELT, INRS-ÉMT, and GERAD.

Regroupement Neuroimagerie/Québec (RNQ)

In recent years, CRM's PhysNum laboratory has developed a strong collaborative network with various partners in neuroimaging in the Montréal area. This network became an officially recognized network with the founding of the Regroupement Neuroimagerie/Québec (RNQ), under the umbrella of the Institut universitaire de gériatrie de Montréal. The RNQ, with its 70 researchers, has recently purchased some key equipment in neuroimaging thanks to a very large grant ($11M). One of the strongest alliances of the CRM within that network is its association with the Inserm laboratory for brain imaging at the FMPMC Pitié-La Salpêtrière (Paris), whose director is Dr. Habib Benali.

Joint Initiatives

The annual meetings of the CMS, SSC, and CAIMS, as well as some of their training and promotion activities, are jointly sponsored by the CRM, the Fields Institute for Research in Mathematical Sciences, PIMS, and Mprime. The annual meetings of the societies allow Canadian mathematicians and statisticians to keep abreast of their colleagues' work, to organize sessions on emerging topics, and attend lectures given by world-renowned mathematicians or prize winners. One can find more information on the societies by consulting their respective web sites (http://www.cms.math.ca/, http://www.ssc.ca/, and http://www.caims.ca/). Note that there was no CAIMS Annual Meeting in 2011 because an international congress in applied mathematics (ICIAM) took place in Canada during that year. The CRM supported the Association for Women in Mathematics (AWM) Embedded Meeting at ICIAM 2011.

2011 CMS Summer Meeting
June 3–5, 2010, University of Alberta
http://cms.math.ca/Events/summer11/

39th Annual Meeting of the Statistical Society of Canada
June 12–15, 2011, Acadia University
http://www.ssc.ca/en/meetings/2011/

2011 CMS Winter Meeting
December 10–12, 2011, Delta Chelsea Hotel, Toronto
http://cms.math.ca/Events/winter11/

ICIAM 2011
July 18–22, 2011, Vancouver Convention Centre

AWM Embedded Meeting @ ICIAM 2011
July 18–19, 2011, Vancouver Convention Centre

Mathematical Education

As part of its mandate to promote and stimulate research in the mathematical sciences, at every level, the CRM provides funding and support for many activities and programs related to mathematical education and the training of researchers. Many of these activities and programs are carried out jointly with the ISM (Institut des sciences mathématiques). As a result, much of the information contained in the present section is taken from the ISM annual report.

Institut des sciences mathématiques (ISM)

Created in 1991 by the departments of mathematics and statistics of the four Montréal universities, the ISM is a consortium of eight Québec universities (Bishop's University, Concordia, Laval, McGill, Université de Montréal, UQAM, UQTR, and Université de Sherbrooke), six of which offer a Ph.D. program in Mathematics. As an institute to which belong almost all the Québec researchers in the mathematical sciences, the ISM has at its disposal vast material and intellectual resources, and as a result, Montréal and Québec itself have become one of the main centres of training and research in the mathematical sciences in North America. The ISM is funded by the Ministère de l'Éducation, du Loisir et du Sport du Québec and by the eight universities in the consortium.

The reader will find below an overview of the activities and programs of the ISM.

- Coordination and harmonization of graduate programs

The ISM was created to bring together the strengths of its member departments, in order to turn them into a great school of mathematics. Thus the ISM coordinates the graduate studies of the mathematics departments, supports the sharing of expertise among its researchers and facilitates student mobility between the Montréal universities.

- Scholarships and financial support

The ISM helps students and beginning researchers carry out their research activities in several ways, for instance through the ISM Scholarships for Graduate Studies, the Carl Herz Scholarship (financed by the Carl Herz Foundation), the Travel Bursaries, the Undergraduate Summer Scholarships, and the CRM–ISM postdoctoral fellowships.

- Scientific activities

Since its creation, the ISM has initiated several activities that are by now an integral part of the Québec scientific scene: the CRM–ISM Mathematics Colloquium, the CRM–ISM–GERAD Statistics Colloquium, the CRM–ISM Probability Seminar, and the ISM Graduate Student Conference.

- Promotion of the mathematical sciences

The ISM produces the *Accromath* magazine and distributes it freely in all the cégeps and secondary schools in Québec. In this way, it contributes to spreading mathematical knowledge among teachers, young students, and the general public. Each year, ISM professors give talks attended by thousands of cégep students; these talks present the latest breakthroughs in mathematics and the careers available to mathematics graduates.

As the above list demonstrates, the CRM has several joint activities with the ISM, in particular two colloquia, a joint program of postdoctoral fellowships, and the planning of graduate courses related to the thematic programs of the CRM. Since the summer of 2003, the CRM has also supported the Undergraduate Summer Scholarships program, which allows postdoctoral fellows to supervise undergraduate students doing research.

CRM–ISM Postdoctoral Fellowships

The CRM–ISM postdoctoral fellowships enable promising young researchers to devote themselves to their research work. The ISM organizes a single competition on behalf of the eight universities of the consortium, and it receives a large number of applications, which are then evaluated by the 150 ISM professors. The selection of the fellows is rigorous and only one in forty applicants is awarded a fellowship. The applications are handled electronically in order to streamline the selection process and economize the resources consumed during the selection. The postdoctoral fellows play a crucial role in the Montréal universities: they collaborate with the established researchers, stimulate their work, and bring new ideas from other great centres of mathematical research. They also are a vital link between the professors and the students, espe-

cially when they organize on their own study groups on emerging topics.

CRM–ISM 2011–2012 Postdoctoral Fellows

Vorrapan Chandee (Ph.D., Stanford) works with Chantal David and Andrew Granville on analytic and probabilistic number theory, L-functions, the theory of random matrices, and quadratic forms.

Tiago Fonseca (Ph.D., UPMC) works with Marco Bertola, John Harnad, and Jacques Hurtubise. His research interests are in algebraic and enumerative combinatorics and in integrable quantum systems.

Nabil Kahouadji (Ph.D., Paris Diderot) collaborates with Niky Kamran. He works in differential geometry, Cartan-Kähler theory, conservation laws, geometric aspects of PDEs, and mathematical physics.

Dimitris Koukoulopoulos (Ph.D., UI Urbana-Champaign) works with Andrew Granville on analytic, probabilistic, and additive number theory.

Antonio Lei (Ph.D., Cambridge) works with Henri Darmon in algebraic number theory.

Guyslain Naves (Ph.D., Joseph Fourier) works with Adrian Vetta. His research interests are in combinatorial optimization, graph theory, and approximation algorithms.

Vivien Ripoll (Ph.D., Paris Diderot) works with Christophe Hohlweg on combinatorics and the geometry of Coxeter groups and real and complex reflection groups.

Matthew Roberts (Ph.D., Bath) works with Louigi Addario-Berry in probability theory.

Yakov Savelyev (Ph.D., Stony Brook) works with Octav Cornea and François Lalonde in symplectic and differential geometry. His main interests are Floer theory and Gromov-Witten theory in dynamical systems and mathematical physics.

ISM Doctoral Fellowships

In 2007–2008 the ISM initiated a doctoral fellowship program in order to recruit outstanding Ph.D. students. The doctoral fellowships provide financial support for up to four years to outstanding, new students to pursue a doctoral program at one of the ISM member universities. The students fill an application form online and the applications are made available to all the ISM professors. An inter-university selection committee, which takes the department recommendations into account, makes the final selection of scholars. Each year the ISM has been able to attract an exceptional student to Québec. A doctoral fellowship for the academic year 2012–2013 was awarded to Almaz Butaev, who comes from Malaysia and will pursue a Ph.D. in mathematics at Concordia University under the supervision of Galia Dafni.

In spite of its success, this program will be discontinued next year because of budgetary constraints.

Undergraduate Summer Scholarships

In collaboration with the CRM and the ISM professors, the ISM awards summer scholarships to promising undergraduates who want to do research during the summer and plan to study mathematics at the graduate level. These undergraduates are supervised by postdoctoral fellows, who in general are supervising students for the first time. The reader will find below the list of the undergraduate scholars.

Valentine Chiche-Lapierre (Concordia)
Scholarship co-financed by Galia Dafni
Supervisor : Suresh Eswarathasan
Topic : Applications of analysis to error-correcting codes
Duration : May 1 – June 30, 2012 (2 months)

Spencer Frei (McGill)
Scholarship co-financed by Gantumur Tsogtgerel
Supervisor : Brian Seguin
Topic : Existence, regularity, and approximation for elliptic systems with variational structure
Duration : May 1 – July 31 (3 months)

Nicolas Gonzalez (McGill)
Scholarship co-financed by Tony Humphries
Supervisor : Renato Calleja
Topic : Numerical study of a family of differential equations with two state-dependent delays that are independent of each other
Duration : May 1 – August 3 (3 months)

Vincent Grenier-Gauthier (Laval)
Scholarship co-financed by André Fortin
Supervisor : Driss Yakoubi
Topic : Formulation complètement eulérienne de l'interaction fluide-structure pour le problème du piston
Duration : May 1 – August 31 (4 months)

Marc-Adrien Mandich (McGill)
Scholarship co-financed by Vojkan Jakšić
Supervisor : Philip Grech
Topic : Entropy flux in the stationary state of a finite univariate sample S connected at its left and right ends to two infinitely extended reservoirs at distinct temperatures and chemical potentials
Duration : May 1 – August 31 (4 months)

Francis Rodrigue (Montréal)
Scholarship co-financed by Matilde Lalín
Supervisor : Mathew Rogers
Topic : An exploration of Bernoulli numbers and Bernoulli polynomials
Duration : May 1 – August 31 (4 months)

Xi Sisi Shen (McGill)
Scholarship co-financed by Pengfei Guan, Adrian Vetta, and Bruce Reed
Supervisor : Aaron Williams
Topic : Combinatorial generation
Duration : May 1 – August 31 (4 months)

ISM Graduate Student Conference

Each year the ISM sponsors and supports the organization of the ISM Graduate Student Conference ("Colloque pan-québécois des étudiants de l'ISM"). Organized by and for the students of the partner universities, the 13th Conference was held on June 1–3, 2012, at UQAM. It was organized by Jérôme Fortier, Sandra Larrivée, and Maxime Scott, and attended by around 100 participants. The program featured plenary lectures given by professors and presentations by students. The plenary lectures were given by Thomas Brüstle from the Université de Sherbrooke (*On maximal Green sequences*), André Joyal from UQAM (*Petite histoire des cogèbres colibres*), Jean-François Renaud from UQAM (*Théorie des fluctuations pour le processus de Lévy spectralement négatif*), Dominic Rochon from the Université du Québec à Trois-Rivières (*Dynamique bicomplexe*), and Adrian Vetta from McGill University (*A quick introduction to algorithmic game theory*).

The following students gave talks during the Conference: Anas Abdallah (Laval), Abdolrasoul Baharifard (Laval), Mohammad Bardestani (Montréal), Cyril Joël Batkam (Sherbrooke), Erwan Biland (Laval), Éloïse Boiteau (Laval), Laurence Boulanger (Montréal), Alexandre Desfossés-Foucault (Montréal), Ibrahima Dione (Laval), Kael Dixon (McGill), Yasser Farhat (Laval), Ludovick Gagnon (Laval), Philippe Gagnon (Montréal), Sophie Léger (Laval), Mostafa Mache (Laval), Jim Parks (Concordia), Benoît Pouliot (Laval), Eric Rowland (UQAM), Maxime Scott (UQAM), Michael Snarski (McGill), Hugo Tremblay (UQAM), and Malik Younsi (Laval).

Promotion of the Mathematical Sciences

Produced by the ISM and financed by the ISM, the CRM, the CMS, and the Mitacs network, the *Accromath* magazine aims to draw more young people to the mathematical sciences. *Accromath*, whose editor-in-chief is André Ross, has two issues per year and is available free of charge in all the high schools and cégeps of Québec. *Accromath* is designed by an exceptional team of researchers and instructors with a broad experience in the promotion of mathematics; it provides high school and cégep teachers with stimulating and topical articles on the most recent discoveries and applications, as well as articles on the history of mathematics and its links with the arts.

Accromath is widespread in Québec but is also distributed in other French-speaking regions and countries. Currently 2400 persons or institutions (mostly teachers from Québec) subscribe to the magazine. This year *Accromath* was awarded the Anatole-Decerf Prize, a prestigious prize awarded every two years by the Société mathématique de France in recognition of work in the pedagogy or popularization of mathematics. For the first time ever the recipient of the prize was a team working outside of Europe. The members of the selection committee stressed the high scientific and educational quality of the magazine. France Caron received the prize on behalf of the Editorial Board at the Institut Henri–Poincaré on June 15, 2012.

Other Joint Initiatives

Canadian Undergraduate Mathematics Conference 2011

June 15–19, 2011, Université Laval

Sponsored by Université Laval, Département de mathématiques et statistique de l'Université Laval, AESMUL, CMS, AESGUL, CRM, Mitacs Student Advisory Committee, AARMS, ASSQ, Exfo, FRQNT, CAIMS, Fields, Thomas Ransford (Analysis Research Chair), CMS Student Committee, ISM, GIREF, SSC, Service de placement de l'Université Laval, Line Beauchamp (ministre

de l'Éducation, du Loisir et du Sport), Michelle Courchesne (présidente du Conseil du Trésor), ADSEG, CADEUL, AÉLIÉS, AMQ, Fondation de l'Université Laval, Air Canada, Coop Zone

Organizers:

Anika Pascale Papillon (Laval), Andréa Deschênes (Laval), Laurent Pelletier (Laval), Dominique Maheux (Laval), Jean-Sébastien Lévesque (Laval)

Keynote Speakers:

Yvan Saint-Aubin (Montréal), Yves Demay (Nice Sophia Antipolis), Jean-Marie De Koninck (Laval), Frédéric Gourdeau (Laval), Aurélie Labbe (McGill), Pamela Gorkin (Bucknell), Frederick Rickey (USMA), Thomas Brüstle (Sherbrooke; Bishop's)

Number of participants: 165

The Canadian Undergraduate Mathematics Conference (CUMC) is one of North America's largest undergraduate conferences and Canada's premier conference for undergraduate students interested in mathematics and related fields (statistics, physics, computer science, economics, etc.). During the conference students get the valuable opportunity to practice giving mathematical talks on a topic of their choice, encounter ideas from areas of mathematics outside of their expertise, and listen to renowned keynote speakers from a variety of disciplines. The keynote speakers invited each year are either prominent figures or rising stars in their fields, and most importantly they care about undergraduates and their exposure to mathematics.

55e Congrès de l'Association Mathématique du Québec

October 14–15, 2011, Polytechnique Montréal

As usual the CRM was a sponsor of the "Association Mathématique du Québec" conference, which took place at the École Polytechnique de Montréal and whose theme was *Les mathématiques à construire* (*Mathematics to build*).

"Sciences et mathématiques en action" and "Association québécoise des jeux mathématiques"

The CRM contributes to the "Sciences et mathématiques en action" program, created by Professor Jean-Marie De Koninck from Université Laval in order to popularize mathematics and science for high school students and the general public. We refer the reader to the site www.smac.ulaval.ca for more information. The CRM also supports the Association québécoise des jeux mathématiques (aqjm.fsg.ulaval.ca).

Research Laboratories

In 2011–2012 the CRM was encompassing nine research laboratories at the heart of the Québec mathematical community. These research groups act as focal points for local scientific activity and participate actively in the scientific programs of the CRM .

Applied Mathematics

Description

The CRM Applied Mathematics Laboratory is a research network of some 21 applied mathematicians, engineers, computer scientists, and chemists, based in Montréal. The Laboratory exists primarily to stimulate research and collaboration in the applied mathematical research areas of its members by fostering discussion and the creation of ideas through conferences, workshops, and seminars, and the furtherance of research through its visitors' program and the appointment of talented postdoctoral fellows. The Laboratory is also very concerned with the training of young researchers and supports travel and conference attendance of its postdoctoral fellows.

The research interests of the Laboratory members are quite diverse although there are a number of common threads that make interchange and collaboration both possible and fruitful. Active areas of research represented within the Laboratory include, for example, the application of dynamical systems theory to complex phenomena, high-dimensional chaos, and biology. There is an interest in numerical linear algebra and its applications, including the design, analysis, and implementation of effective computer algorithms. Amongst the membership one will also find expertise in numerical simulation, applied dynamical systems, quantum chemistry, turbulence, combustion, biomechanics, numerical methods in fluid mechanics and electromagnetism, hp-finite element methods, molecular dynamics, control, optimization, preconditioners, and large-scale eigenvalue problems.

News and highlights

In 2011–2012 the Laboratory welcomed two new members. Jean-Philippe Lessard joined the Department of Mathematics and Statistics of Université Laval in August 2011 after having previously been an NSF postdoc in the Institute for Advanced Study, Princeton and, more recently, serving as Group Leader of the Computational Mathematics section in the Basque Center for Applied Mathematics in Bilbao, Spain. His research interests include dynamical systems, partial differential equations, and delay differential equations. Emmanuel Lorin de la Grandmaison is an Associate Professor in the School of Mathematics and Statistics of Carleton University. His research interests include partial differential equations, numerical analysis (in particular, for hyperbolic systems and complex applications of finite volumes), and mathematical modelling.

This year Laboratory members received many honours, prizes, and nominations.

- The American Society of Mechanical Engineers (ASME) Design Engineering Division Technical Committee on Multibody Systems and Nonlinear Dynamics (TC-MSND) gave Eusebius Doedel an honorary award at the ASME 2011 International Design Engineering Technical Conferences & Computers and Information Engineering Conferences, held in August 28–31, 2011 in Washington, DC, USA.
- Peter Bartello was named President of the Canadian Meteorological and Oceanographic Society from June 2012.
- Jacques Bélair was nominated a member of the steering committee of the Centre for Applied Mathematics in Bioscience and Medicine (McGill).
- Tucker Carrington was a visiting professor at the ETH Zürich from May to November 2012.
- Eliot Fried was a visiting professor in the Mechanical Engineering Department at the University of Washington from 2011 to 2012.
- George Haller has been appointed professor of nonlinear dynamics at ETH Zürich (he is on leave of absence from McGill).
- Emmanuel Lorin was a visiting professor for two months at the Université de Grenoble. He has also been nominated to the selection committee of the FRQNT for Ph.D. mathematics bursaries.
- Jean-Paul Zolésio was a visitor professor in the Department of Mathematics, Nebraska University, Lincoln in October 2011 and in the Department of Mathematics, North Carolina State University in May 2012.

The 2011–2012 year was an outstandingly productive one for the Laboratory! At least 97 refereed journal publications bearing the names of members of the applied maths laboratory have appeared during that period. To this impressive total should be added an important number of accepted articles, refereed conference proceedings, and book chapters. In addition, Jean-Paul Zolésio coauthored (with Michel Delfour) the book: *Shapes and Geometries: Metrics, Analysis, Differential Calculus, and Optimization*, 2nd edition, July 2011, SIAM. To quote from the SIAM website: "*This considerably enriched new edition provides a self-contained presentation of the mathematical foundations, constructions, and tools necessary for studying problems where the modeling, optimization, or control variable is the shape or the structure of a geometric object.*"

Beyond the usual NSERC Discovery grants, some significant additional grant money was attracted by various members of the laboratory.

• André Bandrauk was successful in attracting grant money for Québec-Germany cooperation, awarded by the Ministère du Développement économique, de l'Innovation et de l'Exportation - Québec. The project funding comes to $\$150,000$ in total. A. Bandrauk has also secured funding from the FRQNT for the Équipe Attoseconde (the amount of the grant is $225,000).

• An amount of $5000 from the Mprime Network (formerly Mitacs) was awarded to Peter Bartello for the Workshop on Balance, Boundaries and Mixing in the Climate Problem, organised by P. Bartello and two others, and held at the CRM in September 2011.

• An amount of $19,000 was awarded by PIMS to Peter Bartello and three Canadian colleagues for some Special sessions on Mathematics of Planet Earth at the 2013 Congress of the Canadian Meteorological and Oceanographic Society.

• Tucker Carrington is the principal investigator for a project entitled "Understanding the methane cycle in planetary atmospheres," which will last for three years and has been allocated $350,000.

• Robert G. Owens is the principal investigator for a Mitacs-funded project ($80,000) entitled "Improvement of the capabilities of an analytical instrument and its applications in polymer materials characterization and formulation."

The members of the CRM applied maths laboratory continue to have a very significant presence at international scientific conferences and it is not possible to list all the seminars and conference presentations given over the past 12 months due to their overwhelming number. Here are some of the most important keynote or plenary speaker invitations received.

• Peter Bartello delivered a keynote talk and pedagogical lecture entitled "From balance to stratified turbulence" at the Joint US National Center for Atmospheric Research-Institute for Mathematics Applied to Geosciences Theme-of-the-Year 2012: "Connections between Rotating, Stratified Turbulence and Climate: Theory, Observations, Experiments, and Models," Boulder, Colorado, USA, May 2012.

• Tucker Carrington was a plenary speaker at the International Symposium on Molecular Spectroscopy 67th Meeting held in Columbus, Ohio, June 18–22, 2012. His talk had the title "Calculating ro-vibrational spectra using an Eckart frame."

• Rustum Choksi was an invited speaker at the Workshop on Geometry of Interfaces and Capillarity, Granada, Spain, June 2012. The subject of his talk was "On Minimizing Interfaces for a Variational Problem with Long-Range Interactions."

• Eliot Fried was an invited speaker and tutor at the conference Nonlocal Continuum Models for Diffusion, Mechanics, and Other Applications (SAMSI, North Carolina, June 25–29, 2012) and gave a tutorial with the title "Established Continuum Approaches to Spatial Nonlocality."

Students, postdoctoral fellows, and visitors

A priority for the applied maths laboratory, reflected clearly in the use of its funds over the last few years, has been the training and encouragement of younger scientists in applied mathematical research. To date this has been primarily through the support of postdoctoral researchers with the aim of seeing them prepared for a life in academia or industry. A new initiative this year is the provision of up to four bursaries for doctoral students of full laboratory members.

Dr. Renato Calleja, who was a postdoctoral fellow at McGill from 2009 to 2012 under the supervision of Tony Humphries, is leaving us. From September to December 2012, R. Calleja will be a postdoctoral fellow at the Institute for Mathematics and its Applications (IMA) at the University of Minnesota. Then from January to August 2013 he will be a Visiting Assistant Professor at the School of Mathematics of the Georgia Institute of Technology. Finally, in August 2013, he

will have a tenure-track position at the Instituto Tecnológico Autónomo de México (ITAM) in Mexico City. Dr. Brian Seguin will continue one more year at McGill under the supervision of Eliot Fried. Dr. François Fillion-Gourdeau, a postdoc of André Bandrauk and Emmanuel Lorin, enjoys partial support from the laboratory and is also supported by the Fields Institute and the CRM. Recently, he was invited by the Isaac Newton Institute for Mathematical Sciences in Cambridge to take part in the conference on New Developments in Relativistic Quantum Mechanics and Applications (July 30–August 3, 2012). F. Fillion-Gourdeau is being joined by two new arrivals: Dr. Ihsan Topaloğlu, who will work with Gantumur Tsogtgerel and Rustum Choksi, and Dr. Dmitry Kolomenskiy, whose work is of interest to Jean-Christophe Nave and Robert Owens. Dr. Topaloğlu's research interests lie mainly in the calculus of variations and partial differential equations. Dr. Kolomenskiy is one of only 4 new CRM postdoctoral fellows appointed in 2012. During his time in Montreal he will develop numerical techniques for the incompressible Navier-Stokes equations with irregular time-dependent boundaries (in order to study insect flight and unmanned aerial vehicles aerodynamics).

This year the laboratory decided to make available 4 bursaries of $5000 each for up to three years with the following rules:

(a) An application for a bursary will consist of the student's CV and a letter of recommendation from the supervisor;
(b) The competition deadline will be in November to coincide with the NSERC scholarship application deadline;
(c) The bursaries will be available at any time after the first year of the Ph.D. program being followed by the successful student;
(d) The bursaries will be awarded for one year in the first instance and renewed each year, provided the progress of the Ph.D. candidate is satisfactory (a letter from the supervisor to this effect will be sufficient);
(e) Decisions will be made by a small ad-hoc committee drawn from laboratory members not requesting a Ph.D. bursary and based on the size of the current grants held by the supervisor (the smaller the total, the higher the laboratory funding priority) and the excellence of the Ph.D. student (as assessed from the CV and letter of recommendation) with a 50-50 weighting.

In the 2011–2012 academic year 12 M.Sc. students, 25 Ph.D. students, and 11 postdoctoral fellows were supervised or cosupervised by members of the Applied Mathematics Laboratory.

Seminars

The main regular laboratory activity is the weekly research seminar. This functions extremely well, despite the diversity of the research interests of laboratory members, and attendance is good. Over the past two semesters the laboratory has hosted almost 30 different speakers, drawn mainly from North America, but also including collaborators from Europe and Australia/Oceania. Rustum Choksi, Jean-Christophe Nave, and Gantumur Tsogtgerel are thanked for organizing an excellent seminar program over the past twelve months and for volunteering to continue the good work in 2012-2013.

Workshops, special sessions, and others

The members of the laboratory have been very active during the past year in helping organize international conferences, workshops and other scientific events. Here are the highlights. (These meetings have been arranged in chronological order and the name of the responsible lab member is given in parentheses.)

• Workshop on Balance, Boundaries and Mixing in the Climate Problem, September 2011, CRM (Peter Bartello).

• Workshop on "Advanced Techniques in Nonlinear Dynamics," Instituto de Física, Benemérita Universidad Autónoma de Puebla, Mexico, February 2012 (Eusebius Doedel).

• Conference on Nonlocal PDE and Variational Problems, Institute for Pure and Applied Mathematics, UCLA, March 2012 (Rustum Choksi).

• Workshop on "Connections Between Regularized and Large-Eddy Simulation Methods for Turbulence," Banff International Research Station, May 13–18, 2012 (Eliot Fried).

• Workshop entitled "Calcul rigoureux dans les systèmes dynamiques" at the Université Laval, May 23, 2012 (Jean-Philippe Lessard).

• The 46th Congress of the Canadian Meteorological and Oceanographic Society (CMOS) took place from May 29th to June 1st 2012. This Congress was organized jointly with the 21st American Meteorologi-

cal Society (AMS) Conference on Numerical Weather Prediction (NWP) and the 25th AMS Conference on Weather Analysis and Forecasting (WAF). These two conferences are organized every other year outside the annual AMS meeting. In 2012 the Conferences were held in Montreal and organized in collaboration with CMOS. The conferences benefit from a joint scientific committee to plan the sessions on NWP and WAF, themes that are common to both groups (Peter Bartello).

Members of the Laboratory

Regular members

Robert G. Owens (Montréal), Director
Mechanics, numerical simulation of complex fluids

André D. Bandrauk (Sherbrooke)
Quantum chemistry

Peter Bartello (McGill)
Turbulence, CFD

Jacques Bélair (Montréal)
Dynamical systems in physiology

Anne Bourlioux (Montréal)
Modelling, numerical simulation in turbulent combustion

Xiao-Wen Chang (McGill)
Numerical linear algebra and applications

Rustum Choksi (McGill)
Calculus of variations, nonlinear partial differential equations, problems arising in materials science, self-assembly of diblock copolymers, and magnetic domain formation in type-1 superconductors and ferromagnets

Eusebius J. Doedel (Concordia)
Numerical analysis, dynamical systems, differential equations, bifurcation theory, scientific software

Eliot Fried (McGill)
Mechanics and thermodynamics of continuous media

George Haller (McGill)
Theory of nonlinear dynamical systems, fluid mechanics, Hamiltonian systems, singular perturbation theory

Antony R. Humphries (McGill)
Numerical analysis, differential equations

Emmanuel Lorin de la Grandmaison (Carleton)
Numerical analysis for hyperbolic systems, quantum chemistry, complex applications of finite volumes, computer science

Sherwin A. Maslowe (McGill)
Asymptotic methods, fluid mechanics

Jean-Christophe Nave (McGill)
Numerical analysis, PDE, interface problems, level set methods, fluid mechanics, computer graphics

Gantumur Tsogtgerel (McGill)
Applied mathematics, partial differential equations, general relativity

Jian-Jun Xu (McGill)
Asymptotics and numerical analysis, nonlinear PDEs, materials science

Associate members

Tucker Carrington (Queen's)
Chemical dynamics

Martin J. Gander (Genève)
Domain decomposition, preconditioning

Jean-Philippe Lessard (Laval)
Dynamical systems, rigourous computational methods, PDEs, delay differential equations, topological methods

Nilima Nigam (Simon Fraser)
Applied analysis, numerical methods in electromagnetism

Paul F. Tupper (Simon Fraser)
Numerical analysis, stochastic processes, statistical mechanics

Thomas P. Wihler (Bern)
Numerical analysis, computational methods for PDEs

Jean-Paul Zolésio (INRIA Sophia Antipolis)
Control, optimization

CICMA – Centre Interuniversitaire en Calcul Mathématique Algébrique

Description

CICMA brings together researchers working in number theory, geometric group theory, and algebraic geometry. Algebraic geometry is a broad discipline with strong connections to a variety of areas ranging from arithmetic to theoretical physics. Eyal Goren and Adrian Iovita are leading experts in applying algebro-geometric techniques to problems motivated by number theory, notably the study of Shimura varieties and p-adic cohomology theories. John McKay is one of the instigators of the moonshine program, which ties together in a surprising way certain notions in the theory of modular forms, arithmetic geometry, and theoretical physics. Geometric group theory is a vibrant subject that has melded geometric and algebraic methods in deep and powerful ways, leading to novel insights in both subjects. Dani Wise and Mikael Pichot are world-renowned specialists in this central area.

Contemporary algebraic number theory has developped over the last decades following two major trends. On one hand, there is the theory of special values of L-functions attached to arithmetic objects, originating in the work of Gauss and Dirichlet and leading to the modern conjectures of Deligne, Beilinson, and Bloch-Kato. On the other hand, the Langlands program postulates a close link between arithmetic L-functions and automorphic representations. Analytic number theory studies profound and subtle questions about the distribution of prime numbers, using powerful techniques from analysis, notably the theory of functions of a complex variable and spectral theory. Number theory in all its different flavours is particularly well represented in the laboratory, with Darmon, Goren, Iovita, and Kassaei on the arithmetic and automorphic side, and David, Granville, Kisilevsky, Koukoulopoulos, and Lalín on the more analytic side of the subject.

Workshops and instructional conferences

The 2011–2012 academic year saw many members of CICMA involved in the organization of workshops and prestigious instructional conferences at the local, national, and international level.

• From June 26 to July 2, 2011, CICMA members Andrew Granville and Dimitris Koukoulopoulos, in collaboration with Youness Lamzouri (a former CICMA student), K. Soundararajan, and Frank Thorne, ran one of the workshops in the AMS's new "Mathematics Research Communities" series. The workshop topic was "The Pretentious View of Analytic Number Theory" and it covered Granville and Soundararajan's ambitious program to reorganize a large swath of analytic number theory around the surprisingly powerful and versatile notion of pretentiousness.

• On October 7-9, 2011, Andrew Granville and Valentin Blomer organised the Third Montreal-Toronto Workshop in Number Theory at the Fields Institute, on the theme of "New developments in analytic number theory." This was the third installment of a workshop series initiated by Goren and Kudla, which has grown into a regular and reliably successful bi-annual event.

• On November 6-11, 2011, CICMA members Chantal David and Matilde Lalín organized the second of the "Women in Numbers" conferences at the Banff International Research Station. Aimed exclusively at women working in number theory in a broad sense, the WIN conferences are now arguably the most influential events of their kind on the international stage.

• On January 9-14, 2012, Henri Darmon organised and participated in an International Winter School on the Birch and Swinnerton-Dyer conjecture at the Basic Science Research Institute in Pohang, South Korea.

• On April 28-29, 2012, Eyal Goren organised, in collaboration with Steven Kudla, the Fourth Montreal-Toronto Workshop in Number Theory at the CRM, on the theme "Cycles on Kuga fibre varieties."

• On May 5-12, 2012, CICMA members Henri Darmon and Eyal Goren ran the annual Bellairs Workshop in number theory at McGill's Bellairs Research Institute in Barbados. The theme of this well-attended instructional workshop was "Pro-unipotent fundamental groups: arithmetic and diophantine aspects." Minhyong Kim (Oxford), who has pioneered a program to study diophantine questions via a technique of anabelian descent, gave the principal lecture series (describing this innovative approach).

Students and postdoctoral fellows

Several graduate students supervised by CICMA members defended their Ph.D. theses in the 2011–2012 year:

- Mohammed Bardestani (supervised by Granville);
- Daniel Fiorilli, who was supervised by Granville and was awarded an NSERC postdoctoral fellowship to work at the IAS in Princeton. He has now moved on to Michigan and received the Governor General's gold medal for his Ph.D. thesis;
- Cameron Franc, who was supervised by Darmon and went on to a postdoctoral position at UC Santa Cruz and Stanford;
- Tristan Freiberg, who was supervised by Granville and has taken up a postdoctoral fellowship at the KTH in Sweden;
- Yu Zhao, who was supervised by Darmon and was awarded a postdoctoral fellowship at the Academia Sinica in Beijing.

In the 2011–2012 academic year 26 M.Sc. students, 48 Ph.D. students, and 15 postdoctoral fellows were supervised or cosupervised by CICMA members.

Seminars

The Quebec-Vermont Number Theory Seminar, CICMA's main scientific activity, is held every second Thursday for a full day and is attended by about 30-45 participants from Montreal, Vermont, Quebec City, and Ottawa. In 2011–2012 Henri Darmon and Eyal Goren were the organizers of the seminar, which included many well-attended lectures. Information on the Quebec Vermont seminar can be found at http://www.math.mcgill.ca/darmon/qvnts/qvnts.html.

Regular members of the Laboratory

Henri Darmon (McGill), Director
Algebraic number theory, arithmetic geometry, L-functions, Diophantine equations, elliptic curves

Hugo Chapdelaine (Laval)
Algebraic number theory, algebraic geometry

Chris J. Cummins (Concordia)
Group theory, modular functions, moonshine

Chantal David (Concordia)
Analytic number theory, L-functions

Jean-Marie De Koninck (Laval)
Analytic number theory: distribution of prime numbers, factorization of numbers, asymptotic behaviour of arithmetic functions, Riemann zeta function

David S. Dummit (Vermont)
Algebraic number theory, arithmetic algebraic geometry, computational mathematics

David Ford (Concordia)
Computational number theory, algorithmic number theory

Jayce R. Getz (McGill)
Number theory

Eyal Z. Goren (McGill)
Arithmetic geometry, algebraic number theory, moduli spaces of abelian varieties, Hilbert modular forms, p-adic modular forms

Andrew Granville (Montréal)
Analytic number theory, arithmetic geometry, combinatorics

Heekyoung Hahn (McGill)
Eisenstein series, L-functions, trace formula, q-series, theta functions and partitions

Adrian Iovita (Concordia)
Number theory, p-adic cohomology

Olga Kharlampovich (McGill)
Combinatorial group theory and Lie algebras

Hershy Kisilevsky (Concordia)
L-functions, Iwasawa theory, elliptic curves, class field theory

John Labute (McGill)
Pro-p-groups, Lie algebras, Galois theory

Matilde Lalín (Montréal)
Mahler measures, L-functions, zeta functions

Claude Levesque (Laval)
Algebraic number theory, units, class number, cyclotomic fields

Michael Makkai (McGill)
Mathematical logic

John McKay (Concordia)
Computational group theory, sporadic groups, computation of Galois groups

M. Ram Murty (Queen's)
Number theory: Artin's conjecture, elliptic curves, modular forms, automorphic forms, Langlands program, Selberg's conjectures, sieve methods, cryptography

Damien Roy (Ottawa)
Transcendental number theory

Peter Russell (McGill)
Algebraic geometry

Francisco Thaine (Concordia)
Cyclotomic fields, cyclotomy, rational points on curves

CIRGET – Centre Interuniversitaire de Recherches en Géométrie Et Topologie

Description

Geometry and topology are fundamental disciplines of mathematics whose richness and vitality, evident throughout human history, reflect a deep link to our experience of the universe. They are a focal point of modern mathematics and indeed several domains of mathematics have recently shown a strong trend towards a geometrization of ideas and methods: two cases in point are mathematical physics and number theory. CIRGET, based at UQAM, is composed of seventeen full members, four associate members, and a large number of postdoctoral fellows and graduate students working in this broad field. The main themes to be pursued in the coming years include the topological classification of 3-dimensional manifolds; the quantization of Hitchin systems and the geometric Langlands program; the classification of special Kähler metrics; the study of symplectic invariants, especially in dimension 4; non-linear partial differential equations in Riemannian geometry, convex geometry, and general relativity; and Hamiltonian dynamical systems.

News and highlights

This year CIRGET was most pleased to welcome Frédéric Rochon, our new Tier 2 Canada Research Chair. Rochon is one of the top young experts in the field of global analysis on singular spaces, notably index theory on manifolds with boundary. In collaboration with Richard Melrose, Rochon has established an impressive program of generalizing the K-theoretic approach of the Atiyah- Patody-Singer theorem to the case of manifolds with boundary. A regular collaborator with several members of the group, Dmitry Jakobson, an analyst from McGill University with interests in spectral geometry, quantum chaos, number theory, and graph theory, also joined the centre as an associate member. We warmly welcome both new members to the group.

Our graduate students continue to thrive and we are delighted to announce that our recent Ph.D. graduate Mark Hagen, who worked under the supervision of Dani Wise, was awarded the Carl Herz Prize for his work in geometric group theory.

Students, postdoctoral fellows, and visitors

Graduate students and postdoctoral fellows are an integral part of CIRGET scientific life, organizing working groups and seminars, mentoring undergraduate students, and occasionally giving specialized courses. Many of our postdoctoral fellows are staying at CIRGET in 2012–2013, but those who have completed their stays at CIRGET are moving on to good positions: Mathieu Anel is continuing his postdoctoral studies at the ETH in Zurich; Fabrizio Donzelli has a position at the University of Ottawa; Roman Golovko is now a Lecturer at the Israel Institute of Technology (Technion); Eric Harper has a postdoctoral position at McMaster; Sungmo Kang is now a professor at Chonnam National University in Korea; and Karol Palka has taken up a position at the University of Warsaw.

Our Ph.D. graduates have also found good positions. Radu Cebanu is now a postdoctoral fellow at Boston College; Xiangwen Zhang and François Charest are both postdocs at Columbia University; François Charette is doing a postdoc at Tel Aviv and at the ETH in Zurich; and Mark Hagen has accepted a position as an RTG Assistant Professor at the University of Michigan (Ann Arbor).

CIRGET members also greatly benefit from the many international visitors who come to work with them. In 2011–2012, 29 visitors stayed for short periods at the Centre.

In the 2011–2012 academic year 7 summer research students, 27 M.Sc. students, 28 Ph.D. students, and 26 postdoctoral fellows were supervised or cosupervised by CIRGET members.

Seminars

In 2011–2012, CIRGET invited five colloquium speakers for the CRM–ISM mathematics colloquium lecture series: Paul Biran (ETH, Zurich), Bun Wong (Riverside), Alan Huckleberry (Ruhr University of Bochum), Jason Starr (SUNY at Stony Brook), and Ludmil Katzarkov (Miami and Vienna).

CIRGET's everyday scientific life revolves around its weekly seminars and working groups where professors, postdoctoral fellows and students meet on a reg-

ular basis. The CIRGET Geometry and Topology Seminar, organized by Steven Lu, is a general seminar series attended by all CIRGET members. Of the 37 talks given this year, 28 were given by invited speakers who stayed at the centre for short research visits. The Algebraic Geometry Seminar, organized by Karol Palka, hosted 21 talks. In addition, Mathieu Anel, a CIRGET postdoctoral fellow, organized the CIRGET–LaCIM seminar with Viven Ripoll, a LaCIM postdoc. The aim of the seminar was to bring together members of the two laboratories so as to allow them to share research interests. A total of 18 talks were given during the year. Finally CIRGET graduate students from UQAM, the Université de Montréal, and McGill participated in the CIRGET Junior Seminar, organized by doctoral students Kael Dixon and Ben Smith. This seminar gives graduate students a forum to present their research to their peers. A total of 22 talks were given this year.

CIRGET working groups meet on a regular basis to explore specific topics over a period of several months or more. This year two working groups were active: Adam Clay organized a group that worked on low-dimensional topology and Vestislav Apostolov organized a group that worked on Hermitian geometry.

Workshops, special sessions, and other

The following workshops were organized by CIRGET members at the CRM in 2011–2012. The interested reader will find their reports in the section General Program.

Workshop on Moving Frames in Geometry
June 13–17, 2011
Organizers: Niky Kamran (McGill), Abraham Smith (McGill), Francis Valiquette (McGill)

Complex Analytic and Algebraic Trends in the Geometry of Varieties
August 15–17, 2011
Organizers: Karol Palka (UQAM), Peter Russell (McGill), Steven Shin-Yi Lu (UQAM)

Members of the Laboratory

Regular members

Vestislav Apostolov (UQAM), Director
Complex geometry, Kähler geometry

Steven Boyer (UQAM)
Topology of manifolds, low-dimensional geometry and topology

Abraham Broer (Montréal)
Algebraic transformation groups, invariant theory

Virginie Charette (Sherbrooke)
Discrete group actions on affine varieties, Lorentz manifolds, Riemann surfaces discretization, discrete differential geometry

Olivier Collin (UQAM)
Invariants of knots and 3-manifolds arising from global analysis

Octav Cornea (Montréal)
Algebraic topology, dynamical systems

Pengfei Guan (McGill)
Partial differential equations, geometric analysis, several complex variables

Jacques Hurtubise (McGill)
Algebraic geometry, integrable systems, gauge theory, moduli spaces

André Joyal (UQAM)
Algebraic topology, category theory

Niky Kamran (McGill)
Geometric approach to partial differential equations

François Lalonde (Montréal)
Symplectic topology and geometry, global analysis on manifolds, infinite-dimensional transformation groups

Steven Lu (UQAM)
Chern number inequalities, semistability of tensorial sheaves, log jets, log and hyperbolic geometry, algebraic degeneracy

Iosif Polterovich (Montréal)
Geometric analysis, spectral theory, functional analysis, differential geometry, partial differential equations

Frédéric Rochon (UQAM)
Geometric analysis, global analysis on singular spaces, index theory on manifolds with boundary

Peter Russell (McGill)
Algebraic geometry

Johannes Walcher (McGill)
Mirror symmetry for open strings, nongeometric string compactifications

Daniel T. Wise (McGill)
Geometric group theory, low-dimensional topology

Associate members

S. Twareque Ali (Concordia)
Coherent states, wavelets, quantization techniques, harmonic analysis, Wigner functions

John Harnad (Concordia)
Mathematical physics, classical and quantum physics, geometrical methods, integrable systems, group theoretical methods, random matrices, isomonodromic deformations, isospectral flows

Dmitry Jakobson (McGill)
Pure mathematics, global analysis, spectral geometry, quantum chaos, harmonic analysis, eigenvalues and eigenfunctions

John A. Toth (McGill)
Microlocal analysis, partial differential equations

GIREF – Groupe Interdisciplinaire de Recherche en Éléments Finis

Description

The recent advances in computer hardware and software allow researchers to model and simulate physical phenomena whose complexity is unheard of. These problems are characterized by nonlinear laws, nondifferentiable friction laws, large-deformation geometries, complex solid-solid or fluid-solid interactions, problems in multiphysics, etc. Such problems can be found everywhere in industrial environments, especially in the design and fabrication of high-technology products. Thus the members of GIREF ("Groupe Interdisciplinaire de Recherche en Éléments Finis," or in English "Interdisciplinary Research Group in Finite Element Methods") aim to develop original numerical methods for solving cutting-edge industrial problems in nonlinear mechanics. Their work concerns pure mathematics, computer science, software engineering, and engineering. The GIREF members propose general methods that can be used for diverse industrial applications. The some 27 member researchers reflect the interdisciplinary nature of the Laboratory and are based at the Université Laval, the École Polytechnique de Montréal, as well as the Universities of Moncton, Ottawa, and Alberta.

News and highlights

GIREF is continuing its partnership with the Société Michelin through the development or their joint modelling tool (MEF++). A team led by Éric Chamberland is rewriting some components of MEF++ in order to take advantage of parallel computing. The GIREF members have started to make computations of more than one hundred million degrees of freedom on the supercomputer of the CLUMEQ network. We will follow up on that story… The first phase of the NSERC Research Chair in high performance scientific computing came to an end in October 2011. André Fortin, the chairholder, prepared an application for the renewal of the chair, in partnership with Michelin. The NSERC Research Chair was renewed for five years with a total amount of approximately two million dollars.

Here is a list of the projects currently pursued at GIREF; the reader will find more details on the GIREF web site (giref.ulaval.ca). The names of investigators are given within parentheses.

- The MEF++ project (A. Fortin, M. Fortin, R. Guénette, J. Urquiza, A. Cloutier)
- NSERC Research Chair in high performance scientific computing (A. Fortin, principal investigator, and J. Urquiza, associate investigator)
- Numerical modelling in the wood sciences (P. Blanchet, M.-L. Dano, A. Cloutier, A. Fortin, Y. Fortin, G. Gendron, D. Pelletier)
- Modelling of flows in natural environments (J.-L. Robert, R. Therrien, Y. Secretan)
- Biomedical modelling (A. Garon, M. Delfour, A. Fortin, Y. Bourgault, Y. Belhamadia)
- Numerical modelling in biology (L. Buono, G. Daigle, A. Fortin, D. Fortin, M. Fréchette, J. Urquiza)
- Parallel computing (all the members of GIREF)
- Design of bistable structures (M.-L. Dano, A. Fecteau, M. Jean Saint- Laurent)
- Modelling of thermally-induced torsion within composite tubes (M.-L. Dano, N. Verreault)

Students, postdoctoral fellows, and visitors

The GIREF students were particularly honoured this year. Benoît Pouliot was awarded the "Médaille du lieutenant-gouverneur du Québec," Éloïse Boiteau was awarded a Hydro-Québec scholarship, and Sophie Léger was awarded the Fernand-Landry scholarship.

In the 2011–2012 academic year one undergraduate student, 15 M.Sc. students, 15 Ph.D. students, and 3 postdoctoral fellows were carrying out research at GIREF.

Seminars

In 2011–2012 the seminar held by GIREF included 21 talks.

Members of the Laboratory

Regular members

André Fortin (Laval), Director
Finite elements method, instationary viscous flows, mixing problems

André Garon (Polytechnique Montréal), Deputy Director
Thermohydraulics, fluid mechanics, finite elements method, hydraulic turbines, mechanics of biofluids: stents and pumps

Youssef Belhamadia (Alberta)
Mathematical modelling and numerical simulation of phase change problems, adaptive meshing for instationary problems in 2 and 3 dimensions, numerical modelling of cryosurgery, numerical modelling of the electromechanical wave in the heart

Yves Bourgault (Ottawa)
Computational fluid dynamics, numerical methods, finite elements method, mathematical modelling, mechanics of continuous media

Michel C. Delfour (Montréal)
Control, optimization, design, shells, calculus, biomechanics

Michel Fortin (Laval)
Numerical analysis of partial differential equations, numerical methods in fluid mechanics, optimization and optimal control for partial differential equations

Robert Guénette (Laval)
Numerical methods in non-Newtonian fluid mechanics, rheological models, Hamiltonian formulation

Hassan Manouzi (Laval)
Numerical analysis, applications of mathematics to engineering

Dominique Pelletier (Polytechnique Montréal)
Fluid mechanics and heat transfer, finite elements method, adaptive finite elements methods for compressible and incompressible flows, modelling and simulation of laminar and turbulent viscous flows, modelling and simulation of fluid-structure interactions

Roger Pierre (Laval)
Numerical analysis of partial differential equations

José Urquiza (Laval)
Numerical analysis, control of partial differential equations

Associate members

Pierre Blanchet (FPInnovations)
Nanotechnology for wood products

Alain Charbonneau (UQO)
Numerical simulation of optical wave guides, finite elements method, numerical methods, statistical machine translation, automated text categorization

Alain Cloutier (Laval)
Forestry, forest engineering

Marie-Laure Dano (Laval)
Mechanics and production of composite materials, intelligent mechanical systems

Claire Deschênes (Laval)
Axial hydraulic turbines

Guy Dumas (Laval)
Mechanical engineering, physics of fluids

Mohamed Farhloul (Moncton)
Finite elements and finite volumes method, partial differential equations, applications of the mixed finite elements method to fluid mechanics, numerical analysis

Marie-Isabelle Farinas (UQAC)
Modelling, numerical simulation, computational fluid mechanics, design of turbo engines (cardiac pump), optimization

Vincent François (UQTR)
Integration of the finite elements method into computer-aided design

Yves Fortin (Laval)
Forestry, forest engineering

Augustin Gakwaya (Laval)
Aerospatial and aeronautical engineering, numerical modelling, computer-assisted design

Guy Gendron (Laval)
Composite materials, optimization and modelling of structures

Jean-François Hétu (NRC-IMI)
Numerical modelling of processes

Jean-Loup Robert (Laval)
Numerical models of free surface flows, transport and

diffusion models with stochastic components, unified modelling in a saturated and aerated environment

Yves Secretan (INRS-ETE)
Numerical methods for finite elements, mesh generation and adaptation, error estimation, hydrodynamics in 2 dimensions, advection-diffusion phenomena

René Therrien (Laval)
Underground water flows, hydrology, geothermics

LaCIM – Laboratoire de Combinatoire et d'Informatique Mathématique

Description

LaCIM (French acronym meaning "Combinatorics and Mathematical Computer Science Laboratory") is home to mathematics and theoretical computer science researchers whose interests comprise discrete mathematics and the mathematical aspects of computer science. Founded in 1989, LaCIM includes 15 regular members, 5 associate members, and 16 collaborating members. It welcomes postdoctoral fellows and its regular members supervise or cosupervise many M.Sc. and Ph.D. students, as well as undergraduate and cégep summer research students. Many renowned mathematicians visit LaCIM and collaborate with its members in the following areas: enumerative and bijective combinatorics, theory of species, algebraic combinatorics, combinatorics of finite and infinite words, discrete geometry, theory of languages and automata, Gray codes, bioinformatics, and combinatorial optimization.

News and highlights

Thanks to the LIRCO, an international laboratory of the French CNRS that includes French researchers as well as members of LaCIM, many French researchers (a dozen in 2011–2012) have visited LaCIM. LaCIM has now 8 postdoctoral fellows, including 4 that arrived this year: Alejandro Morales, Puiman Ng, Mathieu Guay-Paquette, and Qiu Yu. Furthermore 8 undergraduates carried out research internships during the summer of 2012, including some who had received an NSERC scholarship for doing so. François Bergeron took part in an evening dedicated to science (*Science et contes*) at the "Cœur des science" (UQAM); he also took part in the "Gala des Concours scientifiques Montmorency." François Bergeron and Gilbert Labelle regularly gave lectures on mathematics in cégeps and colleges.

Students, postdoctoral fellows, and visitors

During the summer of 2011 LaCIM hosted the following researchers: Carsten Lange (Freie Universität Berlin); Matthew Dyer (Notre-Dame); Cesar Ceballos (Freie Universität Berlin). In the fall of 2011, LaCIM hosted: Mark Haiman (Berkeley); Frédéric Patras (Nice); Viviane Pons (Marne-la-Vallée); Samuele Giraudo (Marne-la-Vallée); Susanna Fishel (Arizona State); Valérie Berthé (LIAFA Paris). Finally, in the winter of 2012, LaCIM hosted the following researchers: Federico Ardila (San Francisco); Tom Denton (York); Carolina Benedetti (York); Roland Friedrich (Humboldt); Luigi Santocanale (Marseille); Doron Zeilberger (Rutgers); Nicolas Thiéry (Orsay); Brant Jones (James Madison).

In the 2011–2012 academic year 9 undergraduate students, 21 M.Sc. students, 37 Ph.D. students, and 14 postdoctoral fellows were supervised or cosupervised by LaCIM members.

Workshops, special sessions, and others

The following events were organized by LaCIM members. The reader will find reports on them in the section General Program.

Combinatorial Algebra Meets Algebraic Combinatorics
January 20–22, 2012, UQAM
Organizers: François Bergeron (UQAM), Franco Saliola (UQAM), Luis Serrano (UQAM)

SAGE Days at CRM
May 5–11, 2012, CRM
Organizers: Srečko Brlek (UQAM), Sébastien Labbé (UQAM), Franco Saliola (UQAM)

LaCIM members also organized mini-courses and a workshop under the title "Coxeter groups meet convex geometry", from August 13 to 22, 2011. The organizers were Christophe Hohlweg, Jean-Philippe Labbé, Carsten Lange, and Vivien Ripoll. The mini-courses were given by Christophe Hohlweg (*Geometry of Coxeter groups and root systems*), Carsten Lange (*Introduc-*

tion to polytopes, Cambrian lattices and Cambrian fans, generalized permutahedra), Vincent Pilaud (*Brick polytopes and generalized associahedra*), and Matthew Dyer (*Bruhat intervals and polyhedral cones*).

The XXIIIrd Meeting on Representation Theory of Algebras (September 16 and 17, 2011, at Bishop's University) was organized by a team of 7 researchers, including three LaCIM members: Ibrahim Assem, Thomas Brüstle, and Shiping Liu, all from the Université de Sherbrooke.

Members of the Laboratory

Regular members

Srečko Brlek (UQAM), Director
Combinatorics of words, algorithmics

Ibrahim Assem (Sherbrooke)
Representation theory

Anne Bergeron (UQAM)
Bioinformatics

François Bergeron (UQAM)
Combinatorics, algebra, representations of finite groups

Thomas Brüstle (Sherbrooke & Bishop's)
Algebraic combinatorics, cluster algebras, triangulations of surfaces, stochastic differential equations, mathematical models in finance

Cedric Chauve (Simon Fraser & UQAM)
Enumerative combinatorics, trees, bioinformatics

Sylvie Hamel (Montréal)
Bioinformatics and algorithms, theory of languages and automata, algebraic combinatorics

Christophe Hohlweg (UQAM)
Algebra, algebraic combinatorics, convex geometry

Gilbert Labelle (UQAM)
Enumerative combinatorics, analysis

Shiping Liu (Sherbrooke)
Representation theory

Vladimir Makarenkov (UQAM)
Computational biology, mathematical classification

Marni Mishna (Simon Fraser)
Algorithms and enumerative, analytical, and algebraic combinatorics

Christophe Reutenauer (UQAM)
Algebraic combinatorics, noncommutative algebra, automata theory, coding theory, free algebras

Franco Saliola (UQAM)
Algebraic combinatorics, group representations

Timothy R. S. Walsh (UQAM)
Algorithmics, enumerative combinatorics, graph theory

Associate members

Pierre Lalonde (Maisonneuve)
Enumerative and bijective combinatorics, alternating sign matrices, enumeration of involutions with respect to various parameters, use of Pfaffians and determinants in enumeration

Cédric Lamathe (UQAM)
Combinatorics of tree-like structures, theory of species, indicator series of partially labeled structures and asymmetric structures

Luc Lapointe (Talca)
Algebraic combinatorics, symmetric functions, integrable systems, supersymmetries

Odile Marcotte (UQAM & CRM)
Combinatorial optimization, integer programming, graph theory

Dominic Rochon (UQTR)
Complex analysis, hypercomplex numbers

Collaborating members

Marcello Aguiar (Texas A&M)
Algebraic combinatorics, non-commutative algebra, Hopf algebras and quantum groups, category theory

Robert Bédard (UQAM)
Representations of finite groups, Lie theory

Luc Bélair (UQAM)
Mathematical logic, model theory

Nantel Bergeron (York)
Applied algebra

Pierre Bouchard (UQAM)
Commutative algebra, algebraic geometry and combinatorics

Michel Bousquet (Vieux-Montréal)
Enumeration of combinatorial structures, planar maps and cacti, theory of species, Lagrange inversion formulas

Yves Chiricota (UQAC)
Computer graphics, mathematical methods in computer graphics, combinatorics, computational geometry, symbolic computation

Sylvie Corteel (LIAFA & CNRS)
Enumerative and bijective combinatorics, partitions of integers, q-series

Adriano Garsia (UC San Diego)
Algebraic combinatorics, symmetric functions, harmonic and coinvariant spaces, quasiharmonic and quasi-invariant functions

Alain Goupil (UQTR)
Combinatorics, algebra, linear representations of groups, symmetric group

André Joyal (UQAM)
Algebraic topology, category theory

Jacques Labelle (UQAM)
Combinatorics, topology

Louise Laforest (UQAM)
Data structures, combinatorics, asymptotic analysis, quaternary trees

Daniel Lemire (TÉLUQ)
Database theory, data warehousing, multidimensional databases (OLAP), data mining, time series, collaborative filtering, information retrieval

Simon Plouffe
Integer sequences, generalized expansions of real numbers

Xavier G. Viennot (Bordeaux 1)
Enumerative, algebraic, and bijective combinatorics, interactions between combinatorics, theoretical informatics, and theoretical physics

Mathematical Analysis

Description

At the same time classical and central to modern mathematics, analysis involves the study of continuous systems, from dynamical systems to solutions of partial differential equations and spectra of operators. In 2011–2012 the Laboratory included 28 regular and 10 associate members working at 9 different universities in Québec, Ontario, the United Kingdom, and France. The members of the Laboratory work in the following areas: harmonic analysis, complex analysis and several complex variables, potential theory, functional analysis, Banach algebras, microlocal analysis, analysis on manifolds, nonsmooth analysis, spectral theory, partial differential equations, geometric analysis, ergodic theory and dynamical systems, control theory, mathematical physics, applied mathematics, probability, nonlinear analysis, nonlinear differential equations, topological methods in differential equations, fluid dynamics, and turbulence.

News and highlights

Robert Seiringer received an E.W.R. Steacie Memorial Fellowship award in 2012. Laboratory members coorganized a series of lectures by Tadashi Tokieda (Cambridge) that took place in April 2012. Obviously Laboratory members devoted much time and energy to the organizing of the thematic semester on "Geometric Analysis and Spectral Theory", which took place at the CRM in 2012. The semester featured 6 workshops (including one in June 2012 and one in July 2012) and series of lectures by three Aisenstadt chairs. The interested reader will find reports on all those activities in the section Thematic Program. Some Laboratory members were also among the organizers of the Summer School (SMS) on "Metric Measure Spaces: Geometric and Analytic Aspects" (CRM, June 27–July 8, 2011). Some members of the Analysis Laboratory (e.g., Galia Dafni, Javad Mashreghi, and Vojkan Jakšić) were successful in attracting external funding for hosting visitors from France.

Students, postdoctoral fellows, and visitors

In the 2011–2012 academic year 3 undergraduate students, 38 M.Sc. students, 43 Ph.D. students, and 19 postdoctoral fellows were supervised or cosupervised by members of the Mathematical Analysis Laboratory.

Seminars

The members of the Mathematical Analysis Laboratory organize several seminars at four main locations. The Université Laval hosts an Analysis Seminar, which featured 15 talks in 2011-2012. Alina Stancu (Concordia), Alexey Kokotov (Concordia), and Dmitry Jakobson (McGill) jointly organized the McGill/Concordia Analysis Seminar, which featured 38 talks in 2011–2012. Dmitry Jakobson and Iosif Polterovich (Université de Montréal) organized a seminar in spectral theory that included 20 meetings. The Seminar on geometric and computational topology held at the Université de Sherbrooke featured one talk in 2011–2012 and the McGill/Concordia Working seminar in analy-

sis featured two talks (during the winter of 2012). In addition, eight CRM-ISM Colloquium speakers were invited by Laboratory members.

Workshops, special sessions, and others

Apart from the SMS and the thematic semester workshops mentioned above, the Laboratory sponsored the following event, whose report is included in the section General Program.

Complex Analysis and Potential Theory
A Conference in Honour of Paul M. Gauthier and Kohur Gowrisankaran
June 20–23, 2011, CRM
Organizers: André Boivin (Western Ontario), Javad Mashreghi (Laval)

Vojkan Jakšić and Robert Seiringer, both of them Laboratory members, were among the organizers of the following school, whose report is also to be found in the section General Program.

Summer School on Non-Equilibrium Statistical Mechanics
July 1–29, 2011, CRM
Organizers: Laurent Bruneau (Cergy-Pontoise), Vojkan Jakšić (McGill), Roberto Livi (Firenze), Claude-Alain Pillet (Toulon), Robert Seiringer (McGill)

Members of the Laboratory

Regular members

Dmitry Jakobson (McGill), Director
Pure mathematics, global analysis, spectral geometry, quantum chaos, harmonic analysis, eigenvalues and eigenfunctions

Line Baribeau (Laval)
Complex and functional analysis, Banach algebras, holomorphic iterations, discrete groups

Abraham Boyarsky (Concordia)
Dynamical systems

Francis H. Clarke (Lyon 1)
Nonlinear and dynamic analysis, control theory, calculus of variations

Galia Dafni (Concordia)
Harmonic analysis, partial differential equations, complex variables

Donald A. Dawson (Carleton)
Probability, stochastic processes

S. W. Drury (McGill)
Harmonic analysis, matrix theory

Richard Fournier (Dawson & CRM)
Complex analysis, function theory

Marlène Frigon (Montréal)
Nonlinear analysis, differential equations, fixed point theory, critical point theory, multivalent analysis

Paul M. Gauthier (Montréal)
Complex analysis, holomorphy, harmonicity, analytic approximation

Pawel Gora (Concordia)
Ergodic theory, dynamical systems, fractal geometry

Frédéric Gourdeau (Laval)
Banach algebras, cohomology, amenability, functional analysis

Vojkan Jakšić (McGill)
Mathematical physics, quantum statistical mechanics, random Schrödinger operators

Tomasz Kaczynski (Sherbrooke)
Topological methods, Conley index, applications to dynamical systems

Ivo Klemes (McGill)
Harmonic analysis, trigonometric series

Alexey Kokotov (Concordia)
Spectral geometry of Riemann surfaces, hyperbolic partial differential equations

Paul Koosis (McGill)
Harmonic analysis

Javad Mashreghi (Laval)
Complex analysis, harmonic analysis, Hardy spaces

Iosif Polterovich (Montréal)
Geometric analysis, spectral theory, functional analysis, differential geometry, partial differential equations

Thomas J. Ransford (Laval)
Complex and harmonic analysis, functional analysis and theory of operators, spectral analysis, potential theory

Dominic Rochon (UQTR)
Complex analysis, hypercomplex numbers

Jérémie Rostand (Laval)
Complex analysis, experimental mathematics

Christiane Rousseau (Montréal)
Dynamical systems, bifurcations, qualitative theory, polynomial systems, analytic invariants, integrable systems

Dana Schlomiuk (Montréal)
Global analysis, dynamical systems, singularities, bifurcations, algebraic curves, primary integral

Robert Seiringer (McGill)
Many-body quantum systems, Bose-Einstein condensates

Alexander Shnirelman (Concordia)
Applications of geometric analysis to fluids and "weak" solutions of the Euler and Navier-Stokes equations

Alina Stancu (Concordia)
Geometric analysis

Ron J. Stern (Concordia)
Functional analysis and theory of operators, linear and nonlinear systems, non-smooth analysis, stability, optimal order

John A. Toth (McGill)
Spectral theory, semi-classical analysis, microlocal analysis, Hamiltonian mechanics

Associate members

Octavian Cornea (Montréal)
Algebraic topology, dynamical systems

Richard Duncan (Montréal)
Ergodic theory, martingale theory, probability theory in Banach spaces

Kohur Gowrisankaran (McGill)
Potential theory

Pengfei Guan (McGill)
Partial differential equations, geometric analysis, several complex variables

John Harnad (Concordia)
Mathematical physics, classical and quantum physics, geometrical methods, integrable systems, group theoretical methods, random matrices, isomonodromic deformations, isospectral flows

Niky Kamran (McGill)
Geometric approach to partial differential equations

Dmitry Korotkin (Concordia)
Integrable systems, isomonodromic deformations, classical and quantum gravity, Frobenius varieties

Nilima Nigam (Simon Fraser)
Applied analysis, numerical methods in electromagnetism

Yiannis N. Petridis (University College London)
Automorphic forms and their spectral theory, analytic number theory, spectral and scattering theory of manifolds

Samuel Zaidman (Montréal)
Functional analysis and differential equations in abstract spaces, pseudo-differential operators

Mathematical Physics

Description

The mathematical physics group is one of the oldest and most active at the CRM. It consists of 18 regular members, 8 local associate members, all full-time faculty members at one of the participating universities, and 6 external associate members working permanently at universities and research laboratories in Europe or the United States. The group carries out research in many of the most active areas of mathematical physics: coherent nonlinear systems in fluids, optics, and plasmas; classical and quantum integrable systems; the spectral theory of random matrices; percolation phenomena; conformal field theory; quantum statistical mechanics; spectral and scattering theory of random Schrödinger operators; quasi-crystals; relativity; spectral transform methods; foundational questions in quantization; asymptotics of eigenstates; coherent states; wavelets; supersymmetry; the symmetry analysis of PDEs and difference equations; representation theory of Lie groups and quantum groups; and the mathematical structure of classical and quantum field theories.

News and highlights

Professor Alexander Maloney, of the physics department at McGill University, became an associate member in March 2012. Professor Alexander Turbiner (Instituto de Ciencias Nucleares, UNAM, Mexico) and Peter Zograf (Steklov Mathematical Institute, St. Petersburg) also became associate members (in this case, external associate members) in March, 2012.

Laboratory members received many prizes and distinctions in 2011–2012. Marco Bertola was accorded the Dean's Award for Distinguished Scholarship at Con-

cordia University in November 2011. Robert Brandenberger held a Killam Research Fellowship until August 2011. He was also awarded the CAP/CRM Prize for Mathematical Physics in 2011. Michel Grundland's paper, coauthored with Sarah Post and entitled "Generalized symmetries of integrable equations and soliton surfaces" (J. Phys. A: Math. Theor. 44, 165203) was chosen for inclusion in the Institute of Physics (IOP) Select list. John Harnad was reappointed for a further three years as Affiliate Member, Perimeter Institute of Theoretical Physics, and also as Fellow of the Science College, Concordia University. Other Lab members who have been named affiliates of the Perimeter Institute are: Robert Brandenberger, Keshav Dasgupta, Alexander Maloney, Manu Paranjape, and Johannes Walcher.

Yvan Saint-Aubin won the Excellence in Teaching Award of the Canadian Mathematical Society in 2011. In 2011–2012 Jacques Hurtubise served as President of the Canadian Mathematical Society. Robert Seiringer was awarded a Steacie Memorial Fellowship by NSERC in 2012, and a Willian Dawson Scholarship at McGill. Pavel Winternitz was awarded the Česká Hlava Prize on November 18, 2011, for two cycles of articles on superintegrable systems and on symmetries of difference equations. He was also awarded the Best Paper Prize by the *Journal of Physics A* for the paper "An infinite family of solvable and integrable quantum systems on a plane" (together with Frédérick Tremblay and Alexander Turbiner). Luc Vinet was awarded the CAP-CRM Prize for 2012 (see the section CRM Prizes).

Several Laboratory members were also appointed to editorial or scientific governing boards in 2011–2012. For instance John Harnad was named member of the editorial board of the new journal *Analysis and Mathematical Physics*, published by Springer Verlag. Bertrand Eynard was named member of the board of the journal *Random Matrices, Theory and Applications* (World Scientific). Robert Seiringer continued to be Associate Editor for *Letters in Mathematical Physics* and member of the editorial boards of the *Journal of Statistical Physics* and the *Journal of Mathematical Physics*.

Invited talks by Laboratory members at international conferences and workshops in 2011–2012 are too numerous to be all listed here but we will mention some of them.

• Syed Twareque Ali was an invited plenary lecturer (giving an Expository Quantum Series of five lectures) at Putra University, Selangor, Malaysia (January 9–13, 2012).

• Marco Bertola was an invited lecturer at the Winter School on Random Matrices and Integrable Systems (Les Houches, France, March 4-9, 2012).

• Robert Brandenberger gave invited lectures at a number of international workshops and conferences in 2011–2012, in particular: "Scenarios of Early Universe Cosmology: Physical and Philosophical Challenges" (Workshop on Philosophy of Cosmology, Granada, Spain, September 22–23, 2011), and "Fluctuations in Non-Singular Bouncing Cosmologies from Type II Superstrings" (Workshop on String Theory and Cosmology, Pennsylvania, March 16–18, 2012).

• Robert Conte was invited to give a lecture at the "Geometrical Methods in Mathematical Physics" International Conference (Moscow State University, December 12–17, 2011).

• Keshav Dasgupta was an invited lecturer at the Great Lakes String Conference (Chicago, April 29–May 1, 2011).

• Bertrand Eynard was an invited speaker at the workshop "Stochastic Analysis" at Oberwolfach on May 29–June 4, 2011, and at the Moscow, September 2011 workshop on Random Processes, Conformal Field Theory and Integrable Systems. He also gave an invited lecture series on "Map Enumerations" at the Summer School in Random Geometry (Iceland, August 2011).

• Jean-Pierre Gazeau gave an invited talk entitled "Frame quantization or exploring the world like a starfish" at the conference FLAME12 (Acoustics Research Institute, Vienna, May 2012).

• Michel Grundland was an invited speaker at the International Conference on Quantum Theory and Symmetries 7 (Prague, August 2011).

• John Harnad gave the invited talk "Tau functions and convolution symmetries" at the XIIIth International Conference on Geometry, Integrability and Quantization (Varna, Bulgaria, June 3–8, 2011). He was also an invited participant at the Program on Complex Analysis and Integrable Systems held at the Mittag-Leffler Institute (Stockholm, September 9–November 30, 2011).

• Jacques Hurtubise gave invited talks at the Newton Insitute and the University of Leeds (in the summer of 2011).

• Dmitry Korotkin gave invited talks at the conference "Painlevé equations and related topics" (Euler International Mathematical Institute, St. Petersburg, Russia, June 17–23, 2011), at the conference "Geometrical Methods in Mathematical Physics" (Moscow State

University, Moscow, December 12–17, 2011), and at the AMS Special Session on "Algebraic and Geometric Aspects of Integrable Systems and Random Matrices" (Boston, January 5–7, 2012).

• Manu Paranjape was an invited speaker at the 2011 CAP congress (St. John's, Newfoundland, June 13–17, 2011).

• Luc Vinet gave invited talks at the International Conference on Asymptotics and Special Functions (Hong Kong, China, May 29–June 3, 2011), the OPSFA 11 conference on Orthogonal Polynomials, Special Functions and Applications (Madrid, Spain, August 29–September 2, 2011), the International Conference on Special Functions and Orthogonal Polynomials of Lie Groups and their Applications (Decin, Czech Republic, August 14–20, 2011), and the conference on Quantum Theory and Symmetries 7 (Prague, Czech Republic, August 7–13, 2011).

• Pavel Winternitz gave the closing talk ("Review of current status of Superintegrability, Symmetries and Perturbation Theory (SPT)") at the conference on Symmetries and Perturbation Theory (Otranto, Italy, June 5–12, 2011), an invited talk ("Superintegrability with higher order integrals of motion") at the conference on Quantum Theory and Symmetries 7 (Prague, Czech Republic, August 7–13, 2011), and an invited talk on superintegrability at the Symposium on Superintegrability, Exact Solvability, and Special Functions (Cuernavaca, México, February 21–24, 2012).

Students, postdoctoral fellows, and visitors

The following were the postdoctoral fellows and research associates working under the supervision of one or more of the regular members of the Laboratory (the names of the supervisors are listed in brackets): Ferenc Balogh (J. Harnad); Alexander Bihlo (P. Winternitz); Tiago Dinis da Fonseca (M. Bertola, J. Harnad); Melita Hadzagic (J. Patera); Caroline Kalla (D. Korotkin, V. Shramchenko); Aleksi Kurkela (R. Brandenberger); Josh Lapan (R. Brandenberger, J. Walcher); Shunji Matsuura (R. Brandenberger, K. Dasgupta, J. Walcher); Sarah Post (A. Grundland, L. Vinet, P. Winternitz); Danilo Riglioni (P. Winternitz); Pat Scott (R. Brandenberger); Jihye Seo (R. Brandenberger, K. Dasgupta, J. Walcher, J. Harnad); Marzena Szajewska (J. Patera); Brett Underwood (R. Brandenberger); Yi Wang (R. Brandenberger); Matthias Westrich (V. Jakšić, R. Seiringer); Guofo Yu (L. Vinet).

The former students and postdoctoral fellows of the PhysMath Laboratory are doing well. Oksana Yermolayeva received a renewal of her Marie Curie Research Fellow position (Université Paris 6) for 2011–2012. In the summer of 2011, Mattia Cafasso was appointed maître de conférences at the Université d'Angers. Seung-Yeop Lee was appointed Assistant Professor at the University of Southern Florida after having completed his appointment as Sherman Fairchild Research Fellow at Caltech. Dong Wang continued a similar extended research appointment at the University of Michigan. In 2011–2012 Benjamin Young continued an extended postdoctoral appointment in Stockholm; in 2012 he was appointed assistant Professor at the University of Oregon. Olivier Marchal continued his postdoctoral position at the University of Alberta, begun in January 2011; he was appointed maître de conférences at the Institut Camille Jordan (Lyon). Tiago Dinis da Fonseca was recruited for a further postdoctoral appointment by the Laboratoire de Physique Théorique (CNRS, Université de Savoie). Ferenc Balogh obtained a further postdoctoral appointment at the Scuola Internazionale Superiore di Studi Avanzate (SISSA) in Trieste. In 2012 Sarah Post was named Assistant Professor in the Mathematics Department of the University of Hawaii at Monoa.

In the period between June 2011 and August 2012 there were a total of 38 scientific visitors at the PhysMath Laboratory. These included seminar speakers, collaborators in joint research projects, and external associate members. In the 2011–2012 academic year 11 undergraduate students, 29 M.Sc. students, 44 Ph.D. students, and 27 postdoctoral fellows were supervised or cosupervised by members of the Mathematical Physics Laboratory.

Seminars

The usual weekly Seminar Series in Mathematical Physics took place at the CRM every Tuesday afternoon from September 2011 until May 2012, with active participation by members, visitors, postdoctoral fellows, and students. Yvan Saint-Aubin was the organizer of this seminar series in 2011–2012. Approximately half the talks were given by visiting invited speakers, and the rest by regular and associate Laboratory members, postdoctoral fellows, and Laboratory visitors. In addition, the Working Seminar on Integrable Systems, Random Matrices, Random Processes continued, taking place every Thursday afternoon at

Concordia, with active participation of many Laboratory members, postdoctoral fellows, students, and visitors. In 2011–2012 this seminar was organized by Tiago Dinis da Fonseca.

Workshops and Special Sessions

We mention here some of the events organized by Laboratory members.

• Syed Twareque Ali was coorganizer of the XV International Workshop on Wavelets, Differential Equations, Number Theory, Mechanics and Applications (University of Havana, February 20–24, 2012).

• Marco Bertola was coorganizer of the workshop on Formal and Analytic Solutions of Differential and Difference Equations (Banach Mathematical Research and Conference Center, Bedlewo, Poland, August 2011).

• Robert Brandenberger was the main organizer of the BIRS 5-day workshop entitled "Self Adjoint Extensions and Singularity Resolution in String Theory and Quantum Gravity" (BIRS, Canada, August 21–26, 2011).

• Jacques Hurtubise was coorganizer of the workshop "Advances in hyperkähler and holomorphic symplectic geometry" (BIRS, Canada, March 11–16, 2012).

• Robert Seiringer was coorganizer of the summer school "Current Topics in Mathematical Physics" at the Erwin Schrödinger Institute (Vienna, Austria, August 16–24, 2011).

• Johannes Walcher was a coorganizer of the workshop "Hodge theory and string duality" (BIRS, Canada, December 4–9, 2011).

Members of the Laboratory

Regular members

John Harnad (Concordia), Director
Mathematical physics, classical and quantum physics, geometrical methods, integrable systems, group theoretical methods, random matrices, isomonodromic deformations, isospectral flows

S. Twareque Ali (Concordia)
Coherent states, wavelets, quantization techniques, harmonic analysis, Wigner functions

Marco Bertola (Concordia)
Axiomatic quantum field theory, invariant theory of discrete groups, random matrices, isomonodromic deformations

Robert Brandenberger (McGill)
Theoretical Cosmology

Keshav Dasgupta (McGill)
Heavy ion collision theory in the energy range 30MeV/nucleon to many GeV/nucleon

Alfred Michel Grundland (UQTR)
Symmetry of differential equations in physics

Richard L. Hall (Concordia)
Spectra of Schrödinger, Klein-Gordon, Dirac and Salpeter operators, many-body problems, relativistic scattering theory, iterative solution to ODEs and boundary-value problems

Jacques Hurtubise (McGill)
Algebraic geometry, integrable systems, gauge theory, moduli spaces

Véronique Hussin (Montréal)
Group theory, Lie algebras and applications in physics, supersymmetries in classical and quantum mechanics

Dmitry Korotkin (Concordia)
Integrable systems, isomonodromic deformations, classical and quantum gravity, Frobenius varieties

Pierre Mathieu (Laval)
Conformal field theory, classical and quantum integrable systems, affine Lie algebras

Manu Paranjape (Montréal)
Theoretical particle physics: field theory, solitons, noncommutative geometry, alternative gravity

Jiří Patera (Montréal)
Applications of group theory, quasi-crystals, Lie algebras

Yvan Saint-Aubin (Montréal)
Conformal field theory, statistical mechanics, 2-dimensional phase transition model

Robert Seiringer (McGill)
Quantum many-body systems, Bose-Einstein condensates, Ginzburg-Landau theory, Gross-Pitaevskii theory, bosons

Vasilisa Shramchenko (Sherbrooke)
Frobenius manifolds, integrable systems, Riemann-Hilbert problems, isomonodromic deformations of systems of linear differential equations, function theory on Riemann surfaces

Luc Vinet (Montréal)
Symmetry properties of systems, special functions

Johannes Walcher (McGill)
Mirror symmetry for open strings, non-geometric string compactifications

Pavel Winternitz (Montréal)
Methods of group theory in physics, nonlinear phenomena, symmetries of difference equations, superintegrability

Associate members

Robert Conte (CEA/Saclay)
Integrable and partially integrable systems, Painlevé analysis, exact solutions, finite difference equations

Chris Cummins (Concordia)
Group theory, modular functions, moonshine

Stéphane Durand (Édouard-Montpetit)
Classical and quantum physics, mathematical physics, symmetries, parasupersymmetries, fractional supersymmetries, KdV equations, quantum mechanics, relativity

Bertrand Eynard (CEA/Saclay)
Matrix models, integrable systems, string theory, relationship between matrix models, integrability, and algebraic geometry

Jean-Pierre Gazeau (Paris Diderot)
Coherent states, wavelets, relativistic quantum frames, symmetry groups for beta-lattices

Alexander Its (IUPUI)
Soliton theory, integrable systems, special functions, mathematical physics

Dmitry Jakobson (McGill)
Pure mathematics, global analysis, spectral geometry, quantum chaos, harmonic analysis, eigenvalues and eigenfunctions

Vojkan Jakšić (McGill)
Mathematical physics, quantum statistical mechanics, random Schrödinger operators

Niky Kamran (McGill)
Geometric approach to partial differential equations

François Lalonde (Montréal)
Symplectic topology and geometry, global analysis on manifolds, Hamiltonian systems

Decio Levi (Roma Tre)
Symmetries of differential and difference equations, integrable nonlinear equations on the lattice and reductive perturbation theory on the lattice

Alexander Shnirelman (Concordia)
Applications of geometrical analysis to fluids and "weak" solutions of the Euler and Navier-Stokes equations

John A. Toth (McGill)
Spectral theory, semi-classical analysis, microlocal analysis, Hamiltonian mechanics

Carolyne M. Van Vliet (Montréal & Miami)
Non-equilibrium statistical mechanics, fluctuations and stochastic processes, quantum transport in condensed matter, electronic behavior in submicron quantum devices

PhysNum

Description

Applied mathematics now plays an important role in the biomedical field and especially the neurosciences. The research activity at PhysNum has two main themes: pharmacometrics and brain imaging. In particular

- Jean-Marc Lina (École de technologie supérieure) and Habib Benali (Université Pierre et Marie Curie) work on the multimodal imaging of the spinal cord;
- Lina and Christophe Grova (McGill University) work on multiresolution and multimodal imaging in magneto-electrophysiology;
- Benali and Maxime Descoteaux (Université de Sherbrooke) study models of the anatomical and functional connectivity of the brain;
- Grova studies neurovascular models in epilepsy;
- Lina studies sparse representations, inverse problems, and brain wave synchronization; and
- Lina analyzes scale-invariant processes in electrophysiology.

Fahima Nekka and her team conduct research in pharmacometrics, a discipline whose goal is to interpret and describe pharmacological phenomena in a quantitative manner, so as to support rational therapeutic decisions and improvement of patient health. They have developed a whole framework of probabilistic pharmacometrics in which different sources of variability and the nonlinearity of the system are accounted for. The team is working on compliance metrics and ranking and on direct and inverse problems related to patient drug behaviour and the therapeutic effect of drugs. It

is conceiving tools that shed new light on drug development and evaluation in terms of efficacy and bioequivalence; revisiting classical concepts in pharmacology and updating their formulation; developing models for drug interactions; integrating physiology with behaviour to create a real fingerprint of drugs; integrating advanced hematopoietic models with PK/PD to improve concurrent therapy consisting of oncological drugs and their adjuvants.

News and highlights

Here are a few of the current projects of PhysNum members.

• One of the main research endeavours of PhysNum researchers is the development of mathematical models in multimodal brain imaging, with the goal of understanding brain plasticity in humans. There are numerous applications of this research: sleep and aging (Lina); the consequences of a brain or spinal cord trauma (Benali); diagnosis of Alzheimer's Disease (Benali); preoperative investigation in the case of intractable epilepsy (Grova).

• An MRI methodology has been developed for obtaining high-resolution images of the cat's spinal cord. PhysNum researchers have applied this methodology to cats with complete and partial spinal injuries and showed that the injuries can be identified in a robust fashion and the integrity of white matter can be quantified. They have extended their results to humans by using MRIs with 3 teslas.

• Lesage and Benali have used diffuse imaging for visualizing the cat's spinal cord and demonstrated that metabolic activities can be quantified.

• Lina and Grova are trying to detect the sources of epileptic activity in drug-resistant patients. To do this they are using multiscale approaches for producing functional images relevant to a sparse representation of the cortical activity. These approaches enable one to locate precisely the generators of fast oscillations that characterize epilepsy.

• Fahima Nekka and her team are developing and adapting mathematical methodologies for drug evaluation and use.

• Fahima Nekka and her team are studying the variability in drug use and its therapeutic consequences.

Students

In the 2011–2012 academic year 19 M.Sc. students, 12 Ph.D. students, and 8 postdoctoral fellows were supervised or cosupervised by PhysNum members. Among the students of the brain imaging group within PhysNum, let us mention C. Bonnery (M.Sc.); T. Hedrich (M.Sc.); J. Godbout (M.Ing.); Y. Zérouali (Ph.D.); R. Chowdhury (Ph.D.); A. Machado (Ph.D.); P. J. Toussaint (doctoral student at LINeM); and C. Matteau-Pelletier (Ph.D.).

Members of the Laboratory

Regular members

Jean-Marc Lina (ÉTS), Director
Wavelets, statistical modelling and brain imaging, machine learning

Alain Arnéodo (ÉNS Lyon & CNRS)
Fractals and wavelets

Habib Benali (UPMC)
Quantitative analysis in brain imaging, medical imaging and multimodal systems

Maxime Descoteaux (Sherbrooke)
Medical imaging, image analysis and processing, computer vision, applied mathematics

Christophe Grova (McGill)
Statistical signal processing, localization of epileptic spikes using distributed sources modelling, and multimodal analysis of EEG source localization and simultaneous EEG-fMRI data analysis

Frédéric Lesage (Polytechnique Montréal)
Conformal theory, integrable systems, inverse problems, optical imaging

Fahima Nekka (Montréal)
Pharmacokinetics, development of mathematical tools from fractal geometry and harmonic analysis for extracting information, applications to pharmacology and medicine

Statistics

Description

Statistics is central to many endeavours in society. Be it through surveys from sampling, clinical trials to study various biomedical treatments, or experimental designs in agriculture or industry, statistical methodology can be found everywhere in science. Recently, statistics has undergone a revolution in its techniques and approaches. This revolution has been driven by the need to analyze very large data sets and data with more complex structure, and by the advent of powerful computers. For example, statistical methodology is now addressing problems whose structure is very complex, such as the analysis of brain images or genome data, and new methodology is being developed, such as data mining, for large data sets. Note that the name of the Laboratory must be interpreted broadly, as some of its members are actuaries, probabilists, or biostatisticians.

One of the aims of the Laboratory is to structure the Québec statistical community so that it can participate in this revolution at a time when an important renewal of academic personnel is taking place. This structure allows the Québec community to participate in Canada-wide programs organized by the three Canadian mathematics institutes. The Laboratory is formed of the leaders of the Québec school of statistics, who work on topics such as statistical learning and neural networks, survey sampling, analysis of functional data, statistical analysis of images, dependence structures, Bayesian analysis, analysis of time series and financial data, and resampling methods.

News and highlights

On May 31, 2012, L.-P. Rivest completed a 5th year as Laboratory Director. C. Genest replaced him on June 1st. This decision was ratified by a unanimous vote held in April. A vote of thanks to L.-P. Rivest was recorded at a regular meeting of Laboratory members on April 13, 2012.

The Statistics Laboratory is a highly distinguished group. It is home, among others, to three winners of the Statistical Society of Canada's prestigious Gold Medal, three Canada Research Chairs, and the holder of a James McGill Chair. There were also some important nominations this past year.

- N. Ghazzali was appointed Rector of the Université du Québec à Trois-Rivières for a 5-year term, effective February 1, 2012.
- C. Léger became President of the Statistical Society of Canada, effective July 1, 2012.
- C. Genest was appointed Director of the Institut des sciences mathématiques for a three-year term, effective June 1, 2012.
- R. Steele became President of the Biostatistics Section of the Statistical Society of Canada for a one-year term, effective July 1, 2012.
- Independently of the above, R. Steele is now serving as Director of the Electronic Services for the Statistical Society of Canada, and he was recently appointed chair of the Graduate Affairs Committee in the Department of Mathematics and Statistics at McGill.
- É. Marchand was appointed to NSERC's Evaluation Group 1508: Mathematics and Statistics for a three-year term, effective July 1, 2012.

In 2011–2012 Laboratory members received many honours and awards. Among them we would like to mention the following.

- J. O. Ramsay became the 38th Honorary Member of the Statistical Society of Canada (SSC) in June 2012 (26 of them are alive; the SSC has over 1000 members).
- C. Genest became (after L.-P. Rivest last year) the second Honorary Member of the Association des statisticiennes et statisticiens du Québec (ASSQ) in June 2012.
- R. Platt received a prestigious award as a "Chercheur national" from the Fonds de recherche en santé du Québec (FRSQ). This high-profile research funding and salary supplement program recognizes the excellence of a limited number of outstanding researchers.
- T. Duchesne was the only Canadian to become a member of the International Statistical Institute this year. Membership in the ISI is by cooptation only; places are limited.
- Y. Bengio received an award for his "Manifold Tangent Classifier" at the 25th Annual Conference on Neural Information Processing Systems (held in Granada, Spain, in December 2011). Furthermore he won the first place in the Transfer Learning Challenge at this conference's workshop on "Challenges in Learning Hierarchical Models: Transfer Learning and Optimization."

• Y. Bengio also won the first place in the final phase of the 2011 Unsupervised and Transfer Learning Challenge, an international machine learning competition.

• D. Dupuis and B. Rémillard were awarded Research Professorships at HEC Montréal for the period 2012–2015. Their positions are in Statistics and Financial Engineering, respectively.

• D. Dupuis received "Le prisme," an annual award given to a graduate of the Faculty of Science at the Université de Moncton who distinguished him/herself in a science career.

• J. Garrido was the 2011–2012 recipient of the Dean's Award for Academic Service in the Faculty of Science at Concordia University.

• D. Haziza won a prestigious, university-wide "Prix d'enseignement" at the Université de Montréal for 2012. In 2011, he had already been awarded a similar prize by the Faculté des arts et des sciences of the same university.

• The textbook entitled *Le logiciel R, maîtriser le langage - effectuer des analyses statistiques* (ISBN: 978-2-8178-0114-8) by the Laboratory member P. Lafaye de Micheaux and his coauthors (R. Drouilhet and B. Liquet) was the runner-up for the 2012 Prix Roberval, an international award given yearly to a work (book, multimedia, etc.) written in the French language and aimed at disseminating technology.

Finally we list below some of the special addresses, plenary talks, and publications by Laboratory members, as well as some of the major events organized by them.

• C. Genest gave the Gold Medal Address at the 40th Annual Meeting of the Statistical Society of Canada in Guelph, Ontario, June 5, 2012. He was also the keynote speaker at an international workshop on "Copulas in Mathematical and Quantitative Finance" held in Kraków, Poland, July 10-11, 2012, as well as plenary speaker at the 5th Canadian Conference in Applied Statistics held in Montréal, July 1-4, 2011.

• Y. Bengio gave an invited talk at the 49th Annual Meeting of the Association for Computational Linguistics held in Portland, Oregon, in June 2011. He also gave an invited lecture at the 2012 Graduate Summer School on Deep Learning organized by the Institute for Pure and Applied Mathematics at the University of California in Los Angeles.

• J. Garrido gave the keynote lecture at the 2nd Québec-Ontario Workshop on Insurance Mathematics, held at the Fields Institute in Toronto, on February 2, 2012. J. Garrido also gave an invited lecture at the CCRM and AFOSR Workshop on Catastrophic Risks held in Stanford, California, in June 2012.

• D. Haziza gave a plenary talk on the treatment of influential observations in surveys at the "Journées de méthodologie statistique" held in Paris, France, in January 2012.

• P. Lafaye de Micheaux gave a plenary talk on the use of the R software in neuro-imaging at the "Premières rencontres R" held in Bordeaux, France, in June 2012.

• M. Morales gave a plenary talk at the 10th International Conference on Operations Research held in La Habana, Cuba, in 2012.

• Y. Chaubey was cochair of both the Scientific Program Committee and the Local Organizing Committee for the 5th Canadian Conference in Applied Statistics held in Montréal, on July 1-4, 2011. He was also a member of the Program Committee and an invited speaker at the 5th International Conference of the Institute for Mathematics, Bioinformatics, Information Technology and Computer Science (IMBIC) held in Kolkota, India, in December 2011.

• D. Dupuis was appointed chair of the Program Committee for the 41st Annual Meeting of the Statistical Society of Canada, to be held in Edmonton, Alberta, on May 26-29, 2013.

• A. Murua was a member of the Program Committee for an International Conference on Signal Processing and Multimedia Applications (SIGMAP) held in Seville in 2011. He is serving in the same capacity for the 2012 meeting of SIGMAP in Rome.

• The Laboratory was well represented at the 8th World Congress in Probability and Statistics, held in Istanbul, Turkey, on July 10-15, 2012. J. Nešlehová organized an Invited Paper Session on Dependence Modeling and L. Popovic and B. Rémillard were invited speakers at two different sessions of the meeting.

• M. Asgharian organized an Invited Paper Session at the 40th Annual Meeting of the Statistical Society of Canada, held in Guelph (Ontario) last June.

• Y. Bengio was invited to give a tutorial on representation learning at the 2012 International Conference on Machine Learning held in Edinburgh, Scotland, and another tutorial on deep learning for neurolinguistic programming at the 50th Annual Meeting of the Association for Computational Linguistics held on Jeju Island, Korea, in July 2012.

• D. Haziza gave a one-day workshop on the use of auxiliary information through balanced sampling and calibration at the International Conference on Established Surveys held in Montréal in June 2012. He was also invited by the Société française de statistique to give a two-day workshop on the treatment of nonresponse in surveys at the Institut Pierre-et-Marie-Curie in Paris, in December 2011.

• C. Genest and J. Nešlehová gave a two-day workshop on dependence modelling at the Scottish Financial Risk Academy in Edinburgh, Scotland, in May 2012.

• In June 2012, A. Khalili gave an invited half-day workshop on "Joint fixed and random effect selection in finite mixtures of linear mixed effect models" at Tehran's University of Medical Sciences, in Iran.

• É. Marchand recently coedited (with D. Fourdrinier and A. Rukhin) a special volume entitled "Contemporary Developments in Bayesian Analysis and Statistical Decision Theory: A Festschrift for William E. Strawderman" (Inst. Math. Statist. Beachwood, OH, USA, 256 pp.).

• Four Laboratory members (C. Genest, D. Dupuis, J. Nešlehová, and B. Rémillard) and two others (J.-F. Plante from HEC Montréal; J.-F. Quessy from UQTR) coedited a special issue of the *Journal of Multivariate Analysis* (vol. 110, 2012) on Copula Modeling and Dependence. This issue (188 pp.) features 12 papers presented during the workshop of the same name organized for the Statistics Thematic Semester, in June 2011.

Students, postdoctoral fellows, and visitors

The Statistics Laboratory is proud to report that 38 M.Sc. students and 15 Ph.D. students completed their degrees between August 1, 2011, and August 31, 2012. In addition there are several student success stories, described below.

• Concordia M.Sc. student W. Liu received the best M.Sc. Thesis award at the IFM2 Mathematical Finance Days Conference in May 2012.

• Concordia M.Sc. student M. Wenger was awarded an NSERC CDSD3 Award in the 2012 Competition.

• UQAM M.Sc. student M.-H. Descary was awarded a Ph.D. position at the École polytechnique fédérale de Lausanne (these positions are rare and very well paid). She was also invited to give a talk at the Canadian Human and Statistical Genetics Meeting held at Niagara-on-the-Lake (April 29 to May 2, 2012).

• UQAM M.Sc. student M. Dupont won the first prize in the category Statistical Genetics for a poster presented at the Canadian Human and Statistical Genetics Meeting held at Niagara-on-the-Lake (April 29 to May 2, 2012).

• McGill (Biostatistics) Ph.D. student M. Schnitzer received a Bourse de stage international from FRQNT to spend a term at the University of California (Berkeley) in September 2011. She also received full funding to support her travel to Bristol, UK, to present her research at the workshop on "Time for Causality - Causal Inference and Dynamic Decisions in Longitudinal Studies."

In the course of the year 2011–2012 the Laboratory welcomed several postdoctoral fellows (whose advisors are listed within parentheses): E. Acar (C. Genest and J. Nešlehová); W. Astle (A. Labbe and D. Stephens); A. Carabarin (C. Genest and B. Rémillard); O. Kortbi (É. Marchand); O. Saarela (E. Moodie and D. Stephens); and R. Samb (S. Froda). Note that E. Acar became an Assistant Professor of Statistics at the University of Manitoba, effective July 1, 2012.

In the 2011–2012 academic year one undergraduate student, 121 M.Sc. students, 88 Ph.D. students, and 13 postdoctoral fellows were supervised or cosupervised by members of the Statistics Laboratory.

Seminars

The Laboratory members organize, and participate in, seven regular series of seminars.

(1) CRM–ISM–GERAD Statistics Colloquium: eight colloquia were held this year, namely on Friday September 9, October 14, November 11, and December 9, 2011, as well as on Friday January 13, February 10, March 9, and April 13, 2012. The organizers were M. Bédard (Montréal), S. Guillotte (UQAM), A. Khalili (McGill), J. Nešlehová (McGill), and L. Popovic (Concordia). Each colloquium was organized around a specific theme; it consisted of two one-hour talks (one talk only in December and January), with a 30-minute break in between and a reception at the end. There were between 40 and 60 attendees on each occasion;

(2) The McGill Statistics Seminar Series: this seminar was held at McGill on Friday afternoons in weeks where there was no colloquium. The organizer was J. Nešlehová. Talks were 60 minutes in length, including a question period (in two cases, two talks

of one half-hour each by graduate students were scheduled on the same day). There were 23 speakers during the year and the attendance varied between 25 and 40 persons;

(3) The McGill Biostatistics Seminar Series: this seminar was organized by the McGill Department of Epidemiology, Biostatistics and Occupational Health and took place on Tuesday afternoons. The organizer was J. Atherton and there were 24 speakers during the year;

(4) The Université Laval Statistics Colloquium: this seminar was generally held at Université Laval on Thursday afternoons in 2011–2012. Its organizers were T. Duchesne and L. Lakhal Chaïeb. There were 19 speakers during the year and the attendance varied between 15 and 40 persons;

(5) The Université de Sherbrooke Statistics Seminar: this seminar series comprised 4 talks in the Fall term and 6 in the Winter term. Its organizers were É. Marchand and T. Bouezmarni. Talks were 50 minutes in length, plus 10 minutes for questions. The attendance varied between 10 and 20;

(6) The Montreal Seminar of Actuarial and Financial Mathematics: this series comprised 7 talks given in the Winter of 2012. Five of them were given at Concordia; one talk was at the Université de Montréal and the other at UQAM. The seminar organizers were J. Garrido, M. Morales, J. Nešlehová, and J.-F. Renaud. Talks were 60 minutes in length, including a question period. The attendance varied between 10 and 20 persons;

(7) The CRM-ISM Probability Seminar: this new seminar series was jointly initiated and organized by L. Addario-Berry, L.-P. Arguin, and Laboratory member L. Popovic. There were 9 talks in the Fall and 5 in the Winter. Partial funding for the event was given by the ISM. The list of speakers and topics was very diverse, with 5 speakers from Europe, 3 from the United States, one from China, and one from the Rest of Canada.

Workshops, special sessions, and others

Every ten years since 1971, Concordia University organizes a large Applied Statistics Conference whose first edition actually played a major role in the foundation of the Statistical Society of Canada. The 5th edition was held in July 2011, in conjunction with the 20th conference of the Forum for Interdisciplinary Mathematics. The conference, which was generously funded by the Statistics Laboratory, attracted over 250 participants. We refer the reader to the section Multidisciplinary and Industrial Program for a report on this event.

Statistics 2011 *Canada*
IMST 2011–*FIM XX*
July 1–4, 2011, Concordia
Local Organizing Committee (Concordia): Yogendra P. Chaubey (chair), Simon Bacon, Satyaveer Chauhan, Patrice Gailliardetz, Jose Garrido, Nikolay Gospodinov, Cody Hyndman, Jochen Jaeger, Tak Mak, Danielle Morin, Fassil Nebebe (Co-chair), Lea Popovic, Arusharka Sen, Debaraj Sen, Mahesh Sharma, Murari Singh, Wei Sun, Robert Weladji

An international workshop entitled "Perspectives on high-dimensional data analysis II" was held at the CRM in the Summer of 2012. It was the second workshop on this theme, following the HD-I conference held at the Fields Institute in 2011. The organizing committee consisted of three Laboratory members and three statisticians from Ontario. The reader will find a report on this event at the end of the section General Program.

International Workshop
Perspectives on High-Dimensional Data Analysis II
May 30 – June 1, 2012, CRM
Organizers: S. Ejaz Ahmed (Brock & Windsor) chair, Abbas Khalili (McGill), David Stephens (McGill), Éric Marchand (Sherbrooke), Peter X. K. Song (Michigan), Ji Zhu (Michigan)

Finally, the Second Graduate Student Workshop on Actuarial and Financial Mathematics was held at Concordia University on December 9, 2011. The event was organized by Laboratory members J. Garrido, M. Morales, and J.-F. Renaud, together with G. Léveillé from the Université Laval. It featured six 45-minute talks by graduate students in actuarial science at Concordia, Laval, the Université de Montréal, and UQAM. For additional details we refer the reader to the site http://www.dms.umontreal.ca/~morales/GWorkshop/.

Members of the Laboratory

Regular members

Louis-Paul Rivest (Laval), Director
Linear models, robustness, directional data, sampling, applications in finance

Belkacem Abdous (Laval)
Biostatistics, health research methodology, construction and validation of measuring tools in the health sector

Jean-François Angers (Montréal)
Decision theory, Bayesian statistics, robustness with respect to prior information, function estimation

Masoud Asgharian (McGill)
Survival analysis, change-point problems, simulated annealing and its variants, optimization

Yoshua Bengio (Montréal)
Statistical learning algorithms, neural networks, nucleus models, probabilistic models, data mining, applications in finance and statistical language modelling

Martin Bilodeau (Montréal)
Multivariate analysis, decision theory, asymptotic methods

Yogendra P. Chaubey (Concordia)
Sampling, linear models, resampling, survival analysis

Pierre Duchesne (Montréal)
Time series, sampling, multivariate analysis

Thierry Duchesne (Laval)
Survival analysis, longitudinal data analysis, missing data, modelling of losses, insurance of catastrophic incidents, nonparametric inference, model selection, warranty

Debbie J. Dupuis (HEC Montréal)
Extreme values, robustness

Sorana Froda (UQAM)
Nonparametric methods in function estimation, applications of stochastic modelling in biology and medicine

Christian Genest (McGill)
Multidimensional data analysis, dependence measures, nonparametric statistics, decision theory, applications in actuarial science, finance, and psychology

Nadia Ghazzali (Laval)
Multidimensional data analysis, neural networks and genetic algorithms, applications in astrophysics and biostatistics

Aurélie Labbe (McGill)
Biostatistics and statistical genetics

Fabrice Larribe (UQAM)
Statistical genetics and biostatistics

Christian Léger (Montréal)
Resampling methods, adaptive estimation, model selection, robustness, applications in data mining

Brenda MacGibbon (UQAM)
Mathematical statistics, decision theory, biostatistics

Éric Marchand (Sherbrooke)
Statistical inference, Bayesian statistics, multivariate analysis and probability

Alejandro Murua (Montréal)
Data mining, machine learning, object recognition, signal processing, and various applications of statistics and probability to bioinformatics and the social and health sciences

François Perron (Montréal)
Decision theory, multidimensional data analysis, Bayesian statistics

James Ramsay (McGill)
Functional data analysis, smoothing and nonparametric regression, curve registration

Bruno Rémillard (HEC Montréal)
Probability theory, empirical processes, time series, nonlinear filtering, applications in finance

Roch Roy (Montréal)
Time series analysis, predictive methods, applications in econometrics and epidemiology

Arusharka Sen (Concordia)
Statistical inference of truncated data, nonparametric function estimation

Russell Steele (McGill)
Bayesian approaches to mixing modelling, multiple imputation

David Stephens (McGill)
Bayesian statistics, Markov Chain Monte Carlo and applications to bioinformatics, statistical genetics, and time series analysis

Wei Sun (Concordia)
Nonlinear filtering and its applications, stochastic analysis, statistical inference, stochastic modelling

David B. Wolfson (McGill)
Change-point problems, survival analysis, Bayesian statistics, optimal design, applications in medicine

Associate members

Juli Atherton (McGill)
Biostatistics, optimal Bayesian design, change-point problems, survival analysis, applications to genetics

Mylène Bédard (Montréal)
Optimal scaling, Metropolis-Hastings algorithms

Anne-Catherine Favre (Laval)
Statistical hydrology, analysis and modelling of time series

José Garrido (Concordia)
Risk theory, insurance statistics

David Haziza (Montréal)
Sampling theory, inference with missing data, robust inference

Lajmi Lakhal Chaïeb (Laval)
Multidimensional analysis of survival data, analysis of recurrent events, semi-parametric models and incomplete data

Geneviève Lefebvre (UQAM)
Bayesian and computational statistics, biostatistics

Erica Moodie (McGill)
Causal inference, optimal dynamic treatment regimes, longitudinal data, dose-response relationships

Manuel Morales (Montréal)
Mathematical finance, applied stochastic processes, ruin theory, actuarial science, Lévy processes, mathematics of insurance

Johanna Nešlehová (McGill)
Multivariate analysis, dependence modelling, nonparametric and asymptotic statistics, multivariate extreme value theory, empirical processes, applications to biostatistics, neuroscience, and risk management

Robert Platt (McGill)
Biostatistics and statistical methods for pediatric and perinatal epidemiology.

Lea Popovic (Concordia)
Probability theory and its applications to evolutionary biology, population genetics, and cell biology

Publications

The CRM publishes monographs, lecture notes, proceedings, software, videos, and research reports. It has several collections. The in-house collection (Les Publications CRM) offers titles in both English and French. The CRM also has publishing agreements with the American Mathematical Society (AMS) and Springer. Since 1992, two collections, edited by the CRM, have been published and distributed by the AMS. They are the *CRM Monograph Series* and the *CRM Proceedings and Lecture Notes*. Springer publishes the *CRM Series in Mathematical Physics*. An asterisk preceding a publication indicates that its author is an Aisenstadt chairholder.

Recent Titles

The following list of recent titles contains books that appeared in 2011–2012 or that will be published soon.

American Mathematical Society
CRM Monograph Series

Joseph H. Silverman, *Moduli Spaces and Arithmetic Dynamics*, vol 30, 2012.

American Mathematical Society
CRM Proceedings & Lecture Notes

Daniel Daigle, Richard Ganong & Mariusz Koras (eds.), *Affine Algebraic Geometry: The Russell Festschrift*, vol. 54, 2011.

Bradd Hart, Thomas G. Kucera, Anand Pillay, Philip J. Scott & Robert A. G. Seely (eds.), *Models, Logics, and Higher-Dimensional Categories*, vol. 53, 2011.

Springer
CRM Series in Mathematical Physics

André D. Bandrauk & Misha Ivanov (eds.), *Quantum Dynamic Imaging*, 2011.

Séminaires de mathématiques supérieures

Vašek Chvátal (ed.), *Combinatorial Optimization: Methods and Applications*, NATO Science for Peace and Security Series - D: Information and Communication Security, vol. 31, IOS Press, 2011.

Decio Levi, Peter Olver, Zora Thomova & Pavel Winternitz (eds.), *Symmetries and Integrability of Difference Equations*, London Mathematical Society Lecture Note Series, vol. 381, Cambridge University Press, 2011

Previous Titles

American Mathematical Society
CRM Monograph Series

Marcelo Aguiar & Swapneel Mahajan, *Monoidal Categories, Species and Hopf Algebras*, vol 29, 2010.

Saugata Ghosh, *Skew-Orthogonal Polynomials and Random Matrix Theory*, vol. 28, 2009.

Jean Berstel, Aaron Lauve, Christophe Reutenauer & Franco V. Saliola, *Combinatorics on Words: Christoffel Words and Repetitions in Words*, vol. 27, 2008.

Victor Guillemin & Reyer Sjamaar, *Convexity Properties of Hamiltonian Group Actions*, vol. 26, 2005.

*Andrew J. Majda, Rafail V. Abramov & Marcus J. Grote, *Information Theory and Stochastics for Multiscale Nonlinear Systems*, vol. 25, 2005.

Dana Schlomiuk, Andrei A. Bolibrukh, Sergei Yakovenko, Vadim Kaloshin & Alexandru Buium, *On Finiteness in Differential Equations and Diophantine Geometry*, vol. 24, 2005.

Prakash Panangaden & Franck van Breugel (eds.), *Mathematical Techniques for Analyzing Concurrent and Probabilistic Systems*, vol. 23, 2004.

Montserrat Alsina & Pilar Bayer, *Quaternion Orders, Quadratic Forms, and Shimura Curves*, vol. 22, 2004.

Andrei Tyurin, *Quantization, Classical and Quantum Field Theory and Theta Functions*, vol. 21, 2003.

Joel Feldman, Horst Knörrer & Eugene Trubowitz, *Riemann Surfaces of Infinite Genus*, vol. 20, 2003.

*Laurent Lafforgue, *Chirurgie des grassmanniennes*, vol. 19, 2003.

*George Lusztig, *Hecke Algebras with Unequal Parameters*, vol. 18, 2003.

Michael Barr, *Acyclic Models*, vol. 17, 2002.

*Joel Feldman, Horst Knörrer & Eugene Trubowitz, *Fermionic Functional Integrals and the Renormalization Group*, vol. 16, 2002.

Jose I. Burgos, *The Regulators of Beilinson and Borel*, vol. 15, 2002.

Eyal Z. Goren, *Lectures on Hilbert Modular Varieties and Modular Forms*, vol. 14, 2002.

Michael Baake & Robert V. Moody (eds.), *Directions in Mathematical Quasicrystals*, vol. 13, 2000.

Masayoshi Miyanishi, *Open Algebraic Surfaces*, vol. 12, 2001.

Spencer J. Bloch, *Higher Regulators, Algebraic K-Theory, and Zeta Functions of Elliptic Curves*, vol. 11, 2000.

James D. Lewis, *A Survey of the Hodge Conjecture*, 2nd edition, vol. 10, 1999 (with an appendix from B. Brent Gordon).

*Yves Meyer, *Wavelets, Vibrations and Scaling*, vol. 9, 1997.

*Ioannis Karatzas, *Lectures on Mathematics of Finance*, vol. 8, 1996.

John Milton, *Dynamics of Small Neural Populations*, vol. 7, 1996.

*Eugene B. Dynkin, *An Introduction to Branching Measure-Valued Processes*, vol. 6, 1994.

Andrew M. Bruckner, *Differentiation of Real Functions*, vol. 5, 1994.

*David Ruelle, *Dynamical Zeta Functions for Piecewise Monotone Maps of the Interval*, vol. 4, 1994.

V. Kumar Murty, *Introduction to Abelian Varieties*, vol. 3, 1993.

Maximilian Ya. Antimirov, Andrei A. Kolyshkin & Rémi Vaillancourt, *Applied Integral Transforms*, vol. 2, 1993.

*Dan V. Voiculescu, Kenneth J. Dykema & Alexandru Nica, *Free Random Variables*, vol. 1, 1992.

American Mathematical Society CRM Proceedings & Lecture Notes

Dmitry Jakobson, Stéphane Nonnenmacher & Iosif Polterovich (eds.), *Spectrum and Dynamics*, vol. 52, 2010.

Javad Mashreghi, Thomas Ransford & Kristian Siep (eds.), *Hilbert Spaces of Analytic Functions*, vol. 51, 2010.

P. Robert Kotiuga (ed.), *A Celebration of the Mathematical Legacy of Raoul Bott*, vol. 50, 2009.

Miguel Abreu, François Lalonde & Leonid Polterovich (eds.), *New Perspectives and Challenges in Symplectic Field Theory*, vol. 49, 2009.

David Avis, David Bremner & Antoine Deza (eds.), *Polyhedral Computation*, vol. 48, 2009.

John Harnad & Pavel Winternitz (eds.), *Groups and Symmetries: From Neolithic Scots to John McKay*, vol. 47, 2009.

Jean-Marie De Koninck, Andrew Granville & Florian Luca (eds.), *Anatomy of Integers*, vol. 46, 2008.

Panos M. Pardalos & Pierre Hansen (eds.), *Data Mining and Mathematical Programming*, vol. 45, 2008.

Stanley Alama, Lia Bronsard & Peter Sternberg (eds.), *Singularities in PDE and the Calculus of Variations*, vol. 44, 2007.

Andrew Granville, Melvyn B. Nathanson & Jozsef Solymosi (eds.), *Additive Combinatorics*, vol. 43, 2007.

Donald A. Dawson, Vojkan Jakšić & Boris Vainberg (eds.), *Probability and Mathematical Physics: A Volume in Honor of Stanislav Molchanov*, vol. 42, 2007.

André Bandrauk, Michel C. Delfour & Claude Le Bris (eds.), *High-Dimensional Partial Differential Equations in Science and Engineering*, vol. 41, 2007.

Vestislav Apostolov, Andrew Dancer, Nigel Hitchin & McKenzie Wang (eds.), *Perspectives in Comparison, Generalized and Special Geometry*, vol. 40, 2006.

Pavel Winternitz, David Gomez-Ullate, Arieh Iserles, Decio Levi, Peter J. Olver, Reinout Quispel & Piergiulio Tempesta (eds.), *Group Theory and Numerical Analysis*, vol. 39, 2005.

Jacques Hurtubise & Eyal Markman (eds.), *Algebraic Structures and Moduli Spaces*, vol. 38, 2004.

Piergiulio Tempesta, Pavel Winternitz, John Harnad, Willard Miller Jr., George Pogosyan & Miguel A. Rodriguez (eds.), *Superintegrability in Classical and Quantum Systems*, vol. 37, 2004.

Hershy Kisilevsky & Eyal Z. Goren (eds.), *Number Theory*, vol. 36, 2004.

H. E. A. Eddy Campbell & David L. Wehlau (eds.), *Invariant Theory in All Characteristics*, vol. 35, 2004.

Pavel Winternitz, John Harnad, C. S. Lam & Jiří Patera (eds.), *Symmetry in Physics*, vol. 34, 2004.

André D. Bandrauk, Michel C. Delfour & Claude Le Bris (eds.), *Quantum Control: Mathematical and Numerical Challenges*, vol. 33, 2003.

Vadim B. Kuznetsov (ed.), *The Kowalevski Property*, vol. 32, 2002.

John Harnad & Alexander R. Its (eds.), *Isomonodromic Deformations and Applications in Physics*, vol. 31, 2002.

John McKay & Abdellah Sebbar (eds.), *Proceedings on Moonshine and Related Topics*, vol. 30, 2001.

Alan Coley, Decio Levi, Robert Milson, Colin Rogers & Pavel Winternitz (eds.), *Bäcklund and Darboux Transformations*, vol. 29, 2001.

John C. Taylor (ed.), *Topics in Probability and Lie Groups*: *Boundary Theory*, vol. 28, 2001.

Israel M. Sigal & Catherine Sulem (eds.), *Nonlinear Dynamics and Renormalization Group*, vol. 27, 2001.

John Harnad, Gert Sabidussi & Pavel Winternitz (eds.), *Integrable Systems*: *From Classical to Quantum*, vol. 26, 2000.

Decio Levi & Orlando Ragnisco (eds.), *SIDE* III—*Symmetry and Integrability of Difference Equations*, vol. 25, 2000.

B. Brent Gordon, James D. Lewis, Stefan Müller-Stach, Shuji Saito & Noriko Yui (eds.), *The Arithmetic and Geometry of Algebraic Cycles*, vol. 24, 2000.

Pierre Hansen & Odile Marcotte (eds.), *Graph Colouring and Applications*, vol. 23, 1999.

Jan Felipe van Diejen & Luc Vinet (eds.), *Algebraic Methods and q-Special Functions*, vol. 22, 1999.

Michel Fortin (ed.), *Plates and Shells*, vol. 21, 1999.

Katie Coughlin (ed.), *Semi-Analytic Methods for the Navier–Stokes Equations*, vol. 20, 1999.

Rajiv Gupta & Kenneth S. Williams (eds.), *Number Theory*, vol. 19, 1999.

Serge Dubuc & Gilles Deslauriers (eds.), *Spline Functions and the Theory of Wavelets*, vol. 18, 1999.

Olga Kharlampovich (ed.), *Summer School in Group Theory in Banff,* 1996, vol. 17, 1998.

Alain Vincent (ed.), *Numerical Methods in Fluid Mechanics*, vol. 16, 1998.

François Lalonde (ed.), *Geometry, Topology and Dynamics*, vol. 15, 1998.

John Harnad & Alex Kasman (eds.), *The Bispectral Problem*, vol. 14, 1998.

Michel Delfour (ed.), *Boundaries, Interfaces and Transitions*, vol. 13, 1998.

Peter G. Greiner, Victor Ivrii, Luis A. Seco & Catherine Sulem (eds.), *Partial Differential Equations and their Applications*, vol. 12, 1997.

Luc Vinet (ed.), *Advances in Mathematical Sciences*: *CRM's* 25 *Years*, vol. 11, 1997.

Donald E. Knuth, *Stable Marriage and Its Relation to Other Combinatorial Problems*, vol. 10, 1996.

Decio Levi, Luc Vinet & Pavel Winternitz (eds.), *Symmetries and Integrability of Difference Equations*, vol. 9, 1995.

Joel S. Feldman, Richard Froese & Lon M. Rosen (eds.), *Mathematical Quantum Theory* II: *Schrödinger Operator*, vol. 8, 1995.

Joel S. Feldman, Richard Froese & Lon M. Rosen (eds.), *Mathematical Quantum Theory* I: *Field Theory and Many-Body Theory*, vol. 7, 1994.

Guido Mislin (ed.), *The Hilton Symposium* 1993, vol. 6, 1994.

Donald A. Dawson (ed.), *Measure-Valued Processes, Stochastic Partial Differential Equations and Interacting Systems*, vol. 5, 1994.

Hershy Kisilevsky & M. Ram Murty (eds.), *Elliptic Curves and Related Topics*, vol. 4, 1994.

Andrei L. Smirnov & Rémi Vaillancourt (eds.), *Asymptotic Methods in Mechanics*, vol. 3, 1993.

Philip D. Loewen, *Optimal Control via Nonsmooth Analysis*, vol. 2, 1993.

M. Ram Murty (ed.), *Theta Functions*, vol. 1, 1993.

Springer
CRM Series in Mathematical Physics

John Harnad (ed.), *Random Matrices, Random Processes and Integrable Systems*, 2011.

Marc Thiriet, *Biology and Mechanics of Blood Flows*, 2008 (2 volumes).

David Sénéchal, André-Marie Tremblay & Claude Bourbonnais (eds.), *Theoretical Methods for Strongly Correlated Electrons*, 2003.

*Roman Jackiw, *Lectures on Fluid Dynamics*, 2002.

Yvan Saint-Aubin & Luc Vinet (eds.), *Theoretical Physics at the End of the Twentieth Century*, 2001.

Yvan Saint-Aubin & Luc Vinet (eds.), *Algebraic Methods in Physics*, 2000.

Jan Felipe van Diejen & Luc Vinet (eds.), *Calogero–Moser–Sutherland Models*, 1999.

Robert Conte (ed.), *The Painlevé Property*, 1999.

Richard MacKenzie, Manu B. Paranjape & Wojciech J. M. Zakrzewski (eds.), *Solitons*, 1999.

Luc Vinet & Gordon Semenoff (eds.), *Particles and Fields*, 1998.

Springer
Lecture Notes in Statistics (subseries CRM)

Marc Moore (ed.), *Spatial Statistics*: *Methodological Aspects and Applications*, vol. 159, 2001.

S. Ejaz Ahmed & Nancy Reid (eds.), *Empirical Bayes and Likelihood Inference*, vol. 148, 2001.

Les Publications CRM

Laurent Guieu & Claude Roger, *L'Algèbre et le Groupe de Virasoro*, 2007.

Luc Lapointe, Ge Mo-Lin, Yvan Saint-Aubin & Luc Vinet, *Proceedings of the Canada–China Meeting on Theoretical Physics*, 2003.

Armel Mercier, *Fonctions de plusieurs variables* : *Différentiation*, 2002.

Nadia El-Mabrouk, Thomas Lengauer & David Sankoff (eds.), *Currents in Computational Molecular Biology*, 2001.

James G. Huard & Kenneth S. Williams (eds.), *The Collected Papers of Sarvadaman Chowla*. Volume I: 1925–1935; Volume II: 1936–1961; Volume III: 1962–1986, 2000.

Michael Barr & Charles Wells, *Category Theory for Computing Science*, 1999.

Maximilian Ya. Antimirov, Andrei A. Kolyshkin & Rémi Vaillancourt, *Mathematical Models for Eddy Current Testing*, 1998.

Xavier Fernique, *Fonctions aléatoires gaussiennes, vecteurs aléatoires gaussiens*, 1997.

Faqir Khanna & Luc Vinet (eds.), *Field Theory, Integrable Systems and Symmetries*, 1997.

Paul Koosis, *Leçons sur le théorème de Beurling et Malliavin*, 1996.

David W. Rand, *Concorder Version Three*, 1996 (software and user guide).

Jacques Gauvin, *Theory of Nonconvex Programming*, 1994.

Decio Levi, Curtis R. Menyuk & Pavel Winternitz (eds.), *Self-Similarity in Stimulated Raman Scattering*, 1994.

Rémi Vaillancourt, *Compléments de mathématiques pour ingénieurs*, 1993.

Robert P. Langlands & Dinakar Ramakrishnan (eds.), *The Zeta Functions of Picard Modular Surfaces*, 1992.

Florin N. Diacu, *Singularities of the N-Body Problem*, 1992.

Jacques Gauvin, *Théorie de la programmation mathématique non convexe*, 1992.

Pierre Ferland, Claude Tricot & Axel van de Walle, *Analyse fractale*, 1992 (software and user guide).

Stéphane Baldo, *Introduction à la topologie des ensembles fractals*, 1991.

Robert Bédard, *Groupes linéaires algébriques*, 1991.

Rudolf Beran & Gilles R. Ducharme, *Asymptotic Theory for Bootstrap Methods in Statistics*, 1991.

James D. Lewis, *A Survey of the Hodge Conjecture*, 1991.

David W. Rand & Tatiana Patera, *Concorder*, 1991 (software and user guide).

David W. Rand & Tatiana Patera, *Le Concordeur*, 1991 (software and user guide).

Véronique Hussin (ed.), *Lie Theory, Differential Equations and Representation Theory*, 1990.

John Harnad & Jerrold E. Marsden (eds.), *Hamiltonian Systems, Transformation Groups and Spectral Transform Methods*, 1990.

M. Ram Murty (ed.), *Automorphic Forms and Analytic Number Theory*, 1990.

Wendy G. McKay, Jiří Patera & David W. Rand, *Tables of Representations of Simple Lie Algebras*. Volume I*: Exceptional Simple Lie Algebras*, 1990.

Anthony W. Knapp, *Representations of Real Reductive Groups*, 1990.

Wendy G. McKay, Jiří Patera & David W. Rand, *SimpLie*, 1990 (software and user guide).

Francis H. Clarke, *Optimization and Nonsmooth Analysis*, Montréal, 1989.

Samuel Zaidman, *Une Introduction à la théorie des équations aux dérivées partielles*, 1989.

*Yuri I. Manin, *Quantum Groups and Noncommutative Geometry*, 1988.

Lucien Le Cam, *Notes on Asymptotic Methods in Statistical Decision Theory*, 1974.

Les Presses de l'Université de Montréal Chaire Aisenstadt

*Laurent Schwartz, *Semimartingales and their Stochastic Calculus on Manifolds*, 1984.

*Yuval Ne′eman, *Symétries, jauges et variétés de groupe*, 1979.

*R. Tyrrell Rockafellar, *La théorie des sous-gradients et ses applications à l'optimisation, fonctions convexes et non convexes*, 1979.

*Jacques-Louis Lions, *Sur quelques questions d'analyse, de mécanique et de contrôle optimal*, 1976.

*Donald E. Knuth, *Mariages stables et leurs relations avec d'autres problèmes combinatoires*, 1976.

*Robert Hermann, *Physical Aspects of Lie Group Theory*, 1974.

*Mark Kac, *Quelques problèmes mathématiques en physique statistique*, 1974.

*Sybreen de Groot, *La transformation de Weyl et la fonction de Wigner : une forme alternative de la mécanique quantique*, 1974.

Other Collaborations with Publishers

Marc Moore, Sorana Froda & Christian Léger (eds.), *Mathematical Statistics and Applications: Festschrift for Constance van Eeden*, Lecture Notes–Monograph Series, vol. 42, 2003 (a collaboration with the Institute of Mathematical Statistics).

Duong H. Phong, Luc Vinet & Shing-Tung Yau (eds.), *Mirror Manifolds and Geometry*, AMS/IP Studies in Advanced Mathematics, vol. 10, 1998 (a collaboration with the AMS and International Press).

Pierre Ferland, Claude Tricot & Axel van de Walle, *Fractal Analysis User's Guide*, 1994 (a collaboration with the AMS).

Hedy Attouch, Jean-Pierre Aubin, Francis Clarke & Ivar Ekeland (eds.), *Analyse non linéaire*, 1989 (a collaboration with Gauthier-Villars).

Videos

Efim Zelmanov, *Abstract Algebra in the 20th Century*, 1997.

Serge Lang, *Les grands courants*, 1991.

Robert Bédard, *Brouiller les cartes*, 1991.

Serge Lang, *Les équations diophantiennes*, 1991.

Laurent Schwartz, *Le mouvement brownien*, 1990.

Laurent Schwartz, *Une vie de mathématicien*, 1989.

Scientific Personnel

CRM Members in 2011–2012

In contrast with most other mathematics institutes around the world, the CRM can count on the solid foundation of regular, associate, and invited members. Each regular member is also a professor at one of the partner institutions: Montréal, Concordia, McGill, UQAM, Laval, Sherbrooke, and Ottawa. Other members are researchers affiliated with the CRM in 2011–2012 as part of exchange agreements with neighbouring universities and industry or are long-term visitors from Canadian and foreign institutions. The presence at the CRM of such an active group of researchers has brought many benefits to the Centre. In particular, the CRM's national program is greatly facilitated by having on hand a large reserve of willing organizers, who even contribute financially to the organization of activities. The largest partnership is with the Université de Montréal, which grants the equivalent of five full-time teaching positions in release time to the CRM. Release agreements with the other Montréal area universities afford the equivalent of two more full-time positions to the CRM. Facilities are also provided to researchers affiliated with junior colleges. Several members are affiliated to the CRM through industrial agreements.

Regular members

Syed Twareque Ali, Concordia
Jean-François Angers, Montréal
Vestislav Apostolov, UQAM
Ibrahim Assem, Sherbrooke
André D. Bandrauk, Sherbrooke
Line Baribeau, Laval
Peter Bartello, McGill
Robert Bédard, UQAM
Jacques Bélair, Montréal
Habib Benali, UPMC & Inserm
Yoshua Bengio, Montréal
François Bergeron, UQAM
Marco Bertola, Concordia
Yves Bourgault, Ottawa
Anne Bourlioux, Montréal
Steven P. Boyer, UQAM
Gilles Brassard, Montréal
Srečko Brlek, UQAM
Thomas Brüstle, Sherbrooke & Bishop's
Virginie Charette, Sherbrooke
Cédric Chauve, Simon Fraser
Vašek Chvátal, Concordia
Francis H. Clarke, Lyon 1
Olivier Collin, UQAM
Octav Cornea, Montréal
Miklós Csűrös, Montréal
Chris J. Cummins, Concordia
Galia Dafni, Concordia
Henri Darmon, McGill
Chantal David, Concordia
Jean-Marie De Koninck, Laval
Michel C. Delfour, Montréal
Maxime Descoteaux, Sherbrooke
Eusebius J. Doedel, Concordia
Pierre Duchesne, Montréal
Thierry Duchesne, Laval
Nadia El-Mabrouk, Montréal
André Fortin, Laval
Richard Fournier, Dawson; Montréal
Marlène Frigon, Montréal
André Garon, Polytechnique Montréal
Paul M. Gauthier, Montréal
Christian Genest, McGill
Eyal Z. Goren, McGill
Andrew Granville, Montréal
Christophe Grova, McGill
Alfred Michel Grundland, UQTR
Pengfei Guan, McGill
Geňa Hahn, Montréal
Richard L. Hall, Concordia
Sylvie Hamel, Montréal
John Harnad, Concordia
Tony R. Humphries, McGill
Jacques Hurtubise, McGill
Véronique Hussin, Montréal
Adrian Iovita, Concordia
Dmitry Jakobson, McGill

Vojkan Jakšić, McGill
Tomasz Kaczynski, Sherbrooke
Niky Kamran, McGill
Olga Kharlampovich, McGill
Hershy Kisilevsky, Concordia
Paul Koosis, McGill
Dmitry Korotkin, Concordia
Gilbert Labelle, UQAM
John Labute, McGill
François Lalonde, Montréal
Benoît Larose, Champlain St-Lambert & Concordia
Christian Léger, Montréal
Frédéric Lesage, Polytechnique Montréal
Sabin Lessard, Montréal
Claude Levesque, Laval
Jean-Marc Lina, ÉTS
Shiping Liu, Sherbrooke
Steven Lu, UQAM
Brenda MacGibbon, UQAM
Michael C. Mackey, McGill
Vladimir Makarenkov, UQAM
Michael Makkai, McGill
Javad Mashreghi, Laval
Sherwin A. Maslowe, McGill
Pierre Mathieu, Laval
John McKay, Concordia
Manuel Morales, Montréal
M. Ram Murty, Queen's
Fahima Nekka, Montréal
Robert G. Owens, Montréal
Manu Paranjape, Montréal
Jiří Patera, Montréal
François Perron, Montréal
Iosif Polterovich, Montréal
Lea Popovic, Concordia
James O. Ramsay, McGill
Thomas J. Ransford, Laval
Bruno Rémillard, HEC Montréal
Christophe Reutenauer, UQAM
Louis-Paul Rivest, Laval
Ivo G. Rosenberg, Montréal
Christiane Rousseau, Montréal
Damien Roy, Ottawa
Peter Russell, McGill
Yvan Saint-Aubin, Montréal
David Sankoff, Ottawa
Dana Schlomiuk, Montréal
Robert Seiringer, McGill
Alexander Shnirelman, Concordia
Vasilisa Shramchenko, Sherbrooke
Alina Stancu, Concordia
Ron J. Stern, Concordia
Alain Tapp, Montréal
Francisco Thaine, Concordia
John A. Toth, McGill
Lennaert van Veen, UOIT
Roger Villemaire, UQAM
Luc Vinet, Montréal
Johannes Walcher, McGill
Timothy R. S. Walsh, UQAM
Thomas P. Wihler, Bern
Pavel Winternitz, Montréal
Daniel T. Wise, McGill
Xiaowen Zhou, Concordia

Associate members

Nantel Bergeron, York
Robert Conte, CEA/Saclay
Stéphane Durand, Édouard-Montpetit
Bertrand Eynard, CEA/Saclay
Martin J. Gander, Genève
Pierre Ille, CNRS & Aix-Marseille
Marc Laforest, Polytechnique Montréal
Decio Levi, Roma Tre
Jun Li, Pharsight
Emmanuel Lorin de la Grandmaison, Carleton
Yiannis N. Petridis, Univ. Coll. London
Elisa Shahbazian, OODA Technologies
Marc Thiriet, CNRS, UPMC & INRIA Rocquencourt
Pierre Valin, Defence R&D Canada
Carolyne M. Van Vliet, Montréal & Miami
Jean-Paul Zolésio, INRIA Sophia Antipolis

Invited members

Mylène Bédard, Montréal
Laurent Habsieger, CNRS & Lyon 1
David Haziza, Montréal
Pierre Lafaye de Micheaux, Montréal
Alejandro Murua, Montréal
Yuanli Zhang

Postdoctoral Fellows

Each year the CRM plays host to a large number of postdoctoral fellows. Their funding is provided through the NSERC and FRQNT postdoctoral programs, a NATO international program administered by NSERC, the CRM (usually in collaboration with the ISM), the CRM's research laboratories, and individual research grants from CRM members. The list below includes postdoctoral fellows in residence at the CRM and those cofunded by the CRM. Some of the fellows were in residence at the CRM for only part of the year. The affiliation given is the institution where the doctorate was obtained.

Elif Fidan Acar, Toronto
Shabnam Akhtari, UBC
Ferenc Balogh, Concordia
Alexander Bihlo, Wien
Winton Brown, Dartmouth Coll.
Mattia Cafasso, SISSA
Renato Calleja, UT Austin
Vorrapan Chandee, Stanford
Nikolai Dimitrov, Cornell
Tiago Dinis da Fonseca, UPMC
Fabrizio Donzelli, Miami
Grégoire Dupont, Lyon 1
Abdelkrim El Basraoui, Ottawa
Suresh Eswarathasan, Rochester
François Fillion-Gourdeau, McGill
Ke Gong, Henan
Igor Gorelyshev, RAS
Philip Grech, ETH Zürich
Melita Hadzagic, McGill
Mariah E. Hamel, UBC
Eric Harper, Miami
Alexander E. Hoffnung, UC Riverside
Nabil Kahouadji, Paris Diderot
Caroline Kalla, Bourgogne
Abdoulaye Kane, Laval
Leila Kheibarshekan, Gent
Dimitris Koukoulopoulos, UI Urbana-Champaign
Antonio Lei, Cambridge
Alok Kumar Maharana, Tata Inst.
Guyslain Naves, Joseph Fourier
Sarah Post, Minnesota
Danilo Riglioni, Roma Tre
Vivien Ripoll, Paris Diderot
Brian Seguin, Carnegie Mellon
Ethan C. Smith, Clemson
Christian Stump, Wien
Marzena Szajewska, Bialystok
Matthias Westrich, Aarhus
Mark Wilde, Southern California
Driss Yacoubi, UPMC
Guofu Yu, Shanghai Jiao Tong

Visitors

Each year the CRM hosts a large number of visitors. The majority come to the Centre to participate in scientific activities organized or co-organized by the CRM. In 2011–2012 there were 13 activities in the thematic program and 821 researchers took part in these activities, 10 of which were held at the CRM itself. There were also 13 activities in the general program, 7 of which were held at the CRM; altogether 665 participants took part in these activities. Finally the multidisciplinary and industrial program featured 3 activities, one of which took place at Concordia University and two at the CRM; 101 researchers participated in the two activities held at the CRM.

Long-term visitors

The following list only includes visitors who were in residence for at least four weeks.

Maia Angelova, Northumbria
Pierre Cagne, ÉNS
Yi-Fu Cai, Arizona State
Leonid Chekhov, Steklov Inst.
Patrick Desrosiers, Talca
Eduardo Dubuc, Buenos Aires
Semen Dyatlov, UC Berkeley
Victor Enolskii, NAS Ukraine
Corneille Auxence Eyallo, Tver SU
Piotr P. Goldstein, Sołtan Inst.
Philip Grech, ETH Zürich
Mark Haiman, UC Berkeley
Christian Hainzl, Tübingen
Bernard R. Hodgson, Laval
Vojkan Jakšic, McGill
Zdenek Kabat, TU Prague
Israel Klich, Virginia
Mathieu Lewin, Cergy-Pontoise
Keivan Mallahi Karai, Jacobs
Tomáš Mikolov, Brno UT
Aïda Ouangraoua, Simon Fraser
Annalisa Panati, Toulon
Petr Paramonov, Moscow SU
Lucas Pastor, Savoie
Claude-Alain Pillet, Toulon
Pedro Real, Sevilla
Michael Rubinstein, Waterloo
Robert Seiringer, McGill
Ramesh Sreekantan, ISI Bangalore
Michael Sullivan, UMass Amherst
Sumati Surya, Raman RI
David Taj, Toulon
Marc Thiriet, CNRS & UPMC
Nicolae Vulpe, IMI Moldova
Eduardo Santillan Zeron, Cinvestav
Oleksiy Zhedanov, Donetsk IPE
Peter Zograf, Steklov Inst.

Short-term visitors

The following visitors were in residence for less than four weeks.

Jeffrey A. Achter, Colorado State
Michael Aizenman, Princeton
Alain Arnéodo, CNRS & ÉNS Lyon
Joan Carles Artés, UA Barcelona
Yosi Avron, Technion
Sven Bachmann, UC Davis
Thomas Ballesteros, Cergy-Pontoise
Jean-Marie Barbaroux, Toulon
Jean-François Barraud, Paul Sabatier
Eva Bayer, EPFL
Valérie Berthé, Montpellier 2
Paul Biran, ETH Zürich
Guillaume Blin, Marne-la-Vallée
Laurent Bruneau, Cergy-Pontoise
Alina Bucur, UC San Diego
Philip Candelas, Oxford
Goce Chadzitaskos, Doppler Inst.
Horia Cornean, Aalborg
Stephan De Bièvre, Lille 1
Clelia De Felice, Salerno
Xenia de la Ossa, Oxford
Maksym Derevyagin, TU Berlin
Jan Derezinski, Warsaw
Bernard Derrida, ÉNS
Charles Doran, Alberta
Vladimir Dorodnitsyn, Keldysh Inst.
Vladimir Dragovic, MI SANU
Konstantin Fedorovskiy, Moscow STU
Brooke Feigon, East Anglia
Oleksandr Filipov, NAS Ukraine
Kevin Ford, UI Urbana-Champaign
Dominique Fourdrinier, Rouen
Grigorios Fournodavlos, Toronto
Alexander Fribergh, NYU
Jixiang Fu, Fudan
Samuele Giraudo, Marne-la-Vallée
Cameron Gordon, UT Austin

List of Students Having Graduated in 2011–2012

The CRM members supervise a large number of graduate students. In this section we give information on the students supervised by CRM members who graduated in 2011–2012. The name of the student is followed by the name of his or her supervisor (or names of his or her supervisors), his or her institution, and his or her program. Some names may be missing from this list, because we have only included those that have been brought to our attention.

Ph.D. Students

Blache Paul Akpoué
Jean-François Angers
Université de Montréal
Statistics

Raluca Apostu
Michael C. Mackey
McGill University
Physiology

Hirbod Assa
Bruno Rémillard and Manuel Morales
Université de Montréal
Mathematics (applied mathematics option)

James Bergstra
Yoshua Bengio
Université de Montréal
Computer Science

Rebecca J. Danos
Robert Brandenberger
McGill University
Physics

Michel Dieme
Roger Pierre and A. Séné
Université Laval
Mathematics

Matthew Doyle
Yves Bourgault
University of Ottawa
Engineering

Nicolas Dutil
Claude Crépeau
McGill University
Computer Science

Layan Ahmad El-Hajj
John A. Toth
McGill University
Mathematics

Ashkan Ertefaie
David A. Stephens and Masoud Asgharian
McGill University
Mathematics

Myriam Fillion
Fabrice Larribe
Université du Québec à Montréal
Environmental Sciences

Daniel Fiorilli
Andrew Granville
Université de Montréal
Mathematics (pure mathematics option)

Mark Hagen
Daniel T. Wise and Dmitry Jakobson
McGill University
Mathematics

Othmane Kortbi
Éric Marchand
Université de Sherbrooke
Mathematics

Jun Li
Yogendra P. Chaubey
Concordia University
Mathematics

Li Ma
Wei Sun
Concordia University
Mathematics

Felicia Magpantay
Anthony R. Humphries
McGill University
Mathematics

Romuald H. Momeya Ouabo
Manuel Morales and Louis G. Doray
Université de Montréal
Statistics

Ramin Okhrati
José Garrido
Concordia University
Mathematics

Murray Patterson
Cédric Chauve
Simon Fraser University
Bioinformatics

Myriam Rioux
Yves Bourgault and Youssef Belhamadia
University of Ottawa
Mathematics

Patrice Rivard
Line Baribeau
Université Laval
Mathematics

Joël Sango
Pierre Duchesne
Université de Montréal
Statistics

Marius Serban
Jiří Patera
Université de Montréal
Mathematics (pure mathematics option)

Marzena Szajewska
Zbigniew Pasternak-Winiarski and Jiří Patera
University of Bialystok and Université de Montréal
Mathematics

Jie Zhang
Thomas Brüstle
Université de Sherbrooke
Mathematics

Xiangwen Zhang
Pengfei Guan
McGill University
Mathematics

Jun Zhou
José Garrido
Concordia University
Mathematics

M.Sc. Students

Yassine Ajjaouj
Lajmi Lakhal Chaieb
Université Laval
Statistics

Shervin Asgari
Arusharka Sen
Concordia University
Mathematics

Tigran Atoyan
David A. Stephens
McGill University
Statistics

Edward Baraghis
Frédéric Lesage
École Polytechnique de Montréal
Electrical Engineering

Justine C. Barolet
Michel C. Delfour
Université de Montréal
Mathematics (applied mathematics option)

Mouloud-Beallah Belbahri
David Haziza
Université de Montréal
Statistics

Alexandre Beaulne
Bruno Rémillard and Pierre Laroche
HEC Montréal
Financial Engineering

Audrey Béliveau
David Haziza
Université de Montréal
Statistics

Jonathan Belletête
Manu B. Paranjape
Université de Montréal
Physics

Michaël Bernier
Maxime Descoteaux
Université de Sherbrooke
Mathematics

Alexandre Bérubé-Beaulne
Bruno Rémillard
HEC Montréal
Financial Engineering

Mélanie Boisvert
Virginie Charette and Ibrahim Assem
Université de Sherbrooke
Mathematics

Clément Bonnery
Frédéric Lesage
École Polytechnique de Montréal
Electrical Engineering

Arnaud Boré
Maxime Descoteaux
Université de Sherbrooke
Mathematics

Audrey Champagne-Paradis
Ivo G. Rosenberg
Université de Montréal
Mathematics (pure mathematics option)

Alexandre Couët
André Fortin
Université Laval
Mathematics

Jean-François Cyr
Richard Duncan
Université de Montréal
Mathematics

Gaël David
Virginie Charrette
Université de Sherbrooke
Mathematics

Victoria De Quehen
Eyal Z. Goren and Peter Russell
McGill University
Mathematics

Mouhamed El Moctar Diop
Bruno Rémillard
HEC Montréal
Financial Engineering

Philippe Dompierre
Ibrahim Assem
Université de Sherbrooke
Mathematics

Andrea Doroftei
Nadia El-Mabrouk
Université de Montréal
Computer Science

Katherine Edwards
Bruce Shepherd
McGill University
Mathematics

Walid El Maksoud
Thierry Duchesne
Université Laval
Statistics

Yara Elias
Andrew Granville
Université de Montréal
Mathematics

Mohamad Elmasri
Arusharka Sen
Concordia University
Statistics

Andrea Ferraguti
Adrian Iovita
Concordia University
Mathematics

Vincent Genest
Yvan Saint-Aubin
Université de Montréal
Physics

Charles-Édouard Giguère
Martin Bilodeau and Jean Séguin
Université de Montréal
Statistics

Esteban Herrera-Cordero
François Lalonde
Université de Montréal
Mathematics (pure mathematics option)

Niamh Higgins
Erica E. M. Moodie
McGill University
Epidemiology

Lennart Hilbert
Michael C. Mackey
McGill University
Physiology

Audrey Juhasz
Ron J. Stern
Concordia University
Mathematics

Loredana Kis
Jean-François Angers
Université de Montréal
Statistics

Marc-André Lacasse
Andrew Granville
Université de Montréal
Mathematics

Ruomeng Lan
Alexander Shnirelman
Concordia University
Mathematics

Julie Langlois
Jérémie Rostand
Université Laval
Mathematics

Alexandre Laurin
Chris J. Cummins
Concordia University
Mathematics

Guillaume Lavoie
Iosif Polterovich
Université de Montréal
Mathematics (pure mathematics option)

Elena Lavrova
Iosif Polterovich
Université de Montréal
Mathematics (pure mathematics option)

Martin Leclerc
Lajmi Lakhal Chaieb
Université Laval
Statistics

Philippe Lemieux-Mellouki
Hugo Chapdelaine and Claude Levesque
Université Laval
Mathematics

Arnaud Lepage-Jutier
Alexander Maloney
McGill University
Physics

Ahmad Mahmoody
Cédric Chauve
Simon Fraser University
Bioinformatics

Matei Mireuta
Mylène Bédard
Université de Montréal
Statistics

Abdelkarim Mohammedi
Louis-Paul Rivest
Université Laval
Statistics

Jonathan Moscovici
Alain C. Vandal and Roland Grad
McGill University
Statistics

Claudiu Mircea Motoc
Geneviève Lefebvre
Université du Québec à Montréal
Statistics

Jungbae Nam
Hershy Kisilevsky
Concordia University
Mathematics

Nicolas Paquin
Gilbert Labelle and Robert Bédard
Université du Québec à Montréal
Mathematics

Larissa Paulo
Louis-Paul Rivest
Université Laval
Statistics

Michèle Picard-Flibotte
Thierry Duchesne and Christian Genest
Université Laval
Statistics

Antoine Poirier
Andrew Granville
Université de Montréal
Mathematics (pure mathematics option)

Iuliana Adriana Popper
Pavel Winternitz
Université de Montréal
Mathematics (pure mathematics option)

Mireille Prevost
Vojkan Jaksic and Robert Seiringer
McGill University
Mathematics

Oscar Alberto Quijano Xacur
José Garrido
Concordia University
Mathematics

Yasmine Raad
Alina Stancu
Concordia University
Mathematics

Ashok Rajaraman
Cédric Chauve
Simon Fraser University
Bioinformatics

Gerasimos Rassias
Bruno Rémillard
HEC Montréal
Financial Engineering

Santiago Ravassi
Lea Popovic and Galia Dafni
Concordia University
Mathematics

Sudipta Saduhkhan
David A. Stephens
McGill University
Statistics

Robinson Saint-Frard
Pierre Duchesne
Université de Montréal
Statistics

Alexis Selezneff
Thomas J. Ransford
Université Laval
Mathematics

Mikhail Misha Smilovic
Daniel T. Wise, Jacques Hurtubise and Dmitry Jakobson
McGill University
Mathematics

Mengjue Tang
Yogendra P. Chaubey
Concordia University
Mathematics

Alexandre Tomberg
Vojkan Jakšić and Robert Seiringer
McGill University
Mathematics

Artour Tomberg
Jacques Hurtubise and Robert Seiringer
McGill University
Mathematics

Joel Tousignant-Barnes
Dmitry Jakobson and John A. Toth
McGill University
Mathematics

Pierre-Olivier Vallerand-Beaudry
Tomasz Kaczynski and Virginie Charette
Université de Sherbrooke
Mathematics

Vasile Vanciu
Sorana Froda and René Ferland
Université du Québec à Montréal
Statistics

Richard Vermette
Thierry Duchesne and Christian Genest
Université Laval
Statistics

Jing Wang
Christian Léger
Université de Montréal
Statistics

Matthieu Willems
Vladimir Makarenkov
Université du Québec à Montréal
Computer Science

Karim Zerouali
Frédéric Lesage
École Polytechnique de Montréal
Electrical Engineering

Quan Zhou
David A. Stephens
McGill University
Statistics

Petr Zorin
Richard L. Hall
Concordia University
Mathematics

Governance and Scientific Guidance

The CRM structure consists of a Board of Directors, an Assembly of Members, an International Scientific Advisory Committee, a Local Scientific Committee, an Executive Committee, and a Committee of Directors of Laboratories. In 2011-2012, the members of the Local Scientific Committee were Steven P. Boyer (Université du Québec à Montréal), Gilles Brassard (Université de Montréal), André Fortin (Université Laval), Andrew Granville (Université de Montréal), Dmitry Jakobson (McGill University), and François Lalonde (Université de Montréal; Director of the CRM). The Executive Committee consists of the CRM Director and the Deputy Directors. For more information, the reader may consult the web site crm.math.ca/apropos/CRM_structure_an.shtml.

Board of Directors

The Board of Directors is composed of:

- The Director (ex officio);
- A member of the Executive Committee nominated by the Board for a two-year mandate;
- Two regular members nominated by the Assembly for three-year mandates, normally renewable once;
- A Laboratory Director, nominated by the Committee of Directors of Laboratories for a two-year mandate, normally renewable once;
- The Vice-Principal, Research, of each of the main partner universities of the CRM, or his representative;
- A Vice-Principal, Research, of one of the other partner universities of the CRM, chosen by these universities on a rotating basis for a two-year mandate.

Here are the members of the Board of Directors for 2011–2012.

Jacques Beauvais, Vice-Rector (Research)
Université de Sherbrooke

Graham Carr, Vice-President (Research)
Concordia University (from January 1, 2012)

Olivier Collin
Université du Québec à Montréal

Louise Dandurand, Vice-President (Research)
Concordia University (until December 31, 2011)

Rose Goldstein, Vice-Principal (Research)
McGill University

John Harnad
Concordia University

Joseph Hubert, Vice-Rector (Research)
Université de Montréal (until December 31, 2011)

François Lalonde, Director of the CRM
Université de Montréal

Odile Marcotte, Deputy Director of the CRM
Université du Québec à Montréal

Yves Mauffette, Vice-Rector (Research)
Université du Québec à Montréal

Christiane Rousseau
Université de Montréal

Geneviève Tanguay, Vice-Rector (Research)
Université de Montréal (from January 1, 2012)

Chantal David (Concordia University) and **Octav Cornea** (Université de Montréal), Deputy Directors of the CRM, were invited members.

Committee of Directors of Laboratories

The Committee of Directors of Laboratories is composed of the Director, the Directors of the ten CRM Laboratories and the Deputy Directors of the Centre. It meets at least once a year to discuss any question that concerns the laboratories. The Directors of the laboratories are:

Steven P. Boyer (UQAM)
CIRGET — Geometry and Topology

François Bergeron (UQAM)
LaCIM — Combinatorics and Theoretical Computer Science

Henri Darmon (McGill University)
CICMA — Number Theory and Algebra

André Fortin (Université Laval)
GIREF — Modelling and Numerical Simulation

Eliot Fried (McGill University)
Applied Mathematics

John Harnad (Concordia University)
Mathematical Physics

Dmitry Jakobson (McGill University)
Mathematical Analysis

Jean-Marc Lina (École de technologie supérieure)
PhysNum — Medical Imaging and Pharmacometrics

Louis-Paul Rivest (Université Laval)
Statistics

International Scientific Advisory Committee

The International Scientific Advisory Committee consists of distinguished researchers from Canada and abroad. Its members are either mathematicians or scientists with close ties to the mathematical sciences. The Advisory Committee is kept informed regularly of the activities of the Centre through the Director. The Committee makes recommendations about the general scientific orientations of the CRM and gives advice about proposed scientific activities.

Martin Barlow received his undergraduate degree from the University of Cambridge in 1975 and completed his doctoral degree with David Williams at the University College of Swansea in Wales (1978). Since then he has been a leading researcher in probability theory, in particular diffusion in fractals and other disordered media. He held a Royal Society University Research Fellowship at the University of Cambridge from 1985 to 1992, when he joined the Mathematics Department at the University of British Columbia. He is currently Professor of Mathematics at UBC. He has held a number of visiting professorships at leading universities. Martin Barlow gave an invited lecture at the 1990 ICM in Kyoto and was an invited lecturer at the prestigious Saint-Flour Summer School in 1995. In 2008 he received the Jeffery-Williams Prize of the Canadian Mathematical Society and in 2009 the CRM –Fields–PIMS Prize. Other distinctions include the Rollo Davidson Prize from the University of Cambridge and the Junior Whitehead Prize from the London Mathematical Society. He has been a leader of the international probability community as a lead organizer of numerous conferences, Associate Editor of all the top probability journals, and Editor-in-Chief of the Electronic Communications in Probability. He has been a Fellow of the Institute of Mathematical Statistics since 1995 and of the Royal Society of Canada since 1998. In 2006 he was elected Fellow of the Royal Society (London).

Allan Borodin received his B.A. in Mathematics in 1963 (from Rutgers University), his M.Sc. in Electrical Engineering and Computer Science in 1966 (from Stevens Institute of Technology), and his Ph.D. in Computer Science in 1969 (from Cornell University). He was a systems programmer at Bell Laboratories in New Jersey from 1963 to 1966 and a Research Fellow at Cornell from 1966 to 1969. Since 1969, he has been a professor in the Department of Computer Science at the University of Toronto, where he became a full professor in 1977. He was department chair from 1980 to 1985. Professor Borodin is a world leader in the mathematical foundations of computer science and has made fundamental contributions to many areas, including algebraic computations, resource tradeoffs, routing in interconnection networks, parallel algorithms, on-line algorithms, and adversarial queuing theory. Professor Borodin has been the editor of many journals, including the SIAM Journal on Computing. He has held positions on, or been active in, dozens of committees and organizations, both inside and outside the University, and has held several visiting professorships internationally. In 1991 Professor Borodin was elected a Fellow of the Royal Society of Canada and in 2008 he received the CRM –Fields–PIMS Prize.

Stephen E. Fienberg is Maurice Falk University Professor of Statistics and Social Science at Carnegie Mellon University. He is the Carnegie Mellon codirector of the Living Analytics Research Centre. Fienberg received his hon. B.Sc. in Mathematics and Statistics from the University of Toronto (1964) and his A.M. and Ph.D. degrees in Statistics from Harvard University (1965, 1968).

Professor Fienberg has served as Dean of the College of Humanities and Social Sciences at Carnegie Mellon and as Vice President for Academic Affairs at York University, in Toronto, as well as on the faculties of the University of Chicago and the University of Minnesota. He has been a founding editor of a number of statistical journals. He has been Vice President of the American Statistical Association and President of the Institute of Mathematical Statistics and the International Society for Bayesian Analysis.

Fienberg's research includes the development of statistical methods, especially tools for categorical data analysis and the analysis of network data, algebraic statistics, causal inference, statistics and the law, machine learning, and the history of statistics.

Fienberg is a member of the U.S. National Academy of Sciences, and a fellow of the Royal Society of Canada, the American Academy of Arts and Sciences, and the American Academy of Political and Social Science, as well as a fellow of the American Association for the Advancement of Science, the American Statistical Association, the Institute of Mathematical Statistics, and an elected member of the International Statistical Institute.

Susan Friedlander is currently Director of the Center for Applied Mathematical Sciences and Professor of Mathematics at the University of Southern California. She obtained her Doctoral degree at Princeton University in 1972. She has published extensively in the areas of differential equations and fluid mechanics. She has been very active on numerous committees and evaluation panels, including the Council of the American Mathematical Society and the Board on Mathematical Sciences and Their Applications of the National Academies. She has also been involved continuously in the organization of conferences and workshops; in particular she was a member of the AMS-Shanghai Joint Meeting Program Committee. She has served on numerous AMS editorial boards and university committees. She has been honoured with several academic awards, including the Institut Henri-Poincaré Medal, the Gauthier-Villars Prize for Nonlinear Analysis, and the University of Illinois Scholar Award (in 2003). Over the years, she has been a frequent invited lecturer in the United States and around the world

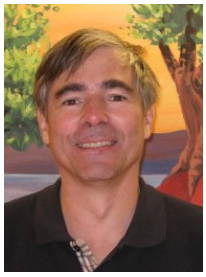
Mark Goresky has been a member of the Institute for Advanced Study in Princeton since 1994. He received his B.Sc. from the University of British Columbia in 1971 and a Ph.D. from Brown University in 1976. In 1986 he was elected to the Royal Society of Canada. He was awarded the Jeffery-Williams Prize of the Canadian Mathematical Society in 1996 and the Steele Prize of the American Mathematical Society in 2002 (jointly with R. MacPherson). He was a member of the editorial board of the Canadian Journal of Mathematics from 1997 to 2000 and is currently a member of the editorial board of the Bulletin of the American Mathematical Society. He is a world expert in geometric representation theory.

Mark L. Green has been a professor in the UCLA Department of Mathematics since 1982. He received his Ph.D. from Princeton University in 1972 and was Director of the Institute for Pure and Applied Mathematics from 2001 to 2008. Mark Green has received numerous honours during his career. In particular, he was an invited speaker at the International Congress of Mathematicians in Berlin in 1998. He was a plenary speaker at the Abel Centennial held in Oslo in 2002 and the Hodge Centennial held in Edinburgh in 2003. Professor Green's services to the mathematical community are extensive. He was a member of the Board of Trustees at the Claremont Center for the Mathematical Sciences and a member of the Board of Directors of the Center for Mathematics and Teaching. Professor Green also served on the NSERC Major Resources Support Committee and was the editor of the Journal

of Algebraic Geometry. His research interests are in commutative algebra, algebraic geometry, and applied mathematics.

Jacques Hurtubise obtained a B.Sc. in mathematics in 1978 from the Université de Montréal and a Ph.D. in mathematics in 1982 from the University of Oxford, where he was a Rhodes scholar. From 1982 to 1988 he was a professor at UQAM. Since 1988 he has been a professor in the Department of Mathematics and Statistics of McGill University (of which he has been the chairman since 2009). His research interests are in gauge theory, algebraic geometry, integrable systems, and mathematical physics. He was a Fellow of the Institute for Advanced Study at Princeton in 1987–1988 and a Centennial Fellow of the American Mathematical Society in 1993–1994. In 1993 Jacques Hurtubise was awarded the Coxeter–James Prize by the Canadian Mathematical Society. In 2004 he became a Fellow of the Royal Society of Canada. From 2010 to 2012 he was the President of the Canadian Mathematical Society. Jacques Hurtubise was or is a member of numerous committees of NSERC, FRQNT, and the Council of Canadian Academies.

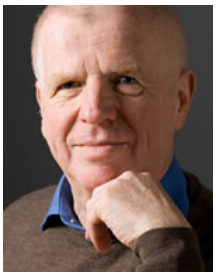
Barbara Lee Keyfitz has been a professor at the Ohio State University since January 2009. She served as Director of the Fields Institute for Research in Mathematical Sciences from 2004 to 2008. From 2000 to 2008, she was John and Rebecca Moores Professor of Mathematics at the University of Houston, which she joined in 1987, following appointments at Columbia, Princeton, and Arizona State University. She studied at the University of Toronto and obtained her Ph.D. at the Courant Institute (NYU). Barbara Keyfitz is a Fellow of the American Association for the Advancement of Science and the recipient of the 2005 Krieger–Nelson Prize of the Canadian Mathematical Society. She serves as Treasurer of the International Council of Industrial and Applied Mathematics and has been a member of several editorial boards. Her research interests are in the field of nonlinear partial differential equations.



A mathematician and physicist by training, **François Lalonde** holds a Doctorat d'État (1985) from the Université Paris-Sud in the field of differential topology. His fields of interest include symplectic topology, Hamiltonian dynamics and the study of infinite-dimensional groups of transformations. He has been a member of the Royal Society of Canada since 1997 and was a Killam Research Fellowship recipient in 2000–2002. He holds the Canada Research Chair in the field of Symplectic Geometry and Topology at the Department of Mathematics and Statistics of the Université de Montréal. François Lalonde was a plenary speaker at the First Canada–China congress in 1997; part of his work in collaboration with Dusa McDuff was presented in her plenary address at the ICM 1998 in Berlin. He was also an invited speaker at the ICM 2006 in Madrid.

Claude Le Bris obtained his doctorate from the École Polytechnique in France and his accreditation to supervise research from the Université Paris Dauphine in 1997. His research interests include mathematical analysis and numerical methods for partial differential equations and their applications to molecular simulation, multiscale problems, materials science, and continuum mechanics. He is a world-renowned expert in the mathematics of quantum chemistry and the computation of the electronic structure in quantum physics. Claude Le Bris received the Blaise Pascal Prize from the Académie des Sciences in 1999, the "CS 2002 Prize in Scientific Computing," and the Giovanni Sacchi-Landriani Prize from the Istituto Lombardo in 2002. He was Civil Engineer-in-Chief and Research Scientist at the École Nationale des Ponts et Chaussées and scientific leader of the MICMAC project at INRIA. Claude Le Bris has been a member of several program committees of international conferences and thematic years organized by research centres. He was co-editor of *Mathematical Modelling and Numerical Analysis* and editor of the *Applied Mathematics Research eXpress*. He has supervised 12 Ph.D. students and authored five books, 80 articles published in international journals, and 20 articles included into books or conference proceedings. He has given 90 invited lectures at interna-

tional conferences and a series of Aisenstadt lectures at the CRM (in the fall of 2009).



Claus Michael Ringel received the Diplom (1968) and Ph.D. in Mathematics from the Goethe-Universität Frankfurt am Main in 1969 and the Habilitation from the Eberhard Karls Universität Tübingen in 1972. He taught briefly at Carleton University in Ottawa (1970–1972). From 1978 to 2010 he was Professor of Mathematics at the Universität Bielefeld in Germany, where he is now Professor Emeritus. He is in addition Visiting Chair Professor at Shanghai Jiao Tong University in China. Claus Ringel's research is in Representation Theory, the study of concrete realizations of abstract algebraic structures. His work has been profoundly influential in the development of the theory of representations of finite-dimensional algebras, in particular quivers, hereditary algebras, Ringel–Hall algebras, and quantum groups. He has had, and continues to have, a leading role in a number of SFB (Sonderforschungsbereich: Collaborative Research Centre) in Germany in the area of representation theory.

Akshay Venkatesh has been a professor at Stanford University since September 2008. He obtained his Ph.D. from Princeton University in 2002, was C.L.E. Moore Instructor at MIT from 2002 to 2004, and a professor at the Courant Institute (NYU) from 2004 to 2008. Akshay Venkatesh has received many prizes and fellowships since the beginning of his career, in particular the Sloan Foundation Fellowship (2007), the Salem Prize (2007), the David and Lucile Packard Foundation Fellowship (2007–2012), and the SASTRA Ramanujan Prize (2008). In 2010 he was Aisenstadt Chair lecturer at the CRM, within the framework of the thematic semester on Number Theory as Experimental and Applied Science. His research interests are in number theory and automorphic forms, including representation theory, dynamics on homogeneous spaces, and arithmetic algebraic geometry.

Geneviève Tanguay, Vice-Rector (Research), Université de Montréal, is an ex-officio member of the International Scientific Advisory Committee. **Chantal David** (Concordia University), **Octav Cornea** (Université de Montréal), and **Odile Marcotte** (Université du Québec à Montréal), all Deputy Directors of the CRM, are invited members of the Committee.

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Mandate of the CRM

The Centre de recherches mathématiques (CRM) is one of the first and foremost institutes of mathematical research in the world. Indeed it was the first international institute to introduce the famous thematic programs (in 1984, at the same time as the MSRI). These programs were created independently by the two institutes and were an inspiration for the tens of institutes that were created in Europe and Asia after 1984. This model turned out to be the most creative and efficient means of fostering research and its applications to state-of-the-art technology. Although the initial programs were concentrated in pure and applied mathematics, they are now much broader and include all the fields that use sophisticated mathematical methods: theoretical physics, classical and quantum information, medical imaging, statistics, probabilistic methods on large-scale networks, etc.

The CRM was created in 1969 by the Université de Montréal through a special grant from the National Research Council of Canada. It became an NSERC national research centre in 1984. It is currently funded by NSERC (Natural Sciences and Engineering Research Council of Canada), by the Government of Québec through the FRQNT (Fonds de recherche du Québec – Nature et technologies), by the Université de Montréal, as well as McGill University, the Université du Québec à Montréal, Concordia University, the University of Ottawa, the Université Laval, the Université de Sherbrooke, and by private donations. The mission of the CRM is to support research in mathematics and closely related disciplines and to provide leadership in the development of the mathematical sciences in Canada.

The CRM carries on its mission and national mandate in several ways:

- it organizes each year a series of scientific events on a specific theme (high-profile lectures, workshops, summer schools, etc.),
- its general program and its multidisciplinary and industrial program provide funding for conferences and special events at the CRM and across the country,
- each year it invites, through the Aisenstadt Chair, one or more distinguished mathematicians to give advanced courses as part of its thematic program,
- it awards four prizes yearly: the CRM–Fields–PIMS Prize recognizing major contributions to mathematics, the André-Aisenstadt Prize given for outstanding work carried out by a young Canadian mathematician, the CAP–CRM Prize for exceptional achievement in theoretical and mathematical physics, and the CRM–SSC Prize for exceptional contributions to statistics in early career,
- it publishes technical reports and books (some of its collections are published jointly with the AMS or Springer),
- it has an extensive postdoctoral fellowship program, with more than thirty postdoctoral fellows on site, funded in partnership with other organizations and researchers,
- it informs the community of its activities through its newsletter, *Le Bulletin du CRM*, and its web site at http://crm.math.ca/,
- it participates, with the other two Canadian institutes, in groundbreaking national initiatives, for instance the Mprime network (formerly Mathematics of Information Technology and Complex Systems). The institutes sponsor the Annual Meetings of the Mathematical Sciences Societies (CMS, SSC, CAIMS), the development of the mathematical sciences in the Atlantic provinces through AARMS, and other activities organized outside the three institutes. They also participate in the National Institute for Complex Data Structures jointly with the Canadian statistical community.

This national mandate is complemented by, and indeed supported by, a long-standing vocation of promoting research in the mathematical sciences in Québec. For instance,

- the CRM supports research through its ten research laboratories spanning most of the important areas of the mathematical sciences,
- it supports, through partnership agreements, a group of local researchers chosen mainly from departments of mathematics and statistics, but also computer science, physics, economics, engineering, etc.,
- it organizes series of regular seminars and lecture courses on different areas of the mathematical sciences,
- it sponsors joint activities with the Institut des sciences mathématiques (ISM), including the CRM –ISM colloquia, graduate courses offered by distinguished visitors, and a program of postdoctoral fellowships,
- it works actively at developing contacts with industry, especially through the Montreal Industrial Problem Solving Workshops.

The CRM fulfils its national mission by involving the largest possible number of Canadian mathematicians

in its scientific programs, both as participants and as organizers. It also supports many events taking place outside Montréal and the Province of Québec. The CRM is reaching out to the general public through two ongoing programs: the *Accromath* magazine, which was created jointly by the CRM and the ISM and has won many international prizes and the Prix spécial de la Ministre de l'Éducation (in 2008), and the Grandes Conférences du CRM, which allow a broad public to attend lectures given by outstanding international scientists.

The director of the CRM is assisted by two managerial structures: the Board of Directors and the International Scientific Advisory Committee. The Advisory Committee is a group of internationally renowned mathematicians from Canada and abroad, who approve scientific programs and thematic years, choose recipients of the André-Aisenstadt Prize, and suggest new scientific avenues to explore.