



CENTRE  
DE RECHERCHES  
MATHÉMATIQUES

Annual Report  
2009  
2010





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M MATHÉMATIQUES

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2009  
2010



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# **Presenting the Annual Report 2009 – 2010**

THE two thematic programs proposed by the CRM in 2009–2010 were especially original. Each of them was related to the emergence of pure mathematics in a very active scientific discipline. The semester on medical and quantum imaging brought together two groups of researchers, the first one in brain imaging and the second one in molecular and atomic imaging. Both disciplines are witnessing a revolution in their techniques that requires new mathematical ideas and modern and original methods. Neuroimaging is expanding at a fast pace and involves at least four areas of pure and applied mathematics: modelling, signal processing, statistical analysis, and information processing through data fusion.

The thematic semester on imaging also included a focus on atomic imaging, one of the most active fields of modern scientific research. This field is spearheading a revolution not only in chemistry and physics but also in mathematics. Underlying this revolution is the advent, within the last few years, of very high-frequency lasers, of the order of a femtosecond ( $10^{-15}$ ) for molecules and an attosecond ( $10^{-18}$ ) for atoms. But the *reading* of these data requires the processing of fundamental equations that are strongly nonlinear in a nonperturbative regime. This requirement, in turn, calls for a new kind of mathematics, and the thematic semester on imaging took on the challenge. The semester was organized by André Bandrauk, Christophe Grova, Frédéric Lesage and Jean-Marc Lina (and French and American researchers), and included two series of lectures by Aisenstadt Chairholders: Stéphane Mallat, from the École Polytechnique in Paris, and Claude Le Bris from the École des Ponts ParisTech.

The thematic program on number theory as experimental and applied science was also very topical. Its purpose was to demonstrate that number theory, both in its discovery processes and its applications, can draw its inspiration from the experimental sciences. In the discovery process, number theorists are making greater and greater use of powerful software such as SAGE in order to conduct genuine experiments for verifying or falsifying conjectures that are unlikely to be proved or disproved soon. These experiments allow researchers to formulate better and sound conjectures. It is a subtle art, as shown by Professor Jean-Marie De Koninck in the very first Grande Conférence du CRM: some conjectures that have been verified for billions of prime numbers are nonetheless false. As

for its applications, number theory is now being applied in many ways and especially in secure information exchange and cryptography. The semester on number theory was organized by Henri Darmon, Eyal Goren, Andrew Granville, and Michael Rubinstein and included a series of lectures by Aisenstadt Chairholder Akshay Venkatesh (from Stanford University).

The CRM general program allows researchers to organize, either at the center or in the laboratories, workshops and international conferences that the CRM supports in order to foster scientific exchanges smaller in scope than thematic semesters or years. The 11 activities organized under the CRM general program in 2009–2010 were attended by 337 participants.

The CRM is the Canadian mathematical institute that awards the largest number of prestigious Canadian prizes (in collaboration with other institutes). Altogether there are four such prizes. The CRM–Fields–PIMS Prize is awarded to a brilliant Canadian mathematician on account of his exceptional contributions and is considered to be the crowning of his career. In 2010 Gordon Slade, from the University of British Columbia, was the recipient of the CRM–Fields–PIMS Prize. The André-Aisenstadt Prize is awarded to a young Canadian mathematician who has distinguished himself, within a few years, in one of the most difficult areas of contemporary mathematics. In 2010 Omer Angel, from the University of British Columbia, was the recipient of the André-Aisenstadt Prize. The CRM–SSC Prize is awarded to a Canadian statistician for the contributions made during his career. In 2010 Grace Yi, from the University of Waterloo, was the recipient of the CRM–SSC Prize. Finally the CRM–CAP Prize is awarded to a theoretical or mathematical physicist for his contributions to his field. In 2010 Clifford Burgess, professor at McMaster University and member of the Perimeter Institute, was the recipient of the CRM–CAP Prize.

During the 2009–2010 academic year the Grandes Conférences program, introduced in 2006, continued to develop. Four Grandes Conférences were organized in 2009–2010. The topic of the lecture by Michel Waldschmidt (from Université Pierre et Marie Curie) was integer sequences that are defined recursively. The topic of Jean Mawhin (from the Université catholique de Louvain) was the fixed point theorem. Jeffrey Rosenthal, from the University of Toronto, delivered a lecture on probability and Ivars Peterson, from the Mathematical Association of America, a lecture on *Geometreks*.



The Séminaire de mathématiques supérieures (SMS), organized by the CRM nearly every year, is an important summer school, the oldest such school in the world (since the first one took place in 1962). During two weeks, this summer school gathers world-renowned mathematicians who teach mini-courses to a select audience comprising Ph.D. students, postdoctoral fellows and promising young researchers. In June and July 2009, the SMS was jointly sponsored by the CRM, the Institut des sciences mathématiques (ISM), the Fields Institute, the National Science Foundation (NSF), the Université de Montréal, and the University of Waterloo. The topic of the SMS (computational aspects of automorphic forms and  $L$ -functions) was related to those studied during the thematic semester on number theory as experimental and applied science. The SMS was organized by Michael Rubinstein (from the University of Waterloo), Andreas Strombergsson (from Uppsala University), Henri Darmon and Eyal Goren (both from McGill University).

In all, 1,126 people took part in the activities of the thematic, general, multidisciplinary and industrial programs of the CRM during the 2009 – 2010 academic year. To these participants one must add the thousands of people who attended the CRM colloquia, the laboratories seminars, and various schools. The CRM activities attracted people from numerous countries on five continents.

The CRM is deeply grateful to the institutions that support it, in particular NSERC (Canadian government), FQRNT (Québec government), NSF (United States government), the MITACS network, and partner universities: Université de Montréal, UQÀM, Concordia University, McGill University, Université Laval, Université de Sherbrooke, and the University of Ottawa.

*François Lalonde*  
*Director, CRM*

# Thematic Program

THE core of each year's scientific program at the CRM is its thematic program. In 2009 – 2010 the thematic program consisted of two semesters: a semester on “Mathematical Problems in Imaging Science: From the Neuronal to the Quantum World” and a semester on “Number Theory as Experimental and Applied Science.”

The CRM is very grateful to the National Science Foundation (NSF) for providing generous financial support to the young American mathematicians who attended the activities of the thematic program in 2009 – 2010. The CRM is also grateful for the support extended to its thematic program by the following institutions: NSERC, FQRNT, MITACS, the Canadian Institute for Photonic Innovations (CIPI), Microsoft Research, Université de Montréal, McGill University, Concordia University, Université du Québec à Montréal, Université Laval, Université de Sherbrooke, and University of Ottawa. The information provided below comes to a large extent from an article published in the Spring 2010 issue of the *Bulletin du CRM* (see the article by André Bandrauk, Christophe Grova, Misha Y. Ivanov, Frédéric Lesage, and Jean-Marc Lina) and the Fall 2010 issue of the *Bulletin du CRM* (see the article by Henri Darmon, Eyal Goren, Andrew Granville, and Michael Rubinstein). *The reports are presented in the language in which they were submitted.*

## Thematic Programs of the Year 2009 – 2010 “Mathematical Problems in Imaging Science” and “Number Theory as Experimental and Applied Science”

### Mathematical Problems in Imaging Science: From the Neuronal to the Quantum World

Functional neuroimaging is a multidisciplinary research field using *mathematical modelling*, *signal and image processing*, and *statistical analysis*, in order to interpret the data provided by various devices. The combination of these three branches of applied mathematics points to the complexity of neuroimaging, which also stems from the diversity of imaging modalities available to neuroscientists. Functional neuroimaging relies on another branch of mathematics (i.e., *information processing*) to merge the data provided by those modalities. In the last twenty years neuroimaging has derived significant benefits from mathematics, thanks to the expansion of imaging technologies and the design of high-performance analytical methodologies. One of the aims of the organizers was to stimulate interdisciplinary exchanges by including clinical and cognitive aspects into the semester.

The first three workshops of the thematic semester were respectively dedicated to three axes of neuroimaging where mathematics plays a crucial role: the modelling of the neuronal and vascular processes within the brain, the solution of inverse problems in non-invasive imaging, and atomic decompositions for brain imaging. The fourth workshop of the semester explored the mathematical problems arising from the advances in molecular imaging achieved through state-of-the-art laser technology: these ad-

vances have broadened the imaging possibilities and allowed us to control molecular dynamics in spatial dimensions and timescales that were previously out of reach (especially the quantum world of the electron).

The thematic semester on imaging science also included two series of Aisenstadt lectures, given respectively by Stéphane Mallat (École Polytechnique & Courant Institute (NYU)) and Claude Le Bris (École des Ponts ParisTech). The organizing committee of the semester consisted of Sylvain Baillet (Medical College of Wisconsin), André Bandrauk (Université de Sherbrooke), Habib Benali (Université Pierre et Marie Curie), Christophe Grova (McGill University), Stéphane Jaffard (Université Paris-Est Créteil Val de Marne), Claude Le Bris, Frédéric Lesage (École Polytechnique de Montréal), Jean-Marc Lina (École de technologie supérieure), and Fred B. Schneider (Cornell University & NSF).

### Number Theory as Experimental and Applied Science

The year 2010 marked the 50th anniversary of the publication of Eugene Wigner's famous essay on the “unreasonable effectiveness of mathematics in the natural sciences.” The intervening five decades have witnessed an explosion in the variety and scope of the applications of mathematics, to the extent that one can now speak of an ongoing “mathematization” of many branches of science and indeed of society as a whole.

Number theory, traditionally viewed as far removed from the sphere of applications, now plays a central role in questions pertaining to the design of efficient networks as well as in areas like robotics, computer vision, statistics, coding theory, computer security, and cryptography. By extending the reach of calculation and the potential of the experimental method, evermore powerful and sophisticated software packages like MAPLE, MAGMA, and SAGE are transforming the way in which number theorists approach their subject. The thematic semester was devoted to recent developments in number theory with a specific focus on significant practical applications, as well as on the many

ways in which the field stands to be affected by the emergence of new software and technologies.

The thematic semester on number theory as experimental and applied science included three courses, five workshops, a summer school on automorphic forms and  $L$ -functions (from June 22 to July 3, 2009), and lectures by the Aisenstadt Chairholder Akshay Venkatesh (in March 2010). The organizing committee of the semester consisted of Henri Darmon and Eyal Goren (both from McGill University), Andrew Granville (Université de Montréal), and Michael Rubinstein (University of Waterloo).

## Aisenstadt Chairholders in 2009 – 2010

### Stéphane Mallat, Claude Le Bris, and Akshay Venkatesh

Stéphane Mallat and Claude Le Bris were the two Aisenstadt Chairholders for the semester on imaging science and Akshay Venkatesh was the Aisenstadt Chairholder for the semester on number theory.

#### Stéphane Mallat

Stéphane Mallat is one of the foremost experts in wavelet theory, to which he made seminal contributions in the late 1980s and early 1990s. From 1986 to 1996 he was living in the United States, where he obtained his doctorate. He held positions at the Courant Institute (NYU), Massachusetts Institute of Technology, and Tel Aviv University. He is currently a professor at the Centre de mathématiques appliquées of the École Polytechnique. His research interests include applied mathematics, signal processing, music synthesis, image segmentation, and the emergence of geometry in relation to perception. Stéphane Mallat has published more than 40 articles and a book entitled *A Wavelet Tour of Signal Processing*. In 2001 he took part in the launching of the *Let It Wave* start-up, which he then directed during six years. In 2007 Stéphane Mallat became again a full-time professor. Also in 2007, he was awarded the Prize of the EADS Corporate Foundation for the Information Sciences. In 2010 Stéphane Mallat was appointed Chairman of the Scientific Board of the *Fondation Sciences mathématiques de Paris*.

During his stay in Montréal, Stéphane Mallat gave six lectures within the workshop *Dictionary of Atoms: New Trends in Advanced Signal Processing in Functional Brain Imaging* (see p. 16 for a report on this workshop). From Monday, September 14, through Friday, September 18, he gave a 90-minute lecture every day. This

group of lectures was actually a mini-course on sparsity for signal and image inverse problems. Stéphane Mallat introduced mathematical and algorithmic tools for the solution of various inverse problems and discussed open questions in this area. Here are the themes of the five lectures.

- Sparse representations in signal and image processing
- Redundant dictionaries, geometry, and pursuit algorithms
- Super-resolution with sparsity
- Compressed sensing
- Dictionary learning and source separation

Finally, on Friday afternoon, Stéphane Mallat gave a lecture geared towards a general audience and entitled *Grouping to perceive an incompressible world*. In this conference, he explained that sparse approximations are efficient for low-level signal processing, but much less so for pattern recognition. More dimensionality reduction is needed for large-scale pattern recognition and visual psychophysics and physiological finding highlight the importance of grouping mechanisms. Grouping enables one to build signal representations for pattern recognition and to optimize a metric adapted to recognition.

## Claude Le Bris

Claude Le Bris obtained his doctorate at the École Polytechnique in 1993 and his “habilitation” at the Université Paris-Dauphine in 1997. His research interests include mathematical analysis and numerical methods for partial differential equations with applications to molecular simulation, multiscale problems, materials science, and continuum mechanics. He is a world authority on the mathematics of quantum chemistry and the computation of the electronic structure in quantum physics. Claude Le Bris was awarded the Blaise Pascal Prize by the French Academy of Sciences in 1999, the CS 2002 Prize in Scientific Computing (by Communications & Systems), and the Giovanni Sacchi-Landriani Prize by the Istituto Lombardo Accademia di Scienze e Lettere in 2002. He held several positions during his career, in particular those of Civil Engineer-in-Chief and Research Scientist at the École Nationale des Ponts et Chaussées and scientific leader of the MIC-MAC project at INRIA. He was a member of the scientific program committee of several international conferences (such as ICIAM 2011 and SIAM MMS 2008) and thematic programs (such as those organized by the CRM in Montréal, the IMA in Minneapolis, and the BICMR in Beijing). He has had extensive editorial activity as Co-Editor-in-Chief of *Mathematical Modelling and Numerical Analysis* and Editor-in-Chief of *Applied Mathematics Research eXpress*. He has supervised 12 doctoral students. He is also the author of five books, 80 articles in international journals, 20 articles in books and conference proceedings, and he has given 90 invited lectures at international conferences.

The first Aisenstadt lecture given by Professor Le Bris (on October 22, 2009) was entitled *Computational Quantum Chemistry and Physics: Mathematical and Numerical Accomplishments and Challenges*. Computational chemistry and physics provide scientists with qualitatively and quantitatively correct informations that can be used to understand matter. Molecular electronic theory, however, was until recently poorly known by mathematicians and computer scientists. Claude Le Bris explained to his audience that the situation is now different and presented some success stories at the intersection of mathematics, chemistry, and physics. The second lecture by Professor Le Bris (on October 23, 2009) was geared towards a general audience and was entitled *Seeing (and Understanding) the Invisible: The Quantum World*. In this second lecture, Professor Le Bris presented the major accom-

plishments of the past two decades in molecular modelling, from a mathematical perspective. He examined the main challenges of this field from the points of view of mathematical analysis and scientific computing. Claude Le Bris demonstrated that even though it is not always possible to “see” the quantum scale, simulating it provides more than a surrogate for vision and allows us to understand key phenomena.

On October 26, 2009, Claude Le Bris gave a lecture within the Applied Mathematics Seminar. This lecture was entitled *Multiscale Mechanics of Random Materials: A Mathematical Approach*. In this lecture, Professor Le Bris gave an overview of some recent contributions (both theoretical and numerical) to the field of stochastic homogenization. In particular he introduced some variants of the theory of classical stochastic homogenization and, on the numerical front, some approaches for acceleration of convergence in stochastic homogenization (representative volume element, variance reduction, etc.). Finally, the last Aisenstadt lecture by Professor Le Bris took place at the Université de Sherbrooke. It was entitled *The Quantum World and Its Relation to Macroscopic Physics: The Example of Materials Science*. In this lecture Professor Le Bris presented modelling and numerical strategies that couple length scales, and possibly time scales, thus giving birth to a new generation of multiscale models. This coupling enables scientists to insert into models at relatively large scales the information provided by molecular modelling at the quantum and classical scales.

## Akshay Venkatesh

Professor Venkatesh is a leading expert in the fields of automorphic forms and representation theory, with emphasis on the enumeration of arithmetic objects counted by rational points on algebraic varieties, the analytic theory of automorphic forms (along with its relation to quantum chaos and geodesic flows),  $L$ -functions, and applications to spectral theory and equidistribution. He held a Clay Research Fellowship from 2004 to 2006, and was an associate professor at the Courant Institute at New York University. Professor Venkatesh is now a professor at Stanford University. He was awarded the Salem Prize and the Packard Fellowship in 2007, and the 2008 SASTRA Ramanujan Prize.

Professor Venkatesh gave three beautiful lectures at the CRM, during the workshop on computer methods

for  $L$ -functions and automorphic forms, held on March 22 – 26, 2010 (see p. 20 for a report on this workshop). His first lecture, entitled *Playing with Numbers: Some Glimpses of Experimental Number Theory*, was broadly accessible and sparked many lively mathematical discussions at the reception following the lecture. In this first lecture Professor Venkatesh considered the infamous Pell equation and methods for guessing the size of the smallest solution of some equations. He described a heuristic that predicts the size of the smallest solution; this heuristic is actually correct for all small values of a parameter  $d$ . He then told his audience that this heuristic can be generalized to an extraordinary extent and described the links between this topic and the work of Birch and Swinnerton-Dyer, which led to the *Birch – Swinnerton-Dyer Conjecture*. Professor Venkatesh also spoke about the unpredictability of cubic equations and the fact that even calculations can be misleading (it was only recently discovered, through computations, that 30 is the sum of three cubes).

The second lecture by Professor Venkatesh dealt with the torsion in cohomology of arithmetic groups, a topic that is still poorly understood but has generated a great deal of interest because of its tantalizing connections to the arithmetic of finite extensions of the rational numbers and so-called *Galois extensions*. Professor Venkatesh devoted his third lecture to statistics of Galois groups. The problem he addressed is the following: given a finite group  $G$ , evaluate the number of number fields  $K/Q$  of degree  $d$  such that their Galois closure over  $Q$  has Galois group isomorphic to  $G$ . For a detailed description of the lectures by Professor Venkatesh, we refer the reader to the Spring 2010 issue of the Bulletin du CRM (see the article by Henri Darmon, Eyal Goren, and Andrew Granville, of which the present report is a summary).

## 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 Section 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, 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, and Craig Tracy.

## Activities of the Two Thematic Semesters

### SMS 2009 Summer School

#### Automorphic Forms and $L$ -functions: Computational Aspects

June 22 – July 3, 2009, CRM

Sponsored by the CRM, the Fields Institute, the Institut des sciences mathématiques (ISM), the National Science Foundation (NSF), the Université de Montréal, and the University of Waterloo

#### Organizing Committee:

Michael Rubinstein (Waterloo), Andreas Strömbergsson (Uppsala)

#### Local Organizers:

Henri Darmon & Eyal Goren (McGill)

#### Speakers:

Andrew Booker (Bristol), Henri Darmon, Noam D. Elkies (Harvard), Dorian Goldfeld (Columbia), Eyal Goren, Dennis A. Hejhal (Minnesota), Kamal Khuri-Makdisi (AUB), Erez Lapid (HUJI), Michael Ru-

binstein, Harold Stark (Clark), Fredrik Strömberg (TU Darmstadt), Andreas Strömbergsson, Audrey Terras (UCSD), Akshay Venkatesh (Stanford), John Voight (Vermont)

**Number of participants:** 68

This summer school brought together a number of experts who have been leaders in both the theoretical and computational aspects of the theory of automorphic forms and  $L$ -functions. Each of them gave courses lasting between 3 and 5 hours; the aim of those courses was to present graduate students and post-doctoral fellows with the state of the art in the subject and to report on new advances that have not yet been covered in a forum of this kind.

A total of fifteen speakers covered the theory of automorphic forms and  $L$ -functions from various perspectives: analytic, arithmetic, and algebraic, with a focus on techniques for their numerical evaluation. The program for the two weeks was as follows.

- Eyal Goren and Henri Darmon gave introductory courses on elliptic curves, holomorphic modular forms, and  $L$ -functions.
- Dorian Goldfeld spoke on automorphic forms and  $L$ -functions in higher rank, covering material from the first half of his recent book *Automorphic forms and  $L$ -functions for the group  $GL(n)$* , and also discussing the translation between classical language and adelic language.
- Fredrik Strömberg discussed Maass waveforms for  $SL(2, \mathbb{Z})$  and subgroups from a computational point of view; one additional lecture within this course was given by Dennis Hejhal.
- Noam Elkies lectured on K3 surfaces of high Picard number and their moduli.
- Michael Rubinstein spoke about algorithms for the computation of  $L$ -functions.
- Akshay Venkatesh covered the theory of Eisenstein series.
- John Voight gave a course on the algorithmic theory of quaternion algebras.
- Andrew Booker presented techniques from Fourier analysis, such as the FFT and band limited interpolation, for computing  $L$ -functions, and discussed his work with Ce Bian for finding  $GL(3)$  Maass forms.
- Erez Lapid talked about the Arthur – Selberg trace formula and some of its applications.
- Andreas Strömbergsson lectured on computations using the Selberg Trace Formula.
- Audrey Terras discussed zeta and  $L$ -functions of graphs.
- Harold Stark gave an overview on Artin  $L$ -functions.
- Kamal Khuri-Makdisi spoke about modular interpretation and equations for modular varieties.

In addition, two shorter talks were given presenting fairly recent breakthroughs in the computation of  $L$ -functions. In the first talk, Ghaith Hiary (from the University of Waterloo) reported on his new algorithm for fast computation of the Riemann zeta function on the critical line. The time complexity of his algorithm is a function with exponent  $4/13$ , while the best exponent previously known was  $\frac{1}{3}$ . In the second talk, Pankaj Vishe (from New York University) reported on a new fast algorithm for computation of the  $L$ -function associated to a modular form (holomorphic or non-holomorphic). Also Andrew Booker in his last talk presented his fairly recent breakthrough (jointly achieved with Ce Bian): he is able to compute the first few genuine  $GL(3)$   $L$ -functions.

Among the 68 participants, 24 were from Canada, 16 from the USA, 22 from Europe, of which 9 were funded by the Alcant program (“Algebra, Geometry and Number Theory,” a part of the European Erasmus Mundus Programme), and 6 from other parts of the world. The organizers received feedback from a number of students and postdocs who had attended the summer school. All were very pleased with the structure and content of the program and several of them stated that it was the most useful and interesting summer school they had attended.

## Workshop

### Brain Activity Modelling: From Fine to Coarse Scale

August 17 – 22, 2009, CRM

Sponsored by the CRM and MITACS

#### Organizers:

Habib Benali (FMPMC Pitié-Salpêtrière), Theodore J. Huppert (UPCM), Frédéric Lesage (Polytechnique Montréal)

#### Speakers:

Beau Ances (WUSTL), David Boas (Harvard), Richard B. Buxton (UCSD), Julien Cohen-Adad (Harvard), Mathieu Dehaes (Inserm & UPMC), Hélène Girouard (Montréal), Edith Hamel (McGill), Richard Hoge (Montréal), Theodore J. Huppert, Renaud Jolivet (Universitätsspital Zürich), Srinivas Laxminarayan (North-



eastern), Jean-Marc Lina (ÉTS), Réjean Plamondon (Polytechnique Montréal), Jorge Riera (Tohoku), Amir Shmuel (McGill), Ying Zheng (Sheffield)

**Number of participants:** 62

Le premier atelier du semestre sur l'imagerie fut organisé par Frédéric Lesage, Theodore Huppert et Habib Benali. Notre compréhension du cerveau humain et la capacité de mesurer l'activation neuronale ont évolué de façon significative au cours des dernières années. Ces développements sont liés à l'évolution de techniques non invasives de mesure incluant l'ÉlectroEncéphaloGraphie (EEG), la MagnétoEncéphaloGraphie (MEG), la Tomographie par Émission de Positrons (TEP), l'Imagerie par Résonance Magnétique fonctionnelle (IRMf) et l'Imagerie Optique Diffuse (IOD). Ce regard sur le cerveau a permis une meilleure compréhension du traitement effectué par le cerveau en réponse à une stimulation, avec, comme conséquence, l'émergence d'une description détaillée de la réponse neuronale, métabolique et vasculaire.

Cette description demeure incomplète. Les techniques d'EEG et de MEG mesurent la réponse électrophysiologique avec une grande précision temporelle mais offrent une résolution spatiale limitée. Les techniques de TEP, IRMf et IOD permettent de mesurer les réponses métabolique et hémodynamique, dans certains cas avec une grande précision spatiale (IRMf), mais au prix d'une perte en résolution temporelle et d'un regard indirect sur l'activation neuronale. Les études neuronales basées sur l'hémodynamique font donc face à un défi d'interprétation mais sont largement utilisées dans la communauté. En particulier, l'imagerie à résonance magnétique (IRM) de type BOLD a vu son applicabilité exploser au cours des dernières années. Malgré sa grande popularité, l'interaction entre l'activation neuronale, le débit sanguin, la consommation d'oxygène et le volume sanguin limitent son interprétation et plusieurs études récentes cherchent à mieux caractériser ces relations. La modélisation de l'interaction entre débit sanguin, volume sanguin et oxygénation est essentielle afin de distinguer, dans la réponse, les effets de l'anatomie vasculaire des processus métaboliques sous-jacents (CMRO<sub>2</sub>). Cette observation n'est pas naïve : l'utilisation de l'IRM pour caractériser les maladies ou le vieillissement nécessite cette quantification du signal.

Pour cette raison, l'interprétation des signaux en imagerie fonctionnelle cérébrale (IRMf, Spectroscopie

RMN, MEG/EEG, Imagerie Optique Diffuse) ne peut faire l'économie d'une modélisation mathématique des processus physiologiques cérébraux. Ces modèles du tissu cérébral relient les différents compartiments de l'électrophysiologie au métabolisme énergétique et à l'hémodynamique. Ils se déclinent sous forme de systèmes d'équations différentielles dont la complexité ne réside pas tant dans leur nombre que dans leur couplage et leur non linéarité intrinsèque. Le but de cet atelier était de faire le point sur ces modèles dynamiques en les confrontant avec les différentes modalités de mesure de l'activité cérébrale.

L'atelier commença par un retour sur les processus biologiques et biochimiques impliqués dans la réponse hémodynamique (dans l'exposé d'Edith Hamel) et leurs modélisations (dans l'exposé de Renaud Jolivet). Il s'est ensuite concentré sur les méthodes permettant de caractériser ces processus par l'imagerie. Plusieurs méthodes ont été proposées afin de pallier aux difficultés rencontrées et la plupart de celles-ci furent explorées par les conférenciers. Dans certains cas, elles cherchent à maximiser le nombre de paramètres observés afin de mieux distinguer les facteurs physiologiques qui obscurcissent la réponse neurale ; ces méthodes formaient le sujet des exposés de David Boas, Amir Shmuel et Jorge Riera. Par exemple, l'utilisation d'une préparation d'hypercapnie permet de modifier le débit sanguin cérébral sans affecter le métabolisme sous-jacent (tel qu'expliqué dans l'exposé de Richard Hoge). En utilisant une séquence IRM mesurant à la fois le signal dépendant du niveau d'oxygénation du sang (BOLD) et le débit sanguin (ASL), Richard Buxton a montré dans son exposé qu'il était possible d'estimer une constante de couplage et donc le CMRO<sub>2</sub>. Cette technique ne résout pas tous les problèmes : en particulier, elle utilise une relation (la relation de Grubb entre le débit et le volume sanguin) qui varie d'un individu à l'autre et est sujette à modification dans les populations âgées. La recherche d'autres options et leurs validations sont donc nécessaires, ainsi que Theodore Huppert l'a montré dans son exposé.

La modélisation des processus biochimiques de la réponse vasculaire à une activation neuronale, le processus de consommation d'oxygène, et la quantification de la relation entre l'activité neuronale et la réponse hémodynamique ont tous fait l'objet de séminaires qui permettaient non seulement d'aborder la modélisation des mesures mais aussi de confronter cette modélisation aux données expérimentales les plus récentes.



Les commentaires des participants, leur grand nombre (62), et l'intérêt montré tout au long de l'atelier démontrent qu'il a connu un grand succès. En particulier, les longs séminaires (d'une durée de deux heures et un quart) donnant une introduction aux domaines de recherche ont permis de rejoindre cet auditoire interdisciplinaire. Plus de la moitié des participants étaient des étudiants aux cycles supérieurs.

## **Workshop Inverse Problems in Brain Imaging and Multimodal Fusion**

August 24 – 29, 2009, CRM

Sponsored by the CRM and MITACS

### **Organizers:**

Sylvain Baillet (MCW), Christophe Grova (McGill), Jean-Marc Lina (ÉTS)

### **Speakers:**

Sylvain Baillet, Doug Cheyne (Toronto), Sarang Dalal (Inserm), Jean Daunizeau (UC London), Jan De Munck (VU Amsterdam), Alexandre Gramfort (INRIA Saclay), Stéphane Grimault (Montréal), Christophe Grova, Ramon Guevara (UBC), Matti Hamalainen (Harvard), Eliane Kobayashi (McGill), Jean-Marc Lina, John Mosher (Cleveland Clinic), Srikantan Nagarajan (UCSF), Jorge Riera (Tohoku), Hermann Stefan (Erlangen-Nürnberg), Samu Taulu (Elekta Neuromag Oy), Nelson Jesus Trujillo-Barreto (CNEURO), Zhigang Yao (Pittsburgh)

**Number of participants:** 67

Cet atelier fut dédié à la mémoire de Keith Worsley, professeur à l'Université McGill, et de Line Garnero, chercheur au CNRS. Les enjeux cliniques ainsi que les problématiques liées aux neurosciences cognitives justifient les efforts constants pour définir le cadre méthodologique de la quantification locale de l'activité cérébrale à partir des mesures non invasives et des imageurs 3D mentionnés ci-dessus (EEG, MEG, IOD, IRMf, TEP). L'information produite par les imageurs (IRMf et TEP) est assez bien localisée dans le volume cérébral mais partielle, voire spécifique à certains aspects du fonctionnement, et doit être fusionnée avec les mesures non invasives. L'imagerie cérébrale se trouve ainsi au carrefour de plusieurs disciplines et problématiques dont l'objectif est de donner une carte de l'activité du cerveau la plus juste possible des points de vue spatial et temporel, et qui prenne en compte les

différents compartiments (neuronale, hémodynamique, métabolique) des modèles actuels.

En invitant Jorge Riera, Nelson Trujillo-Barreto et Jean Daunizeau à présenter leurs travaux, les organisateurs de l'atelier ont mis l'accent sur les modèles avancés pour décrire aux échelles les plus petites les générateurs de l'activité bioélectrique mesurable par les techniques d'EEG et de MEG. La formulation numérique du problème direct exprimant la relation entre ces sources intracérébrales et les mesures électromagnétiques de l'EEG et de la MEG fut présentée par Jan De Munck et Matti Hamalainen, qui attirèrent l'attention de l'auditoire sur les performances de l'approche BEM (par « éléments finis de frontière ») pour la résolution des équations de Maxwell dans une modélisation réaliste de la tête. Cette formulation acquise, la localisation de l'activité cérébrale consiste à résoudre le problème inverse, intrinsèquement mal posé.

Outre Matti Hamalainen, qui présenta les grandes lignes des techniques habituelles de régularisation, l'atelier réunit les experts des approches les plus souvent utilisées dans le contexte de l'imagerie fonctionnelle. Ainsi John Mosher et Doug Cheyne présentèrent les avantages du filtrage des données de la MEG et l'EEG dans l'approche Beamformer, Srikantan Nagarajan et Nelson Trujillo-Barreto présentèrent l'état de l'art dans les approches probabilistes bayésiennes, et Sylvain Baillet présenta une technique par flot optique permettant une description particulièrement novatrice de la dynamique fonctionnelle. Christophe Grova et Jean-Marc Lina, quant à eux, présentèrent les derniers résultats en fusion MEG et EEG dans une approche d'inférence par maximum d'entropie. Les aspects numériques d'optimisation furent abordés par Alexandre Gramfort alors que les enjeux cliniques (concernant l'épilepsie) et de neurosciences (concernant la mémoire) firent l'objet des exposés d'Eliane Kobayashi et de Stéphane Grimault. Ces exposés placèrent la problématique de la localisation de l'activité cérébrale dans son véritable contexte, tout en justifiant les travaux méthodologiques et mathématiques des exposés précédents.

L'atelier inclut notamment les présentations orales de 12 conférenciers invités (y compris 5 cours complets de trois heures donnés par des chercheurs mondialement reconnus en résolution du problème inverse en électrophysiologie), 10 conférences d'une heure sur des sujets plus spécifiques ou appliqués, et quatre tables rondes (dont certaines furent enflammées !). Un des conféren-

ciers, John Mosher, confia à Christophe Grova qu'il avait mis en place une étude spécifique pour répondre à une question posée pendant ces tables rondes ; les résultats de cette étude ont été présentés lors de la conférence internationale Biomag 2010 (à Dubrovnik, en avril 2010). Malgré un programme plutôt chargé, la participation fut excellente tout au long de la semaine, et la plupart des participants demandèrent spontanément quand aurait lieu le prochain atelier de ce genre au CRM.

## Workshop

### Dictionary of Atoms: New Trends in Advanced Signal Processing in Functional Brain Imaging

September 14 – 19, 2009, CRM

Sponsored by the CRM and MITACS

#### Organizers:

Stéphane Jaffard (UPEC), Frédéric Lesage (Polytechnique Montréal), Jean-Marc Lina (ÉTS)

#### Speakers:

Farras Abdelnour (Pittsburgh), Richard G. Baraniuk (Rice), Andrew Bolstad (MIT), Maureen Clerc (INRIA Sophia Antipolis), Arnaud Delorme (Paul Sabatier & CNRS), Ronald A. DeVore (South Carolina), Rémi Gribonval (INRIA Rennes), Stéphane Jaffard, Michael Lustig (Stanford), Stéphane Mallat (École Polytechnique), Dimitri Van De Ville (EPFL), Fabrice Wendling (Inserm & Rennes 1)

**Number of participants:** 45

Pendant la dernière décennie, les signaux bioélectriques tels que ceux de l'EEG illustrèrent une des problématiques du traitement du signal les plus intéressantes. En effet, la mesure de l'activité de plusieurs milliards de neurones à partir de quelques capteurs de potentiel électrique placés sur la surface de la tête est une réduction dimensionnelle considérable, qui devrait compromettre toute tentative de localisation de cette activité par EEG. Le second atelier du semestre sur l'imagerie (voir ci-dessus), qui portait sur les méthodes de localisation de sources cérébrales à partir des mesures électrophysiologiques, a montré qu'il était possible de résoudre ces problèmes inverses et que, dans une certaine mesure, cette réduction dimensionnelle préservait l'information pertinente de l'activité neuronale. Ce point de vue, bien qu'intuitif, est intimement relié à la notion de compression.

Le troisième atelier du semestre sur l'imagerie portait donc sur l'échantillonnage parcimonieux (*compressed sensing*) et la résolution de problèmes inverses, dans le contexte des neurosciences. Ce contexte fut introduit grâce aux deux exposés de Dimitri Van De Ville. Le premier portait sur l'analyse espace-échelle (ondelettes) en Imagerie de Résonance Magnétique fonctionnelle ; le second présentait la construction d'atomes fonctionnels spécifiques à la modélisation des réponses hémodynamiques. Le contexte des neurosciences fut également présenté par Arnaud Delorme, spécialiste des analyses temps-fréquence en électrophysiologie. La transition vers la compression parcimonieuse du point de vue mathématique fut assurée par Michael Lustig, qui présenta ses travaux de pionnier sur l'application de l'échantillonnage parcimonieux en IRM. Cet exemple illustre parfaitement l'enjeu de l'échantillonnage parcimonieux, qui consiste à revisiter le théorème de l'échantillonnage de Nyquist-Shannon en tenant compte de la compressibilité de l'information mesurée.

L'exposé de Ronald DeVore a su remettre en perspective les fondements de l'échantillonnage parcimonieux et les conditions de reconstruction (décodage) du signal échantillonné parcimonieusement. Ces aspects furent aussi couverts en détail par Rémi Gribonval, dont les trois exposés couvrirent autant la théorie que les applications en traitement du signal (la séparation de sources, notamment). Les présentations de Richard Baraniuk placèrent l'échantillonnage parcimonieux dans le contexte de la modélisation des signaux et des questions de réduction dimensionnelle. Les présentations de Maureen Clerc et d'Andrew Bolstad reprirent l'analyse temps-fréquence dans le contexte de l'étude des signaux électrophysiologiques. L'exposé de Fabrice Wendling porta sur la modélisation de ces signaux dans le contexte de l'épilepsie et suggéra des problématiques pratiques à la communauté des mathématiciens participant à l'atelier.

L'atelier bénéficia de la présence de Stéphane Mallat, titulaire de la chaire Aisenstadt, dont les exposés portèrent, de manière générale, sur la résolution de problèmes inverses du point de vue théorique (sous l'angle de la mesure parcimonieuse) et du point de vue pratique (c'est-à-dire de la compression d'images).

**Workshop****Quantum Dynamic Imaging**

October 19 – 23, 2009, CRM

Sponsored by the CRM, the Canadian Institute for Photonic Innovations (CIPI), the NSF, and the Université de Sherbrooke

**Organizers:**

André Bandrauk (Sherbrooke), Misha Y. Ivanov (Imperial College London), Claude Le Bris (École des Ponts ParisTech), Fred B. Schneider (Cornell & NSF)

**Speakers:**

Klaus Bartschat (Drake), Heiko Bauke (MPI Kernphysik), Thomas Brabec (Ottawa), Tucker Carrington (Queen's), Szczepan Chelkowski (Sherbrooke), Agapi Emmanouilidou (UC London), Farhad Faisal (Bielefeld), Hans-Christian Hege (Zuse-Institut Berlin), Christoph H. Keitel (MPI Kernphysik), Jean-Claude Kieffer (INRS-EMT), Michael Koppitz (Zuse-Institut Berlin), Claude Le Bris, Catherine Lefebvre (Sherbrooke), François Légaré (INRS-EMT), Chii-Dong Lin (Kansas State), Emmanuel Lorin de la Grandmaison (Carleton), Jörn Manz (FU Berlin), Alfred Maquet (UPMC), T. Tung Nguyen-Dang (Laval), Renate Pazourek (TU Wien), Fred B. Schneider, Olga Smirnova (Max-Born-Institut), Anthony F. Starace (Nebraska), Kazuo Takatsuka (Tokyo), Ken Taylor (Queen's, Belfast), Jonathan Tennyson (UC London), Turgay Ahmet Uzer (Georgia Tech), Zachary Walters (Max-Born-Institut), Djemel Ziou (Sherbrooke)

**Number of participants:** 65

This workshop, the first of its kind ever held in Canada, focused on the theoretical and mathematical problems associated with the imaging of quantum phenomena in matter from the femtosecond scale ( $10^{-15}$  s) for nuclear motion to the attosecond scale ( $10^{-18}$  s) for electron motion. Motion of a proton (one of the most important nuclei) and motions in chemistry and biology (e.g., DNA) have a natural time scale of 7 femtoseconds. Motion of electrons, responsible for chemical binding and electron transfer processes in natural phenomena, has a characteristic time scale of about 100 attoseconds (it takes an electron 152 attoseconds to go around the hydrogen atom). Both proton and electron motion can only be described by quantum mechanics, i.e., by high-dimensional partial differential equations (HDPDEs). Furthermore such motions can only be monitored by ultrashort laser pulses. Thus the interaction of matter with such pulses can only be described by HDPDEs such as time-dependent Schrödinger and

Dirac equations (for relativistic phenomena) coupled with Maxwell equations (to take photons into account).

The speakers who were invited to the workshop are acknowledged experts in the development of the theories and numerical methods necessary for treating photon-atom-molecule interactions in the nonlinear non-perturbative regime. In particular the generation of attosecond pulses is a spin-off of such theories of the nonlinear non-perturbative laser-matter interactions. The workshop was further enhanced by two Aisenstadt Chair lectures delivered by Claude Le Bris. He described the mathematical problems and progress in developing and validating numerical methods for imaging quantum phenomena with sub-femtosecond temporal and sub-ångström spatial resolution. In addition to the 23 invited lectures, six post-doctoral fellows were invited to give presentations of their most recent work. Of further interest to the workshop participants were three lectures by information technology experts. These experts addressed a very important problem: that of using the quantum imaging methods discussed in the workshop and the massive amount of multidimensional information encoded in the time-dependent many-body wavefunctions for the eventual production of “molecular movies.” This is a new direction in molecular imaging, whose aim is to make quantum information available to researchers in the molecular sciences, allowing them to visualize quantum phenomena in their natural (from the femto to attosecond) timescale.

The organizers (A. Bandrauk, M. Ivanov, C. Le Bris, and F. Schneider) are very grateful for the financial support extended by the NSF, the Canadian Institute for Photonic Innovations (CIPI), the Université de Sherbrooke, and NSERC, which supports (among other endeavours) the CRM thematic program.

**Course****Expander Graphs**

January 4 – February 26, 2010

**Lecturer:** Eyal Goren (McGill)**Number of participants:** 15

The mini-course on expander graphs consisted of 10 hours giving an overview of some of the main topics in this area (Ramanujan graphs and complexes, the Alon – Boppana theorem and the spectrum of infinite trees, known constructions of Ramanujan graphs, the

zig-zag product, Cayley graphs and expansion), and a report on very recent breakthroughs concerning expansion in finite simple groups. In addition, certain applications of expander graphs were presented. The program was organized so as to serve as preparation and motivation for the CRM workshop on graphs and arithmetic, which took place on March 8–12, 2010. The participants included about 10 graduate students and 5 postdoctoral fellows.

## Course

### Computational Aspects of Quaternion Algebras and Shimura Curves

January 4 - April 30, 2010

**Lecturer:** John Voight (Vermont)

**Number of participants:** 15

The graduate course *Computational Aspects of Quaternion Algebras and Shimura Curves* was very successful. We covered a variety of subjects in four months, including the basic theory of quaternion algebras over fields and the relationship to quadratic forms, the structure theory of quaternion algebras and orders over local and global fields, graphs, adelic methods (Eichler’s theorem of norms, strong approximation, and the mass formula), quaternion unit groups, Shimura curves, and the relationship to supersingular elliptic curves and theta functions. These topics were closely related to the five week-long workshops that were held during this period.

Throughout the course we stressed explicit methods. We met twice in the lab to work with the algorithms in practice, and in the second lab the participants were invited to solve the class number 1 problem for ternary quadratic forms over the rational numbers, combining the theory learned in the classroom and computation. The graduate students enrolled in the course were very pleased with it. For instance, a master’s student commented that he had learned a lot of material for his future research, another that the course content would be immediately useful to him, and a third one that the course was “very timely” in terms of his thesis work.

### MAGMA 2010 Conference on $p$ -adic $L$ -functions

February 22 – 26, 2010, CRM

Sponsored by the MAGMA Computer Algebra Group of the University of Sydney

## Organizers:

Matthew Greenberg (Calgary), Xavier-François Roblot (Lyon 1), Mark Watkins (Sydney), Christian Wuthrich (Nottingham)

## Speakers:

Joël Bellaïche (Brandeis), Bryden Cais (McGill), Hugo Chapdelaine (Laval), John H. Coates (Cambridge), Henri Darmon (McGill), Samit Dasgupta (UC Santa Cruz), Lassina Dembélé (Duisburg-Essen), Matthew Greenberg, Ralph Greenberg (Washington), Masato Kurihara (Keio), Zhibin Liang (Capital Normal), Marc Masdeu Sabaté (McGill), Kazuo Matsuno (Tsuda College), Jeehoon Park (McGill), Glenn Stevens (Boston), Lawrence C. Washington (Maryland), Mark Watkins, Christian Wuthrich

**Number of participants:** 46

To kick off its thematic semester on *Number Theory as an Experimental and Applied Science*, the CRM played host to the Magma 2010 Conference on  $p$ -adic  $L$ -functions. This conference brought together forty participants, both students and researchers, from Australia, Canada, China, England, France, Japan, and the United States, with the goal of developing applications of computer algebra and “ $p$ -adic numerical analysis” to fundamental problems of number theory.

The conference opened with a wide-ranging lecture by Henri Darmon on the application of  $p$ -adic  $L$ -functions to the explicit construction of many gems of arithmetic, from units in rings of algebraic integers to rational points on abelian varieties. This theme was expanded upon in the lectures of Hugo Chapdelaine, Samit Dasgupta, and Marc Masdeu Sabaté. Another major theme of the conference was the interplay between theoretical insight and advances in explicit computation. This was particularly evident in a sequence of lectures dealing with overconvergent modular symbols. Joël Bellaïche lectured on an exciting new theoretical development, namely the application of the theory of overconvergent modular symbols to the construction of critical  $p$ -adic  $L$ -functions. Matthew Greenberg and Glenn Stevens discussed other aspects of these symbols, focusing on their explicit nature and their suitability for implementation in computer algebra systems.

Iwasawa theory also featured prominently in the program. In a talk with the provocative title *Why Iwasawa Theorists Need  $p$ -adic  $L$ -Functions*, Christian Wuthrich convinced the Iwasawa theorists that they do need

*L*-functions. Expanding on this theme, Lawrence Washington spoke about a question in algebraic number theory motivated by Iwasawa theory while Ralph Greenberg gave constructions for (analytic and algebraic)  $p$ -adic  $L$ -functions associated with Artin representations. On the computational side, Kazuo Matsuno discussed 2-adic cyclotomic  $\mu$ -invariants of ordinary elliptic curves while Zhibin Liang explained the theory and calculations related to the conjecture of Birch and Swinnerton-Dyer for elliptic curves with complex multiplication.

Topics related to  $p$ -adic automorphic forms and  $p$ -adic Hodge theory were also on the agenda. Jeehoon Park presented a construction of Teitelbaum-type  $L$ -invariants for Hilbert modular forms on definite quaternion algebras. Lassina Dembélé gave evidence for a multiplicity one conjecture for mod  $p$  quaternionic automorphic forms. Bryden Cais discussed connections between Hida families of modular forms and  $p$ -adic Hodge theory. The conference was capped off by a wonderful colloquium lecture delivered by John Coates on the past, present, and future of Iwasawa theory and  $p$ -adic  $L$ -functions. The hospitality and excellent environment for scientific exchange provided by the CRM were appreciated by all and facilitated a productive and highly successful conference.

### Course Point Counting and Cohomology

March 1 – April 30, 2010

**Organizer:** Henri Darmon (McGill)

#### Speakers:

Francesc Castella (McGill), Henri Darmon, Adam Logan (Waterloo), Aurel Page (Bordeaux 1)

**Number of participants:** 10

This mini-course consisted of 10 hours of lectures given by Henri Darmon (4 hours), Aurel Page (2 hours), Francesc Castella (2 hours), and Adam Logan (2 hours). The mini-course discussed point counting algorithms for varieties over finite fields arising from (étale and  $p$ -adic) cohomology and was an introduction to the workshop on the same topic (see below). The basic principle used by all those algorithms is that the zeta function of a variety over a finite field is the characteristic polynomial of the Frobenius endomorphism acting on the cohomology of the variety. The first point counting method is based on the  $l$ -adic cohomology; it is due to Schoof, and works well only for elliptic

curves. This method was presented by Aurel Page. The methods based on  $p$ -adic cohomology (which is closely related to the de Rham cohomology of the variety computed with differential forms, and seems better suited for explicit computations) were presented by the other lecturers. Darmon talked about the AGM method of Satoh based on the arithmetic-geometric mean, and Logan talked about the approach of Lauder exploiting the differential equation associated to the Gauss–Manin connection for computing the zeta functions of the varieties as a whole.

### Workshop on Graphs and Arithmetic

March 8 – 12, 2010, CRM

Sponsored by the CRM and the NSF

#### Organizers:

Eyal Goren (McGill), Andrew Granville (Montréal), Weng-Ching Winnie Li (Penn State)

#### Speakers:

Omer Angel (UBC), Jean Bourgain (IAS), Boris Bukh (Cambridge), Mei-Chu Chang (UC Riverside), Anne de Roton (Henri Poincaré), Yang Fang (Penn State), Elena Fuchs (Princeton), Alexei Glibichuk (UNAM), Harald Andrés Helfgott (Bristol), Jerome William Hoffman (Louisiana State), Ming-Hsuan Kang (Penn State), Dubi Kelmer (Chicago), Alex Kontorovich (Brown), Weng-Ching Winnie Li, Alex Lubotzky (HUJI), M. Ram Murty (Queen's), László Pyber (Alfréd Rényi), Igor Shparlinski (Macquarie), Adrian Ubis (UA Madrid), Peter Varju (Princeton), Chian-Jen Wang (NTHU), Gilles Zémor (Bordeaux 1), Tamar Ziegler (Technion)

**Number of participants:** 52

The connections between graphs and arithmetic emerged from several directions, via explicit constructions, via uniformization, and via arithmetic properties of subgroups of Lie groups. Ultimately, all these results rest on spectral properties or structural properties of algebraic groups, where the crucial input is often supplied by number theory (in the wide sense) and algebraic geometry. The theory of expander graphs has fertilized number theory, geometry, and theoretical computer science. This workshop had several focal points: (i) Ramanujan complexes; (ii) expansion in finite simple groups and in Lie groups; (iii) connection between expanders and geometry; and (iv) the affine sieve. It also included lectures on related topics that do not fall under these classifications, notably: (a) the lecture by Tamar Ziegler, who reported on the spectac-

ular result of Green – Tao – Ziegler concerning primes in linear forms; and (b) the lecture by the Aisenstadt prize winner, Omer Angel, concerning limits of graphs and local vs. global phenomena in graphs.

Here are some details concerning the program. The description is partial and the interested reader can consult the CRM website for more details.

- The topic of Ramanujan complexes arises naturally as one studied the quotient of buildings by arithmetic groups (the usual  $(p + 1)$ -regular graphs, where  $p$  denotes a prime, are quotients of the  $(p + 1)$ -regular tree, which is the Bruhat – Tits building for  $\mathrm{PGL}_2$ ). Several lectures examined this notion and proved the Ramanujan property for the case of  $\mathrm{GL}_3$  (Chian-Jen Wang) and  $\mathrm{Sp}_4$  (Yang Fang), and  $\mathrm{PGL}_n$  was discussed (Ming-Hsuan Kang). Many of the results obtained here were formulated in terms of the zeta function in the complex plane and are joint work with Winnie Li. The talk by William Hoffman explored the relations of this topic to arithmetic geometry.
- Harald Helfgott gave an overview of the work done in this area since his seminal *Annals* paper, and László Pyber reported on a remarkable breakthrough, stating, roughly, that in all finite simple groups of bounded Lie rank, a symmetric set of generators  $A$  grows uniformly:  $AAA$  has a large cardinality compared to that of  $A$ , unless there is some obvious obstruction. This result was obtained independently by Pyber – Szabó and Breuillard – Green – Tao. By the result of Bourgain – Gamburd one expects to be able to make this family into a family of expanders. Peter Varju talked about expansion in  $\mathrm{SL}_d(\mathbb{Z}/q\mathbb{Z})$ . Jean Bourgain talked about spectral gaps in  $\mathrm{SU}(d)$  and Dubi Kelmer considered  $\mathrm{PGL}_2^d$ .
- Alex Lubotzky talked about connections between expanders and geometry, with emphasis on hyperbolic manifolds, and Elena Fuchs talked about these connections in the context of Apollonian circle packings.
- Alex Kontorovich reported new results concerning the affine sieve, a topic that appeared in other talks as well. In addition, we had several inspiring talks going in other directions: codes (Gilles Zémor), almost Ramanujan graphs (Ram Murty), Sum-products (Alexey Glibichuk, Boris Bukh), character sums (Mei-Chu Chang), distribution of primes (Adrian Ubis, Anne de Roton) and relation to matrix theory (Igor Shparlinski).

The workshop was attended by 52 participants coming from Canada, the United States, England, Hungary, China, Spain, Australia, Mexico, France, Japan, and Israel. It was an exciting event, where many important results that have not yet appeared in print, or for which a preprint doesn't even exist yet, were reported. It gave a panorama of the subject, as well as important emerging directions.

## Workshop Computer Methods for $L$ -functions and Automorphic Forms

March 22 – 26, 2010, CRM

Sponsored by the CRM and the NSF

### Organizers:

Craig Citro (Washington), Bas Edixhoven (Leiden), Michael Rubinstein (Waterloo), William Stein (Washington)

### Speakers:

Amod Agashe (Florida State), Salman Baig (Washington), David Farmer (AIM), William B. Hart (Warwick), Ghaith Hiary (Waterloo), Michael Rubinstein, Nathan C. Ryan (Bucknell), William Stein, Akshay Venkatesh (Stanford), John Voight (Vermont), Mark Watkins (Sydney)

**Number of participants:** 48

The purpose of this gathering, funded by the CRM and also by an NSF Focused Research Group grant, was to give researchers an opportunity to collaborate on research related to  $L$ -functions and automorphic forms. Afternoons were reserved for work, while mornings were devoted to talks. Ten morning lectures were held, with talks on various computational aspects of  $L$ -functions and automorphic forms given by the following researchers: A. Agashe, S. Baig, D. Farmer, W. Hart, N. Ryan, M. Rubinstein, J. Voight, W. Stein, and M. Watkins. Several optional technical talks were given in the afternoons. In addition Akshay Venkatesh gave three Aisenstadt Chair lectures, one of which was geared towards a broad audience.

During the workshop several working groups were formed, in order to address the following topics: Classical Modular Forms; Siegel Modular Forms; Ranks of Elliptic Curves in Families of Twists; Maass Forms; Hilbert Modular Forms; Analytic Algorithms; and Elliptic Curves over Function Fields. For example, the Maass Forms group continued their work on computing  $L$ -functions corresponding to Maass forms for

higher rank groups. They focused mainly on extending their work to congruence subgroups of  $SL(3, \mathbb{Z})$ . Their code was working well by the end of the week and they computed roughly 20  $L$ -functions satisfying a functional equation of the same form as that of a Maass form of non-trivial level. The  $L$ -functions they computed are not self-dual and hence cannot be expressed as symmetric square  $L$ -functions of Maass forms on a congruence subgroup of  $SL(2, \mathbb{Z})$ . The program, however, also found the symmetric square  $L$ -functions for several Maass forms on  $\Gamma(2)$ .

The working group on Ranks of Elliptic Curves discussed different strategies for finding high-rank elliptic curves in the family of quadratic twists of a given elliptic curve. The workshop also gave an opportunity to several postdocs and graduate students for discussing their ideas with participating researchers.

## Workshop Computer Security and Cryptography

April 12 – 16, 2010, CRM

Sponsored by the CRM and Microsoft Research

### Organizers:

Tanja Lange (TU Eindhoven), Kristin E. Lauter (Microsoft Research), Joseph Silverman (Brown)

### Speakers:

Daniel J. Bernstein (UIC), Alexandra Boldyreva (Georgia Tech), Melissa E. Chase (Microsoft Research), Sanjit Chatterjee (Waterloo), Jung Hee Cheon (Seoul National University), Kirsten Eisentraeger (Penn State), Steven Galbraith (Auckland), Koray Karabina (Waterloo), Thorsten Kleinjung (EPFL), Victor S. Miller (CCR – Princeton), Payman Mohassel (Calgary), David Molnar (Microsoft Research), Michael Naehrig (Microsoft Research), Christopher Peikert (Georgia Tech), Christiane Peters (TU Eindhoven), Christophe Petit (UC Louvain), Christophe Ritzenthaler (Méditerranée), Renate Scheidler (Calgary), Éric Schost (Western Ontario), Peter Schwabe (TU Eindhoven), Hovav Shacham (UCSD), Igor Shparlinski (Macquarie), Alice Silverberg (UC Irvine), Andrew V. Sutherland (MIT), Vinod Vaikuntanathan (IBM Research), Bianca Viray (UC Berkeley)

**Number of participants:** 78

The Workshop on Computer Security and Cryptography featured a plethora of distinguished lecturers speaking on a variety of current research topics: integer factorization algorithms and their implications

for the security of the RSA scheme; analysis of elliptic and hyperelliptic curve cryptography, including security analyses and applications to pairing-based cryptography; a new proposal for fully homomorphic encryption; and hash function attacks.

The 27 presentations covered major areas of cryptography and security and provided a good balance between survey talks and presentations of recent results. The talks can be grouped into the following areas.

1. Factorization of large integers (including the impact on the security of RSA-based cryptosystems)
  - A successful new attack on RSA-768 (achieved through a distributed effort carried out by four institutes)
  - Presentation and discussion of RSA-1024 attack predictions
2. ECC and DLP attacks (including the impact on the security of ECC-based cryptosystems)
  - Presentation of improved attacks with auxiliary inputs
  - Examination and improvement of birthday paradox constants
  - Presentation of an attack on ECC2K-130 (achieved through a distributed effort carried out by twelve institutes)
3. Pairing-based cryptography
  - Efficient implementation results (new record announced)
  - Presentation of a generic group model security
  - Presentation of curve generation challenges and solutions
  - Presentation and improvement of Complex Multiplication methods for generating elliptic and hyperelliptic curves
  - Survey of hyperelliptic curve pairings
4. Code and lattice-based cryptosystems (post-quantum cryptography)
  - Proposal of new systems (LWE: Learning with Errors public key cryptosystems)
  - Survey of code-based cryptography (McEliece parameters)
  - Explanation of known attacks and examination of their relevance (HNP, i.e., Hidden Number Problem)
5. Fully homomorphic encryption: Proposal of an approximate GCD-based system (Eurocrypt 2010 paper)
6. Presentation of hash function attacks
  - SAT solvers (as compared with MD2 and MD5)

- Preimage and collision attacks on Cayley-graph-based hash functions
- 7. Discussion and coordination of computational resources (Cloud Computing, distributed computing efforts,...)
- 8. Presentation of recent new cryptographic applications
  - Encrypted database search
  - Anonymous credentials

We received extremely positive feedback from the participants, both about the quality of the presentations and about the opportunities to interact and to discuss outside the talks. Several participants pointed out that they made new contacts and that they have started new collaborations.

## Workshop

### Counting Points: Theory, Algorithms and Practice

April 19 – 23, 2010, CRM

#### Organizers:

Kiran S. Kedlaya (MIT), Jean-François Mestre (Paris Diderot)

#### Speakers:

Nick Alexander (UC Irvine), Daniel J. Bernstein (UIC),

Luis Finotti (Tennessee), Pierrick Gaudry (LORIA & CNRS), David Harvey (NYU), Kristin E. Lauter (Microsoft Research), Reynald Lercier (DGA & Rennes 1), Christiane Peters (TU Eindhoven), Christophe Ritzenhaler (Méditerranée), David Roe (Harvard), Adriana Salerno (Bates College), Igor Shparlinski (Macquarie), Benjamin Smith (INRIA Saclay), Andrew V. Sutherland (MIT), John Voight (Vermont), Daqing Wan (UC Irvine)  
**Number of participants:** 39

The activities of this workshop were disrupted by the eruption of the Eyjafjallajökull volcano, which closed the European airspace for several days. As a result, the organizers recruited some graduate students and postdoctoral fellows who were attending the activities and who graciously agreed to give last minute talks. Among these we would like to mention Nick Alexander, Christiane Peters, Adriana Salerno, and Benjamin Smith. The result was a very nice mix of talks by senior and junior participants. There were also some productive discussions about large-scale computing after the lecture of Dan Bernstein, and some useful back-and-forth discussions between people using different flavours of  $p$ -adic cohomology for computations (e.g., David Harvey and John Voight).

## 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.

**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

### Affine Algebraic Geometry: A Conference in Honour of Peter Russell

June 1–5, 2009, McGill University

Sponsored by the CRM, McGill University, the University of Ottawa, the University of Warsaw, and York University

#### Organizers:

Daniel Daigle (Ottawa), Richard Ganong (York), Jacques Hurtubise (McGill), Mariusz Koras (Warsaw), Steven Lu (UQÀM)

#### Speakers:

Jason Bell (Simon Fraser), Pierrette Cassou-Noguès (Bordeaux 1), Daniel Daigle, Hubert Flenner (Ruhr Bochum), Gene Freudenburg (Western Michigan), Rajendra Gurjar (Tata Inst.), Zbigniew Jelonek (Jagellonian), Mariusz Koras, Herbert Kurke (Humboldt), Shigeru Kuroda (Tokyo Metropolitan), Steven Lu, Kayo Masuda (Kwansei Gakuin), Vikram Mehta (Tata Inst.), Masayoshi Miyanishi (Kwansei Gakuin), Lucy Moser-Jauslin (Bourgogne), Pavaman Murthy (Chicago), Stepan Orevkov (Paul Sabatier), Karol Palka (Warsaw), Vladimir Popov (Steklov Inst., Moscow), Paul Roberts (Utah), Marko Roczen (Humboldt), Avinash Sathaye (Kentucky), Yoshifumi Takeda (Wakayama Medical), Stéphane Vénéreau (Basel), David Wright (WUSTL)

**Number of participants:** 39

This five-day conference celebrated the contributions of Peter Russell to the area of affine algebraic geometry, as well as to problems in characteristic  $p$  geometry. It assembled participants working in such topics as algebraic group actions on affine spaces, the cancellation problem, embeddings of affine spaces, and the theory of open surfaces. The conference saw a plethora of new results, accompanying the natural reminiscences of a remarkable career.

### Workshop

#### Models, Logics and Higher-Dimensional Categories: A Tribute to the Work of Mihaly Makkai

June 19 – 20, 2009, CRM

#### Organizers:

Bradd Hart (McMaster), Thomas G. Kucera (Manitoba), Philip Scott (Ottawa), Robert A.G. Seely (McGill)

#### Speakers:

Mike Barr (McGill), Victor Harnik (Haifa), André Joyal (UQÀM), Henry Kierstead (Arizona State), Julia F. Knight (Notre Dame), François Lamarche (INRIA Nancy), Joachim Lambek (McGill), Mihaly Makkai (McGill), Robert Paré (Dalhousie), Anand Pillay (Leeds), Gonzalo E. Reyes (Montréal), Charles Steinhorn (Vassar), Marek Zawadowski (Warsaw)

**Number of participants:** 48

This workshop followed the “Makkai workshop” that was held at McGill University on June 18 and featured 8 talks. Mihaly Makkai is a distinguished professor from McGill University who has made important contributions to logic and category theory. There were 13 talks given at the CRM workshop on June 19 and 20, as well as a special historical talk at the end of the first day, covering many aspects of Makkai’s career and influence. The high quality of the presentations, and of the resulting discussions, was a fitting tribute to the contributions of Professor Makkai, especially as they covered a diversity of fields of mathematics and yet displayed a thematic unity. Makkai himself underlined this point in his comments on Friday evening; so did Jean-Pierre Marquis in his workshop lecture on the philosophy of Makkai’s mathematics.

Professor Makkai’s work features a remarkably successful marriage of ideas and techniques between category theory on one hand and model theory and logic on the other. This marriage was already evident in the 1977 monograph entitled “First Order Categorical Logic” by M. Makkai and G. Reyes, which successfully

combined traditional model theory with Grothendieck toposes. In the following years Professor Makkai built up an impressive body of work in several related fields: categorical model theory, first order logic with dependent sorts, and higher-dimensional category theory. In his work he has proposed a coherent and far reaching view of categorical logic in the foundations of mathematics.

The workshop was timely not only because of Professor Makkai's 70th birthday, but also because of the widening realization that traditional model theory might usefully embrace the categorical methods pioneered by Professor Makkai. Traditional model theory is set-based. In contrast, contexts and techniques from category theory are used more and more in recent model-theoretic work in such areas as algebraic geometry, differential algebra, Mordell – Lang theory, etc. The workshop focused on the main themes of Professor Makkai's career: traditional model theory, categorical model theory and logics, and higher-dimensional category theory.

### 1st Montreal Workshop on Idempotent and Tropical Mathematics

June 29–July 3, 2009, GERAD

Sponsored by the CRM and GERAD

**Organizer:** Édouard Wagner (GERAD & Polytechnique Montréal)

**Local Committee:**

Ivo G. Rosenberg (Montréal), Édouard Wagner

**Speakers:**

Marianne Akian (INRIA & École Polytechnique), Jean-Louis Boimond (Angers), Maria Jesús de la Puente (Complutense), Stéphane Gaubert (INRIA & École Polytechnique), Martin Gavalec (Hradec Králové), Zur Izhakian (Bar-Ilan), Jean-Jacques Loiseau (Nantes & CNRS), William McEneaney (UCSD), Sharify Meisam (INRIA & École Polytechnique), Monika Molnárová (TU Košice), Viorel Nitica (West Chester), Paul Poncet (INRIA & École Polytechnique), Jean-Pierre Quadrat (INRIA Rocquencourt), Sergei Sergeev (Birmingham), Hans Schneider (Wisconsin – Madison), Ivan Singer (Inst. Simion Stoilow), Édouard Wagner

**Number of participants:** 25

L'atelier a duré 4 jours au lieu de 5, parce qu'un collègue russe très attendu n'a pu obtenir son visa à temps. Après des allocutions d'ouverture prononcées par Édouard Wagner, Chantal David (directrice ad-

jointe du CRM) et Roland Malhamé (directeur du GERAD), la partie scientifique de l'atelier commença par un exposé du professeur Hans Schneider. Le professeur Schneider annonça également que la revue *Linear Algebra and Its Applications* publierait un numéro spécial consacré aux contributions des participants et d'autres collègues.

Les sujets abordés au cours de la première journée ont témoigné de la très grande diversité des applications des mathématiques tropicales, allant de la théorie des jeux (M. Akian) à l'algèbre des matrices (Z. Izhakian), en passant par les fonctions convexes et la complexité dans les espaces tropicaux (W. McEneaney). Cette démonstration s'est poursuivie le mardi 30 juin, avec des exposés portant sur l'analyse de la circulation et de la congestion dans une ville (J.-P. Quadrat), la commande optimale des systèmes à événements discrets (J.-L. Boimond), les équations implicites aux différences en automatique (J.-J. Loiseau), la théorie de la mesure (P. Poncet) et le calcul du second cycle maximal dans le graphe de précedence d'une matrice à coefficients dans l'algèbre tropicale (Monika Molnárová et Martin Gavalec).

La troisième journée, coïncidant avec la fête nationale du Canada, consista d'un brillant exposé sur le régime permanent des puissances de matrices tropicales (S. Sergeev) et d'un autre sur les valeurs propres des polynômes matriciels (S. Meisam). La dernière journée permit d'apprécier quelques résultats surprenants dans la « tropicalisation » de la géométrie convexe discrète (S. Gaubert) et d'approfondir les sujets suivants : structures des hyperplans tropicaux (V. Nitica), applications du plan tropical dans lui-même (de la Puente) et valeurs propres d'applications d'intervalles (M. Gavalec). Enfin É. Wagner introduisit un type de complexité inédit, la complexité formelle de la solution de certaines inégalités max-linéaires.

Tout au long de l'atelier, les participants (y compris plusieurs étudiants) se réunirent par petits groupes, afin d'étudier un concept ou un nouveau problème. Ces échanges étaient un des buts de l'atelier, qui connut donc un franc succès.

### 15th IAPR International Conference on Discrete Geometry for Computer Imagery

September 30 – October 2, 2009, UQÀM

Sponsored by the CRM, the Government of Québec (ministry of Education), and the Canada Research

Chair in algebra, combinatorics, and mathematical computer science

**Steering Committee:**

Eric Andres (Poitiers), Gunilla Borgefors (Uppsala), Achille Braquelaire (Bordeaux 1), Jean-Marc Chassery (Grenoble INP), David Coeurjolly (Lyon 1 & CNRS), Ullrich Köthe (Hamburg), Annick Montanvert (Grenoble INP), Kálmán Palágyi (Szeged), Gabriella Sanniti di Baja (Ist. E. Caianiello)

**Program Committee:**

Reneta Barneva (SUNY Fredonia), Michel Couprie (ESIEE), Alain Daurat (Strasbourg), Isabelle Debled-Rennesson (LORIA), Christophe Fiorio (Montpellier 2 & CNRS), Pieter Jonker (TU Delft), Christer Kislman (Uppsala), Walter Kropatsch (TU Wien), Jacques-Olivier Lachaud (Savoie), Rémy Malgouyres (Auvergne), Renzo Pinzani (Firenze), Pierre Soille (IPSC), Édouard Thiel (Méditerranée), Peter Veelaert (Gent)

**Co-chairs of the Organizing Committee:**

Srečko Brlek, Christophe Reutenauer (UQÀM)

**Invited Speakers:**

Valérie Berthé (Montpellier 2 & CNRS), Anders Kock (Emeritus Professor, Aarhus), Pierre Gauthier (UQÀM)

**Number of participants:** 85

La série de congrès sur la géométrie discrète pour l'imagerie est parrainée par le regroupement *International Association for Pattern Recognition*. Le but de ces congrès est de rassembler des chercheurs travaillant en géométrie discrète et topologie et en modèles discrets et appliquant leurs travaux à l'analyse et la synthèse d'images. La géométrie discrète joue un rôle croissant dans les domaines de la modélisation des formes, de la synthèse d'images et de l'analyse d'images. Elle étudie les définitions topologiques et géométriques des objets ou images discrétisés et fournit un cadre théorique et algorithmique pour l'imagerie par ordinateur. Le congrès tenu à l'UQÀM comporta trois conférences données par les conférenciers invités, deux sessions de courtes présentations et des présentations de 25 minutes regroupées dans des sessions portant sur les thèmes suivants :

- représentation, reconnaissance et analyse des formes discrètes,
- outils discrets et combinatoires pour la segmentation et l'analyse d'images,
- topologie discrète et combinatoire,
- modèles pour la géométrie discrète,
- transformations géométriques et
- tomographie discrète.

**Holographic Cosmology Workshop**

October 2 - 4, 2009, McGill University

Sponsored by the Mathematical Physics Laboratory

**Organizer:** Robert Brandenberger (McGill)

**Participants:**

Stephon Alexander (Haverford), Chong-Sun Chu (Durham), Daniel Kabat (Lehman Coll., CUNY), Albion Lawrence (Brandeis), David Lowe (Brown), Fotini Markopoulou (Perimeter Inst.), Samir Mathur (Ohio State), Savdeep Sethi (Chicago), Harold Steinacker (Wien)

The goal of this workshop was to gather a small number of experts to discuss recent approaches to non-perturbative quantum gravity and their possible applications to cosmology. Specifically, approaches based on the AdS/CFT correspondence, matrix models, and non-commutative and emergent gravity models were discussed during the workshop.

**First Bavaria – Québec Mathematical Meeting**

November 30 – December 3, 2009, CRM

Sponsored by the Government of Québec (department of international relations) and the Analysis Laboratory

**Organizers:**

Richard Fournier (Dawson), Stephan Ruscheweyh (Würzburg)

**Speakers:**

Line Baribeau (Laval), Marco Bertola (Concordia), Hans-Peter Blatt (KU Eichstätt-Ingolstadt), Nicolas Chevrot (Laval), Galia Dafni (Concordia), Serge Dubuc (Montréal), Dimiter Dryanov (Concordia), Daniel Fiorilli (Montréal), Paul M. Gauthier (Montréal), Andrew Granville (Montréal), Youness Lamzouri (IAS), Javad Mashreghi (Laval), Qazi Ibadur Rahman (Montréal), Oliver Roth (Würzburg), Gerhard Schmeisser (Erlangen-Nürnberg), Jörn Steuding (Würzburg)

**Number of participants:** 31

Ce colloque est un des fruits de la collaboration entre ses deux organisateurs, commencée en 1985 alors que Richard Fournier effectuait un stage postdoctoral en Bavière sous la supervision de Stephan Ruscheweyh. Dans le cadre de son programme d'échanges avec la Bavière, le ministère des Relations internationales a accepté d'accorder un montant de 6 000 \$ pour l'organisation de cette première rencontre mathématique Bavière-Québec. Presque tous les mathé-

maticiens québécois travaillant en théorie des fonctions participèrent au colloque. Après l’allocution d’ouverture de Peter Russell, directeur du CRM (prononcée en trois langues), les conférences portèrent sur les sujets suivants (entre autres) : la fonction zêta de Riemann, la distribution des nombres premiers, les grandes valeurs prises par les fonctions  $L$ , le problème de Nevanlinna-Pick, les théorèmes de Landau et Schottky, l’entropie de Kolmogorov, une décomposition atomique de l’espace de Hajlasz-Sobolev  $M_1^1$  sur les variétés, et les approximants rationnels. Les organisateurs ont trouvé tous les exposés intéressants mais veulent souligner les exposés remarquables de Bertola, Blatt, Granville, Roth et Schmeisser.

### Workshop Topics in Riemannian and Poisson Geometry

April 8 – 9, 2010, UQÀM  
Sponsored by CIRGET

#### Organizers:

Marco Gualtieri (Toronto), Jacques Hurtubise (McGill), Ruxandra Moraru (Waterloo)

#### Speakers:

Alberto Cattaneo (Zürich), Andrew Dancer (Oxford), Nigel J. Hitchin (Oxford), Paul Gauduchon (École Polytechnique)

There has been a great deal of interest recently in various forms of generalized geometry, such as generalized complex and Kähler geometry. The relation between such geometries and other special structures, for example ASD conformal metrics, bihermitian geometry, and Poisson structures, has been at the core of intensive recent research in this rapidly developing field. This two-day workshop was a satellite workshop of the BIRS 5-day program entitled “Workshop on generalized complex and holomorphic Poisson geometry” (April 11 – 16, 2010). Approximately 25 researchers attended the workshop held at UQÀM.

### Workshop Virtual Properties of 3-Manifolds

April 19 – 23, 2010, UQÀM  
Sponsored by CIRGET

#### Organizers:

Ian Agol (UC Berkeley), Steven Boyer (UQÀM)

#### Speakers:

Ian Agol, Nathan Dunfield (UIUC), Stefan Friedl (War-

wick), Tim Hsu (San José State), Jeremy Kahn (Stony Brook), Alan Reid (UT Austin), Claire Renard (Paul Sabatier), Daniel Wise (McGill), Xingru Zhang (Buffalo)

Over the past decade several major breakthroughs have been made concerning the classification of 3-dimensional manifolds. These include Perelman’s solution of the geometrization conjecture and the solutions by Agol and Calegari – Gabai of the tameness conjecture for Kleinian groups. Such results have provided a platform for a renewed attack on other fundamental problems and in particular on one of the major lines of contemporary research, i.e., properties of 3-dimensional manifolds that hold up to taking a finite degree cover (virtual properties). For instance, Thurston has conjectured that a hyperbolic 3-manifold admits a finite cover that is a fibration over the circle. In general, there is a natural sequence of conjectures concerning such properties. New methods from Heegaard Floer theory, contact topology, geometric group theory, and algebraic number theory, combined with more traditional methods such as 3-dimensional hyperbolic geometry, are likely to be influential in the study of these properties. The goal of the workshop was to showcase these interactions in order to foster future developments. On April 19 – 21, Daniel Wise gave a series of talks on his work on separability for hyperbolic groups with quasiconvex hierarchies. The workshop itself took place on April 22 and 23 and focused primarily on topics related to the virtual positive first Betti number conjecture and virtual fibered conjectures for 3-manifolds. Approximately 30 researchers attended the workshop, including many graduate students and postdoctoral fellows.

### The Bellairs Workshop in Number Theory Moduli Spaces and the Arithmetic of Dynamical Systems

May 2 – 9, 2010, Bellairs Research Institute  
Sponsored by CICMA

#### Organizers:

Xander Faber (McGill), Patrick Ingram (Waterloo)

**Principal Speaker:** Joseph H. Silverman (Brown)

#### Other speakers:

Laura DeMarco (UIC), Adam Epstein (Warwick), Michelle Manes (Hawaii), Michael Tepper (Penn State Abington)

**Number of participants:** 25

The goal of the workshop was to provide a common background on the uses of moduli spaces in dynamical systems, especially their relationship to arithmetic. The topics that were discussed include the following: moduli spaces of dynamical systems on projective space, varieties parameterizing dynamical systems along with extra structure (e.g., periodic points of fixed period), dynamical systems over function fields. A number of current developments in the subject were discussed, with the aim of stimulating new activity and collaboration. The main speaker, Joseph Silverman, gave a two-hour lecture each day from Monday to Friday, while the evening lectures were given by Laura DeMarco, Adam Epstein, Michelle Manes, graduate students, and Michael Tepper.

### First Montreal Spring School in Graph Theory

May 2 – 29, 2010, McGill University

**Organizer:** Bruce Reed (McGill)

**Speakers:**

Maria Chudnovsky (Columbia), Bruce Reed, Paul Seymour (Princeton)

**Number of participants:** 69

Much of mathematics is driven by conjectures, and this is particularly true of Graph Theory. Two of the great conjectures that drove, stretched, and teased, a generation of graph theorists are Wagner’s Conjecture and The Strong Perfect Graph Conjecture (due to Berge). In the past decade both have been proved: the former by Robertson and Seymour and the latter by Chudnovsky, Robertson, Seymour, and Thomas. Each of the proofs (and this is especially true of the former) represents the culmination of a grand project of research that has built up a whole structural theory surrounding the required result.

For a new generation of graph theorists these results may be taken as given. That does not mean, however, that they should be ignored. The wealth of knowledge and techniques built up in proving these results is a bounty that the new generation is lucky to inherit. The First Montreal Spring School in Graph Theory was an opportunity for young researchers from Canada and around the world to learn of this bounty from three top academics in the field. In all we had over 60 participants at the school, coming from 15 countries.

In 1937 Wagner proved that a graph  $G$  is planar if and only if it contains neither  $K_5$  nor  $K_{3,3}$  as a minor. He then considered a more abstract problem: does there exist, for each surface  $\Sigma$ , a similar characterization (a finite list of excluded minors) for graphs embeddable in  $\Sigma$ ? Wagner noticed that to ensure the existence of such characterizations, it suffices to prove that in every infinite sequence of graphs there is one that is a minor of another. This latter statement became known as Wagner’s Conjecture. Wagner’s Conjecture was proved by Robertson and Seymour as part of their grand project on graph minors.

Results from this entire project were covered in the lecture course “Structural results obtained from excluding graph minors”, taught by Bruce Reed, who, incidentally, is in the final stages of completing a book on the graph minors project. The key structural theorem of the course states (approximately) that all graphs without a fixed graph  $H$  as a minor can be obtained by gluing together (in an appropriate way) certain “topologically simple” graphs. At the end of the course we turned to Wagner’s Conjecture. It is by no means trivial to deduce Wagner’s Conjecture from the structure theorem, but the structure theorem does allow us to get a grip on the problem that is essential to its resolution.

One colours a graph by assigning a colour to each vertex in such a way that no two adjacent vertices receive the same colour. If there is a set of  $\omega$  vertices (a clique) that are all mutually adjacent, then it is clear that at least  $\omega$  colours will be needed to colour the graph. It is somewhat interesting to know that for a certain graph, this number of colours suffices, i.e., the number of colours needed equals the size of the largest clique. It is much more interesting to know that for a certain graph  $G$ , this property holds not only for  $G$  but also for all induced subgraphs of  $G$  (i.e., graphs that can be obtained from  $G$  by deleting vertices). If this is the case then we say that  $G$  is perfect.

It is easy to find graphs that are not perfect. For example, odd cycles of length at least five are imperfect, and so are their complementary graphs (i.e., those obtained by switching edges and non-edges). Thus for a graph to be perfect it is necessary that it contain neither an odd cycle of length at least five, nor the complement of such a cycle, as an induced subgraph. The Strong Perfect Graph Conjecture, due to Berge (1960), states that this necessary condition is also sufficient. The other course in the school, “Structural results obtained by excluding induced subgraphs”, which included a proof of the

Strong Perfect Graph Conjecture, was taught jointly by Paul Seymour and Maria Chudnovsky.

In Paul Seymour's lectures we were introduced to a structure theorem for graphs (now known as Berge graphs) that have neither odd cycles of length at least five nor their complements as induced subgraphs. The structure theorem shows that such graphs either belong to one of a few families of basic graphs, or admit one of a few types of decompositions. Since the families of basic graphs are known to be perfect, and graphs admitting such decompositions are known to be perfect, the proof of the Strong Perfect Graph Conjecture follows. Maria Chudnovsky's lectures (one quarter of the course) focused on more recent results and open conjectures, including recent advances related to the Erdős – Hajnal Conjecture (a conjecture that is still open).

The participants showed their gratitude at the end of the school by buying a few small gifts for the lecturers. In particular, Paul received a set of five cigars, each with the name of a conjecture written on it. Each time he (on his own or with collaborators) proves one of these conjectures, he is allowed to smoke the corresponding cigar. The participants are probably hoping that there will be another school (in 10 years from now) based on the proofs of these conjectures!

## Workshop on Evolutionary Genomics Acfas 2010

May 10, 2010, Université de Montréal

**Organizer:** Nadia El-Mabrouk (Montréal)

### Speakers:

Denis Bertrand (Montréal), Mathieu Blanchette (McGill), Cedric Chauve (Simon Fraser), Miklós Csűrös (Montréal), Andr ea Doroftei (Montréal), Sylvie Hamel (Montréal), Paul Horton (AIST), David Sankoff (Ottawa)

Ce colloque fut organis e dans le cadre du congr es de l'Acfas en 2010, qui eut lieu   l'Universit  de Montr al. Entre 15 et 20 personnes y particip rent. Voici les titres des pr sentations.

- *Evolution of the mitochondrial proteome* (P. Horton)
- *G nomes ancestraux de levures* (C. Chauve)
- *Compl ter les g nes manquants des  chafaudages   l'aide de l' vidence comparative* (D. Sankoff)
- *Le r le de la r gulation « longue-distance » dans la pr -servation de la synt nie* (M. Blanchette)
- *M dianes de  $m$  permutations* (S. Hamel)
- *G nomes pr -dupliqu s ancestraux* (D. Bertrand)
- *Correction des arbres de g nes* (A. Doroftei)
- * volution de l'organisation exon-intron chez les eucaryotes* (M. Csűr s)

## CRM–ISM Colloquium Series

The CRM, together with the Institut des sciences math matiques du Qu bec (the Qu bec universities graduate mathematics consortium), runs two Montr al colloquium series, one in mathematics and the other in statistics (the latter jointly with GERAD, an operations research centre located in the Andr -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 2009 – 2010 the colloquium coordinators were Steven Lu (UQ M) and John Toth (McGill).

September 25, 2009

Svetlana Katok (Penn State)

*Structure of Attractors for  $(a, b)$ -Continued Fraction Transformations*

October 9, 2009

Ravi Ramakrishna (Cornell)

*What is a Galois Representation?*

October 30, 2009

Glenn Stevens (Boston)

*$p$ -adic Variation in the Theory of Automorphic Forms*

November 6, 2009

Christopher Sogge (Johns Hopkins)

*Kekeya – Nikodym Averages and  $L_p$  Norms of Eigenfunctions*



- |  |   |
|--|---|
| November 20, 2009<br>James Lewis (Alberta)<br><i>New Invariants on Algebraic Cycles</i>  | February 12, 2010<br>Frank Sottile (Texas A&M)<br><i>Orbitopes</i>  |
| November 27, 2009<br>Shing-Tung Yau (Harvard)<br><i>Canonical Metrics on Kähler Manifolds</i>                                      | February 19, 2010<br>Jeremy Quastel (Toronto)<br><i>Large Scale Behaviour of the Continuum Random Polymer and KPZ</i>                     |
| December 4, 2009<br>Erez Boas (Bordeaux 1)<br><i>Galois Modules in Arithmetic and Geometry</i>                                     | February 26, 2010<br>John Coates (Cambridge)<br><i>Iwasawa Theory</i>   |
| December 18, 2009<br>François Lalonde (Montréal)<br><i>La nouvelle géométrie algébrique réelle</i>                                 | March 5, 2010<br>Balint Virag (Toronto)<br><i>Random Schrödinger Operators and Random Matrices</i>  |
| January 8, 2010<br>Henri Darmon (McGill)<br><i>Diophantine Equations: What Numbers Reveal About Shape and Structure</i>            | March 12, 2010<br>Winnie Li (Penn State)<br><i>Recent Progress on the Arithmetic of Non-congruence Modular Forms</i>                      |
| January 15, 2010<br>Jim Bryan (UBC)<br><i>The Orbifold Vertex: Counting Curves on Orbifolds by Counting Piles of Colored Boxes</i> | March 19, 2010<br>Michael Larsen (Indiana)<br><i>Word Maps over Simple Groups</i>   |
| January 29, 2010<br>Kumar Murty (Toronto)<br><i>The Euler – Kronecker Constant of a Number Field</i>                               | April 9, 2010<br>Nigel Hitchin (Oxford)<br><i>Magnetic Monopoles and Projective Geometry</i>  |
| February 5, 2010<br>Robert McCann (Toronto)<br><i>Optimal Multidimensional Pricing Facing Informational Asymmetry</i>              | April 16, 2010<br>Panagiota Daskalopoulos (Columbia)<br><i>Surface Evolution under Curvature Flows – Existence and Optimal Regularity</i> |

### CRM – ISM – GERAD Statistics Colloquium

In 2009 – 2010 the organizing team of the Statistics Colloquium included Geneviève Lefebvre (UQÀM), Mylène Bédard (Montréal), Lea Popovic (Concordia), and Russell Steele (McGill).

- |   |  |
|---|--|
| October 2, 2009<br>Zhiqiang Tan (Rutgers)<br><i>Marginal and Nested Structural Models Using Instrumental Variables</i>                  | October 30, 2009<br>Jean-François Plante (HEC Montréal)<br><i>Méthodes pondérées pour les statistiques de rangs multivariés</i>                      |
| October 9, 2009<br>Samuel Kou (Harvard)<br><i>Equi-energy Sampler: From Statistical Inference to Statistical Mechanics</i>              | November 6, 2009<br>Don Fraser (Toronto)<br><i>Statistical Tools: Is There Any Merit in Calibration?</i>   |
| October 23, 2009<br>Pranab K. Sen (UNC-Chapel Hill)<br><i>The Theil – Sen Estimator of the Slope in a Measurement Error Perspective</i> | November 13, 2009<br>Jeffrey Rosenthal (Toronto)<br><i>Comment optimiser l’algorithme Metropolis?</i>  |
|   | November 27, 2009<br>Benoit Liqueur (Bordeaux Segalen)<br><i>Choice of Estimators Based on Different Observations: Modified AIC and LCV Criteria</i> |

December 4, 2009

Bovas Abraham (Waterloo)

*Real Experiments, Real Mistakes, Real Learning*

January 22, 2010

Galin Jones (Minnesota)

*Output Analysis for Markov Chain Monte Carlo*

January 29, 2010

Pierre Lafaye de Micheaux (Montréal)

*Goodness-of-fit Tests in ARMA and VARMA Models, with a Comparison Against the Jarque – Bera Test*

February 12, 2010

Johanna Nešlehová (McGill)

*From Archimedean to Liouville copulas*

February 19, 2010

Abbas Khalili (McGill)

*Estimation and Feature Selection in Mixture-of-Experts Models, and Mixture Regression Models with Diverging Number of Parameters*

February 26, 2010

Michael R. Kosorok (UNC-Chapel Hill)

*Reinforcement Learning Strategies for Clinical Trials in Non-Small Cell Lung Cancer*

March 5, 2010

Simon Guillotte (Prince Edward Island)

*Un modèle de tamis bayésien pour l'inférence sur les lois de valeurs extrêmes bivariées*

March 12, 2010

Dylan Small (Pennsylvania)

*Error Free Milestones in Error Prone Measurements*

March 19, 2010

Robert Strawderman (Cornell)

*Conditional GEE for Recurrent Event Data*

April 9, 2010

Changbao Wu (Waterloo)

*Analysis of Longitudinal Surveys with Missing Responses*

# **Multidisciplinary and Industrial Program**

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

## Activities of the Multidisciplinary and Industrial Program

### Third Montréal Industrial Problem Solving Workshop

#### A CRM – MITACS Event

August 17 – 21, 2009, CRM

Financed by MITACS and ncm<sub>2</sub> (Network for Computing and Mathematical Modeling) with a contribution by Pratt & Whitney

#### Organizing committee:

Jean-Marc Rousseau (CIRANO & ncm<sub>2</sub>, chair), Fabian Bastin (Montréal), Eric Bosco (Director, Business Development, MITACS), Michel Gendreau (Polytechnique Montréal), Bernard Gendron (Director, CIRRELT), Roland Malhamé (Director, GERAD), Odile Marcotte (Deputy Director, CRM), Catherine Mavriplis (Ottawa), Christiane Rousseau (Director, CRM)

#### Participating researchers:

Pierre Baptiste (Polytechnique Montréal), Fabian Bastin, Kamel Bentahar (Oxford), Anne Bourlioux (Montréal), Michel Gendreau, Alain Hertz (Polytechnique Montréal), Angelo Lucia (Rhode Island), Apala Majumdar (Oxford), Odile Marcotte, Catherine Mavriplis (Ottawa), Laurent Michel (Connecticut), Robert Pellerin (Polytechnique Montréal), Stephen Peppin (Oxford), Mohammed A. Qazi (Tuskegee), Tim Reis (Oxford), Louis-Martin Rousseau (Polytechnique Montréal)

#### Industrial representatives:

Étienne Ayotte-Sauvé (CanmetENERGY), Yvan Beauregard (Pratt & Whitney), Pierre Gauthier (Rolls-Royce Canada), Joseph Nader (FPInnovations), Jean-Claude Rizzi (IREQ), Patrick St-Louis (GIRO Inc.), Guy Vanier (IREQ)

**Number of participants:** 16 researchers, 7 industrial representatives, and 25 students and postdoctoral fellows

As part of its multidisciplinary and industrial program, the CRM organizes workshops where academic researchers, industry representatives, students, and postdoctoral fellows model and solve problems brought forward by industrial partners. The Third Montréal Industrial Problem Solving Workshop (IPSW) was held on August 17 – 21, 2009, and its par-

ticipants worked on six problems proposed by the following organizations: Pratt & Whitney, Natural Resources Canada, Rolls-Royce Canada, IREQ, GIRO, and FPInnovations (FERIC division). The organizers are very grateful to the persons who helped them gather the problems, in particular Anne Bourlioux and Christiane Rousseau (from the Université de Montréal) and Catherine Mavriplis (from the University of Ottawa). Note that four of the problems were supplied by institutions (Natural Resources Canada, IREQ, GIRO, FPInnovations) that were represented at the Second Montréal Industrial Problem Solving Workshop.

The first problem, supplied by Pratt & Whitney, concerned the optimization of the realized value during the post-certification phase of product development. This problem was tackled successfully by the participants, who modelled it as a linear problem and solved it before the end of the workshop. The second problem, supplied by the CanmetENERGY centre of Natural Resources Canada, consisted of computing the minimal energy needed to operate a distillation column in order to carry out a specific separation task. The team studying this problem made a lot of progress towards the proof of an important theorem! The third problem, provided by Rolls-Royce Canada, involved the study of methods for locating large and small vortical structures within a reacting flow. This is a difficult problem, whose solution is necessary to assess the behaviour of reacting flows in gas turbine engines.

The fourth problem, supplied by IREQ, the Hydro-Québec research institute, dealt with the optimization of dynamic transfer limits in an energy transportation network. The power transfer capacity of such a network is subject to many limits, which depend (among other factors) upon certain company decisions. The problem is then to optimize the limits for a set of sub-network configurations, and the team working on this problem was able to model the problem and start solving it. The fifth problem, supplied by GIRO, dealt with the real-time placement of labels on a geographical map. The team members made several suggestions that the industrial representative found original and useful.

Finally, the sixth problem, provided by FPInnovations, concerned the scheduling of trucks in the forestry industry.

Although the majority of participants were from Montréal, many participants came from other cities or countries to attend the workshop: 2 from Ottawa, 4 from Toronto, 4 from the University of Oxford, and 3 from the United States. An intern from the Netherlands also took part in the workshop. The atmosphere of the workshop was very friendly and the industrial representatives were enthusiastic about the work carried out during the workshop; some of them wondered why no workshop was being planned for 2010! The organizers explained to them that an industrial problem solving workshop requires a lot of effort by several groups of people, and that the Montréal community intends to hold a workshop every two years (starting in 2009). The community also has to take into account the dates of the other Canadian IPSWs. The reader may find more details on the workshop web site ([crm.math.ca/probindustriels2009/index\\_e.shtml](http://crm.math.ca/probindustriels2009/index_e.shtml)).

### **NICDS Workshop The Analysis of Directional Data with Applications to Biomechanics and Biomedical Imaging**

November 25 – 27, 2009, CRM

Sponsored by the National Institute for Complex Data Structures (NICDS)

#### **Organizers:**

Peter T. Kim (Guelph), Louis-Paul Rivest (Laval)

#### **Speakers:**

Christian Beaulieu (Alberta), Aurelio Cappozzo (Foro Italico), Moo K. Chung (Wisconsin – Madison), Jim Dickey (Western Ontario), Giseon Heo (Alberta), Peter E. Jupp (St Andrews), Peter T. Kim, H el ene Massam (York), Michael Pierrynowski (McMaster), James O. Ramsay (McGill), Louis-Paul Rivest, Jeffrey J. Thomson (Guelph), Hongtu Zhu (UNC-Chapel Hill)

**Number of participants:** 36

The inaugural talk, by Aurelio Cappozzo, gave a general overview of classical problems in biomechanics emphasizing the recent functional method that uses statistical models to determine the geometric characteristics of human joints. The other talks in biomechanics presented functional and manifold data for specific problems such as the investigation of back pain among heavy equipment workers and the interaction

of hoof and track surface in race horses. The topic of the second day was the analysis of data collected using the MRI imaging technique that measures water diffusion in the brain. After a nice introduction to MRI imaging by Christian Beaulieu, speakers presented statistical models for MRI data dealing with large dimensions (more than one million data points in a typical brain) and the 3D spatial structure of this type of data. The matrix Wishart distribution was proposed as a potentially useful tool for this type of data. More examples of non standard data analysis, with manifold sample spaces, were given on the third day. In the last presentation, Jim Ramsay highlighted the need to develop object-oriented statistical methods that use the mathematical structure of the manifold on which the data is defined to construct statistical models for such data. He emphasized the strong links of this topic with the forthcoming SAMSI thematic year on object-oriented inference and invited the participants to take part in this activity.

### **NICDS Workshop Statistical Methods for Geographic and Spatial Data in the Management of Natural Resources**

March 3 – 5, 2010, CRM

Sponsored by the National Institute for Complex Data Structures (NICDS)

#### **Organizers:**

DongMei Chen (Queen’s), Thierry Duchesne & Anne-Catherine Favre (Laval), Subhash R. Lele (Alberta)

#### **Keynote speakers:**

Brian Klinkenberg (UBC), Philippe Naveau (IPSL), James V. Zidek (UBC)

#### **Invited speakers:**

Olaf Berke (Guelph), Nicolas Bousquet (EDF R&D), Rob Deardon (Guelph), Vincent Fortin (Environment Canada), R emy Gar on (EDF-DTG), Jonah L. Keim (Matrix Solutions Inc.), Subhash Lele, Song Liang (Ohio State), James Merleau (IREQ), Evelyn Merrill (Alberta), M eriem Sa id (Laval), Dominique Tapsoba (IREQ)

#### **Other speakers:**

Julie Carreau (INRIA Rh one-Alpes), Thomas-Charles Fortier-Filion (CEHQ), Marie-Jos e Fortin (Toronto), Nicholas Gralewicz (Victoria), Patrick Leighton (Montr eal), Jed Long (Victoria), Alain Mailhot (INRS-ETE), Colin Robertson (Victoria), Patrick Simard (INRS-ETE), Stephen Smith (BIO), William Weimin Yoo (Waterloo), Zhijie Zhang (Queen’s)

**Number of participants:** 67

Cet atelier a été conçu suite à un appel fait par l'Institut national sur les structures de données complexes (INSDC). Il s'agit d'un atelier inaugural dont l'objectif est de réunir des étudiants, stagiaires et chercheurs des milieux académique et industriel ayant des intérêts de recherche liés à l'application de méthodes statistiques pour l'analyse de données géographiques et/ou spatiales aux problèmes liés à la gestion des ressources naturelles. Le support financier de l'INSDC a permis d'attirer plusieurs conférenciers de l'extérieur du Québec, incluant une forte délégation de conférenciers français ainsi que plusieurs participants des États-Unis et de l'Ouest canadien.

L'atelier était divisé en deux parties : les exposés scientifiques (jours 1 et 2) et une période de discussion sur les opportunités de financement accompagnée d'échanges entre des chercheurs formant des petits groupes et ayant des intérêts de recherche communs (jour 3). Les 13 exposés du jour 1 (2 de 50 minutes, 6 de 30 minutes et 5 de 20 minutes) portaient tous sur des sujets liés au sous-thème « hydrologie, météorologie, climatologie ». On y a discuté de modèles spatiaux de dispersion de l'ozone (Zidek), de méthodes d'interpolation spatiale des mesures de précipitations (V. Fortin, Carreau, Tapsoba, Fortier-Filion), de modélisation d'événements climatiques extrêmes (Naveau, Garçon) ainsi que d'autres problèmes méthodologiques spécifiques en analyse ou en modélisation de données spatiales.

Les 7 exposés de la matinée du jour 2 traitaient de méthodes employées dans l'analyse et la modélisation de la propagation de maladies zoonotiques. On y a présenté une revue des méthodes utilisées pour modéliser la distribution spatiale des espèces (Klinkenberg) ainsi que des approches particulières à des maladies précises ou en présence de difficultés statistiques particulières. Finalement, les 6 exposés de l'après-midi du jour 2 étaient dédiés à des problèmes en écologie. On a discuté des méthodes et approches utilisées pour construire des fonctions de sélection des ressources (Lele, Merrill, Keim) ainsi que des modèles spatiaux pour divers problèmes en écologie (M.-J. Fortin, Smith, Gralawicz).

Les participants se sont révélés très heureux du programme, même s'il était très varié et très chargé. Les exposés des jours 1 et 2 ont tous suscité beaucoup d'intérêt dans l'auditoire. Les nombreuses questions et dis-

cussions entraînées par les exposés ont fait que ces deux journées se sont terminées beaucoup plus tard que prévu en dépit de la discipline des conférenciers ! Qui plus est, à la demande générale, les aides visuelles que les conférenciers ont utilisées lors de leurs présentations ont été mises sur le site web de l'atelier. Les discussions du jour 3 ont été tout particulièrement appréciées. Plusieurs idées de financement (programmes spéciaux du CRSNG, idées d'ateliers pour chacun des sous-thèmes, problèmes de recherche susceptibles de générer du financement pour des projets en équipe, possibilités de stages MITACS) ont été identifiées.

Les discussions en petits groupes ont déjà mené à de nouvelles collaborations. En outre, Lele et Forester prévoient travailler sur la modélisation des habitats disponibles et leur prise en considération dans les méthodes d'estimation pondérées, et leur entretien a permis à Lele de terminer un article passant en revue les méthodes d'ajustement de fonctions de sélection des ressources. Chen et Deardon ont entrepris une collaboration sur la modélisation de la propagation de la grippe A (H1N1) en Ontario. Il semblerait que les chercheurs d'Hydro-Québec et d'Électricité de France ont échangé de nombreuses idées sur des problèmes communs.

**Workshop****Analysis of Multiphase Biomembranes**

April 24 – 26, 2010, McGill University

Sponsored by the Applied Mathematics Laboratory

**Organizer:** Eliot Fried (McGill)

**Speakers:**

Luca Deseri (Trento), Qiang Du (Penn State), Guy Genin (WUSTL), James T. Jenkins (Cornell), Mikko Kartunnen (Western Ontario), David Steigmann (UC Berkeley), Huai-Ying Zhang (McGill)

**Number of participants:** 28

By all accounts, the workshop was a great success. It was devoted primarily to tutorial lectures given by Professors Du, Jenkins, and Steigmann. In addition, hour-long research presentations were given by Professors Deseri, Genin, Kartunnen, and Steigmann and a Ph.D. student, Ms. Zhang.

Professors Jenkins and Steigmann provided in-depth derivations of the partial differential equations governing equilibrium configurations of single- and multi-component biomembranes. They also presented analytical and numerical results regarding solutions to these equations. Professor Du provided a comprehen-

sive overview of numerical methods for solving both static and dynamic problems for single- and multi-component biomembranes, with a strong focus on phase-field based methods. It is perhaps not particularly surprising that the many students who attended the workshop benefited from these lectures. In addition, faculty members with knowledge of the field also found that these lectures provided valuable perspective.

The research talks were also highly informative. Professor Deseri presented a new theory for phase transitions in multicomponent biomembranes derived on the basis of Gamma-convergence. Professor Genin presented an overview of state-of-the-art imaging techniques with the goal of providing theorists and analysts with background needed to connect their results with experimental measurements. Professor Karttunen discussed the latest atomistic simulation techniques for biomembranes. Professor Steigmann presented very exciting results for problems involving biomembranes on surfaces. Finally, Ms. Zhang presented results from her thesis research concerning molecular diffusion on biomembrane surfaces.

Despite occurring over a weekend with unusually fine weather, attendance was consistently high throughout the workshop. All attendees appeared to have considered the time spent to be most worthwhile. They were asked to respond to a few questions concerning the workshop, and the analysis of their answers reveals that

- they learned a lot during the workshop,
- the workshop was “a one-of-a-kind opportunity to discuss membrane physics across disciplines and length scales” (in the words of one participant),
- the participants made new contacts, and
- the workshop organization was excellent.

### **CRM – GIREF Conference on Adaptive Meshing and Error Estimation and Special Day in Honour of Michel Fortin**

May 25 – 27, 2010, Université Laval

#### **Organizers:**

André Fortin & José Manuel Urquiza (Laval)

#### **Speakers:**

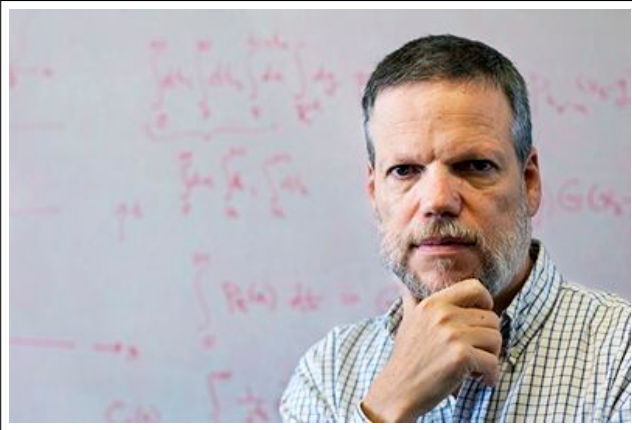
Youssef Belhamadia (Alberta), François Bertrand (Polytechnique Montréal), Richard Bois (Laval), Yves Bourgault (Ottawa), Julien Bruchon (ÉNSM Saint-Étienne), Éric Chamberland (Laval), Thierry Coupez (Mines ParisTech), Michel Delfour (Montréal), Julien Dompierre (Laurentian), Mohamed Farhloul (Moncton), Michel Fortin (Laval), Martin Gander (Genève), Robert Guénette (Laval), François Guibault (Polytechnique Montréal), Wagdi Habashi (McGill), Frédéric Hecht (UPMC), Hassan Manouzi (Laval), Zoubida Mghazli (Ibn Tofail), Yvan Mokwinski (Polytechnique Montréal), Dominique Pelletier (Polytechnique Montréal), Marco Picasso (EPFL), Roger Pierre (Laval), Jean-François Remacle (UC Louvain), Myriam Rioux (Ottawa), Abdellatif Serghini Mounim (Laurentian), Olivier Sigouin (Laval), Azzeddine Soulaïmani (ÉTS), Pascal Turbis (Montréal), Bocar A. Wane (Laval)

The conference itself took place on May 25 and May 27, 2010, while May 26 was the Special Day in Honour of Michel Fortin, a Université Laval Emeritus Professor who was also the founder and first director of GIREF (*Groupe Interdisciplinaire de Recherche en Éléments Finis*), an interdisciplinary research group in finite element methods. GIREF, which is now a CRM laboratory, includes both theoreticians and practitioners working in numerical modelling and the finite elements method for solving PDEs (a field in which Dr. Fortin is a world leader). Here is a partial list of the topics of the conference and Special Day, all related to the research interests of Dr. Fortin and his GIREF colleagues: adaptive finite elements, anisotropic meshing, adaptive meshing, approximation of stochastic PDEs through the finite elements method, asymptotic topological development and adaptive meshing, numerical methods for moving boundary problems, surface remeshing using harmonic maps, and applications to cardiac medicine and aircraft protection system design. Martin Gander gave a lecture on the history of variational problems from Euler to modern computing and the finite element methods, in which he highlighted the contributions of Walther Ritz, a Swiss physicist and mathematician. Roger Pierre gave a talk about Michel Fortin’s legacy, and Dr. Fortin himself gave a lecture on optimal adaptation and meshings.

## CRM Prizes



## CRM–Fields–PIMS Prize 2010 Awarded to Gordon Slade



Gordon Slade from the University of British Columbia was awarded the 2010 CRM – Fields – PIMS Prize in recognition of his outstanding work in rigorous statistical mechanics and probability. He is renowned for developing a technique known as the lace expansion into a systematic calculus, which he has applied to diverse and famous problems including the self-avoiding walk, percolation, branched polymers, random graphs, and numerical techniques for the exact enumeration of self-avoiding walks. In 1992 Hara and Slade proved that in five or more dimensions, the end-to-end distance of a self-avoiding walk grows according to the same  $\sqrt{n}$  law as that exhibited by a simple random walk and that the scaling limit of a self-avoiding walk is Brownian motion.

In 1989 Hara and Slade proved that the Aizenman – Newman triangle condition holds for critical percolation in high dimensions. The triangle condition implies a large collection of properties for the critical cluster that are collectively summarized by the term “mean field theory.” Since this initial impetus, a quite complete understanding of critical percolation clusters in high dimensions has grown out of work with his co-authors Derbez, Hara, van der Hofstad, and den Hollander. In particular, the scaling limit of oriented percolation is the super-Brownian motion and the existence and properties of the incipient infinite percolation cluster have been established in certain cases. By related methods, Slade and his co-authors have es-

tablished a very complete description of the critical window for the Hamming cube with randomly deleted edges.

These results concern the most difficult problems in central areas of probability and statistical physics. These are questions motivated by physical problems that are easy to state and notoriously difficult to solve. The use of the lace expansion to establish mean field behaviour for the self-avoiding walk and critical percolation above the critical dimension is one of the major developments in probability theory in the last fifteen years.

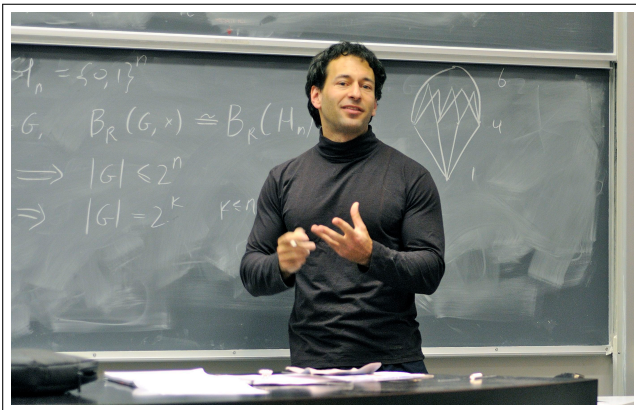
Gordon Slade received his undergraduate degree from the University of Toronto in 1977 and completed his doctoral degree with Lon Rosen and Joel Feldman at the University of British Columbia in 1984. He was Lecturer at the University of Virginia from 1985 to 1986. In 1986 he joined the faculty of McMaster University and since 1999 he has been Professor of Mathematics at the University of British Columbia. More details on the contributions of Professor Slade to mathematics may be found in [Le Bulletin du CRM \(Spring 2010\)](#).

### 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), and Martin Barlow (2009).

## André-Aisenstadt Prize 2010 Awarded to Omer Angel

The 2010 André-Aisenstadt Prize was awarded to Omer Angel of the University of British Columbia. Dr. Angel won a gold medal at the 1993 International Math Olympiad, and went on to obtain his Ph.D. from the Weizmann Institute in 2003 under the supervision of Itai Benjamini and Oded Schramm. After postdoctoral experiences at the Université Paris-Sud 11 and University of British Columbia, and a faculty position at the University of Toronto, he joined the faculty at the University of British Columbia in 2008. He works in probability theory, on percolation, random walks, and random spatial processes of all sorts, with applications to other areas of mathematics, physics, and even biology. He has many impressive results, of which we now describe two.



In early work Angel, with Schramm, put the local study of random triangulations on firm ground by proving the existence of a limit object. Subsequently he showed how to sample such a uniform random triangulation, devising a tool that allowed him to determine the critical percolation probability and establish the widely held belief (amongst physicists) that a random met-

ric on a manifold has Hausdorff dimension 4. In more recent work, Angel, Holroyd, Romik, and Virag gave a very precise description of some of the statistics of a random sorting network, allowing them to make the remarkable conjecture that a typical short (random) path between objects on a lattice stays close to a geodesic (under the standard embedding).

A detailed description of the contributions of Omer Angel may be found in *Le Bulletin du CRM* (Spring 2010).

### 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, candidates 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), and Valentin Blomer (2009).

## CAP-CRM Prize 2010 Awarded to Clifford Burgess

The 2010 CAP – CRM Prize in Theoretical and Mathematical Physics was awarded to Dr. Clifford Burgess, from McMaster University and the Perimeter Institute, for his prolific and influential work in theoretical physics. Professor Burgess has made an impact over an unusually broad range of fields during his twenty years of research in Canada. His contributions span superstring theory, early universe cosmology, particle phenomenology, astrophysics, and condensed matter physics. His pioneering work in constructing new

models of cosmological inflation based on string theory opened new areas of research. His ongoing research in this area has brought string theory to a stage where models of the early universe are regularly tested against the precision data of new cosmological experiments.

Burgess has also made innovative contributions in neutrino physics, double beta decay, and precision accelerator measurements. Burgess is a renowned expert



in the applications of effective field theory and has written a number of authoritative reviews on the topic. He has also co-authored a graduate textbook on particle physics. With over 120 published research articles, he is one of Canada's most prolific and highly cited particle theorists. His research consistently demonstrates a very high quality and remarkable creativity, and as a result, Professor Burgess has attained an outstanding international profile in the theoretical physics community.

Clifford Burgess carried out doctoral work in Theoretical Particle Physics at the University of Texas at Austin under the supervision of Steven Weinberg. After doing a postdoctoral stint at the Institute for Advanced

Study in Princeton, he joined the faculty at McGill University in 1987 and was made James McGill Professor in 2003. He is presently a professor in the Department of Physics and Astronomy at McMaster University and an Associate Member at the Perimeter Institute. Professor Burgess was a Killam Fellow from 2005 to 2007 and was elected Fellow of the Royal Society of Canada in 2008. A detailed description of the contributions of Clifford Burgess may be found in *Le Bulletin du CRM* (Spring 2011).

### 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 C. Myers (2005), John Harnad (2006), Joel S. Feldman (2007), Richard Cleve (2008), and Hong Guo (2009).

### CRM–SSC Prize 2010 Awarded to Grace Yi



Grace Y. Yi, Professor in the Department of Statistics and Actuarial Science at the University of Waterloo, is the 2010 winner of the CRM–SSC Prize. Within 10 years of her Ph.D., she has contributed in a significant way to the development of statistical methods for longitudinal

studies and the analysis of time-to-event data, especially for the treatment of missing observations and measurement errors. Her work on the asymptotic behaviour of parametric and semi-parametric inference techniques has also been influential in statistics and biostatistics.

Professor Yi studied mathematics at Sichuan University in the People's Republic of China, where she obtained a B.Sc. in 1986 and an M.Sc. in 1989. She then

came to Canada to study statistics. She received an M.A. from York University in 1996 and completed her Ph.D. at the University of Toronto in 2000, under the supervision of Don Fraser. After postdoctoral studies with Richard J. Cook, she was appointed Assistant Professor at the University of Waterloo in 2001. She was promoted to Associate Professor in 2004 and is now a Full Professor. In 2004, Professor Yi received a University Faculty Award from the Natural Sciences and Engineering Research Council of Canada (NSERC). Her research has been supported by NSERC since the beginning of her career.

Grace Yi has been quite successful in advancing foundational work and developing novel methodology for health and medical research applications. She was invited to present her work at numerous national and international conferences, including the Annual Meeting of the Statistical Society of Canada, the Joint Statistical Meetings, the Statistics Canada Symposium, and meet-

ings of the International Biometrics Society and the International Chinese Statistical Association. She has served as an Associate Editor for The Canadian Journal of Statistics and the Journal of Applied Probability and Statistics. Professor Yi has also been a Biostatistics and Research Methods Advisor and an external Biostatistics reviewer for the Grant Review Panel of the Canadian Breast Cancer Foundation, Ontario Region. She has done extensive refereeing work for statistical journals and granting agencies.

A detailed description of the contributions of Professor Yi may be found in [Le Bulletin du CRM \(Spring 2011\)](#).

### **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.

Grace Yi is the twelfth 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), and Hugh Chipman (2009).

# 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 four lectures geared towards a general audience in 2009 – 2010. Three of the lectures took place at the Université de Montréal: a lecture by Professor Jean Mawhin on October 8, 2009, a lecture by Professor Jeffrey Rosenthal on November 12, 2009, and a lecture by Ivars Peterson on February 4, 2010. Another lecture was given by Professor Michel Waldschmidt at Université Laval on September 25, 2009. 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 2009 – 2010, the Grandes Conférences program was under the stewardship of Christiane Rousseau and Yvan Saint-Aubin, professors at the department of mathematics and statistics of the Université de Montréal.

## *Arithmetic Problems Posed by Rabbits, Cows, and the Da Vinci Code*

Michel Waldschmidt (Université Pierre et Marie Curie)

by Claude Levesque (Université Laval)



On Friday evening, September 25, 2009, a CRM “Grande Conférence” given by Professor Michel Waldschmidt from the Université Pierre et Marie Curie was held in the

magnificent Hydro-Québec auditorium at Université Laval. The talk addressed arithmetic questions posed by rabbits, cows, and the Da Vinci Code. You guessed it, we are talking about the sequence  $\{F_n\}_{n \in \mathbb{N}}$  of Fibonacci numbers, for which  $F_{n+2} = F_{n+1} + F_n$  holds with  $F_0 = 0$  and  $F_1 = 1$ . From the outset, let me stress that Professor Waldschmidt gave an excellent talk for a general audience.

The publicity in *Le Soleil* and *Le Journal de Québec* newspapers, as well as the delightful CRM posters depicting Professor Waldschmidt under a horde of rabbits, were quite effective. As for the lecture given by Professor Yvan Saint-Aubin last year, the auditorium was filled to capacity: at least 250 people were present. The poster read as follows:

*... Fibonacci studied the growth of a population of rabbits that reproduced according to the following law. Each couple that reached two years of age gave birth every year to a new couple.*

*The Fibonacci sequence is thus 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, 610, 987, 1597, 2584, ....*

*In the Da Vinci Code, the first eight numbers of this sequence, i.e., 1 – 1 – 2 – 3 – 5 – 8 – 13 – 21, are used as a password. Integer sequences, be they those used to count Fibonacci's rabbits, a sunflower's spirals, Narayana's cows, or other sequences defined in an analogous way, raise a certain number of arithmetic questions, some of which have been resolved recently, while others still challenge present-day mathematicians. These mathematicians work for “the honour of the human spirit.”*

Michel Waldschmidt began by presenting the problem of Narayana's cows. Narayana was an Indian mathematician from the 14th century, who proposed the following problem: a cow produces one calf every year. Beginning in its fourth year, each cow produces one calf at the start of each year. How many cows and calves are there after 17 years? The speaker described what happens each year to conclude that the number of cows is equal to the total number of cows in the previous year plus the total from two years prior. He was careful not to explicitly write that we are dealing with a third-order linear recurrence  $\{v_n\}_{n \in \mathbb{N}}$  with  $v_1 = v_2 = v_3 = 1$ . He then brought up a piano piece composed by Tom Johnson based on this Narayana sequence. Johnson's work is composed as follows: a long sound corresponds to a cow and a short sound corresponds to a calf; at each stage, the piece is constructed with the musical score from the previous stage followed by the musical score from two stages previous to that. The speaker played a sample of this music, and though the result did not seem to meet the approval of

all members of the audience, we at least had the satisfaction of understanding how Tom Johnson composes his music!

Waldschmidt then presented Archimedes' cattle problem, a riddle in the form of an epigram that involves calculating the number of cattle in the sun god's herd. The audience was delighted to hear that a sphere with the diameter of the Milky Way, that light would take ten thousand years to cross, would contain just a minute part of this herd, if we assume that the size of each animal does not exceed that of the most minuscule bacterium.

After explaining what the exponential sequence  $2^n$  is by calculating the number of ancestors of any given person, he moved on to the problem of bees whose births are subject to the following rule: *The males only have a mother, while the females have a mother and a father.* It turns out that the number of bees, at a certain stage, is equal to the sum of the two previous stages. The presentation was accompanied with slides, allowing us to see the evolution of the swarm of bees from one generation to the next, to the great delight of the audience.

Next up came Fibonacci's rabbits, complete with slides to show the evolution of the population; each picture was worth a thousand words. Professor Waldschmidt did not need a recurrence formula to introduce Fibonacci's numbers! He took advantage of this to mention that according to Alfred Lotka's theory of stable populations, if each couple gives birth to a couple only the first two seasons, the number of couples born each year will still follow Fibonacci's law. He then went on to explain phyllotaxy, the order by which leaves or small branches are implanted on the stem of a plant, or, by extension, the arrangement of elements on a fruit, a flower, a bud, or a capitulum (according to Wikipedia).

One of the high points of the conference was the game "love-you, love-you-not." It involves removing one petal at a time from a daisy while repeating in a cyclical fashion:

(1) I love you,      (2) A little,      (3) A lot,  
 (4) Passionately,      (5) Madly,      (6) Not at all,  
 until we reach the last petal. As the number of petals is often a Fibonacci number, this means in effect considering the sequence of remainders obtained after dividing the Fibonacci sequence numbers by 6. Since this series begins with 1, 1, 2, 3, 5, 2, 1, 3, 4, 1, 5, 0, 5, ... and since the first multiple of 6 (in the Fibonacci sequence) is 144, it is highly unlikely that the last petal will fall on the sixth choice. It is just a short step to conclude that daisies teach us that we are in love with just about everybody..., or at least we should be.

The speaker then brought up the eight-number secret code for the Da Vinci Code safe: 13 – 3 – 2 – 21 – 1 – 1 – 8 – 5, that is, the first eight numbers of the Fibonacci sequence that simply need to be put back into the proper order. He continued by presenting the golden rectangle and the golden number. Then came the Penrose tilings, all accompanied by beautiful images. At the end of the talk, Professor Waldschmidt mentioned the following unresolved problem: Is there an infinity of Fibonacci numbers that are prime?

Professor Waldschmidt concluded by citing the following letter written by Jacobi on July 2, 1830, to Legendre: *"Mr. Fourier was of the opinion that the principal goal of mathematics is the public interest and the explanation of natural phenomena; but a philosopher such as he should have known that the only goal of science is the honour of the human spirit, and that for this reason a question about numbers is every bit as worthwhile as a question about the system of the world."*

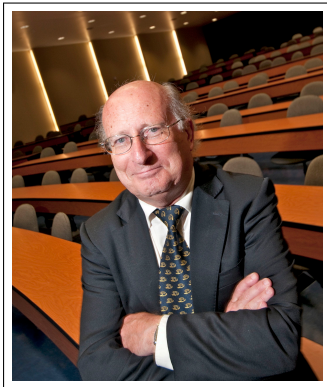
The members of the audience would certainly have liked to ask questions, but the organizer judged that everybody needed some respite after such a colourful contact with the fauna and flora. It was then that the cows' milk and the bees' honey were miraculously transformed into wine offered by the CRM. The members of the audience were encouraged to ask their questions around a table laden with appetizers, and glasses of wine or juice: *Carpe diem. In vino veritas!*

*Brouwer's Fixed-Point Theorem: a Mathematical Chameleon*

Jean Mawhin (Université catholique de Louvain)

by Christiane Rousseau (Université de Montréal)

On October 8, 2009, the CRM “Grandes Conférences” series featured Jean Mawhin, Professor Emeritus at the Université catholique de Louvain, who gave a talk with the catchy title: “Brouwer’s Fixed-Point Theorem: a Mathematical Chameleon.” The conference began as a radio news broadcast with news briefs on the economy, science, culture, and leisure, as well as vacation weather, all peppered by editorial comments! Here, for example, is a news brief on the economy: “In a non-cooperative game with any number of players, there is always a social equilibrium,” and the weather: “At any moment in time, there exists on Earth two antipodal points with the same atmospheric pressure and the same temperature.” The common theme for all of these news briefs, as you have probably guessed, is Brouwer’s fixed-point theorem.



The speaker then defined the notion of a fixed point of a transformation, illustrated abundantly through examples of usual geometric transformations: symmetries, rotations, etc. He showed the importance of the hypothesis that the transformation is continuous. He also brought to light the importance of the “topology” of the set, since a rotation of a circle into itself does not have a fixed point. Brouwer’s fixed-point theorem asserts that every continuous transformation of the unit ball,  $B^n$ , into itself has a fixed point. Jean Mawhin gave the idea underlying the proof in the cases  $n = 1$  and  $n = 2$  before moving on to the history of the theorem discovery. He then defined the notions of retraction and retract of a set, which he illustrated amply before explaining that Brouwer’s fixed-point theorem is equivalent to Borsuk’s theorem (“ $S^n$  is not a retract of  $B^{n+1}$ ”).

Professor Mawhin also explained how rotations of a space into itself can detect the parity of this space, thanks to another one of Brouwer’s great theorems, according to which if  $n$  is even, every transformation of the sphere  $S^n$  into itself has either a fixed point, or a

point whose image is its antipode. The audience was then treated to all possible equivalent formulations, including the following: we can set a sphere’s hair with a crew cut, but if we try to comb the hair smoothly, there will always be one noncompliant hair! The news brief on vacation weather was demonstrated using the Borsuk – Ulam theorem: “every transformation of  $S^n$  into  $R^n$  maps some pair of antipodal points to the same point.” As another application, the speaker described in detail the manner in which one can slice a sandwich or two pancakes fairly using a single cut.

The public then played the Sperner game with the speaker and verified with him that this game is not fair for the person who starts playing. The generalization to  $n$ -dimensional space was presented, as well as the fact that this game is equivalent to Brouwer’s fixed-point theorem. The audience was then treated to applications of this theorem to mathematical economics, through non-cooperative games, Nash equilibria, and Nash’s famous theorem stating that every non-cooperative game with  $n$  players has an equilibrium; this result is one of the contributions that won John Nash the Nobel Prize for Economics in 1994. The public could let their imagination run free as Professor Mawhin spoke about the generalizations to infinite-dimensional spaces, about what is no longer true and what is still true in such spaces, and about the strange characteristics of drums in infinite-dimensional spaces.

Jean Mawhin went on to present the development of generalizations of Brouwer’s fixed-point theorem in infinite-dimensional spaces (including Schauder’s and Tikhonov’s theorems), and explained that Brouwer’s fixed-point theorem is at the crossroads of several mathematical disciplines and has many applications to mechanics, physics, chemistry, biology, economics, and demography. He challenged the audience to find the next applications! Professor Mawhin concluded his colourful conference by recalling that the theory of fixed points is a mixture of seemingly futile and seemingly serious questions and that “their study has contributed in equal parts to the honour of the human spirit and the knowledge of nature.” The evening ended with a very lively wine and cheese party.



## Coin Flipping and Other Questions of Probability

Jeffrey Rosenthal (University of Toronto)

On November 12, 2009, the “Grandes Conférences” series featured Jeffrey Rosenthal, who obtained a Ph.D. from Harvard University and is now professor at the University of Toronto. Dr. Rosenthal was awarded many honours for his research (including the CRM – SSC Prize in 2006) and his teaching (in particular



prizes from Harvard University and the University of Toronto). He has gained recognition as an outstanding popularizer and one of his books, entitled *Struck by Lightning: The Curious World of Probabilities* (the basis for his “Grande Conférence” lecture, delivered in French), was very successful (cf. the

site [probability.ca/sbl/](http://probability.ca/sbl/)). For instance this book was the eighth on the list of *Best Books of 2005: Editors’ Picks in Nonfiction* on the Amazon site ([amazon.ca](http://amazon.ca)).

Dr. Rosenthal’s lecture had a very apt title, since all the key concepts of his lecture were introduced through coin flipping experiments! This pedagogical point of view may seem narrow; the concepts introduced, however, were subtle and difficult to grasp. Dr. Rosenthal was able to convince his audience that probabilistic methods are very useful for describing phenomena in diverse fields, some of which are well known (lotteries, casino games, polls, coincidences in everyday life) and others not so much (the spread of illnesses, clinical studies for testing new medication, etc.). Dr. Rosenthal’s lecture was a magnificent display of his pedagogical skills.

## Geometreks – Ivars Peterson (Mathematical Association of America)

by Christiane Rousseau (Université de Montréal)



Ivars Peterson is a well-known author of many mathematics and science books for the general public, and was a scientific journalist for the magazine *Science News* for more than 25 years. His initial training in physics and chemistry led him to consider applications of mathematics to all fields

of science. The talk that he gave on February 4, 2010, at the CRM was entitled *Geometreks*. The audience was invited to take a tour of the world surrounding us, and to observe the mathematics underlying the architecture and art that we see every day. The lecture was abundantly illustrated with photographs, most of which taken by the speaker all over the world.

A large part of the lecture was about the observation of architectural creations, each more spectacular than the next: the National Gallery of Art in Washington with its acute angles; Kenneth Snelson’s Needle Tower

(also in Washington), which maintains its balance even though its beams do not touch one another; the Man in the Community Pavilion at Expo 67; church arches; the Gateway Arch in St. Louis (Missouri), whose shape is an inverted catenary; and the curves in the profile of the Eiffel Tower. Ivars Peterson illustrated how certain window grids resemble Riemann sums from integration theory. The observation of famous buildings revealed, among other things, several occurrences of the Gaussian distribution in the ageing of buildings.

Ivars Peterson also described the mathematics of Reuleaux’s triangle, a geometric shape with the property that it always touches two parallel lines whose distance is equal to the diameter of the shape. The speaker brought up the paradoxes by passing through “No Name Street” and mentioning the fact that every integer is characterized by a property. For instance, the number 1729 is the first number that can be written in two ways as the sum of two cubes, since we have the relations  $1729 = 1^3 + 12^3$  and  $1729 = 9^3 + 10^3$ . Another detour led the audience to the Encyclopedia of Integer Sequences, which allows one to find the specific properties of certain sequences of integers.

Ivars Peterson also showed the audience how numbers have inspired artists. For example, Arlene Stamp was inspired by the writing of integers in base two when she created her friezes, and by the decimals of  $\pi$  when she created a mural in a Toronto subway station. Helaman Ferguson's fountain is inspired by Fibonacci numbers. Geometry inspired Sol LeWitt in his pyramid with four sides, his colourful murals, and his open, incomplete cubes, as well as Arthur Silverman, Robinson Fredenthal, and Ted Bieler, for their sculptures using polyhedrons. A visit to the National Gallery of Canada in Ottawa provided the pretext for a digression on the game of pursuit and the remarkable spirals generated by the pursuers.

The speaker showed the United States Pavilion at Expo 67 (now the Biosphere) and drew the audience's attention to the hexagonal structure of the cells. Using an animation, he explained why pentagons are necessary to complete the structure. Ivars Peterson shared

with the audience his enthusiasm for Möbius strips by showing that they appear in many sculptures, as well as in the well-known symbol for recycling, which is sometimes reproduced incorrectly: the border of the true symbol is a trivial knot, while the border of the false symbol is a trefoil knot.

Towards the end of his lecture, Ivars Peterson spoke about fractals, which are marvellous models for shapes found in nature. He finished the conference by showing a sculpture by Helaman Ferguson, "Umbilical Torus," whose section is a hypocycloid and whose surface motifs imitate a Peano curve. Ivars Peterson's message to the audience was to open one's eyes and notice all of the mathematics in our surroundings. The bright eyes at the end of the talk and the conversations during the wine and cheese party demonstrated that the message had been well received!

# 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, PIMS, the Canadian Mathematical Society (CMS), MITACS, the Canadian Applied and Industrial Mathematics Society (CAIMS), the Statistical Society of Canada (SSC), the Canadian Association of Physicists (CAP), as well as with other societies and institutes abroad.

## CRM Partners

### **The Fields Institute (FI) and the Pacific Institute for the Mathematical Sciences (PIMS)**

Since the early 1990s two other research institutes have joined the CRM on the Canadian scene: Toronto's Fields Institute (FI) 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 Mathematics of Information Technology and Complex Systems network (MITACS). The three institutes were also involved in other initiatives, such as the CRM – Fields Prize awarded in recognition of outstanding accomplishments in the mathematical sciences in Canada. It was created in 1994 and in 2005 became the CRM – Fields – PIMS Prize. The administrative responsibility for this prize rotates between the three institutes.

### **International and National Collaborations**

In 2009 – 2010, the CRM collaborated in particular with the following institutions: Inserm, INRIA, the Banff International Research Station (BIRS), the Groupe d'études et de recherche en analyse des décisions (GERAD), the National Institute for Complex Data Structures (NICDS), and the Tata Institute of Fundamental Research (including the Centre for Applicable Mathematics, located in Bangalore).

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 and Lecture Notes. The 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 (USA), École normale supérieure, the Isaac Newton Institute, the Institut des Hautes Études Scientifiques, 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 Mathematics of Information Technology and Complex Systems Network (MITACS)**

MITACS (Mathematics of Information Technology and Complex Systems) is a pan-Canadian network for mathematics whose creation was proposed by the three Canadian mathematical sciences institutes, the CRM, Fields and PIMS. MITACS was officially launched on February 19, 1999. By March 1999, all 21 initial research projects were under way. MITACS leads 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, MITACS initiates and fosters linkages with industrial, governmental, and not-for-profit organizations. The only network of centres of excellence for the mathematical sciences, MITACS currently involves more than 300 scientists and 600 students (from almost 50 universities) working on approximately 30 projects. MITACS 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.

MITACS also extends financial support to some events organized by the CRM and other institutions. In particular, in 2009–2010, it supported in part the first three workshops of the thematic semester on imaging science (see the Section [Thematic Program](#)) and the *Third Montréal Industrial Problem Solving Workshop* (see the Section [Multidisciplinary and Industrial Program](#), p. 34).

### The National Institute for Complex Data Structures (NICDS)

In 2008–2009, the Canadian statistical community took the initiative and transformed the NPCDS, a national network in statistics created by the statistical community and the three Canadian mathematics institutes, into an institute, the NICDS. The NICDS was created in response to a pressing need to involve statisticians in collaborations with researchers from various disciplines. Its mandate is to enrich and enlarge the national research enterprise through a powerful new model for the statistical sciences. This model has three striking, unique features:

- the creation of interdisciplinary research teams with quantitative leadership;
- the training of the next generation of quantitative researchers to ensure that they will become well versed in the language of multiple disciplines and be prepared to hold leadership positions in long-term scientific collaborations;
- the raising of the national profile of the statistical sciences.

In the context of this model, and supported by a proactive management team, the NICDS elicits research proposals and builds research projects that are national in scope and involve numerous disciplines and partners.

In 2009–2010, the NICDS sponsored two workshops at the CRM: the workshop on *Analysis of Directional Data with Applications to Biomechanics and Biomedical Imaging* and the workshop on *Statistical Methods for Geographic and Spatial Data in the Management of Natural Resources* (see the Section [Multidisciplinary and Industrial Program](#), p. 35).

### NICDS Projects

- Statistical Methods for Complex Survey Data  
Project Leader: Changbao Wu (Waterloo)
- Canadian Consortium on Statistical Genomics  
Project Leader: Rafal Kustra (Toronto)
- Data Mining with Complex Data Structures  
Project Leaders: Hugh Chipman (Acadia), Antonio Ciampi (McGill), Theodora Kourti (McMaster), Helmut Kröger (Laval)
- Design and Analysis of Computer Experiments for Complex Systems  
Project Leader: Derek Bingham (Simon Fraser)
- Forests, Fires and Stochastic Modelling  
Project Leaders: John Braun (Western Ontario), Charmaine Dean (Simon Fraser), Dave Martell (Toronto)
- Spatial/Temporal Modelling of Marine Ecological Systems  
Project Leaders: Michael Dowd, Joanna Flemming, Chris Field (Dalhousie), Rick Routledge (Simon Fraser)
- Statistical Innovation for the Analysis of Complex Data in Medical and Health Science  
Project leaders: Richard Cook (Waterloo), Michal Abrahamowicz (McGill), Paul Gustafson (UBC), Wendy Lou (Toronto), Peter Song (Waterloo), Liqun Wang (Manitoba)

### 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 incep-

tion, 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 Centre de recherches mathématiques, the Fields Institute, and the Pacific Institute for the Mathematical Sciences 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.

### AARMS Scientific Activities

- Theory Canada 5  
June 3 – 6, 2009, University of New Brunswick  
Local organizer: Viqar Husain (New Brunswick)
- International Workshop/Special session of 2009 Summer CMS meeting: Groups and Hopf Algebras  
June 3 – 8, 2009, Memorial University  
Local organization: Atlantic Algebra Centre
- Graph Searching: special session, CMS summer meeting  
June 6 – 8, 2009, Memorial University  
Organizer: Anthony Bonato (Ryerson)
- Mathematics Education: special session, CMS summer meeting  
June 6 – 8, 2009, Memorial University  
Organizer: Sherry Mantyka (Memorial)
- International Conference on Nielsen Theory  
June 9 – 13, 2009, Memorial University  
Local organizer: Philip Heath (Memorial)
- Bluenose Numerical Analysis Days 2009  
July 10, 2009, Acadia University  
Local organization: Ronald Haynes (Memorial), Richard Karsten (Acadia), Paul Muir (Saint Mary's), Patrick Keast (Dalhousie)
- APICS Math/Stats/CS conference 2009  
October 23 – 25, 2009, Dalhousie University  
Local organization: David Iron, Richard Nowakowski, Art Sedgwick (Dalhousie)
- Sixth Annual East Coast Combinatorics Conference  
April 29 – 30, 2010, Saint Mary's University  
Organizers: Art Finbow, Bert Hartnell (Saint Mary's)
- W. J. Blundon Seminar  
May 19 – 21, 2010, Memorial University  
Organization: High School Competitions Committee, Department of Mathematics and Statistics, Memorial University

### 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 with 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 québécois de la recherche sur la nature et les technologies (FQRNT), the CRM finances the activities of its ten 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 descriptions 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 Centre de recherches mathématiques (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 2009-2010 there was one such talk at the University of Ottawa.

- *Categorification of quantum groups*  
Mikhail Khovanov (Columbia), April 23, 2010

### Network for Computing and Mathematical Modeling (ncm<sub>2</sub>)

The CRM is one of the founding members of the Network for Computing and Mathematical Modeling (ncm<sub>2</sub>), 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 com-

merce. The ncm<sub>2</sub> was founded by the CRM, the Centre de recherche en calcul appliqué (CERCA), the Center for Interuniversity Research and Analysis of Organizations (CIRANO), the Centre for Research on Transportation (CRT), GERAD, the Centre de recherche informatique de 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<sub>2</sub>: CIRANO, CIRRELT, CRM, GERAD, and INRS-ÉMT.

### Québec Neuroimaging Initiative (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. 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 FMPMC Pitié-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, PIMS, and MITACS.

### 2009 Annual meeting of the Statistical Society of Canada

May 31 – June 3, 2009, University of British Columbia  
Sponsored by the CRM, the Fields Institute, PIMS, MITACS, the University of British Columbia (Faculty of Science, Department of Statistics, School of Population and Public Health), Simon Fraser University (Department of Statistics and Actuarial Science), University of Victoria (Department of Mathematics and Statistics), Michael Smith Laboratories, Capital One, FPIInnovations, STATA, and Syreon Corporation

#### Program Committee Chair:

Wendy Lou (Toronto)

#### Local Arrangements Committee:

Matias Salibián-Barrera, chair; Lang Wu; Nancy Heckman (UBC)

The 37th Annual Meeting of the SSC was a great success, and included an impressive number of communications (more than 370). The meeting featured a session in honour of Jack Kalbfleisch's 65th birthday and memorial sessions in honour of Randy Sitter and Keith Worsley, respectively. It also featured many addresses and lectures, in particular the following ones.

- SSC Presidential Invited Address (Chris Wild, Auckland).
- Special Invited Session of the Survey Methods Section (Jean-François Beaumont, Statistics Canada).

- Isobel Loutit Invited Address on Business and Industrial Statistics (William Woodall, Virginia Tech).
- Gold Medal Award Address (Luc Devroye, McGill).
- Special Invited Session of the Probability Section (Peter Guttorp, Washington).
- Canadian Journal of Statistics Award Address (Qing Pan, George Washington; Douglas Schaubel, Michigan).
- Special Invited Session of the Biostatistics Section (Charles McCulloch and John Neuhaus, UCSF).
- Pierre Robillard Award Addresses (Baojiang Chen, Washington; Grace Yi & Richard Cook, Waterloo).
- Address of the winner of the CRM – SSC Prize (Hugh Chipman, Acadia).

### CMS – CSHPM Summer Meeting 2009

June 6 – 8, 2009, Memorial University

Sponsored by the CRM, the Fields Institute, PIMS, MITACS, AARMS, Memorial University, and the Canadian Language & Literacy Research Network

#### Meeting Directors:

David Pike & Danny Dyer (Memorial)

In June 2009 the CMS summer meeting was organized jointly with The Canadian Society for History and Philosophy of Mathematics (CSHPM). The meeting featured talks by the following plenary speakers: Elizabeth J. Billington (Queensland), Jeremy Gray (Open & Warwick), Michael Mackey (McGill), Susan Montgomery (Southern California), Michael Sigal (Toronto), and Gaoyong Zhang (NYU-Poly). The Excellence in Teaching Award was awarded to David Poole (Trent), the Jeffery – Williams Prize to Stephen Kudla (Toronto), and the Krieger – Nelson Prize to Yael Karshon (Toronto). Helaman Ferguson, sculptor and mathematician, gave a public lecture entitled *Mathematics in Stone and Bronze*.

Here is a list of the 18 sessions, along with their organizers.

#### *Algebraic Combinatorics*

Organizers: Steve Kirkland & Karen Meagher (Regina)

#### *Algebraic Geometry and Topology (Canada/Korea)*

Organizers: Alejandro Ádem (UBC), Jong Hae Keum (KIAS)

#### *Algebraic Group Actions and Invariant Theory*

Organizers: Eddy Campbell & Juanjun Chuai (Memorial), David Wehlau (RMCC & Queen's)

#### *Combinatorial Designs and Related Topics*

Organizers: Václav Linek (Winnipeg), Nabil Shalaby (Memorial)

#### *Financial Mathematics*

Organizers: Cody Hyndman (Concordia), Rogemar Mamon (Western Ontario)

#### *Geometric Harmonic Analysis and Partial Differential Equations*

Organizer: Jie Xiao (Memorial)

#### *Graph Searching*

Organizers: Anthony Bonato (Ryerson), Danny Dyer (Memorial), Gary McGillivray (Victoria)

#### *Groups and Hopf Algebras*

Organizers: Yuri Bahturin (Memorial), Margaret Beattie (Mount Allison), Eric Jespers (VUB), Wolfgang Kimmerle (Stuttgart), Mikhail Kotchetov (Memorial), David Radford (UIC), Sudarshan Sehgal (Alberta), Earl Taft (Rutgers)

#### *History and Philosophy of Mathematics (CSHPM)*

Organizer: Tom Drucker (Wisconsin – Whitewater)

#### *History of the Relationship Between Mathematics and the Physical Sciences (CSHPM)*

Organizer: Tom Archibald (Simon Fraser)

#### *Interactions Between Algebraic Geometry and Ring Theory*

Organizers: Jason Bell (Simon Fraser), Colin Ingalls (New Brunswick)

#### *Mathematical Physics*

Organizers: Marco Merkli & Chris Radford (Memorial)

#### *Nonlinear Dynamics and Applications*

Organizers: Gail Wolkowicz (McMaster), Yuan Yuan & Xiaoqiang Zhao (Memorial)

#### *Numeracy/Mathematics Education*

Organizers: Sherry Mantyka (Memorial) and Canadian Language and Literacy Research Network

#### *Numerical Analysis and Scientific Computing*

Organizers: Jahrul Alam (Memorial), Wenyan Liao (Calgary)

#### *Operator Algebras*

Organizers: Andrew J. Dean (Lakehead), George Elliott (Toronto), Marco Merkli (Memorial)

#### *Reaction-Diffusion Systems and Their Applications*

Organizers: David Iron & Theodore Kolokolnikov (Dalhousie), Chunhua Ou (Memorial)

#### *Topological Algebra, Topology, and Functional Analysis*

Organizers: Alex Karashev (Nipissing), Gábor Lukács (Manitoba), Paul Szeptycki (York)



**CAIMS 2009**

June 10 – 14, 2009, University of Western Ontario  
Sponsored by the CRM, the Fields Institute, PIMS, MITACS, the University of Western Ontario (Faculty of Science, Department of Applied Mathematics)

**Scientific Program Committee Chair:**

Rob Corless (Western Ontario)

**Organizing Committee:**

Xingfu Zou, chair; Geoff Wild; Matt Davison (Western Ontario)

This meeting was actually the 30th Anniversary Annual Meeting of CAIMS. The organizers welcomed nearly 200 participants, from over a dozen countries, and the program included more than 140 communications. The meeting featured talks by the following plenary speakers: Marty Golubitsky (Ohio State & Houston), Nick Trefethen (Oxford), Alun Lloyd (NC State), Cliff Burgess (Perimeter Inst.), and Peter Forsyth (University of Waterloo). The Cecil Graham Doctoral Dissertation Award was awarded to Raluca Eftimie and Colin Macdonald, whose presentations were entitled (respectively) *Modeling group formation and activity patterns in self-organizing aggregations* and *Computing on surfaces with the closest point method*. The presentation of Mark Lewis, winner of the CAIMS Research Prize, was entitled *Mathematical challenges in the modelling of biological invasions*.

The meeting also featured a wide variety of excellent talks in each of the following six themes (whose organizers are listed within parentheses): Dynamical Systems (Yuan Yuan and Pei Yu), Scientific/Symbolic Computation (Rob Corless), Mathematical Biology (Chris Bauch and Geoff Wild), Complex Fluids (Colin Denniston), Theoretical Physics (Gerry McKeon), and Mathematical Finance (Tony Ware and Adam Metzler). In addition the program included minisymposia on Functional Differential Equations (Yuming Chen and Qinwen Hu), Nonlinear Analysis and Differential Equations (K. Q. Lan), Mathematical Neuroscience (Sue Ann Campbell), Numerical Solutions of PDEs (Ray Spiteri and Paul Muir), Modern Thermodynamics (Chris Essex), and New Directions in Mathematical Modelling of Hydrogen Fuel Cells (Brian Wetton), and a special Ph.D. Student Minisymposium on Mathematical Finance (Adam Metzler).

**Second Joint Meeting of the Canadian Mathematical Society and the Sociedad Matemática Mexicana 2009**

August 13 – 15, 2009, University of British Columbia  
Sponsored by the CRM, the Fields Institute, PIMS, MITACS, CMS, and SMM

**Scientific Committee:**

Alejandro Ádem (UBC), Fernando Brambila (SMM & UNAM), Walter Craig (McMaster), Isidoro Gitler (Cinvestav), Andrew Granville (Montréal), José Seade (UNAM)

The meeting organizers had the honour of welcoming the following plenary speakers: James Arthur (Toronto), Onésimo Hernández-Lerma (Cinvestav), Niky Kamran (McGill), Rachel Kuske (UBC), José Seade (UNAM), Alberto Verjovsky (UNAM Cuernavaca).

Here is a list of the 10 sessions, along with their organizers.

*Algebra*

Organizers: Christof Geiss (UNAM), Arturo Pianzola (Alberta)

*Algebraic Geometry and Singularity Theory*

Organizers: Ed Bierstone (Toronto), Leticia Brambila (CIMAT), Jacques Hurtubise (McGill), José Seade (UNAM)

*Analysis*

Organizers: Salvador Pérez-Esteve (UNAM), Malabika Pramanik (UBC)

*Combinatorics and Graph Theory*

Organizers: Hortensia Galeana (UNAM), Luis Goddyn (Simon Fraser), Miguel Pizaña (UAM Iztapalapa)

*Differential Geometry*

Organizers: Niky Kamran (McGill), Oscar Palmas (UNAM), Adolfo Sanchez Valenzuela (CIMAT)

*Dynamical Systems*

Organizers: Florin Diacu (Victoria), Renato Itturiaga (CIMAT), Ernesto Pérez-Chavela (UA Madrid)

*Optimization and Approximation*

Organizers: Michael Friedlander (UBC), Pedro González-Casanova (UNAM), and Luis Verde-Star (UAM Iztapalapa)

*Partial Differential Equations*

Organizers: Monica Clapp (UNAM), Nassif Ghoussoub (UBC), Pablo Padilla (UNAM)

*Probability*

Organizers: Ana Meda (UNAM), Ed Perkins (UBC)

*Topology*

Organizers: José Luis Cisneros-Molina (UNAM), Ian Hambleton (McMaster), Miguel Xicotencatl (Cinvestav)

**2009 CMS Winter Meeting**

December 5 – 7, 2009, University of Windsor  
Sponsored by the CRM, the Fields Institute, PIMS, MITACS, and the University of Windsor

**Meeting Director:**

Dan Britten (Windsor)

**Chair of the Local Arrangements Committee:**

Ejaz Ahmed (Windsor)

The organizers had the honour of welcoming the following plenary speakers: Jonathan Borwein (ANU), Anthony To-Ming Lau (Alberta), Naomi Leonard (Princeton), Nancy Reid (Toronto), Christine Shoemaker (Cornell), and David Vogan (MIT). The Adrien Pouliot Award was awarded to Walter Whiteley (York) and the Coxeter – James Prize to Patrick Brosnan (UBC). The Doctoral Prize was awarded to Mark Braverman (Toronto) and the G. de B. Robinson Award to Vladimir Manuilov (Moscow State) and Klaus Thomsen (Aarhus). The Graham Wright Award for Distinguished Service was awarded to Christiane Rousseau (Montréal).

Here is a list of the 16 sessions, along with their organizers.

*Banach Algebras and Abstract Harmonic Analysis*

Organizers: Zhiguo Hu & Mehdi Monfared (Windsor)

*Complex Analysis*

Organizers: André Boivin & Tatyana Foth (Western Ontario)

*Convex and Variational Analysis*

Organizers: Heinz Bauschke & Shawn Wang (UBC Okanagan)

*Exact and Approximate Methods for Nonlinear Differential Equations*

Organizers: Alexei F. Cheviakov & George W. Patrick (Saskatchewan)

*Lie Algebras and Representation Theory*

Organizers: Nicolas Guay (Alberta), Michael Lau (Windsor)

*Lie Groups and Automorphic Forms*

Organizers: Hadi Salmasian (Ottawa), Wai Ling Yee (Windsor)

*Mathematical Models in Environmental Sciences*

Organizer: Rick Caron (Windsor)

*Mathematical Statistics*

Organizers: Jiahua Chen (UBC), Chi Song Wong (Windsor)

*Mathematics Education*

Organizer: Dragana Martinovic (Windsor)

*Matrix Theory and Statistics*

Organizers: Ejaz Ahmed & Abdul Hussein (Windsor)

*Measure, Probability, and Stochastic Processes*

Organizers: Sévérien Nkurunziza & Tim Traynor (Windsor)

*Non-Linear Control Theory*

Organizers: Andrew Lewis & Abdol-Reza Mansouri (Queen's)

*Number Theory*

Organizers: Kevin Hare (Waterloo), Soroosh Yazdani (McMaster)

*Operator Algebras*

Organizers: Mitja Mastnak (Saint Mary's), Dilian Yang (Windsor)

*Real and Complex Singularities*

Organizer: Janusz A. Adamus (Western Ontario)

*Recent Trends in Discrete Geometry*

Organizers: Károly Bezdek (Calgary), Antoine Deza (McMaster)

# 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 seven Québec universities (Concordia, Laval, McGill, Montréal, UQÀM, UQTR, and 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 of Québec and by the seven universities in the consortium.

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

### Coordination and harmonization of mathematical 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 ISM Graduate Student Conference and the ISM Graduate Student Seminar.

### Promotion of the mathematical sciences

The ISM produces the *Accromath* journal 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 seven 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. Also they are a vital link between the professors and the students, especially when they organize on their own study groups on emerging topics.

## 2009 – 2010 Postdoctoral Fellows

**Mattia Cafasso** (Ph.D. 2008, SISSA) is working with Marco Bertola (Concordia) in mathematical physics and geometry. He gave a lecture on his research results in October 2009 (within the mathematical physics seminar).

**Norman Do** (Ph.D. 2009, Melbourne) is working with Jacques Hurtubise (McGill) in geometry and topology. He was an active member in the geometry and topology research group during his stay in Montréal and will pursue his postdoctoral studies in Melbourne, with financial support from the Australian government.

**Grégoire Dupont** (Ph.D. 2008, Lyon 1) is working in algebra with Ibrahim Assem, Virginie Charette, and Thomas Brüstle at the Université de Sherbrooke. In 2010 he supervised the research of an undergraduate student. He gave several lectures within the algebra seminar at Sherbrooke and also a lecture at the Club mathématique de Sherbrooke for undergraduate students.

**Christian Stump** (Ph.D. 2008, Wien) is working in combinatorics and theoretical computer science with François Bergeron, Christophe Reutenauer, and Christophe Hohlweg at UQÀM. During the Winter 2010 term, he co-organized the weekly seminar for the combinatorics group at UQÀM.

**Benjamin Young** (Ph.D. 2008, UBC) is working with Jacques Hurtubise (McGill) in mathematical physics. In 2010, he supervised an undergraduate research fellow. B. Young will pursue his postdoctoral studies at MSRI (Berkeley) for a six-month period, before moving to Stockholm in order to work within a research group on random matrices.

## ISM Doctoral Fellowships

In 2007 – 2008 the ISM initiated a doctoral fellowships program in order to recruit outstanding Ph.D. students. The doctoral fellowships provide financial support to outstanding, new students to pursue a doctoral program at one of the ISM member universities. Awarded for a two-year period, and renewable for a further two years, each scholarship is worth \$20,000 per year. The students fill an application form online and the applications are made available to all the ISM professors. In 2009 – 2010 the Ph.D. student Sepideh Farsinezhad is holding such a fellowship; she is working in statistics at McGill University. Two fellowships for 2010 – 2011 were awarded: the first one to Kirill Shmakov, who

holds a master's degree from the Saint Petersburg State University in Russia and will do a Ph.D. in physics at Concordia University; the second one to Erwan Biland from Paris, who will be cosupervised by a professor from Université Laval and a professor from Université Paris Diderot. E. Biland's research topic is in number theory.

## 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.

**Ibrahim Al Balushi** (Concordia)

Scholarship cofinanced by Alina Stancu

Supervisor: Nikolay Dimitrov

Topic: *Optical caustics from a differentiable viewpoint*

Duration: 2 months (July – August)

**Marjorie Banville** (Montréal)

Scholarship cofinanced by Sabin Lessard

Supervisor: Amir Kermany

Topic: *Using the ancestral selection graph to study genetic variability*

Duration: 4 months (May – August)

**Jean-Philippe Burelle** (Sherbrooke)

Scholarship cofinanced by Ibrahim Assem and Virginie Charette

Supervisor: Grégoire Dupont

Topic: *Quantum cluster algebras*

Duration: 4 months (September – December)

**Cyndie Cottrell** (McGill)

Scholarship cofinanced by Jacques Hurtubise

Supervisor: Benjamin Young

Topic: *Enumerative combinatorics*

Duration: 3 months (May – July)

**Maria Eberg** (McGill)

Scholarship cofinanced by Louigi Addario-Berry

Supervisor: Simon Griffiths

Topic: *Random Graph models*

Duration: 11 weeks (June 15 – August 31)

**Dieter Fishbein** (McGill)

Scholarship cofinanced by Henri Darmon

Supervisor: Bryden Cais

Topic: *Rational points on elliptic curves*

Duration: 11 weeks (May 3 – July 20)

**Robert Gibson** (McGill)

Scholarship cofinanced by Gantumur Tsogtgerel

Supervisor: Renato Calleja

Topic: *Development of a new geometric discretization scheme for wave maps equations*

Duration: 2 months (June 16 – August 15)

**Jifeng Shen** (McGill)

Scholarship cofinanced by Daniel Wise

Supervisor: Nicholas Touikan

Topic: *Geometric group theory*

Duration: 4 months (May – August)

### ISM Graduate Student Conference

The 12th ISM Graduate Student Conference (*Colloque panquébécois annuel des étudiants*) was held on May 28 – 30, 2010, at the Université Laval. About 60 students from Québec and France attended the conference, which was organized by Jérôme Fortier, Maxime Fortier Bourque, Quentin Rajon, and Malik Younsi. The plenary lectures were given by Christian Genest (Laval), Yvan Saint-Aubin (Montréal), Marco Picasso (EPFL), Michael Yampolsky (Toronto), and François Watier (UQÀM).

The following students gave talks during the Graduate Student Conference: Benoît Pouliot (Laval), Colin Jaufret (Montréal), Daniel Fiorilli (Montréal), Jean-Philippe Labbé (UQÀM), Patrice Rivard (Laval), Richard Bois (Laval), Hela Romdhani (Laval), François Bolduc (Laval), Tayeb Aïssiou (McGill), Jérôme Fortier

(Laval), Servat Nyandwi (Laval), Bocar Amadou Kane (Laval), Patrick Lacasse (Laval), Ibrahima Dionne (Laval), Quentin Rajon (Laval), and Denis Talbot (Laval).

### Promotion of the mathematical sciences

Produced by the ISM and financed by the ISM, the CRM, the MITACS network, and the Canadian Mathematical Society (CMS), the *Accromath* magazine aims to draw more young people to the mathematical sciences. *Accromath*, whose editor-in-chief is André Ross, instructor of mathematics at the Cégep Lévis-Lauzon, is available free of charge in all the high schools and cegeps 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 cegep 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.

Currently 1,800 persons or institutions (mostly teachers from Québec) subscribe to the magazine. In June 2009 the magazine was awarded the *prix spécial de la ministre de l'Éducation, du Loisir et du Sport*. Renowned throughout the world, *Accromath* was awarded a special mention for the *prix d'Alembert*, granted once every two years by the Société mathématique de France (SMF) in order to reward a person or group that has been able to generate interest for mathematics within a broad audience. For more information on *Accromath*, we refer the reader to the site [accromath.ca](http://accromath.ca).

## Other Joint Initiatives

### CMS Mathematics Camps

In order to promote mathematics, the CMS provides extracurricular activities for high school students, especially a National Math Camp and Regional Math Camps. Each year the CMS also offers training camps for the Canadian Team selected for competing at the International Mathematical Olympiad. The CRM sponsors these camps, along with the Fields Institute, PIMS, the Association mathématique du Québec, PromoScience (NSERC), the host universities, various foundations, and most Canadian provinces (cf. [cms.math.ca/MathCamps/](http://cms.math.ca/MathCamps/)).

### 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 [smac.ulaval.ca](http://smac.ulaval.ca) for more information. The CRM also supports the Association québécoise des jeux mathématiques ([aqjm.fsg.ulaval.ca](http://aqjm.fsg.ulaval.ca)).

# Research Laboratories

**I**N 2009 – 2010 the CRM was encompassing ten 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 19 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

Firstly, we are very pleased to announce that two new members will soon join the laboratory, following the successful appointment of Rustum Choksi and Jean-Christophe Nave to faculty positions in the Mathematics Department of McGill University. We congratulate them on their success and look forward to collaborating with them actively in the years to come. The year 2009 – 2010 has been a most fruitful one for members

of the Laboratory. In 2009, Eliot Fried was made the Tier 1 Canada Research Chair in Interfacial and Defect Mechanics, and Jacques Bélair became president of the Canadian Applied and Industrial Mathematics Society, a post that he will hold until 2011. In addition to the appearance in print of numerous articles in refereed international journals and conference proceedings, book chapters, manuals, and technical reports by laboratory members over the last year, the publication in 2009 by Cambridge University Press of *The Mechanics and Thermodynamics of Continua* (written by Eliot Fried, Morton Gurtin from Carnegie Mellon, and Lallit Anand from MIT) is worthy of a special mention.

Members of the laboratory were also very active on the international and Canadian applied mathematical scenes in 2009 – 2010. Below is a highlight of just some of the invited conference talks given by members during this period. Jacques Bélair was a keynote speaker at the meeting of the Société Francophone de Biologie Théorique that took place in Belvédère, Tunisia (June 17 – 19, 2010). He has also given invited talks at the CAIMS meeting in London, Ontario in 2009 and will give an invited talk at the 2010 CAIMS meeting in St. John's, Newfoundland. Eusebius Doedel delivered two mini-symposium talks at the SIAM Conference on Emerging Topics in Dynamical Systems and Partial Differential Equations in Barcelona (June 2010) and spoke in a special session on Recent Advances on Bifurcation Problems at the 8th AIMS Conference on Dynamical Systems, Differential Equations and Applications in Dresden, Germany (May 2010).

Tucker Carrington spoke on *Ro-vibrational spectroscopy of Van der Waals molecules* at both the 93rd Canadian Chemistry Conference and Exhibition, Toronto (May 2010) and the International Symposium on Molecular Spectroscopy, 65th Meeting (June 2010). In February 2010 he also gave an invited talk at the 26th GAMM-Seminar Leipzig on Tensor Approximations and High-Dimensional Problems (Leipzig). In 2009 Professor Carrington was invited to speak at the following meetings: Seventh International Conference of Computational Methods in Sciences and Engineering, Rhodes (October 2009); Workshop on Coping with



Complexity: Model Reduction and Data Analysis, Ambleside, UK (September 2009); Workshop on Linear and Nonlinear Eigenproblems for PDEs, Mathematisches Forschungsinstitut Oberwolfach, Germany (August 2009); Workshop on Quantum Dynamic Imaging, at the Centre de recherches mathématiques, Montréal (October 2009); and the Seventh Canadian Computational Chemistry Conference, held in Halifax, Nova Scotia (July 2009).

Eliot Fried spoke at the workshop on *Small-scale Hydrodynamics: Microfluidics and Thin Films* at the Banff International Research Station for Mathematical Innovation and Discovery (February 2010). In 2009 he was invited to speak at Cosserat + 100, an International Conference on the legacy of *Théorie des corps déformables* by Eugène and François Cosserat in the centenary of its publication (Paris, July 15 – 17, 2009). In the same month he also spoke at the 4th International Symposium on Defect and Material Mechanics, held at the University of Trento. Robert Owens was one of the invited speakers at the IMA Annual Program Year Workshop entitled *Flowing Complex Fluids: Rheological Measurements and Constitutive Modeling*, held at the University of Minnesota in September 2009. We conclude by mentioning visiting positions held by members during 2009 – 2010: Tucker Carrington was a Visiting Professor at the ETH Zürich from June to July 2009 and Robert Owens was *professeur invité* at the Institut de Mathématiques, Université Paul Sabatier, from May 11 to June 8, 2009.

### Students, postdoctoral fellows, and visitors

In addition to the significant financial resources made available by the Applied Mathematics Laboratory for the partial support of workshops and conferences, we have been very enthusiastic supporters of postdoctoral researchers in applied mathematics. This has been possible because of the great prudence shown over the last few years in the management of the resources at our disposal, and the support of postdoctoral researchers is viewed as essential “stimulus spending” for the continued vitality of high-level applied mathematics research in Montréal. Claude Mangoubi (Hebrew University of Jerusalem) worked with Robert Owens for the first six months of 2009, and during the summer of 2009 Tony Humphries and Eusebius Doedel welcomed Renato Calleja to Montréal to work with them for a period of two years. In October 2009, Mounir Bennoune arrived from Toulouse to begin a one-year postdoc-

toral fellowship under the guidance of Robert Owens, and in January 2010, El Miloud Zaoui was appointed to work with André Bandrauk and Emmanuel Lorin de la Grandmaison for a period of one year. Brian Seguin will come to Montréal through a joint funding arrangement between the Applied Mathematics Laboratory and Eliot Fried, bringing the number of postdoctoral fellows supported by the Laboratory at the present time up to four.

In 2009 – 2010 members of the Applied Mathematics Laboratory supervised or cosupervised 16 M.Sc. students, 38 Ph.D. students, and 12 postdoctoral fellows.

### Seminars

The scientific and social life of the Laboratory centers on the weekly seminar. This is not only an opportunity for applied mathematicians in Montréal (and further afield) to hear talks given by experts in their fields from leading academic institutions across the world, but also an opportunity for Laboratory members to collaborate and have detailed discussions with the speakers (thanks to the availability of lab funding allowing speakers to extend their visit to our city). Over the past academic year no fewer than 32 visitors have given talks in the seminar series, drawn from countries in North America, South America, Europe, and Asia. We consider ourselves very fortunate indeed to be able to welcome these colleagues to our city and have learnt much from the experience. Our sincere thanks go to Eliot Fried and Gantumur Tsogtgerel for their organization of the seminar series in the autumn and winter semesters, respectively.

### Workshops, special sessions, and others

The Laboratory has a tradition of directing a substantial proportion of its annual budget to the support of conferences and workshops organized by its members. This year has proved to be no exception and some \$20,000 were made available to the organizers of the workshop mentioned below (and described in Section [Multidisciplinary and Industrial Program](#), p. 36) and a workshop that took place in July 2010 (to be described in the CRM annual report for 2010 – 2011).

*Analysis of Multiphase Biomembranes*  
April 24 – 26, 2010, McGill University  
Organizer: Eliot Fried (McGill)

## Members of the laboratory

### Regular members

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

**Paul Arminjon** (Montréal)  
Numerical methods in fluid mechanics

**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

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

**Eliot Fried** (McGill)  
Mechanics and thermodynamics of continuous media

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

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

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

**Lennaert van Veen** (Concordia)  
Application of dynamical systems theory to complex phenomena and high-dimensional chaos

**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

**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

### Description

CICMA brings together researchers working in number theory, group theory, and algebraic geometry. Contemporary number theory follows 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. Also the Langlands program postulates a close link between arithmetic  $L$ -functions and automorphic representations.

An area where these two currents intersect is the study of elliptic curves. This area is particularly well represented in the laboratory with Darmon, Iovita, and Kisilevsky. On the other hand, analytic number theory

is well represented in CICMA with Andrew Granville, a leader in his field, who brings to the laboratory an expertise in many aspects of analytic number theory. On the group theory side, Kharlampovich and Miasnikov are world-renowned specialists of group varieties and McKay is one of the instigators of the moonshine program.

### News and highlights

This year we were most pleased to welcome several new, young members to CICMA: Matilde Lalín (Université de Montréal), Heekyoung Hahn (McGill University), Jayce Getz (McGill University), and Hugo Chapdelaine (Université Laval). Much of the laboratory's energies were directed towards the organization of the CRM's thematic semester on Number Theory

as an Experimental and Applied Science, which was a great success. Two of our members, Chantal David and Andrew Granville, were invited to participate in a special year organized by the Institute for Advanced Study at Princeton on analytic number theory, so that their time was shared between Princeton and Montréal.

### Students and postdoctoral fellows

Our three finishing postdoctoral fellows are all moving on to good positions. Xander Faber, who was funded by an NSF Fellowship, will continue his postdoctoral studies at the University of Georgia. Bryden Cais has received two tenure-track offers, one from the University of Arizona and another from McMaster University. JeeHoon Park has been offered a permanent position at POSTECH (South Korea).

In 2009 – 2010 members of CICMA supervised or co-supervised 23 M.Sc. students, 52 Ph.D. students, and 9 postdoctoral fellows.

### Seminars

The Québec – Vermont Number Theory Seminar, CICMA's main scientific activity, is held every second Thursday for a full day and is attended by about 30 participants from Montréal, Vermont, Québec City, and Ottawa. In 2009 – 2010, John Voight and Xander Faber were the organizers of the seminar, which included 32 lectures.

### Workshops, special sessions, and others

CICMA was deeply involved in the organization of the CRM's thematic semester on Number Theory as Experimental and Applied Science (January – April 2010), with three members on the organizing committee: Henri Darmon, Andrew Granville, and Eyal Goren. The Semester included a preparatory Summer School on *Automorphic Forms and L-functions: Computational Aspects* (held in 2009), five workshops, and three courses. Akshay Venkatesh (Stanford), the Aisenstadt Chair, gave a series of lectures. We refer the reader to the section of this report on the thematic program for more information on the semester, and to the Section [General Program](#) (p. 28) for a description of the following workshop.

*The Bellairs Workshop in Number Theory  
Moduli Spaces and the Arithmetic of Dynamical Systems*  
May 2 – 9, 2010, Bellairs Research Institute

Organizers: Xander Faber (McGill), Patrick Ingram (Waterloo)

### 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 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 Robert 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

**Alexei G. Miasnikov** (McGill)

Group theory

**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

### 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 UQÀM, is composed of fifteen full members, three 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; quantization of Hitchin systems and the geometric Langlands program; classification of special Kähler metrics; the study of symplectic invariants, especially in dimension 4; nonlinear partial differential equations in Riemannian geometry, convex geometry, and general relativity; and Hamiltonian dynamical systems. The fields of algebraic geometry (in which Steven Lu and Peter Russell are working) and geometric group theory (in which Daniel Wise is working) are also represented at CIRGET.

### News and highlights

CIRGET is currently recruiting a Tier II Canada Research Chair to be based at UQÀM. The new position should officially begin in January 2012. The Chair will be a great boost just

to the group, bringing in a talented young researcher, as well as additional research and infrastructure funds.

Former CIRGET doctoral student Liam Watson was awarded the 2009 Carl Herz Prize for his work in low-dimensional topology, particularly knot homologies and their relations to the topology of 3-manifolds and Heegaard – Floer theory. He also received a Governor General award for his doctoral thesis.

### 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. In 2009 – 2010, CIRGET members supervised or cosupervised 22 postdoctoral fellows, 28 Ph.D. students, and 24 M.Sc. students. In addition, CIRGET members supervised 11 summer research students in 2010, including one from the École normale supérieure de Lyon and another from the École normale supérieure de Cachan.

Most of our postdoctoral fellows and students are continuing on next year, but those who have completed their stays at CIRGET are moving on to good positions: Nicholas Touikan will be continuing his NSERC PDF in Oxford as of November 2010; Norman Do will be working in Melbourne, funded by a three-year Australian government postdoctoral fellowship; and Benjamin Young will be spending six months at the MSRI before moving on to Stockholm to join the random matrices group there. Graduating doctoral student Éveline Legendre will be holding her NSERC Postdoctoral Fellowship at the Instituto Superior Técnico in Lisbon;



Mehdi Lejmi has been awarded an FQRNT Postdoctoral Fellowship and has accepted a postdoctoral position at Vanderbilt University; Tony Reiser has accepted a position at Technion in Haifa; and Michael Wong will be working at the Tata Institute of Fundamental Research in India.

CIRGET members greatly benefit from the many international visitors who come to work with them. In addition to the 29 short-term visitors who came over the 2009 – 2010 year, Silvia Anjos (Instituto Superior Técnico), Michel Boileau (Université de Toulouse), and Paul Gauduchon (École Polytechnique) each stayed at CIRGET for several weeks to collaborate with members.

### Seminars

In 2009 – 2010, CIRGET invited and funded two colloquium speakers for the CRM – ISM mathematics colloquium lecture series: Shing-Tung Yau (Harvard University) and Nigel Hitchin (University of Oxford). Each speaker attracted about 100 participants.

CIRGET's everyday scientific life revolves around its weekly seminars and working groups where professors, postdoctoral fellows, and students meet on a regular basis. The CIRGET Geometry and Topology Seminar, organized by Vestislav Apostolov, is a general seminar series attended by all CIRGET members. Of the 23 talks given this year, 16 were given by invited speakers who stayed at the Centre for short research visits. The Algebraic Geometry Seminar, organized by Steven Lu, Peter Russell, Karol Palka, and Jacques Hurtubise, hosted 21 talks, with 13 speakers coming from outside of Montréal. CIRGET graduate students from UQÀM, Montréal, and McGill continued to participate in the CIRGET Junior Seminar, organized by doctoral student Radu Cebanu. This seminar gives graduate students a forum to present their research to their peers. A total of 20 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 organized, one by postdoctoral fellow Andrea Gambioli on Kählerian geometry, and another by Steven Boyer on low-dimensional topology.

### Workshops, special sessions, and others

CIRGET organized three workshops (listed below) in Montréal this year. The reader may find the descriptions of the first two workshops in the Section **General Program** (p. 28).

#### *Topics in Riemannian and Poisson Geometry*

April 8-9, 2010, UQÀM

Organizers: Marco Gualtieri (Toronto), Jacques Hurtubise (McGill), Ruxandra Moraru (Waterloo)

#### *Virtual Properties of 3-Manifolds*

April 19 – 23, 2010, UQÀM

Organizers: Ian Agol (UC Berkeley), Steven Boyer (UQÀM)

#### *CIRGET Reunion – 13th Anniversary*

May 10 – 12, 2010, UQÀM

Organizers: CIRGET members

Speakers: Stefan Friedl (Warwick), David Gay (Euclid Lab), Paolo Ghiggini (Nantes), Joseph Maher (CSI-CUNY), Genevieve Walsh (Tufts), Silvia Anjos (IST), Rémi Leclercq (Montréal), Martin Pinsonnault (Western Ontario), Tony Rieser (Montréal), Diego Matessi (Amedeo Avogadro), Erwan Rousseau (Strasbourg), Dimiter Vassilev (New Mexico)

This 3-day workshop brought together former CIRGET students and postdoctoral fellows who presented their current research. Each day was organized around one of three central themes: low-dimensional topology, symplectic topology, and differential geometry.

### Members of the laboratory

#### Regular members

**Vestislav Apostolov** (UQÀM), director

Complex geometry, Kähler geometry

**Steven Boyer** (UQÀM)

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** (UQÀM)

Invariants of knots and 3-manifolds arising from global analysis

**Octavian 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** (UQÀM)  
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** (UQÀM)  
Chern number inequalities, semi-stability 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

**Peter Russell** (McGill)  
Algebraic geometry

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

Associate members

**Syed 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

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

## GIREF

### Description

GIREF is an acronym for *Groupe Interdisciplinaire de Recherche en Éléments Finis*, which can be translated into English as “Interdisciplinary Research Group in Finite Element Methods.” The members of this interuniversity group are interested in numerical methods, particularly in finite element, finite difference, and finite volume methods. The research questions considered range from pure research issues to industrial problems. The some 26 member researchers reflect the interdisciplinary nature of the Laboratory and are based at Université Laval, the École Polytechnique de Montréal, as well as the Université de Moncton, University of Ottawa, and University of Alberta.

The Laboratory’s activities involve several industrial partnerships, such as the NSERC Research Chair’s collaboration with tire manufacturer Michelin and joint research activities with FPInnovations to model the drying and deformation of wood-based composite materials. The collaboration of GIREF with the Industrial Materials Institute also continued in the field of polymers.

### News and highlights

In 2009, the Research Chair’s activities in scientific computing intensified. The development of MEF++ – a cutting-edge finite element software to be used by several GIREF members – continued, particularly in the field of large deformation modelling, thanks to the ongoing efforts of our professional researchers, Éric Chamberland, Cristian Tibirna, and Jean Deteix, as well as Michelin’s engineers at the Ladoux Laboratory near Clermont-Ferrand.

Research developments with our industrial partners also lead to applications of a more fundamental nature, such as the simulation of electric wave-propagation in the human heart in the biomedical field. Indeed, the interaction between industrial applications and more fundamental developments is most fruitful. The joint development of MEF++ gives students access to high-performance software with both academic and industrial characteristics. The upgrading of the computers in the GIREF Laboratory as well as the installation of a new supercomputer for the CLUMEQ network provide students with extremely sophisticated state-of-the-art equipment. 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](http://giref.ulaval.ca)). The names of investigators are given within parentheses.

- ACE project (A. Garon, principal investigator, M. Delfour, A. Fortin, Y. Bourgault)
- Furniture design through the finite element method (A. Cloutier, R. Beaugard, A. Fortin, J. Deteix)
- MEF++ project (A. Fortin, É. Chamberland, J. Urquiza, C. Tibirna, J. Deteix)
- Modelling of wood-based floor board behaviour (A. Cloutier, P. Blanchet, A. Fortin, J. Deteix)
- Modelling contact when large deformations occur (A. Fortin, M. Fortin, É. Chamberland, R. Guénette, C. Tibirna)
- Modelling of the self-reduction process observed in the growth of scallops (J. Urquiza, M. Fréchette, G. Daigle)
- Modelling of the hot-pressing of wood panels (A. Fortin, A. Cloutier, J. Deteix)

### Students, postdoctoral researchers, and visitors

Training highly qualified personnel is at the core of our mission. In 2009 – 2010 two postdoctoral fellows, 23 Ph.D. students, and 15 master's students carried out research at GIREF. Two students working at GIREF obtained their master's degree and 8 students obtained their Ph.D.

### Seminars

In 2009 – 2010 GIREF's seminar included 6 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

**Pierre Blanchet** (FPInnovations)  
Nanotechnology for wood products

**Yves Bourgault** (Ottawa)

Computational fluid dynamics, numerical methods, finite elements method, mathematical modelling, mechanics of continuous media

**Alain Charbonneau** (UQO)

Numerical simulation of optical wave guides, finite elements method, numerical methods, statistical machine translation, automated text categorization

**Marie-Laure Dano** (Laval)

Mechanics and production of composite materials, intelligent mechanical systems

**Michel C. Delfour** (Montréal)

Control, optimization, design, shells, calculus, biomechanics

**Marie-Isabelle Farinas** (UQÀC)

Modelling, numerical simulation, computational fluid mechanics, design of turbo engines (cardiac pump), optimization

**Michel Fortin** (Laval)

Numerical analysis of partial differential equations, numerical methods in fluid mechanics, optimization and optimal control for partial differential equations

**Vincent François** (UQTR)

Integration of the finite elements method into computer-aided design

**Guy Gendron** (Laval)

Composite materials, optimization and modelling of structures

**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

**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

**José Urquiza** (Laval)

Numerical analysis, control of partial differential equations

**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

**Yves Fortin** (Laval)

Forestry, forest engineering

**Jean-François Hétu** (NRC-IMI)

Numerical modelling of processes

Associate members

**Alain Cloutier** (Laval)

Forestry, forest engineering

## INTRIQ

### Description

The INstitute for Transdisciplinary Research In Quantum computing (INTRIQ) brings together researchers in quantum information processing coming from physics, computer science, and engineering. The Institute has 23 members from McGill University, Université de Montréal, the École Polytechnique de Montréal and the Université de Sherbrooke. Quantum information is the generalization of the classical notion of information, obtained by including the most fundamental law of physics, i.e., quantum mechanics. Indeed, classical information can be derived from quantum information when decoherence is present. Until now, in most fields related to information, quantum effects have often been neglected. For instance, when information is transmitted through optical fibers, the transmitted information is classical because the number of photons used to transmit this information is so large that quantum effects barely enter the picture and can easily be neglected. However, thanks to the impressive recent advances in the development of optical communication and fiber technologies, it has become possible to send single photons, so that an understanding at the quantum level becomes necessary. In fact, nowadays, commercial devices can be acquired that transmit quantum information (for example, id Quantique and MagiQ). A very similar pattern is starting to emerge in the field of information processing, where the in-

creasing miniaturization of our electronic components will result in information not being processed by billions of electrons at a time but only a small number. This implies that the quantum nature of devices will become more and more important. The same is true of magnetic memories, which might ultimately be based on single spins. Hence it is no longer unreasonable to think that parts of our information support will soon be of a quantum nature.

### News and highlights

The year 2009 – 2010 was excellent for INTRIQ. Firstly, the Université de Sherbrooke obtained a Canada Excellence Research Chair in Quantum Signal Processing and we are now very pleased to welcome Chairholder Bertrand Reulet as one of our members. Gilles Brassard won the Gerhard Herzberg Canada Gold Medal for Science and Engineering and Alexandre Blais was awarded the NSERC E. W. R. Steacie Memorial Fellowship. Also, doctoral student Olivier Landon-Cardinal was awarded a Vanier Canada Graduate Scholarship. In June 2010, Alain Tapp was appointed as the new director of INTRIQ.



## Students and postdoctoral researchers

INTRIQ members supervised or cosupervised 7 postdoctoral fellows, 39 Ph.D. students, and 32 M.Sc. students in 2009 – 2010.

## Workshops, special sessions, and others

This year, two biannual meetings were held: the first in Saint-Sauveur in June, organized by Alain Tapp and Nicolas Godbout, and the second in Sherbrooke, organized by Alexandre Blais. INTRIQ also created a special annual conference in January for students and postdoctoral fellows. This year the INTRIQ Student Conference was organized by Olivier Landon-Cardinal and held at Sutton. We believe that the event was very useful for the students, as it helped them both to get better acquainted with one another and to gain experience giving talks in a less stressful context. It was a successful experiment that shall be repeated in early 2011, in addition to the biannual meetings. In June 2010, INTRIQ was involved from the financial and organizational points of view (Alain Tapp being the main organizer) with the CRM's SMS Summer School, sponsored by NATO. The SMS was a great success, thanks to the 14 outstanding speakers and the more than 60 participants from around the world.

## Members of the laboratory

Quantum information brings together many different fields, including computer science, engineering, and physics, which are all represented in INTRIQ. Here is a list of members, by university.

Université de Montréal

**Michel Boyer** (Computer Science)  
**Gilles Brassard** (Computer Science)  
**Richard Mackenzie** (Physics)  
**Louis Salvail** (Computer Science)  
**Alain Tapp** (Computer Science)

École Polytechnique de Montréal

**José Fernandez** (Computer engineering)  
**Nicolas Godbout** (Engineering physics)  
**Suzanne Lacroix** (Engineering physics)

Université de Sherbrooke

**Alexandre Blais** (Physics)  
**Patrick Fournier** (Physics)  
**David Poulin** (Physics)  
**Michel Pioro-Ladrière** (Physics)

McGill University

**David Avis** (Computer Science)  
**Aashish Clerk** (Physics)  
**Claude Crépeau** (Computer Science)  
**Guillaume Gervais** (Physics)  
**Peter Grütter** (Physics)  
**Hong Guo** (Physics)  
**Patrick Hayden** (Computer Science)  
**Michael Hilke** (Physics), director  
**Zetian Mi** (Electrical Engineering)  
**Prakash Panangaden** (Computer Science)  
**Thomas Szkopek** (Electrical Engineering)

## LaCIM

### 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 16 regular members, 5 associate members, and 14 collaborating members. It welcomes postdoctoral fellows and its regular members supervise or cosupervise many M.Sc. or Ph.D. students, as well as undergraduate and cepeg summer research students. Many renowned mathe-

maticians 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

LaCIM welcomed three new members this year from the Université de Sherbrooke: Ibrahim Assem, Thomas Brüstle, and Shiping Liu. This recent collaboration with Sherbrooke has resulted concretely in the cre-

ation of a new research team funded by FQRNT and including F. Bergeron, C. Reutenauer, I. Assem, and D. Smith. Also Alessandro de Luca joined the Laboratory this year as a postdoctoral fellow.

One of our former graduates, Xavier Provençal (Ph.D., 2008) was offered a position at the Laboratoire de Mathématiques of the Université de Savoie in Chambéry (France), strengthening our international collaboration with CNRS laboratories in France. Aaron Lauve (postdoctoral fellow in 2008) was offered a position at Loyola University Chicago. Alexandre Blondin Massé and Sébastien Labbé were both awarded a Frontenac Scholarship for joint France – Québec thesis supervision, and spent the year in Chambéry and Montpellier, respectively.

At the international level, Srečko Brlek submitted a formal application to INMI (the CNRS mathematics institute) and INS2I (the CNRS computer science institute), in order to create a Laboratoire International Associé (LIA). This application was submitted jointly with Serge Dulucq. He also took part in an application to create an Unité Mixte Internationale (UMI) of CNRS at the CRM; the application was prepared in collaboration with Odile Marcotte.

### Students, postdoctoral fellows, and visitors

Three doctoral students successfully defended their theses this year: Mohamed Abdo (supervisor: T. Walsh), Farid Chekkal (supervisor: C. Reutenauer), and Jean-Philippe Doyon (supervisors: C. Chauve, S. Hamel, H. Philippe). Doyon is currently a postdoctoral fellow at the Laboratoire d'Informatique, de Robotique et de Microélectronique de Montpellier (LIRMM). In 2009 – 2010 LaCIM members supervised or cosupervised 24 M.Sc. students, 35 Ph.D. students, and 9 postdoctoral fellows.

### Seminars

The Combinatorics Seminar, held every Friday morning, was attended regularly by all of the Laboratory members, students, and postdoctoral fellows, as well as other members of the CRM. The majority of the lectures were given by visitors. In all, 22 talks were given in the seminar in 2009 – 2010.

### Workshops, special sessions, and others

The 15th Discrete Geometry for Computer Imagery (DGCI) international conference was held in Montréal (September 30 – October 2, 2009) and featured three invited speakers: Valérie Berthé (LIRMM, Montpellier), Anders Kock (Professor Emeritus, Aarhus, Denmark), and Pierre Gauthier (Université du Québec à Montréal). Berthé gave a precise overview of discrete planes from the point of view of the combinatorics of words, in relation to number theory (in particular multidimensional continued fractions). Kock presented the rudiments of synthetic differential geometry, whose interest resides in the fact that classical differential calculus can be brought to the level of algebraic geometry if we add infinitesimals to the affine line; infinitesimals are nilpotent elements in this case, and differ from those found in non-standard analysis. In this promising approach discrete differential geometry is viewed from a new angle, and the talk spawned much discussion. Gauthier, a specialist in mathematical climate modelling, gave an overview of methods developed from fluid dynamics using Navier – Stokes equations. The high scientific value of this conference caught the attention of journal editors, and two special issues will be published presenting the best articles in *Theoretical Computer Science* and *Pattern Recognition Letters*, respectively.

Several LaCIM members were very active organizing scientific events for the CIRM (Marseille, Luminy) thematic semester *Math-Info 2010: Towards new interactions between mathematics and computer science*, notably Srečko Brlek, as member of the scientific committee, several students (A. Blondin Massé, A. Garon, S. Labbé, M. Robado), and former students who are now postdoctoral fellows (X. Provençal, A. Lacasse, G. Paquin). Franco Saliola (hired as a professor at the Université du Québec à Montréal on June 1, 2010) led the seminar SAGE Days, held on February 22 – 27, 2010, and Srečko Brlek organized the seminar on *The interaction between discrete geometry and combinatorics on words*, held in May – June 2010. The thematic semester attracted many participants, and the ideal surroundings greatly enhanced the activities.

Finally, LaCIM members were active throughout the year as invited lecturers. For example, C. Hohlweg was invited to speak at the 65th Ottawa – Carleton Algebra Day on September 26, 2009, and François Bergeron was invited to speak at the 66th Ottawa – Carleton Al-

gebra Day on April 24, 2010. Christophe Reutenauer was an invited speaker at the 7th international conference WORDS 2009 held in Salerno, Italy, and at the *Combinatorial Algebra Meets Algebraic Combinatorics* Seventh Annual Meeting held at Queen's University (January 22 – 24, 2010).

## Members of the laboratory

### Regular members

**Srečko Brlek** (UQÀM), director  
Combinatorics of words, algorithmics

**Ibrahim Assem** (Sherbrooke)  
Representation theory

**François Bergeron** (UQÀM)  
Combinatorics, algebra, representations of finite groups

**Robert Bédard** (UQÀM)  
Representations of finite groups, Lie theory

**Anne Bergeron** (UQÀM)  
Bioinformatics

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

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

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

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

**Christophe Hohlweg** (UQÀM)  
Algebra, algebraic combinatorics, convex geometry

**Gilbert Labelle** (UQÀM)  
Enumerative combinatorics, analysis

**Shiping Liu** (Sherbrooke)  
Representation theory

**Vladimir Makarenkov** (UQÀM)  
Computational biology, mathematical classification

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

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

**Timothy R. S. Walsh** (UQÀM)  
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** (UQÀM)  
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** (UQÀM & CRM)  
Combinatorial optimization, integer programming, graph theory

**Dominic Rochon** (UQTR)  
Complex analysis, hypercomplex numbers

### Collaborating members

**Marcello Aguiar** (Texas A&M)  
Algebraic combinatorics, noncommutative algebra, Hopf algebras and quantum groups, category theory

**Luc Bélair** (UQÀM)  
Mathematical logic, model theory

**Nantel Bergeron** (York)  
Applied algebra

**Pierre Bouchard** (UQÀM)  
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** (UQÀC)  
Computer graphics, mathematical methods in computer graphics, combinatorics, computational geometry, symbolic computation

**Sylvie Corteel** (Paris Diderot & CNRS)

Enumerative and bijective combinatorics, partitions of integers,  $q$ -series

**Adriano Garsia** (UCSD)

Algebraic combinatorics, symmetric functions, harmonic and coinvariant spaces, quasiharmonic and quasi-invariant functions

**André Joyal** (UQÀM)

Algebraic topology, category theory

**Jacques Labelle** (UQÀM)

Combinatorics, topology

**Louise Laforest** (UQÀM)

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 2009 – 2010 the Laboratory included 30 regular and 8 associate members working at eight different universities in Québec, 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

Several Laboratory members received important honours this year. Alexander Shnirelman was invited to speak at the International Congress of Mathematicians 2010 in Hyderabad; we offer him our congratulations! In 2009, Dmitry Jakobson and Vojkan Jakšić both received NSERC Accelerator Awards. Laboratory members have also been busy with scientific events. Richard Fournier (Dawson College) and Stephan Ruscheweyh (Universität Würzburg) orga-

nized the First Bavaria – Québec Mathematical Meeting in Complex Analysis at the CRM in 2009, an event that shall be repeated in the years to come. Finally, based on a workshop held at the CRM in 2008, the book *Hilbert Spaces of Analytic Functions*, edited by Javad Mashreghi, Thomas Ransford, and Kristian Seip was published in 2010 in the CRM Proceedings and Lecture Notes. The book provides an account of the latest developments in the field of analytic function theory.

### Students, postdoctoral fellows, and visitors

Altogether, in 2009 – 2010, 23 postdoctoral fellows, 51 Ph.D. students, and 39 M.Sc. students were supervised or cosupervised by members of the laboratory.

### Seminars

The members of the Mathematical Analysis Laboratory organize several seminars at four main locations. Laval University hosts an Analysis Seminar, which featured 18 talks in 2009 – 2010, and an Analysis Workshop, which featured 19 talks. Galia Dafni (Concordia University), Alexander Shnirelman (Concordia University), and Dmitry Jakobson (McGill University) jointly organize the McGill/Concordia Analysis Seminar, which featured 32 talks in 2009 – 2010. A Seminar on Dynamical Systems, featuring 1 talk, was also held at Concordia. At the Université de Montréal, Paul Gauthier (Université de Montréal) and Richard Fournier (Dawson College) organize an Analysis Seminar that featured 3 talks in 2009 – 2010, and Christiane

Rousseau organizes the Nonlinear Analysis and Dynamical Systems Seminar, which featured 5 speakers.

Dmitry Jakobson organized a working seminar on moduli spaces of Riemannian metrics (comprising 10 hours) in the Spring of 2010. Vojkan Jakšić organized a student research seminar in mathematical physics in 2010. In addition, five CRM – ISM Colloquium speakers were invited by laboratory members: Bálint Virág (University of Toronto), Jeremy Quastel (University of Toronto), Robert McCann (University of Toronto), Christopher Sogge (Johns Hopkins University), and Svetlana Katok (Pennsylvania State University).

### Workshops, special sessions, and others

Richard Fournier (Dawson College) and Stephan Ruscheweyh (Universität Würzburg) organized the First Bavaria – Québec Mathematical Meeting, which was held at the CRM on November 30 – December 3, 2009. Funded by the Mathematical Analysis Laboratory and the ministère des Relations internationales du Québec, the meeting had the goal of bringing together mathematicians from Bavaria and Québec who share common mathematical interests. This first meeting was devoted to complex analysis in general, real and complex approximation theory, and some topics related to the Riemann Zeta function. The reader will find more details on this meeting in the Section [General Program](#) (p. 27).

*First Bavaria – Québec Mathematical Meeting*  
November 30 – December 3, 2009, CRM

Organizers: Richard Fournier (Dawson), Stephan Ruscheweyh (Würzburg)

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

**Richard Fournier** (Dawson)  
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

**Yiannis N. Petridis** (Lehman Coll., CUNY)  
Automorphic forms and their spectral theory, analytic number theory, spectral and scattering theory of manifolds

**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

**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

**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

**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 sixteen regular members, nine local associate members, all full-time faculty members at one of the participating universities, and six external associate members working permanently at universities and research laboratories in Europe or the U.S. 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

The regular membership of the laboratory was increased in 2009 – 2010 to include Manu Paranjape (full professor at the Department of Physics, Université de Montréal) and Robert Brandenberger (Canada Re-



search Chair in Theoretical Cosmology at the Department of Physics, McGill University), who were previously associate members.

Michel Grundland spent his sabbatical leave during the first half of 2009 at the following institutions: the Università degli Studi di Roma Tre, Università del Salento, École normale supérieure, and the Research Center on Mathematics and their Applications, University of Warsaw. From May 15 to May 22, John Harnad was a Visiting Fellow at the Hanse Wissenschaftskolleg, in Delmenhorst, Germany. Véronique Hussin continued her term as Visiting Professor at Northumbria University, United Kingdom (2006-2012). From June 2009 to May 2010, she was on sabbatical leave at Durham and Northumbria University. Dmitry Korotkin spent May – June, 2010 as a visiting researcher at the Hausdorff Institute of Mathematics, Bonn, Germany. For a three-week period in February and March 2010, Manu Paranjape was an invited lecturer at the African Institute for Mathematical Sciences (AIMS) in Cape Town, South Africa.

Invited talks by laboratory members at international conferences and workshops in 2009 – 2010 are too numerous to be listed here, but some sample events include the following. Marco Bertola was an invited lecturer at the Co-Sponsored School on Integrable Systems and Scientific Computing held at ICTP (June 15 – 20, 2009). Robert Brandenberger gave invited plenary talks at the following meetings: Conference on Holographic Cosmology at the Perimeter Institute (July 15 – 18, 2009); Emergent Gravity IV Conference, held at the Physics Department, UBC (August 24 – 28, 2009); Philosophy of Cosmology Conference, at Oxford University (September 20 – 22, 2009).

Robert Brandenberger was awarded a Killam Research Fellowship for the period September 2009 – August 2011. Jean-Pierre Gazeau was named Chairman of the Standing Committee of the International Colloquium on Group Theoretical Methods in Physics (ICGTMP). John Harnad was named Member of the Provost's Circle of Distinction at Concordia University in June 2009, and in January 2010, he began a three-year term as invited Affiliate Member of the Perimeter Institute. Yvan Saint-Aubin won the *prix du recteur pour un ouvrage didactique* for the book *Mathématiques et Technologie* (jointly with Christiane Rousseau). In 2009 he was also awarded (jointly with Christiane Rousseau) the *prix Adrien-Pouliot* by the Association mathématique du Québec for the same book. Luc Vinet was awarded

the *prix Armand-Frappier* for 2009; this prize is the highest distinction given by the government of Québec for the creation or development of research establishments and for the administration and promotion of research. He was also honoured in 2010 by being named *chevalier de l'Ordre de la Pléiade*.

## Students, postdoctoral fellows, and visitors

In 2009 – 2010 the laboratory members supervised or cosupervised 26 M.Sc. students, 43 Ph.D. students, and 34 postdoctoral fellows. Here is a list of some of these fellows, working under the supervision of one or more of the regular members of the Mathematical Physics Laboratory (the names of the supervisors are listed in parentheses): Robert Buckingham (Harnad, Bertola, Korotkin), Norman Van Do (Hurtubise), Mickael Germain (Patera), Alexandre Hariton (Grundland), Seung Yeop Lee (Harnad), Maryna Nesterenko (Patera), Aleix Prats-Ferrer (Bertola & Harnad), Prim Plansangkate (Korotkin & Ali), Sarah Post (Winternitz & Grundland), David Ridout (Mathieu & Saint-Aubin), Dong Wang (Harnad & Bertola), Benjamin Young (Hurtubise & Harnad), Ismet Yurdusen (Grundland & Winternitz).

The following is a list of visiting researchers in the period June 2009 – May 2010, who were either invited guests of one or more of the regular lab members or guests of the lab. Several of these are long-term collaborators of lab members and/or external associate members. The names of their hosts are indicated in parentheses.

- F. Bagarello, Palermo  
May 19 – 29, 2010 (Ali)
- T. Bhattacharya, IISc Bangalore  
September 17 – 28, 2009
- Indranil Biswas, Tata Inst.  
September 2009 (Hurtubise)
- Harry Braden, Edinburgh  
November – December (2 weeks), 2009 (Harnad)
- Cliff Burgess, McMaster & Perimeter Inst.  
September 25, 2009 (Paranjape)
- Leonid Chekhov, Steklov Inst., Moscow  
Fall 2009 (Korotkin)
- Robert Conte, CEA/Saclay  
May 2010 (Grundland)
- Benjamin Doyon, King's College London  
August 26 – September 4, 2009; June 2010 (Harnad & Mathieu)



- Vladimir Dragovic, SANU & Lisboa  
April 13 – 27, 2010 (Shramchenko)
- Victor Enolskii, Inst. of Magnetism, NAS of Ukraine  
September 1 – December 31, 2009 (Harnad)
- Bertrand Eynard, CEA/Saclay  
March 15-19, 2010 (Harnad & Bertola)
- Jean-Pierre Gazeau, Paris Diderot  
May 23 – 30, 2010 (Ali)
- Peter Goldstein, Warsaw  
August – September 2009 (Grundland)
- Zdenek Kabat, TU Prague  
February 2 – April 10, 2010 (Winternitz)
- Caroline Kalla, Bourgogne  
October 2009 (Korotkin)
- Dalibor Karasek, TU Prague  
February 2 – 26, 2010 (Winternitz)
- Christian Klein, Bourgogne  
September 2009 (Shramchenko)
- Brijesh Kumar, IIT Mumbai  
January 1 – June 30, 2010 (Paranjape)
- Luc Lapointe, Talca  
January 2010 (Mathieu)
- Decio Levi, Roma Tre  
October 30 – November 30, 2009 (Winternitz)
- A. Nicolis, Columbia  
September 20, 2010 (Brandenberger)
- Alexandre Orlov, Shirshov Inst.  
May 17 – June 15, 2009 (Harnad)
- S. Rasanen, CERN & Helsinki  
March 5 – 8, 2010 (Brandenberger)
- D. Robbins, Texas A&M  
September 29 – October 4, 2009 (Brandenberger)
- S. Shyam Roy, IISER Kolkata  
August 15 – December 25, 2009 (Ali)
- Nasser Saad, Prince Edward Island  
June 1 – July 1, 2009 (Hall)
- Saumia Pandiat Sankar, Inst. of Physics,  
Bhubaneswar  
April 4 – September 30, 2010 (Paranjape)
- Kalidas Sen, Hyderabad  
June 1 – July 1, 2009 (Hall)
- K. Skenderis, Amsterdam  
September 29 – October 5, 2009 (Brandenberger)
- Libor Snobl, TU Prague  
September 3 – 27, 2009 (Winternitz)
- Zora Thomova, SUNYIT  
July 13 – 21; November 5 – 8, 2009; January 4 – 6;  
March 4 – 10, 2010 (Winternitz)
- J. Traschen, UMass Amherst  
April 18 – 20, 2010 (Brandenberger)
- Alexander Turbiner, UNAM  
February 28 – March 8, 2010 (Winternitz)
- G. Veneziano, CERN & Collège de France  
September 26 – 30, 2009 (Brandenberger)
- Peter Zograf, Steklov Inst., St. Petersburg  
October – November 2009 (Korotkin)

## Seminars

The usual weekly Seminar Series in Mathematical Physics took place at the CRM every Tuesday afternoon from September 2009 to May 2010, with active participation by members, visitors, postdoctoral fellows, and students. The organizers during the 2009 – 2010 academic year were Yvan Saint-Aubin (Université de Montréal) and Michel Grundland (Université du Québec à Trois-Rivières). Approximately half the talks were given by visiting invited speakers, the rest by regular and associate Laboratory members, postdoctoral fellows, and visitors. In addition, the Working Seminar on Integrable Systems, Random Matrices, Random Processes continued, taking place again every Thursday afternoon at Concordia, with active participation of many Laboratory members, postdoctoral fellows, students, and visitors. The organizers in 2009 – 2010 were Seung-Yeop Lee (CRM) and Benjamin Young (Laboratory postdoctoral fellow, CRM and McGill).

The two invited colloquium speakers sponsored by the Mathematical Physics Laboratory during the period September 2009 – June 2010 were Nigel Hitchin (University of Oxford), who spoke on April 9, 2010, on *Magnetic monopoles and projective geometry*, and Jeremy Quastel (University of Toronto), who spoke on February 19, 2010, on *Large scale behaviour of the continuum random polymer and KPZ*.

## Workshops and Special Sessions

Robert Brandenberger was a principal organizer of two workshops held at McGill University: the Holographic Cosmology Workshop, which took place on October 2 – 4, 2009, and was funded in part by the Mathematical Physics Laboratory; and the 2nd Holographic Cosmology Workshop, which took place on May 9 – 11,

2010. More details on the first of these workshops can be found in the Section **General Program** (p. 27).

*Holographic Cosmology Workshop*

October 2-4, 2009, McGill University

Organizer: Robert Brandenberger (McGill)

S. T. Ali was coorganizer of the XIII International Workshop on Wavelets, Quantization and Differential Equations at the Universidad de La Habana (February 22 – 26, 2010).

## 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

**Syed 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

**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

**Jean LeTourneux** (Montréal)

Symmetry properties of systems, special functions

**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

**Luc Vinet** (Montréal)

Symmetry properties of systems, special functions

**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

**Vasilisa Shramchenko** (Sherbrooke)

Frobenius manifolds, integrable systems, Riemann-Hilbert problems, isomonodromic deformations of systems of linear differential equations, function theory on Riemann surfaces

**John A. Toth** (McGill)

Spectral theory, semi-classical analysis, microlocal analysis, Hamiltonian mechanics

**Carolynne M. Van Vliet** (Miami)

Non-equilibrium statistical mechanics, fluctuations and stochastic processes, quantum transport in condensed matter, electronic behaviour in submicron quantum devices

## PhysNum

### Description

The PhysNum laboratory was created by physicists (hence its acronym, which means *Physique numérique*). At the present time its members conduct research in medical imaging and pharmacokinetics. The researchers whose field is medical imaging take part in the activities of the Laboratoire International de Neuroimagerie et Modélisation (LINeM), which was created in 2008 by three institutions: the Institut national de la santé et de la recherche médicale (Inserm, France), the Université Pierre et Marie Curie (Paris), and the Université de Montréal. In particular, PhysNum researchers have ongoing collaborations with researchers from the Centre de recherche de l’Institut universitaire de gériatrie de Montréal (CRIUGM) and from Unité UMR-S 678 (Inserm). The goal of LINeM is to develop the best mathematical models and tools in diverse areas of neuroimaging. Here are the topics studied by LINeM researchers:

- Physiological and biochemical sources of functional brain imaging signals;
- Cerebral activation networks;
- Haemodynamic responses in optical imaging;
- Inverse problems and wavelets;
- Functional neuroanatomy of the spinal cord;
- Intrinsic optical imaging of the spinal cord and the brain and data analysis;
- Quantitative imaging of aging, and
- Seizure prediction for epileptic patients with implants.

Fahima Nekka and her team conduct research in pharmacometrics, a discipline whose goal is to interpret and describe pharmacological phenomena in a quantitative manner. Pharmacometrics consists of the study of measurement, regression analysis (data fitting), and system reproduction (modelling and simulation), for the estimation, evaluation, understanding, and prediction of pharmaceutical processes in terms of their general trends and variability.

Within this area, Fahima Nekka’s group is working on the efficient integration of different drug-related aspects and mechanisms. The group’s modelling approach, whether driven by hypotheses or data, aims to increase our understanding and to explain the complex relationship between drugs and living systems. The team is working on the following topics:

- Compliance metrics and ranking;
- Metrics to evaluate the clinical impact of variable drug intake behaviour;
- Pharmacometrics and mechanistic modelling in animal drug use;
- Objective evaluation of a treatment efficacy through the extension of classical breakpoint estimation methods to the case of variable pharmacokinetic profiles;
- Development of physiology-based pharmacokinetic (PBPK) models to predict drug-drug interactions; and
- Development and use of global sensitivity approaches for PBPK models.

## News and highlights

In 2009 – 2010 laboratory members working on medical imaging carried out several projects that are listed below. The names of the investigators are given within parentheses and the relationship of these projects with graduate training is described.

*Classification of interictal spikes as measured by the EEGs of epileptic patients* (Lina)

This project gave rise to two master's theses (by S. Deslauriers-Gauthier and A.-S. Dubarry, respectively).

*Parsimonious reconstruction of the cerebral activity using data from non-invasive electrophysiology* (Lina)

This work was carried out in collaboration with C. Grova from McGill and gave rise to a master's thesis by E. Lemay and a topic for a Ph.D. thesis (by Y. Zérouti).

*Time-frequency analysis of intracranial EEG signals* (Lina)

The collaborators of Jean-Marc Lina for this project are S. Jaffard (ÉNS Cachan), P. Abry (ÉNS Lyon), and J. Gotman (Montréal Neurological Institute).

*Measurement of the hemodynamic response through diffuse optical imaging* (Lesage, Lina, Benali)

This project is carried out in collaboration with two students: A. Machado and S. Chapuisat.

*Parsimonious sampling in optical imaging* (Lesage, Lina, Hamelin)

*Neuronal imaging of the visual system* (Lesage)

*Multimodal imaging of the spinal cord* (Benali, Lesage)

This project gave rise to the master's theses of S. Chapuisat and A. Goguin, respectively, and to the topics of postdoctoral internships by J. Cohen-Adad and M. Dehaes.

*Models of anatomical connectivity* (Benali)

*Models of functional connectivity* (Benali)

*Multimodal imaging* (Benali, Lina)

This project gave rise to a collaboration with C. Grova, from McGill, and a master's thesis by E. Lemay.

In 2009 – 2010 Fahima Nekka and her group worked on the following projects.

*Physiologically based pharmacokinetics (PBPK) modelling*

The group worked on the conception of PBPK models to predict the drug disposition (accounting for metabolic and transport activity modulation). In terms

of methodology, the group has developed a global sensitivity approach based on the partial rank correlation coefficient, which has been used on these models to investigate how the uncertainty and variability of the correlated physiological parameters influence the outcome of the drug distribution process.

*In vitro/in vivo*

Unlike the ideal in vitro conditions, where major guidelines for drug efficacy are routinely established for stable drug concentrations, the in vivo conditions induce a high variability and thus raise concerns about the applicability of in vitro-established principles. This in vivo variability may have various origins and forms. One of these sources is structural and is directly linked to the drug disposition and elimination process (ADME), in which the drug concentration (considered as a function of time) is often described using ordinary differential equations. Fahima Nekka's group has developed a mathematical approach that transforms the in vitro results into in vivo predictions. This can be used for optimizing drug regimens in terms of dose and frequency as well as for evaluating drug bioequivalence.

## Students

In 2009 – 2010 the members of PhysNum supervised or cosupervised 8 M.Sc. students, 12 Ph.D. students, and 4 postdoctoral fellows.

## Workshops, special sessions, and others

PhysNum members were deeply involved in the organization of the CRM thematic semester on *Mathematical Problems in Imaging Science: From the Neuronal to the Quantum World*, held from August to December 2009 at the CRM. Lesage and Lina were both on the scientific committee of the thematic semester, while Benali, Lesage, and Lina were all on the organizing committee. The semester included four workshops, with three of the four organized by PhysNum members. We refer the reader to the section [Thematic Program](#) for more details.

## Regular members of the laboratory

**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

**Bernard Goulard** (Montréal)

Brain imaging

**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.

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 benefit from a recently created Canada-wide program for complex data structures (NICDS), 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

Several members received important distinctions this year. For his work in artificial intelligence, Yoshua Bengio (Université de Montréal) was awarded the prix

Urgel Archambault 2009 of ACFAS (Association francophone pour le savoir), granted to a researcher in engineering, mathematics, physics, or computer science. Louis-Paul Rivest (Université Laval) received the Gold Medal from the Canadian Statistical Society for his contributions to multivariate analysis, directional statistics, survey sampling, as well as for his applications thereof in various fields, including ecology, biomechanics, and geophysics. In addition, the Canadian Institutes of Health Research awarded the Maud Menten Prize to Aurélie Labbe (McGill University) for her work on the definition of a genotype in complex diseases. Aurélie Labbe was also awarded a research scholarship from Québec's Fonds de la recherche en santé.

Members of the Statistics Laboratory continued to be influential in the statistical community, giving lectures and plenary talks as invited speakers at many international meetings. For example, Yoshua Bengio was invited to the Deep Learning Workshop (United Kingdom, July 2009), while Jim Ramsay organized workshops on functional analysis and dynamical systems at BIRS and UBC. Nadia Ghazzali (plenary speaker) and Louis-Paul Rivest (invited speaker) participated in the Sixième Colloque francophone sur les sondages (Tangiers, Morocco, March 2010), and Christian Genest was invited to the third annual Conference on Extreme Events and Connected Questions (Stavanger, Norway, May 2010).

The laboratory was actively involved in the organization of the annual conference of the Canadian Statistical Society, which brought more than 550 participants to Québec City last May. Christian Léger (Université de Montréal) was President of the scientific committee and Thierry Duchesne (Université Laval) presided over



the local organizing committee. The excellence and diversity of the programme was such that it managed to attract media attention. Not only was the conference covered by the local Radio-Canada station in Québec City, it was also presented on Radio-Canada's show *Les années lumière* in an 18-minute report, featuring Louis-Paul Rivest and Anne-Catherine Favre (Université Laval).

### Students, postdoctoral fellows, and visitors

Laboratory members are deeply involved in the training of HQP. This year, at least 10 students obtained their doctorate degree. Graduates Aymen Karoui and François Rivest have already accepted positions as professors at UQÀM and the Kingston Military College, respectively. Also 15 Laboratory students completed their master's degree this year. In 2009 – 2010 laboratory members supervised or cosupervised 111 M.Sc. students, 77 Ph.D. students, and 8 postdoctoral fellows (including Taoufik Bouezmarni, who has accepted a position as professor at the Université de Sherbrooke).

### Seminars

The scientific life of the Laboratory revolves around the weekly CRM – ISM – GERAD Statistics Colloquium in Montréal, the Statistics Seminar at Université Laval in Québec, and the Université de Sherbrooke Statistics Seminar in Sherbrooke. In 2009 – 2010, approximately fifty lectures took place in these three cities within the framework of these seminars.

### Workshops, special sessions, and others

The Laboratory organized two international workshops this year in Montréal; the two workshops received funding from the National Institute for Complex Data Structures (NICDS). The reader may find more details on these workshops in the Section [Multidisciplinary and Industrial Program](#) (p. 35).

*Analysis of Directional Data with Applications to Biomechanics and Biomedical Imaging*

November 25 – 27, 2009, CRM

Organizers: Peter Kim (Guelph), Louis-Paul Rivest (Laval)

*Statistical Methods for Geographic and Spatial Data in the Management of Natural Resources*

March 3 – 5, 2010, CRM

Organizers: DongMei Chen (Queen's), Thierry Duchesne & Anne-Catherine Favre (Laval), Subhash R. Lele (Alberta)

### 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

**Charles Dugas** (Montréal)

Actuarial science, finance, learning algorithms, neural networks, universal approximation, survival analysis

**Debbie J. Dupuis** (HEC Montréal)

Extreme values, robustness

**Sorana Froda** (UQÀM)

Nonparametric methods in function estimation, applications of stochastic modelling in biology and medicine

**Christian Genest** (Laval)

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** (Laval)

Biostatistics and statistical genetics

**Fabrice Larribe** (UQÀM)

Statistical genetics and biostatistics

**Christian Léger** (Montréal)

Resampling methods, adaptive estimation, model selection, robustness, applications in data mining

**Brenda MacGibbon** (UQÀM)

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

**Jonathan E. Taylor** (Stanford)

Gaussian processes, multiple comparisons, neuroimaging, HIV protein sequence analysis

**Alain C. Vandal** (McGill)

Biostatistics, nonparametric survival estimation and graph theory, imaging, capture-recapture models

**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

**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** (UQÀM)

Bayesian and computational statistics, biostatistics

**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 2009 – 2010 or that will be published soon.

### American Mathematical Society CRM Monograph Series

Olga Kharlampovich & Alexei Miasnikov, *Algebraic Geometry for a Free Group* (to appear).

Marcelo Aguiar & Swapneel Mahajan, *Monoidal Categories, Species and Hopf Algebras* (to appear).

Saugata Ghosh, *Skew-Orthogonal Polynomials and Random Matrix Theory*, vol. 28, 2009.

### American Mathematical Society CRM Proceedings & Lecture Notes

Daniel Daigle, Richard Ganong, Mariusz Koras (eds.), *Affine Algebraic Geometry: The Russell Festschrift* (to appear).

Bradd Hart, Thomas G. Kucera, Anand Pillay, Philip J. Scott, Robert A. G. Seely (eds.), *Models, Logics, and Higher-Dimensional Categories* (to appear).

Dmitry Jakobson, Stéphane Nonnenmacher, Iosif Polterovich (eds.), *Spectrum and Dynamics* (to appear).

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.

### Springer CRM Series in Mathematical Physics

John Harnad (ed.), *Random Matrices, Random Processes and Integrable Systems* (to appear).

## Previous Titles

### American Mathematical Society CRM Monograph Series

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**
- 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 Pogossyan & 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. Wehlauf (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

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*, 2001.

S. Ejaz Ahmed & Nancy Reid (eds.), *Empirical Bayes and Likelihood Inference*, 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 Mal'liavin*, 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. Knap, *Representations of Real Reductive Groups*, 1990.
- Wendy G. McKay, Jiří Patera & David W. Rand, *SimpleLie*, 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.

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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.

## CRM Preprints

**CRM-3282** E. Kengne, R. Vaillancourt, *Modulational stability of solitary states in a lossy nonlinear electrical line*, Canadian Journal of Physics, 87:11 (November 2009), 1191–1202.

**CRM-3283** H. Yagoub, T. Nguyen-Ba, T. Giordano, R. Vaillancourt, *Convergence of the variable-step variable-order 3-stage Hermite–Birkhoff ODE/DDE solver of order 5 to 15*, Scientific Proceedings of Riga Technical University. Series 5. Computer Science, accepted.

**CRM-3284** C. Dugas, D. Gadoury, *Pointwise exact bootstrap distributions of ROC curves*, August 2009.

**CRM-3285** C. Dugas, N. Chapados, R. Ducharme, X. Saint-Mleux, P. Vincent, *Higher-order feature synthesis for insurance scoring models*, August 2009.

**CRM-3287** C. Dugas, D. Gadoury, *Pointwise exact bootstrap distributions of cost curves*, August 2009.

**CRM-3288** H. Assa, M. Morales, *Risk measures on the space of infinite sequences*, Mathematics and Financial Economics, 2:4 (March 2010), 253–275.

**CRM-3289** F. Labrecque-Synnott, J.-F. Angers, *An extension of zero-modified models to the continuous case*, Metron, submitted.

**CRM-3292** C. Francq, R. Roy, A. Saidi, *Asymptotic properties of weighted least squares estimation in weak PARMA models*, October 2009.

**CRM-3294** D. Schlomiuk, N. Vulpe, *Global classification of the planar Lotka–Volterra differential systems according to the configurations of invariant straight lines*, December 2009.

**CRM-3295** R. A. Elmahdaoui, C. Dugas, *Using credit default swap information in stock trading*, January 2010.

**CRM-3296** M. Morales, P. Olivares, *On the expected discounted penalty function for a risk model perturbed by a spectrally negative Levy process*, March 2010.

**CRM-3297** C. Dugas, *Bandwidth selection for ROC curves revisited*, April 2010.

**CRM-3298** P. Tempesta, *The universal formal group, Almkvist–Meurman type congruences and zeta functions*, May 2010.

**CRM-3299** P. Tempesta, *Integrable maps via associative algebras and number sequences*, May 2010.

**CRM-3300** D. Levi, P. Tempesta, *Multiple-scale analysis of dynamical systems on the lattice*, May 2010.

**CRM-3301** M. Cafaro, P. Tempesta, *Finding frequent items in parallel*, Concurrency and Computation: Practice & Experience, submitted.

**CRM-3302** M. Cafaro, P. Tempesta, *Finding the majority element in parallel*, Theoretical Computer Science, submitted.

**CRM-3304** F. Labrecque-Synnott, J.-F. Angers, *Bayesian estimation and testing for continuous zero-modified models*, March 2010.

## **Scientific Personnel**



## CRM Members in 2009–2010

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: Université de Montréal, Concordia University, McGill University, Université du Québec à Montréal, Université Laval, Université de Sherbrooke, and University of Ottawa. Other members are researchers affiliated with the CRM in 2009–2010 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 have even contributed 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. 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**, UQÀM**Paul Arminjon**, Montréal**Ibrahim Assem**, Sherbrooke**André D. Bandrauk**, Sherbrooke**Line Baribeau**, Laval**Peter Bartello**, McGill**Robert Bédard**, UQÀM**Jacques Bélair**, Montréal**Habib Benali**, UPMC**Yoshua Bengio**, Montréal**François Bergeron**, UQÀM**Marco Bertola**, Concordia**Yves Bourgault**, Ottawa**Anne Bourlioux**, Montréal**Steven Boyer**, UQÀM**Gilles Brassard**, Montréal**Srečko Brlek**, UQÀM**Abraham Broer**, Montréal**Robert C. Brunet**, Montréal**Thomas Brüstle**, Sherbrooke**David Bryant**, McGill**Virginie Charette**, Sherbrooke**Cédric Chauve**, Simon Fraser**Vašek Chvátal**, Concordia**Francis H. Clarke**, Lyon 1**Olivier Collin**, UQÀM**Octavian Cornea**, Montréal**Miklós Csűrös**, Montréal**Chris Cummins**, Concordia**Galia Dafni**, Concordia**Henri Darmon**, McGill**Chantal David**, Concordia**Jean-Marie De Koninck**, Laval**Michel C. Delfour**, Montréal**Eusebius J. Doedel**, Concordia**Rachida Dssouli**, Concordia**Pierre Duchesne**, Montréal**Thierry Duchesne**, Laval**Nadia El-Mabrouk**, Montréal**André Fortin**, Laval**Richard Fournier**, Dawson**Marlène Frigon**, Montréal**André Garon**, Polytechnique Montréal**Paul M. Gauthier**, Montréal**Christian Genest**, Laval**Eyal Z. Goren**, McGill**Bernard Goulard**, Montréal**Andrew Granville**, Montréal**Alfred Michel Grundland**, UQTR**Pengfei Guan**, McGill**Geña 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  
**André Joyal**, UQÀM  
**Tomasz Kaczynski**, Sherbrooke  
**Niky Kamran**, McGill  
**Olga Kharlampovich**, McGill  
**Hershy Kisilevsky**, Concordia  
**Paul Koosis**, McGill  
**Dmitry Korotkin**, Concordia  
**Gilbert Labelle**, UQÀM  
**John Labute**, McGill  
**François Lalonde**, Montréal  
**Benoît Larose**, Champlain St-Lambert & Concordia  
**Christian Léger**, Montréal  
**Frédéric Lesage**, Polytechnique Montréal  
**Sabin Lessard**, Montréal  
**Jean LeTourneux**, Montréal  
**Claude Levesque**, Laval  
**Jean-Marc Lina**, ÉTS  
**Shiping Liu**, Sherbrooke  
**Steven Lu**, UQÀM  
**Brenda MacGibbon**, UQÀM  
**Michael C. Mackey**, McGill  
**Vladimir Makarenkov**, UQÀM  
**Michael Makkai**, McGill  
**Javad Mashreghi**, Laval  
**Sherwin A. Maslowe**, McGill  
**Pierre Mathieu**, Laval  
**John McKay**, Concordia  
**Alexei G. Miasnikov**, McGill  
**M. Ram Murty**, Queen's  
**Fahima Nekka**, Montréal  
**Nilima Nigam**, Simon Fraser  
**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**, UQÀM  
**Louis-Paul Rivest**, Laval  
**Ivo G. Rosenberg**, Montréal  
**Christiane Rousseau**, Montréal  
**Damien Roy**, Ottawa  
**Roch Roy**, Montréal  
**Peter Russell**, McGill  
**Yvan Saint-Aubin**, Montréal  
**David Sankoff**, Ottawa  
**Dana Schlomiuk**, Montréal  
**Alexander Shnirelman**, Concordia  
**Vasilisa Shramchenko**, Sherbrooke  
**Alina Stancu**, Concordia  
**Ron J. Stern**, Concordia  
**Alain Tapp**, Montréal  
**Francisco Thaine**, Concordia  
**John A. Toth**, McGill  
**Paul F. Tupper**, Simon Fraser  
**Lennaert Van Veen**, Concordia  
**Luc Vinet**, Montréal  
**Timothy R. S. Walsh**, UQÀM  
**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**, Collège Édouard-Montpetit  
**Martin J. Gander**, Genève  
**Pierre Ille**, Institut de mathématiques de Luminy  
**Marc Laforest**, Polytechnique Montréal  
**Decio Levi**, Roma Tre  
**Jun Li**, Pharsight

**Emmanuel Lorin de la Grandmaison**, Carleton  
**Yannis N. Petridis**, UC London  
**Elisa Shahbazian**, Lockheed Martin Canada  
**Marc Thiriet**, UPMC & INRIA Rocquencourt  
**Pierre Valin**, Defence R&D Canada  
**Carolyne M. Van Vliet**, Miami  
**Jean-Paul Zolésio**, INRIA Sophia Antipolis

### Invited members

**Mylène Bédard**, Montréal  
**Vyjayanthi Chari**, UC Riverside  
**David Haziza**, Montréal  
**Ian Marquette**, Montréal  
**Manuel Morales**, Montréal  
**Maryna Nesterenko**, Inst. of Math., NAS Ukraine  
**Rishi Rishikesh**, Waterloo

## Postdoctoral Fellows

Each year the CRM plays host to a great number of postdoctoral fellows. Their funding is provided by the NSERC and FQRNT postdoctoral programs, the 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 co-funded 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.

**Nadine Badr**, Paris-Sud 11  
**Mounir Bennoune**, Paul Sabatier  
**Robert Buckingham**, Duke  
**Mattia Cafasso**, SISSA  
**Bryden Cais**, Michigan  
**Renata Calleja**, UT Austin  
**Emmanuel Delsinne**, Caen  
**Nikolai Dimitrov**, Cornell  
**Norman Nam Van Do**, Melbourne  
**Grégoire Dupont**, Lyon 1  
**Xander Faber**, Columbia  
**Igor Gorelyshev**, Russian Academy of Sciences  
**Benoit Hamelin**, Polytechnique Montréal  
**Alexander J. Hariton**, Montréal  
**Jiří Hrivnak**, TU Prague  
**Duc Khiem Huynh**, Bristol  
**Seung-Yeop Lee**, UChicago  
**Ruochuan Liu**, MIT

**Pawel Lorek**, Wrocław  
**Claude Mangoubi Pigier**, HUJI  
**Dan Mangoubi**, Technion  
**Karol Palka**, Warsaw  
**Jeehoon Park**, Boston  
**Prim Plansangkate**, Cambridge  
**Sarah Post**, Minnesota  
**Aleix Prats-Ferrer**, Barcelona  
**David Ridout**, Adelaide  
**Marie-Odette St-Hilaire**, Montréal  
**Christian Stump**, Wien  
**Dong Wang**, Brandeis  
**Igor Wigman**, Tel Aviv  
**Zhenbin Yan**, McMaster  
**Benjamin Young**, UBC  
**İsmet Yurduşen**, ODTÜ  
**El Miloud Zaoui**, Sherbrooke

## 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. Most of these activities take place at the CRM itself or on the campus of the Université de Montréal. In the year 2009–2010, 610 such participants registered in the thematic program workshops, 337 in activities of the general program, and 179 in activities of the industrial and multidisciplinary program.

**Long-term visitors**

The following list only includes visitors who were in residence for at least four weeks.

**Shabnam Akhtari**, MPI Mathematik  
**Goce Chadzitaskos**, Doppler Inst.  
**Victor Enolskii**, Inst. of Magnetism, NAS Ukraine  
**Bertrand Eynard**, CEA/Saclay  
**Luis Finotti**, Tennessee  
**Isidore Fleischer**  
**Gerard Freixas i Montplet**, North Dakota State  
**Alexandre Girouard**, Neuchâtel  
**Piotr Goldstein**, Andrzej Soltan Inst. for Nuclear Studies  
**Jorge Jiménez Urroz**, UPC  
**Zdenek Kabat**, TU Prague  
**Salibor Karasek**, TU Prague  
**Payman L. Kassaei**, King's College London  
**Kamal Khuri-Makdisi**, American University of Beirut  
**Semyon Klevtsov**, ULB  
**Decio Levi**, Roma Tre  
**Zhibin Liang**, Capital Normal  
**Adam Logan**, Waterloo  
**Abdeslem Lyaghfour**, Fields Inst.  
**Lenka Motlochova**, TU Prague  
**Nicolas Nadirashvili**, Provence  
**Alexandre Orlov**, Shirshov Inst.  
**Guillaume Ricotta**, Bordeaux 1  
**Libor Snobl**, TU Prague  
**Ramesh Sreekantan**, ISI Bangalore  
**Marc Thiriet**, UPMC & INRIA Rocquencourt  
**Zora Thomova**, SUNYIT  
**John Voight**, Vermont  
**Nicolae Vulpe**, Inst. de Matematică și Informatică, Moldova

**Esther Widiasih**, Minnesota

**Jie Wu**, Henri Poincaré

**Irina Yehorchenko**, Inst. of Math., NAS Ukraine

**Yuanli Zhang**

**Alexei Zhedanov**, Donetsk IPE

**Jean-Paul Zolésio**, INRIA Sophia Antipolis

**Short-term visitors**

The following visitors were in residence for less than four weeks.

**Gérard Ben Arous**, Courant Inst.

**Hans-Peter Blatt**, KU Eichstätt-Ingolstadt

**Erwin Bolthausen**, Zürich

**Vivek S. Borkar**, Tata Inst.

**Harry W. Braden**, Edinburgh

**Luciano Buono**, UOIT

**Robert Conte**, CEA/Saclay

**Benjamin Doyon**, Durham

**Dimitrios Koukoulopoulos**, UIUC

**Jean Mawhin**, UC Louvain

**Jean-François Mestre**, Paris Diderot

**Marc Mézard**, Paris-Sud 11

**Robert V. Moody**, Alberta

**Leonid Parnovski**, UC London

**Vijay Patankar**, Microsoft Research India

**Severin Pošta**, TU Prague

**Jeffrey S. Rosenthal**, Toronto

**Oliver Roth**, Würzburg

**Stephan Ruscheweyh**, Würzburg

**Avinash Sathaye**, Kentucky

**Gerhard Schmeisser**, Erlangen-Nürnberg

**Daniel Stein**, Courant Inst.

**Jörg Steuding**, Würzburg

**Alexander Turbiner**, UNAM

**Akshay Venkatesh**, Stanford

**List of Students Having Graduated in  
2009–2010**

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 2009–2010. 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

### **Mélanie Beck**

Tony R. Humphries & Martin Gander  
McGill University  
Mathematics

### **Hugue Blier**

Alain Tapp  
Université de Montréal  
Computer science

### **Baptiste Chantraine**

Olivier Collin  
Université du Québec à Montréal  
Mathematics (geometry and topology option)

### **David Cottrell**

Paul F. Tupper  
McGill University  
Mathematics

### **Jean-Philippe Doyon**

Sylvie Hamel, Cédric Chauve & Hervé Philippe  
Université de Montréal  
Computer science

### **Frédéric Dupont-Dupuis**

Gilles Brassard & Patrick Hayden  
Université de Montréal  
Computer Science

### **Amal El Akkraoui**

Peter Bartello  
McGill University  
Applied mathematics

### **Frédérique Fenneteau**

Fahima Nekka  
Université de Montréal  
Pharmaceutical sciences

### **Radu Gaba**

Adrian Iovita  
Concordia University  
Mathematics

### **Hugues Gilbert**

Marlène Frigon  
Université de Montréal  
Mathematics (applied mathematics option)

### **Tamanna Howlader**

Yogendra P. Chaubey  
Concordia University  
Statistics

### **Valérie Hudon**

S. Twareque Ali  
Concordia University  
Mathematics

### **Majid Jaberi Douraki**

Javad Mashreghi & Thomas J. Ransford  
Université Laval  
Mathematics

### **Abdoulaye Sabou Kane**

André Fortin & Robert Guénette  
Université Laval  
Mathematics (statistics option)

### **Mathieu Lajoie**

Nadia El-Mabrouk & Sabin Lessard  
Université de Montréal  
Bioinformatics

### **Youness Lamzouri**

Andrew Granville  
Université de Montréal  
Mathematics (pure mathematics option)

### **Florence Laure Magnifo Kahou**

Ivo G. Rosenberg & Lucien Haddad  
Université de Montréal  
Mathematics (pure mathematics option)

### **Calvin Mbuntcha Wuntcha**

Ivo G. Rosenberg  
Université de Montréal  
Mathematics (pure mathematics option)

### **James Merleau**

Jean-François Angers & Luc Perreault  
Université de Montréal  
Statistics

### **Karim Oualkacha**

Louis-Paul Rivest  
Université Laval  
Mathematics (statistics option)

**François Rivest**

Yoshua Bengio & John Kalaska  
 Université de Montréal  
 Computer science

**Marc-Daniel Ryser**

Paul F. Tupper  
 McGill University  
 Mathematics

**Michael Lennox Wong**

Jacques Hurtubise & Peter Russell  
 McGill University  
 Mathematics

**Zhenyu Yang**

David Sankoff  
 University of Ottawa  
 Mathematics

## M.Sc. Students

**Sébastien Beauregard**

Louis-Paul Rivest  
 Université Laval  
 Statistics

**Gabrielle Boucher**

Fabrice Larribe  
 Université du Québec à Montréal  
 Mathematics (statistics option)

**Laurence Boulanger**

Marlène Frigon  
 Université de Montréal  
 Mathematics (pure mathematics option)

**Leila Bridgeman**

Tony R. Humphries & Thomas P. Wihler  
 McGill University  
 Mathematics

**Sophie Burrill**

Marni Mishna  
 Simon Fraser University  
 Mathematics

**Luca Candelori**

Henri Darmon  
 McGill University  
 Mathematics

**Djamila Chagra**

Alejandro Murua  
 Université de Montréal  
 Statistics

**Caroline Dazé**

Marlène Frigon  
 Université de Montréal  
 Mathematics (pure mathematics option)

**Sonia De Benedictis**

Abraham Broer  
 Université de Montréal  
 Mathematics (pure mathematics option)

**Andrew Fiori**

Eyal Z. Goren  
 McGill University  
 Mathematics

**David Gaboury**

Charles Dugas  
 Université de Montréal  
 Mathematics (actuarial mathematics option)

**Ariane Garon**

Srečko Brlek  
 Université du Québec à Montréal  
 Mathematics

**Gabriel Gauthier-Shalom**

Henri Darmon  
 McGill University  
 Mathematics

**Andrei-Paul Grecianu**

Ivo G. Rosenberg  
 Université de Montréal  
 Mathematics (pure mathematics option)

**Baohua He**

Arusharka Sen  
 Concordia University  
 Statistics

**Yao Huang**

Manuel Morales & Louis G. Doray  
 Université de Montréal  
 Mathematics (actuarial mathematics option)

**Rabi Ibrahim**

Manuel Morales  
 Université de Montréal  
 Mathematics (actuarial mathematics option)

**Colin Jauffret**

Abraham Broer  
 Université de Montréal  
 Mathematics (pure mathematics option)



**Isabelle Lajoie**

Patrick Vincent & Yoshua Bengio  
Université de Montréal  
Computer science

**Alexandre Landry**

Pierre Mathieu  
Université Laval  
Physics

**Omid Makhmali**

Niky Kamran  
McGill University  
Mathematics

**Géraldine Martin**

Sabin Lessard  
Université de Montréal  
Mathematics (applied mathematics option)

**Jérôme Morin-Drouin**

Robert G. Owens  
Université de Montréal  
Mathematics (applied mathematics option)

**Frédéric Picard**

David Haziza  
Université de Montréal  
Statistics

**Jeremy Porter**

Chantal David  
Concordia University  
Mathematics

**W. Phillip Rampel**

Niky Kamran  
McGill University  
Mathematics

**Juan Ignacio Restrepo**

Henri Darmon  
McGill University  
Mathematics

**Sarem Sarem**

Fahima Nekka  
Université de Montréal  
Pharmaceutical sciences

**Robin Sirois-Miron**

Abraham Broer  
Université de Montréal  
Mathematics (pure mathematics option)

**Neda Zare Ney Ney**

Anne Bourlioux  
Université de Montréal  
Mathematics (applied mathematics option)

# **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 2009–2010, 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 Peter Russell (McGill University), 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](http://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 2009–2010.

**Jacques Beauvais**, Vice-Rector (Research)  
Université de Sherbrooke

**Guy Berthiaume**, Vice-Rector (Research)  
Université du Québec à Montréal  
(*until June 30, 2009*)

**Olivier Collin**  
Université du Québec à Montréal

**Louise Dandurand**, Vice-President (Research)  
Concordia University

**Andrew Granville**  
Université de Montréal

**John Harnad**  
Concordia University

**Joseph Hubert**, Vice-Rector (Research)  
Université de Montréal

**Yves Mauffette**, Vice-Rector (Research)  
Université du Québec à Montréal  
(*from July 1st, 2009*)

**Robert Owens**  
Université de Montréal

**Rima Rozen**, Vice-Principal (Research)  
McGill University  
(*from April 1st, 2010*)

**Peter Russell**, Director of the CRM  
McGill University

**Denis Thérien**, Vice-Principal (Research)  
McGill University  
(*until March 31, 2010*)

**Chantal David** (Concordia University) and **Odile Marcotte** (Université du Québec à Montréal), Deputy Directors of the CRM, were invited members.

## 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.



**James Berger** is the Arts and Sciences Professor of Statistics at the Institute of Statistics and Decision Sciences of Duke University and Director of the Statistical and Applied Mathematical Sciences Institute (SAMSI). He received a Ph.D. in mathematics from Cornell University in 1974 and is a past recipient of the Guggenheim and Sloan Fellowships. He was elected to the National Academy of Sciences in 2003. His research has primarily been in Bayesian statistics, foundations of statistics, statistical decision theory, simulation, model selection, and various interdisciplinary areas of science and industry. He has supervised 30 Ph.D. dissertations, published over 140 articles, and written or edited 13 books or special volumes.

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**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.

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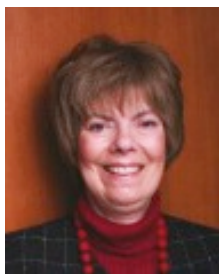


**Mark L. Green** has been a professor at the UCLA Department of Mathematics since 1982. He received his Ph.D. from Princeton in 1972. He was Director of the Institute for Pure and Applied Mathematics from 2001 to 2008. Mark Green has received numerous honours during his career. In particular, he was 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.



**Alice Guionnet** is *directrice de recherche* at the CNRS and teaches at the École normale supérieure de Lyon. She received a Ph.D. from Université Paris-Sud 11 in 1995. In 1999 she was awarded the Oberwolfach Prize (for a young European mathematician under 35 years of age) and in 2009 she received the Loève Prize in Probability. She was an invited speaker at ICIAM 2003 and ICM 2006. She is a member of the editorial board of *Stochastic Processes and their Applications* and editor-in-chief of the *Annales de l'Institut Henri Poincaré*. Her research interests focus mainly on probability theory in relation to mathematical physics.

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**Barbara Lee Keyfitz** has been a professor at Ohio State University since January 2009. She served as Director of the Fields Institute for the 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 (New York University). 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.



**Anthony To-Ming Lau** is a Professor in the Department of Mathematics of the University of Alberta and President of the Canadian Mathematical Society. He holds an undergraduate degree from Berkeley and a Ph.D. in mathematics from the University of British Columbia. His research is in functional analysis and harmonic analysis. He is a member of the editorial board of *Scientiae Mathematicae Japonicae*, the *Journal of Nonlinear and Convex Analysis*, and *Fixed Point Theory and Applications*. He was awarded many prizes and honours, among which the Killam Annual Professorship and the Rutherford Award for Excellence in Undergraduate Teaching.



**Peter Russell** obtained his Ph.D. from UC Berkeley in 1966 under the direction of Maxwell Rosenlicht. After spending three years as a Benjamin Pierce Instructor at Harvard University, he joined the Department of Mathematics and Statistics at McGill University, from which he retired in 2009. He served as chair of that department from 1988 to 1994 and as director of the Institut des sciences mathématiques in 1995–1996 and from 2000 to 2004. His area of interest is algebraic

geometry. Since the 1970s Professor Russell has been active in affine algebraic geometry, which around that time became recognized as a full-fledged subdiscipline of mathematics with close links to algebra, algebraic geometry, and topology.



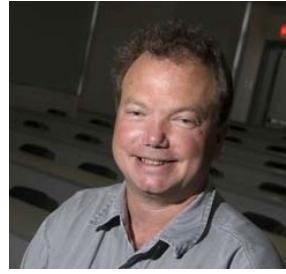
**Catherine Sulem** is a Professor in the Department of Mathematics of the University of Toronto. She received a doctorat d'État from the Université de Paris-Nord in 1983. She was Keynote Speaker at IMACS2003 (International Association for Mathematics and Computers in Simulation) and an invited speaker at a meeting of the American Mathematical Society in 1999. In 1998, she was awarded the Krieger–Nelson Prize by the Canadian Mathematical Society. Her research interests are in nonlinear partial differential equations arising in physics: nonlinear partial differential equations, nonlinear Schrödinger equations and related systems, the water wave problem, the Boltzmann equation, and computational fluid mechanics. Since 2000, she has been an Associate Editor of the *SIAM Journal of Mathematical Analysis*. From 1999 to 2005, she was an Associate Editor of the *Canadian Journal of Mathematics*.



**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 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.



**Mary F. Wheeler** holds the Ernest and Virginia Cockrell Chair in Engineering at the University of Texas at Austin where she is also Professor at the Department of Mathematics. In addition, she is Director of the Center for Subsurface Modeling of the Texas Institute for Computational and Applied Mathematics (TICAM) at the same university. She obtained her Ph.D. from Rice University. She is currently an editor of six journals and is Managing Editor of *Computational Geosciences*. In 1998, she was elected to the National Academy of Engineering. Her research interests include parallel computation and numerical solution of partial differential systems with applications to the modelling of subsurface and surface flows.



**Jean-Christophe Yoccoz** is a Professor at the Collège de France where he holds a Chair in Mathematics (Differential Equations and Dynamical Systems). He obtained a doctorat d'État in 1985. He was awarded

the Fields medal in 1994 and is a member of the Académie des sciences (France), a Chevalier de la Légion d'honneur (1995), and an Officer of the Ordre national du Mérite (2000). His research work concerns the theory of dynamical systems and the Julia and Mandelbrot sets.

**Joseph Hubert**, Vice-Rector (Research), Université de Montréal, is an ex-officio member of the International Scientific Advisory Committee. **Chantal David** (Concordia University), **Andrew Granville** (Université de Montréal), and **Odile Marcotte** (Université du Québec à Montréal), all Deputy Directors of CRM, are invited members of the Committee.

## **CRM Administrative and Support Staff**



## The Director's Office

**Peter Russell**

Director

**Chantal David**

Deputy Director, *Le Bulletin du CRM* and joint publications with the AMS and Springer

**Andrew Granville**

Deputy Director, CRM Prizes

**Odile Marcotte**

Deputy Director, Annual Report and Coordination with Related Fields

## Administration

**Vincent Masciotra**

Head of Administration

**Muriel Pasqualetti**

Administrative Assistant

**Guillermo Martinez-Zalce**

Research Laboratories Administrative Coordinator

**Diane Brulé-De Filippis**

Administrative Assistant

## Scientific Activities

**Louis Pelletier**

Coordinator

**Louise Letendre**

Administrative Assistant

**Sakina Benhima**

Project Manager

## Computer Services

**Daniel Ouimet**

Systems Administrator

**André Montpetit**

Office Systems Manager (half-time)

## Publications

**André Montpetit**

$\TeX$  Expert (half-time)

## Communications

**Suzette Paradis**

Communications Officer and Webmaster

**Statement of Revenue and Expenditures for  
the Fiscal Year Ending on May 31, 2010**

	NSERC	FQNT	Université de Montréal	Other partner universities	From Endowment Funds	Partners & Researchers	Internal sources	Total
<b>REVENUE</b>								
Operating and Infrastructure grants	1,200,000	605,000	—	—	—	—	—	1,805,000
Université de Montréal Grant	—	—	297,500	—	—	—	—	297,500
Université du Québec à Montréal Grant	—	—	—	150,000	—	—	—	150,000
McGill University Grant	—	—	—	90,000	—	—	—	90,000
Concordia University Grant	—	—	—	100,000	—	—	—	100,000
Université Laval Grant	—	—	—	74,382	—	—	—	74,382
University of Ottawa Grant	—	—	—	30,000	—	—	—	30,000
Université de Sherbrooke Grant	—	—	—	15,000	—	—	—	15,000
Equipment grant	48,000	—	—	—	—	—	—	48,000
FQNT grants for international internships	—	46,740	—	—	—	—	—	46,740
Grants National Science Foundation (USA)	—	—	—	—	—	38,188	—	38,188
Contribution from MITACS	—	—	—	—	—	28,500	—	28,500
Ministère des relations internationales du Québec	—	—	—	—	—	6,000	—	6,000
Contributions to Colloquia (ISM & GERAD)	—	—	—	—	—	18,036	—	18,036
Other contributions (conferences & workshops)	—	—	—	—	—	78,587	—	78,587
ISM Contributions for postdoctoral fellowships	—	—	—	—	—	66,125	—	66,125
Matching contributions for postdoctoral fellowships	—	—	—	—	—	179,825	—	179,825
Aisenstadt & Bissonnette Endowments	—	—	—	—	3,335	—	—	3,335
Registration & publications	—	—	—	—	—	—	49,334	49,334
Other	—	—	382	—	—	—	1,000	1,382
<b>TOTAL REVENUE</b>	<b>1,248,000</b>	<b>651,740</b>	<b>297,882</b>	<b>459,382</b>	<b>3,335</b>	<b>415,261</b>	<b>50,334</b>	<b>3,125,934</b>

(continued on next page)

	NSERC	FQNT	Université de Montréal	Other partner universities	From Endowment Funds	Partners & Researchers	Internal sources	Total
<b>EXPENDITURES</b>								
<b>SCIENTIFIC PROGRAM – CENTRE</b>								
<b>Thematic Semester 2009: Mathematic Problems in Imaging Science</b>								
Aisenstadt Chairs	148	10,975	—	—	2,227	—	178	13,529
Thematic postdoctoral fellows	20,500	—	—	—	—	—	—	20,500
Workshops	72,725	—	—	—	—	22,408	11,503	106,637
<b>Total Thematic Semester: Summer – Fall 2009</b>	<b>93,373</b>	<b>10,975</b>	<b>—</b>	<b>—</b>	<b>2,227</b>	<b>22,408</b>	<b>11,682</b>	<b>140,666</b>
<b>Thematic Semester 2010: Number Theory as Experimental Science</b>								
Aisenstadt Chair	—	3,927	—	—	865	—	—	4,792
Invited researchers	21,529	—	—	—	—	—	—	21,529
Thematic postdoctoral fellows	27,250	—	—	—	—	—	—	27,250
Workshops & advanced courses	112,759	—	—	—	—	34,002	728	147,488
<b>Total Thematic Semester: Winter – Spring 2010</b>	<b>161,538</b>	<b>3,927</b>	<b>—</b>	<b>—</b>	<b>865</b>	<b>34,002</b>	<b>728</b>	<b>201,059</b>
<b>General Program</b>	<b>100,320</b>	<b>30,523</b>	<b>100</b>	<b>—</b>	<b>17,712</b>	<b>60,311</b>	<b>17,634</b>	<b>226,599</b>
<b>Industrial/Multidisciplinary Program</b>	<b>12,000</b>	<b>2,697</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>52,590</b>	<b>4,187</b>	<b>71,474</b>
<b>Postdoctoral fellows &amp; students</b>	<b>96,125</b>	<b>—</b>	<b>—</b>	<b>30,000</b>	<b>—</b>	<b>246,750</b>	<b>2,613</b>	<b>375,488</b>
<b>SCIENTIFIC PROGRAM – RESEARCH LABORATORIES</b>								
Course release	—	6,917	—	58,727	—	—	—	65,644
Visiting researchers	—	11,119	—	20,514	—	—	—	31,633
Workshops, seminars	5,000	90,973	996	26,572	4,490	—	609	128,639
Postdoctoral fellows	60,333	55,552	8,333	72,946	—	—	—	197,164
Students	11,600	80,680	40,000	74,230	—	—	—	166,510
Administrative and technical support	—	30,472	—	147,504	—	—	—	217,976
<b>Total RESEARCH LABORATORIES</b>	<b>76,933</b>	<b>275,712</b>	<b>49,329</b>	<b>400,494</b>	<b>4,490</b>	<b>—</b>	<b>609</b>	<b>807,566</b>
<b>Other scientific expenses</b>								
FQNT international graduate internships	—	46,740	—	—	—	—	—	46,740
Course releases	—	7,500	—	—	—	—	6,096	13,596
Posters and publicity for activities	10,059	—	—	—	—	—	—	10,059
Accromoth	—	—	—	—	—	—	7,500	7,500
Joint Math Institutes Open House 2010	1,225	—	—	—	1,060	—	1,035	3,320
SMAC/AQJM	—	5,000	—	—	—	—	—	5,000
Bulletin du CRM, annual report	5,780	—	959	—	—	—	—	6,739
Authors royalties	—	—	—	—	—	—	4,222	4,222
<b>Total Other scientific expenses</b>	<b>17,063</b>	<b>59,240</b>	<b>959</b>	<b>—</b>	<b>1,060</b>	<b>—</b>	<b>18,852</b>	<b>97,174</b>
<b>Personnel (non-academic excluding Laboratories)</b>	<b>370,416</b>	<b>272,828</b>	<b>107,223</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>—</b>	<b>750,466</b>
<b>Academic management, committees, networking</b>	<b>1,757</b>	<b>5,279</b>	<b>110,265</b>	<b>—</b>	<b>1,190</b>	<b>—</b>	<b>141</b>	<b>118,633</b>
<b>Operating and computing costs</b>	<b>75,043</b>	<b>17,809</b>	<b>11,059</b>	<b>—</b>	<b>1,261</b>	<b>221</b>	<b>1,932</b>	<b>107,326</b>
<b>TOTAL EXPENDITURES</b>	<b>1,004,568</b>	<b>678,991</b>	<b>278,934</b>	<b>430,494</b>	<b>28,805</b>	<b>416,282</b>	<b>58,378</b>	<b>2,896,452</b>
<b>2009 – 2010 YEAR-END BALANCE</b>	<b>243,432</b>	<b>(27,251)</b>	<b>18,948</b>	<b>28,888</b>	<b>(25,470)</b>	<b>(1,021)</b>	<b>(8,044)</b>	<b>229,483</b>

(continued on next page)

	NSERC	FQNT	Université de Montréal	Other partner universities	From Endowment Funds	Partners & Researchers	Internal sources	Total
<b>CUMULATIVE YEAR-END BALANCES</b>								
Amount available on June 1, 2009	49,309	83,083	(5,368)	—	112,232	17,713	147,018	403,988
Changes in receivables, payables and reserves	20,584	9,330	2,732	(28,888)	13,511	(3,501)	9,208	22,976
2009 – 2010 year-end balance	243,432	(27,251)	18,948	28,888	(25,470)	(1,021)	(8,044)	229,483
<b>Amount available on May 31, 2010</b>	<b>313,325</b>	<b>65,161</b>	<b>16,312</b>	<b>—</b>	<b>100,274</b>	<b>13,191</b>	<b>148,183</b>	<b>656,447</b>

# **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 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 Centre de recherches mathématiques 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 FQRNT (Fonds québécois de la recherche sur la nature et les technologies), by the Université de Montréal, as well as McGill University, Université du Québec à Montréal, Concordia University, University of Ottawa, Université Laval, 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 Aisenstadt Prize given for outstanding work carried out by a young Canadian mathematician, the CAP – CRM Prize for exceptional achieve-

ment in theoretical and mathematical physics, and the CRM – SSC Prize for exceptional contributions to statistics in early career,

- it publishes technical reports and about ten books per year (and some of its collections are published jointly with the AMS and with 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 [crm.umontreal.ca](http://crm.umontreal.ca),
- it participates, with the other two Canadian institutes, in groundbreaking national initiatives, for instance the MITACS network (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, created 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 ISM (Institut des sciences mathématiques) including the weekly CRM – ISM colloquium, graduate courses offered by distinguished visitors, and a program of postdoctoral fellowships,
- it works actively at developing contacts with industry. Its joint activities with liaison and research centres (CIRANO, CRIM, and MITACS) and research centres doing applied research (CIRRELT, GERAD,



INRS-EMT, and Inserm) led to the creation of industrial networks. The most recent ones involved, in 2004 – 2005, Bombardier Aerospace and the Brain Imaging Unit CRM – IUGM – Inserm.

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 won many international prizes and the *prix spécial de la mi-*

nistre de l'Éducation, du Loisir et du Sport (in 2008), and the *Grandes Conférences du CRM*, which allow a broad public to attend lectures 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.