CENTRE
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MATHÉMATIQUES

2017-2018 ANNUAL REPORT

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Summary

Presentation

Luc Vinet

The year 2017–2018 is a very special one in the history of the Centre de recherches mathématiques because it marks the beginning of a brilliant scientific program celebrating the 50th anniversary of the CRM. The scientific program consists of 20 thematic periods (generally lasting one month) focused on diverse mathematical areas. These periods were proposed by many enthusiastic CRM members and coordinated by Louigi Addario-Berry; I thank them all for their efforts. The 50th anniversary program began in March 2018 with a lecture by Professor Jean-Pierre Bourguignon and activities around geometric analysis, including the Nirenberg Lectures delivered by Eugenia Malinnikova. In 2017–2018 the 50th anniversary program also included thematic periods on the mathematics of machine learning (from April 14 to May 11, 2018) and probability in number theory (from May 14 to June 8, 2018). Thematic periods will continue until November 2019, a month dedicated to mathematical physiology.

The 50th anniversary program was preceded by a thematic semester on risk in complex systems (from August to December 2017) organized by four professors from McGill (Christian Genest, Erica Moodie, Johanna Nešlehová, and David Stephens), two professors from HEC Montréal (Debbie Dupuis and Bruno Rémillard), and a professor from the University of Waterloo (Ruodu Wang). I thank them warmly for their work, which also included the organization of lectures by Aisenstadt Chairholders Claudia Klüppelberg and Alexander McNeil.

I can mention here only a few of the activities that took place in 2017–2018: three summer schools, two workshops in honour of CRM members (Jacques Hurtubise, director of the CRM from 1999 to 2003, and Thomas Ransford), the MAIN conference on artificial intelligence and neuroscience that welcomed 242 students and researchers (with 100 persons on a waiting list!), the Second Mathematical Congress of the Americas (organized to a large extent by Jacques Hurtubise), the Eighth Montreal Industrial Problem Solving Workshop (organized by Odile Marcotte and Stéphane Rouillon), and four “Grandes Conférences du CRM” (organized by Christiane Rousseau and Yvan Saint-Aubin). Finally I would like to mention that an international workshop on quantum mechanics was held in June 2017 in Valladolid to honour Véronique Hussin, the new CRM Deputy Director for publications and communications: I thank her very much for having accepted this position.

The CRM is especially proud of having received, on March 27, 2017, a five-year grant from the Simons Foundation. This is a first for a Canadian mathematics institute and the grant allowed the CRM to host researchers associated with the thematic semester on risk in complex systems or thematic periods within the 50th anniversary program. The grant was also used to host researchers collaborating with members of CRM laboratories: there were two such researchers in 2017 and 11 in 2018. Most Simons CRM Scholars-in-Residence are mentioned in the relevant sections of this report.

The activities of 2017–2018 were made possible through the financial support of several institutions: the FRQNT (Government of Québec), NSERC (Government of Canada), the *Conseil national de la recherche scientifique* (especially the *Unité Mixte Internationale* hosted by the CRM and led by Emmanuel Giroux), the National Science Foundation of the United States, and the Simons Foundation. I am grateful to all of them: their generosity enables the CRM to exert an ever increasing influence on the development of mathematics in Canada and in the world.

Luc Vinet
Director of the CRM
June 2019

Thematic Program

Thematic programs bring together hundreds of researchers from around the world who work on specific themes at the cutting edge of mathematical research. They take part in workshops, conferences, mini-courses, or schools. A thematic program usually lasts between four months and one year. It may include extended stays of visiting researchers at the CRM, as well as lectures given by Aisenstadt Chairholders.

Risk in Complex Systems — Models, Applications, Perceptions, and Policy Implications

August–December 2017

Hazards inherent to complex interconnected systems can lead to disasters of epic proportions with untold environmental, economic, and social consequences. The identification, quantification, prediction, control, and mitigation of risk factors is thus essential to ensure individual protection and system integrity while promoting sustainable development.

This thematic program was seeking to promote the study and use of stochastic models and statistical inference techniques that are relevant for an enhanced understanding of the interplay between risk factors and their potentially catastrophic effects on dynamic systems. Dependence models, extreme-value theory, and time series analysis form the methodological backbone of quantitative risk management. Many important current issues were considered, including the development of models for extreme events and large collections of variables, risk aggregation and model validation through expert use, the assessment and control of systemic risk, and risk propagation in epidemiology, finance, power networks, computer systems, etc.

The workshops were designed to foster interactions among probabilists, statisticians, econometricians, regulators, and risk modellers in finance, insurance, hydrology, as well as in the health, climate, and environmental sciences. They brought together researchers and practitioners from these various areas and presented an excellent opportunity to take stock of recent developments, identify new challenges, and initiate fruitful collaborations. A week-long school was held before the workshops: it was based on the bestseller *Quantitative Risk Management: Concepts, Techniques and Tools* by McNeil, Frey and Embrechts (Princeton University Press, 2015) and provided young investigators and professionals with a hands-on introduction to this rapidly growing field. The school lectures were given by Rüdiger Frey (Wirtschaftsuniversität Wien) and Marius Hofert (University of Waterloo).

The thematic program on risk also featured lectures by two Aisenstadt Chairholders, Claudia Klüppelberg and Alexander J. McNeil (see the section of this report on the Aisenstadt Chair), a specialized course by Professor Johanna Nešlehová at McGill in the Fall of 2017, and public lectures jointly organized with CIRANO and delivered respectively by Pierre Del Moral (INRIA Bordeaux), Roger M. Cooke (Resources for the Future, Washington, DC and Technische Universiteit Delft), Peter Raupach (Deutsche Bundesbank), Michel M. Dacorogna (Prime Re Solutions, Switzerland), and Paul Embrechts (ETH Zürich). Finally let us mention that three Simons CRM Scholars-in-Residence were associated with the thematic program and visited the CRM during the semester: Anne-Laure Fougères (Université Claude-Bernard Lyon 1), Pierre Del Moral (University of New South Wales), and Roger Cooke (Resources for the Future and Technische Universiteit Delft).

Christian Genest

The Local Organizing Committee for this thematic semester included Christian Genest, Erica Moodie, Johanna Nešlehová, and David A. Stephens (all from McGill University), Debbie J. Dupuis and Bruno Rémillard (HEC Montréal), and Ruodu Wang (University of Waterloo). The International Scientific Committee included **Carole Bernard** (Grenoble École de Management), **Rama Cont** (Imperial College London), **Michel Dacorogna** (Prime Re Solutions, Switzerland), **Anthony C. Davison** (École polytechnique fédérale de Lausanne), **Anne-Laure Fougères** (Université Claude-Bernard, Lyon), **Paul Glasserman** (Columbia University), **Daniel J. Graham** (Imperial College London), **Nicholas P. Jewell** (University of California at Berkeley), **Matthias Scherer** (Technische Universität München), **Steven Vanduffel** (Vrije Universiteit Brussel), and **Francis W. Zwiers** (Pacific Climate Impacts Consortium).

Finally we mention that the thematic semester on risk was part of a large program called *Mathematics of Planet Earth*, inaugurated at the CRM by Professor Christiane Rousseau and adopted by many institutions all over the world.

Environmental Risk Modelling and Extreme Events
August 28–31, 2017, CRM

Organizers: Anthony C. Davison (EPFL), Debbie J. Dupuis (HEC Montréal), Francis W. Zwiers (PCIC, Victoria)

The twenty invited speakers made very high-level and diverse presentations, ranging from practical considerations in the political treatment of risk through applications in various domains to statistical models and methods for small probability estimation. Each presenter respected the mandate that he/she had been assigned and, as a result, the workshop covered its full intended scope. Many attendees commented on how the various experts had tried to bridge the differences in methodologies and technical language across the communities.

The talks were well suited for the workshop attendees: some from outside the statistical community left motivated to learn more about extreme-value theory, and statisticians became conscious that domain-specific knowledge could not be ignored if one wished new statistical methodology to be useful. Feedback from the graduate students was also very good.

The workshop attendees actively participated in the discussions, with interesting and thought-provoking comments following almost every talk. Presenters had been asked to provide two questions each to fuel a full group discussion held at the end of the third day. Attendees were once again quite vocal at this group discussion, which covered a range of topics and should help to set future agendas for interaction.

The workshop increased awareness in the statistical and application communities (atmospheric science, environmental science, hydrology, renewable resources, engineering, etc.) of the needs, possibilities, difficulties, and opportunities that the other community faces, and participants have already reported collaborations that have started to address some of the needs. The increase in discussion and collaboration between the two communities is beneficial and will, the organizers hope, spawn similar workshops that could change the culture in the respective communities. In the long term, we could see an increased number of pertinent publications and, eventually, improved practice in applications.

The organizers already have a suggestion from a participant to produce a jointly authored perspectives article for a climate, hydro-meteorological, and statistical sciences audience. Whether they follow exactly that path has not yet been decided, but this suggestion, and the broad range of positive verbal comments from participants from both the statistical and climate sciences, indicate that this workshop has enhanced the appreciation of the contributions that advanced EVT can make to deep and interesting real-world problems.

Debbie Dupuis

Risk Measurement and Regulatory Issues in Business
September 11–14, 2017, CRM

Organizers: Carole Bernard (VU Brussel & Grenoble École de management), Michel Dacorogna (Prime Re Solutions), Steven Vanduffel (VU Brussel), Ruodu Wang (Waterloo)

In the financial industry, the assessment of aggregate risk is a central problem for regulators and risk managers. Specifically, measuring the risk of a high-dimensional portfolio of investments or claims is at the centre of the computation of solvency requirements within the Solvency II and Basel III regulatory frameworks. A better understanding of the performance of risk models in presence of uncertainty is key for regulators, bankers, and insurers wishing to reach better strategic decisions and strengthen the stability of the worldwide financial system (i.e., by managing systemic risk).

Uncertainty typically arises naturally in that it is often due to data limitation, random errors, and the use of wrong assumptions, especially in the setting of high-dimensional models. This problem is further amplified by the fact that solvency capital calculations are required at a very high confidence level. As different models lead to different regulatory capital calculations and thus cause arbitrage in regulatory capital, robustness and back-testing issues for risk measurement procedures are now a focal point of regulatory interest. Model validation of internal risk models is at the centre of discussions among regulators in the Basel Regulatory Framework for Banks, or in the Solvency II system for the insurance industry. This includes also the elicitation of expert opinions when data are sparse and the widespread use of Economic Scenario Generators (ESGs), which are used to project financial markets and macroeconomics variables.

This workshop brought together experts from the financial industry and the regulatory authorities, as well as academics active in the fields of statistics, probability, finance, and insurance. It fostered interrelationships and allowed participants to discuss recent advances, exchange ideas, start new collaborations, and contribute to the training of graduate students in this important area of research. The presentations covered banking and insurance and focused on key issues such as back-testing, model risk and robustness, the handling of big data, and the interplay between internal and standard models. After each presentation there was time for discussion and those discussions were lively and constructive. In particular, several invited speakers took a very active part in the discussions and brought up very interesting remarks. One of the key conclusions was that back-testing and the evaluation of model uncertainty have made significant progress. Many methods and theoretical developments were presented and it is expected that these will be used by industry stakeholders in their processes of model validation.

We strove to keep a good balance between researchers at different career levels; there were four young scholars (Capponi, Hofert, Mailhot, Nolde), five mid-career scholars (Bauer, Hummel, Puccetti, Tsanakas, Zhou), and ten senior scholars (Acerbi, Cont, Embrechts, Filipovic, Gordy, Kratz, Marceau, Rüschendorf, Schied, Stahl). Out of these 19 researchers 15 were from academia and four from industry (Acerbi, Gordy, Hummel, Stahl). All invited speakers were very well prepared and made very high-level presentations, ranging from industry considerations to more theoretical approaches on how risk should be measured and managed in the financial and insurance industry. Many attendees commented on the high level of the presentations and on the importance of getting experts from industry and academia together.

Each presentation lasted between 35 and 40 minutes and was followed by a discussion of five to ten minutes. The differences between perspectives were in evidence and the presence of some senior researchers fostered sharp questions and discussions.

The theme of the panel was “risk management and regulatory practice” and it dealt with the interplay between risk management and regulation. The panel was led by Michel Dacorogna and involved four of the invited speakers: Etienne Marceau, Damir Filipovic, Marie Kratz, and Gerhard Stahl.

The panel succeeded beyond expectations. The discussion was centred around the following questions:

- How does risk management practice influence the development of the risk-based regulation?
- Is heavy regulation putting a burden on good risk management practice?
- How is quantitative risk management influenced by the new regulation?
- What is the future of internal models versus standard models, given the issues of model risk and back-testing? Do we need to abandon the former and move towards the latter?
- How can academics help to ensure better regulation?

Workshop participants and panellists had very active and interesting discussions, in particular on the impact of incentive schemes in the industry and on the difference between the banking and insurance industries. It was a welcomed prolongation of the discussions that were held during the talks and that could not be pursued due to lack of time and scheduling considerations.

The workshop included two public lectures: a lecture on Monday night by Paul Embrechts on “Risk Management for Insurance and Banking: Then, Now and Tomorrow,” and a lecture on Wednesday night by Michel Dacorogna on “A Change in Paradigm for the Insurance Industry.” Both of these lectures were very well prepared, provided an insightful view on the future, and were well attended. The first lecture was attended by a slightly broader and more diverse audience, because it came first and had a broader scope (dealing with banking and insurance). The workshop also included a poster session (with posters prepared by graduate students). In the concluding remarks, the organizers agreed that given the tremendous challenges faced by our societies in the area of risk management, collaborations and exchanges between the professional and academic worlds are the key to the discovery of innovative solutions.

Measurement and Control of Systemic Risk
September 26–28, 2017, CRM

Organizers: Rama Cont (Imperial College London), Paul Glasserman (Columbia), Bruno Rémillard (HEC Montréal)

Sponsored by the National Bank of Canada and the Montreal Structured Finance and Derivatives Institute

The organizers had decided to organize a three-day workshop (from Tuesday to Thursday), which in retrospect was a very good idea, given that many participants were not from academia. There was no downtime and all participants liked the workshop. Even the last presentation (on Thursday afternoon) was attended by many people. All the lectures were of very high quality and the attendees were very active: there were always many questions, during and after the presentations.

Six lectures took place during the first day, of which five were given by researchers from the banking or regulatory sector. An exchange on regulation issues was included in the workshop, featuring among others Ian Buckley and Jérôme Henry, who were responsible (until recently) for robustness tests for European banks. Seven high-level lectures took place during the second day and were followed by a reception (including five poster presentations). The third and last day featured six lectures.

Bruno Rémillard

The workshop will have a great impact in terms of networking. For instance Ian Buckley (from the Canadian Securities Transition Office) met with most persons who work on systemic risk in Canada; these meetings were crucial for his future work. One of the participants works for the *Autorité des marchés financiers* (AMF) and benefited from the opportunity to meet world specialists in systemic risk. Fourteen of the twenty presentations were made available on the web site of the workshop, which will enable collaborations between researchers and presenters. Finally let us mention that one of the lecturers (Peter Raupach, Deutsche Bundesbank) also gave a highly successful presentation at noon on Monday at the CIRANO research centre.

Johanna Nešlehová

Dependence Modelling Tools for Risk Management October 2–5, 2017, CRM

Organizers: Anne-Laure Fougères (Lyon 1), Johanna Nešlehová (McGill), Matthias Scherer (TU München)

Sixty-eight researchers from academia, government, and industry attended the conference, including several postdoctoral fellows and graduate students. The twenty-one invited speakers were experts from both academia and industry: they presented their research on innovative tools in dependence modelling. This included (but was not limited to) dependence structures, statistical inference for copula models, computational challenges, dependence modelling in econometrics, spatio-temporal dependence models, dependence modelling in insurance, and network/graphical models. The workshop gathered very high-level and diverse presentations; each speaker respected the mandate that he/she had been assigned, so that the workshop covered its full intended scope.

The talks were well suited for the workshop attendees: they gave overviews of several specific research areas, and generated several discussions, with interesting and thought-provoking comments following almost every talk. Feedback from the graduate students was also very good. Two "spotlight talk" sessions were devoted to introducing the posters presented in two evening sessions, and each participant was invited to present in five minutes his/her work.

The workshop attendees actively participated in the discussions, which allowed various exchanges in methodologies and references between statisticians, risk managers and practitioners, or researchers in both Finance and Actuarial Sciences. We allocated ample time for discussions, in particular during the two poster sessions and welcome reception. The spotlight talks gave the conference participants the motivation to ask numerous questions during the poster sessions.

The conference led (through many discussions) to an increased awareness, within the statistical and application communities (econometrics, finance, actuarial science, engineering, etc.), of the needs, opportunities, and difficulties that the other community faces. A special issue of the *Journal of Multivariate Analysis* was devoted to dependence modelling; it was guest-edited by Anne-Laure Fougères, Alexander McNeil, Johanna G. Nešlehová (managing guest editor), and Matthias Scherer. Submissions were by invitation and the invitation was extended only to the invited speakers and poster presenters of the workshop; the special issue appeared in July 2019. In our opinion this special issue will have a strong and unifying impact on the sharing of advanced research tools in dependence modelling for risk management in a broad sense.

Erica E. M. Moodie

David A. Stephens

Risk Modelling, Management and Mitigation in Health Sciences December 11–13, 2017, CRM

Organizers: Daniel J. Graham (Imperial College London), Nicholas P. Jewell (UC Berkeley), Erica E. M. Moodie (McGill), David A. Stephens (McGill)

Risk assessment and quantification is a critical part of the design, implementation, and assessment of health research and health-care provision and development, from the design of clinical trials in drug development to post-marketing surveillance of outcomes and the assessment of risk to health from environmental, occupational, and individual-specific factors.

This final workshop in the Thematic Semester on Risk sought to bring together a diverse group of researchers in an interdisciplinary conversation on challenges and analytic solutions for risk-related questions in health research. Specifically, the workshop addressed aspects of the quantification and mitigation of risk in health sciences. Different themes included the modelling and analysis of occupational and environmental health, mitigation of risk in the context of infectious diseases, risk assessment in trial design for toxicity/efficacy in trials, and the quantification of adverse event risk in post-marketing surveillance. Statistical methods involving spatial and causal modelling, clinical trial design, and personalized treatment strategies play a crucial role in understanding and representing the risks involved.

The two and a half-day workshop included speakers and participants from a wide variety of career stages, geographical locations, and academic backgrounds, ranging from clinicians and public health physicians to epidemiologists to theoretical statisticians and computer scientists. The poster session on the first evening provided a forum for younger trainees to present their work and interact with the world-class academics who had come to give invited lectures. The smaller size of the meeting allowed for significant networking and the forging of new connections.

Past Thematic Programs

The CRM has held a thematic program 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.

March–July 2017 Algebra and Words in Combinatorics

August–December 2016 Probabilistic Methods in Geometry, Topology, and Spectral Theory

April-July 2016 Computational Mathematics in Emerging Applications

June 2015–January 2016 AdS/CFT, Holography, Integrability

2014–2015 Number Theory, from Arithmetic Statistics to Zeta Elements

January–June 2014 Lie Theory

July–December 2013 Mathematics of Planet Earth 2013 — Thematic Semester on Biodiversity and Evolution

January–November 2013 Mathematics of Planet Earth 2013 — The Pan-Canadian Program on Models and Methods in Ecology, Epidemiology and Public Health

January–September 2013 Mathematics of Planet Earth 2013 — International Program in Celestial Mechanics

2012–2013 Moduli Spaces, Extremality and Global Invariants

January–June 2012 Geometric Analysis and Spectral Theory

June–December 2011 Quantum Information

January–June 2011 Statistics

July–December 2010 Geometric, Combinatorial and Computational Group Theory

January–April 2010 Number Theory as Experimental and Applied Science

August–December 2009 Mathematical Problems in Imaging Science

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

2008–2009 Probabilistic Methods in Mathematical Physics

January–June 2008 Dynamical Systems and Evolution Equations

June–December 2007 Applied Dynamical Systems

January–June 2007 Recent Advances in Combinatorics

June–December 2006 Combinatorial Optimization

2005–2006 Analysis in Number Theory

2004–2005 The Mathematics of Stochastic and Multiscale Modelling

2003–2004 Geometric and Spectral Analysis

2002–2003 Mathematics in Computer Science

2001–2002 Groups and Geometry

2000–2001 Mathematical Methods in Biology and Medicine

1999–2000 Mathematical Physics

1998–1999 Number Theory and Arithmetic Geometry

1997–1998 Statistics

1996–1997 Combinatorics and Group Theory

1995–1996 Applied and Numerical Analysis

1994–1995 Geometry and Topology

1993–1994 Dynamical Systems and Applications

1992 Probability and Stochastic Control (special semester)

1991–1992 Automorphic Forms in Number Theory

1991 Operator Algebras (thematic 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)

50TH ANNIVERSARY PROGRAM

As mentioned at the beginning of this annual report, the celebration of the CRM 50th anniversary started in March 2018 and will last for more than one year. To mark this milestone, the CRM has prepared a diversified and intensive scientific program that should have a major impact on research in the mathematical sciences. During the academic year ending in June 2018, the activities specifically linked to the 50th anniversary included a lecture for launching the anniversary and three short programs on geometric analysis, the mathematics of machine learning, and probability in number theory (respectively). A "Grande Conférence du CRM" (delivered by Simon Singh) was also part of the 50th anniversary: the reader may find a report on this lecture in the section on the "Grandes Conférences."

Launch of the CRM 50th Anniversary Activities

Lecture by Jean-Pierre Bourguignon (European Research Council) March 9, 2018, CRM

On March 9, 2018, the CRM had the honour of welcoming Jean-Pierre Bourguignon, an eminent French mathematician. Professor Bourguignon is a great friend of the CRM and at the present time he is President of the European Research Council. His lecture was entitled *Mathématiques, science et technologie, une nouvelle donne* (the subtitle was *Quelques exemples inspirés par les actions du CRM*). The first part of his lecture was devoted to the new links between mathematics, on the one hand, and science and technology, on the other. Professor Bourguignon then addressed the importance of the institutes in the development of mathematical research. To conclude, he showed that fundamental concepts and programs had emerged at the CRM or in the work of researchers with close links to the CRM: he mentioned in particular the Langlands program, the Montreal functor (introduced by Pierre Colmez), and the work of Bertrand Eynard on topological recursion.

Short Program on Geometric Analysis March 12–16, 2018

Workshop on Geometric Analysis March 12–16, 2018, CRM

Organizers: Pengfei Guan (McGill), Alina Stancu (Concordia and ISM), Gábor Székelyhidi (Notre Dame), Jérôme Vétois (McGill), Ben Weinkove (Northwestern)

The Workshop on Geometric Analysis was the first in a series of scientific activities celebrating the 50th anniversary of the CRM. Geometric analysis is one of the most active fields in mathematics, as demonstrated by several major breakthroughs in recent years. The workshop successfully brought together some of the world's leading experts in the area to discuss recent major developments and highlight new research trends. The lectures covered broad and prominent current areas of the field.

- Geometric flows: Joel Spruck presented recent progress on the classification of translating solitons that are solutions to the mean curvature flow, introducing some novel tools in nonlinear partial differential equations. Juncheng Wei's lecture dealt with the formation of blow-up solutions to the two-dimensional harmonic map flow into the sphere, the construction of such solutions providing new important examples on the behaviour of the geometric flow. In a different direction, Mohammad Najafi Ivaki discussed a flow approach to solving the elliptic L^p Christoffel–Minkowski problem in convex geometry.
- Complex structures and Kähler geometry: Tristan Collins talked on recent results obtained with his collaborators on the mirror manifolds of special Lagrangian submanifolds of a Calabi–Yau manifold, and the connection of solvability to the corresponding fully nonlinear PDE with a notion of stability. Lei Ni's lecture dealt with

comparison and vanishing theorems on Kähler manifolds (using a new notion of orthogonal Ricci curvature in Kähler geometry). Xiangwen Zhang discussed a recent exciting breakthrough on the Fu–Yau Hessian equation on Kähler manifolds that is connected to superstring theory in mathematical physics.

- Regularity estimates and the rigidity problem: Regularity is one of the most important topics in nonlinear PDE. Bo Guan discussed a new method for deriving a priori estimates for second derivatives of solutions to a large class of geometric fully nonlinear elliptic equations. Guohuan Qiu's lecture dealt with a new C^2 interior estimate for scalar curvature equations in higher dimensions, resolving a long-standing problem for a class of convex solutions. Yu Yuan lectured on the Bernstein problem for the Hessian equation, presenting a unified approach to quadratic asymptotes of solutions over exterior domains.

- Inverse problems, area data, and conformal infinity: Spiros Alexakis discussed the problem of reconstructing the metric of a three-dimensional Riemannian manifold from area data on the boundary. Gábor Székelyhidi discussed an existence result for a Poincaré–Einstein metric with a given conformal infinity in a collar neighborhood, extending old results of Fefferman–Graham and Kichenassamy for real analytic data to smooth ones.

- Geometric problems in spectral theory, optimal transportation, and nonlinear PDEs: Ailana Fraser lectured on the extremal eigenvalue problem on Riemannian manifolds. Young-Heon Kim discussed an optimization problem involving geometric averages between probability measures. Frédéric Robert's lecture dealt with the asymptotic profiles of singular solutions to a nonlinear elliptic PDE.

Overall the atmosphere of the workshop was very enthusiastic and filled with many fruitful discussions and exchanges. The workshop took place around the CRM Nirenberg Lectures in Geometric Analysis. The combination of these two activities was highly appreciated by the participants and contributed to making this week an exciting and memorable scientific event.

Eugenia Malinnikova

CRM Nirenberg Lectures in Geometric Analysis
Eugenia Malinnikova (NTNU)
March 12, 14, and 16, 2018, CRM

The annual lecture series in geometric analysis in honour of Louis Nirenberg was inaugurated by the CRM in 2014. This year the Nirenberg Lectures were integrated into the workshop on Geometric Analysis organized by P. Guan, A. Stancu, and J. Vétois, and were the first ones in a series of events dedicated to the 50th anniversary of the CRM.

The 2018 CRM Nirenberg lectures were delivered by Professor Eugenia Malinnikova from the Norwegian University of Science and Technology (Trondheim) during the week of March 12–16, 2018. Malinnikova's research interests include potential theory, complex and harmonic analysis, and elliptic PDEs and their discrete models. In particular she has done fundamental work in the study of elliptic PDEs. Together with Alexander Logunov she received the 2017 Clay Research Award for introducing "a novel geometric combinatorial method to study doubling properties of solutions to elliptic eigenvalue problems." This has led to the solution of some long-standing open problems in spectral geometry, notably, regarding the bounds on the size of the nodal sets of harmonic functions in R^n and Laplace eigenfunctions on compact Riemannian manifolds (the Nadirashvili's and Yau's conjectures). In recognition of their achievements, Malinnikova and Logunov were invited to speak at the 2018 ICM in Rio de Janeiro.

The Nirenberg lecture series given by Eugenia Malinnikova consisted of three talks. The first lecture was entitled "Frequency function and unique continuation." In 1966, Shmuel Agmon introduced the method of logarithmic convexity for weighted norms of solutions of second order equations. These ideas were developed by Almgren, and later by Garofalo and Lin, in particular, to prove unique continuation results for a wide class of second order elliptic equations. Malinnikova gave an introduction to Almgren's frequency function techniques, monotonicity formulas, and quantitative unique continuation results, including the three-ball inequality and the Cauchy uniqueness inequality. In particular she discussed a quantitative version of the Cauchy uniqueness theorem for solutions of elliptic PDEs. She then formulated two recent "combinatorial" results on the propagation of smallness (due to Logunov) that were crucial for further developments: the Simplex Lemma and the Hyperplane Lemma. Towards the end of the talk, propagation of smallness results from the sets of co-dimension less than one were discussed. In particular, Malinnikova raised a question about propagation of smallness from sets of co-dimension greater than 2, as well as a conjecture by F.-H. Lin about an upper bound on the size of the "vanishing gradient" set in terms of the doubling index for the gradient.

The title of the second lecture was "Eigenfunctions of Laplace-Beltrami operator: application of the frequency function to the estimates of the nodal sets." The properties of the frequency function can be applied to estimates of the zero sets of eigenfunctions of the Laplacian on compact manifolds. In dimension two, the first results were obtained by Donnelly and Fefferman in the 1980s. Their upper bounds on the size of the zero sets were slightly improved in the recent work of Malinnikova and Logunov, the new ingredient being the combinatorial properties of the frequency function discussed in the first lecture of the series. A more detailed analysis of the frequency function led Logunov to new estimates for the nodal sets in higher dimensions; some of those results were also surveyed. In particular Malinnikova sketched the ideas of the proof of Nadirashvili's conjecture on the lower bound for the size of the nodal sets of harmonic functions, which implies a sharp lower bound in Yau's conjecture for the size of the nodal sets of Laplace eigenfunctions.

The third lecture (on Remez inequality and propagation of smallness for solutions of second order elliptic PDEs) was aimed at a general mathematical audience. The Remez inequality states that the maximum of a polynomial over an interval is controlled by its maximum over a subset of positive measure of the interval. The coefficient in the inequality depends on the degree of the polynomial, and the equality is attained by Chebyshev polynomials. Recently Malinnikova (jointly with Logunov) obtained a generalization of the Remez inequality to the solutions of the general second order elliptic PDEs (and their gradients). The degree of the polynomial is replaced by the Almgren frequency of the solution, which is investigated using geometric methods. In the talk Malinnikova presented this result and its connections to other important features of the solutions of elliptic PDEs, such as quantitative unique continuation and propagation of smallness. She also explained how her work with Logunov yielded an answer to an old question of Landis and improved earlier results of Nadirashvili and Vesella.

The lecture series generated a lot of interest among the members of the Montréal mathematical community. The lectures were attended by many students and postdocs, as well as by the participants of the Workshop on Geometric Analysis.

Short Program on Mathematics of Machine Learning April 14–May 11, 2018

This thematic activity focused on mathematical challenges in machine learning. The spectacular success of machine learning in a wide range of applications opens up many exciting theoretical challenges in a number of mathematical fields, including probability, statistics, combinatorics, optimization, and geometry. The CRM brought together researchers in machine learning and mathematics to discuss these problems. The principal topics included combinatorial statistics, online learning, and deep neural networks.

The program was a great success, bringing together top mathematicians such as Gérard Ben Arous and Grigoris Paouris with the top machine learners of their generation such as Yoshua Bengio (recent Turing award winner), Peter Bartlett, or Nicolo Cesa-Bianchi. The up-and-coming generation of theoretical machine learners was also extremely well represented, with Emmanuel Abbe, Sasha Rakhlin, Sham Kakade, Émilie Kaufmann, Alexandra Carpentier, Nicolas Le Roux, Gergely Neu, Daniel Hsu, and Gautam Kamath. This (non exhaustive) list covers a broad range of institutions from North America (including essentially all top US schools) and Europe. The two keynote lectures by Yoshua Bengio and Joëlle Pineau, respectively, were great successes too, with full-room attendance.

Overall the program tapped into the recent excitement around artificial intelligence, while maintaining the highest academic standards. This program was an opportunity for cross-fertilization between mathematics and machine learning. There remain many opportunities for deeper interactions between those fields and the material produced by our program (including the videos of the first workshop) will hopefully prove to be a valuable resource for that endeavour. Note that four Simons CRM Scholars-in-Residence visited the CRM within the framework of the program and helped foster that kind of interactions: Nicolas Broutin (Sorbonne), Jian Ding (University of Pennsylvania), Gábor Lugosi (Universitat Pompeu Fabra), and Nike Sun (University of California, Berkeley).

Yoshua Bengio

Opening Keynote Lecture: "Deep Learning for AI" Yoshua Bengio (Montréal) April 16, 2018, CRM

There has been rather impressive progress recently with brain-inspired statistical learning algorithms based on the idea of learning multiple levels of representation, also known as neural networks or deep learning. They shine in artificial intelligence tasks involving perception and generation of sensory data like images or sounds and to some extent in understanding and generating natural language. We have proposed new generative models which lead to training frameworks very different from the traditional maximum likelihood framework, and borrowing from game theory. Theoretical understanding of the success of deep learning is work in progress but relies on representation aspects as well as optimization aspects, which interact.

At the heart of these learning mechanisms is their ability to capitalize on the compositional nature of the underlying data distributions, meaning that some functions can be represented exponentially more efficiently with deep distributed networks compared to approaches like standard non-parametric methods that lack both depth and distributed representations. On the optimization side, we now have evidence that local minima (due to the highly non-convex nature of the training objective) may not be as much of a problem as thought a few years ago, and that training with variants of stochastic gradient descent actually helps to find better-generalizing solutions quickly. Finally new interesting questions and answers are arising regarding learning theory for deep networks: why even very large networks do not necessarily overfit and how the representation-forming structure of these networks may give rise to better error bounds that do not depend absolutely on the iid data hypothesis.

Workshop on Modern Challenges in Learning Theory
April 23–26, 2018, CRM

Organizers: Sébastien Bubeck (Microsoft), Luc Devroye (McGill), Gábor Lugosi (Pompeu Fabra)

Learning theory is a field that lies at the intersection of statistics, probability, computer science, and optimization. This mathematical theory is concerned with theoretical guarantees for machine learning algorithms. The workshop on modern challenges in learning theory focused on the novel mathematical challenges that emerged from recent methodological breakthroughs such as deep learning and online learning.

Here are some highlights of this workshop.

- Peter Bartlett presented a decomposition theorem, which essentially shows that any smooth function can be represented as a composition of functions very close to the identity. While being inspired by neural networks, this problem stimulated discussions related to differential geometry among the participants.
- Marc Bellemare from Google Brain Montreal presented a thought-provoking algorithm, based on learning an entire distribution for problems where one is in fact only interested in learning the mean. It seems that neural networks extract "more information" in this process, leading to better features. This approach remains mysterious and is ripe for mathematical analysis.
- Émilie Kaufmann talked about bandit for games, and several discussions ensued around that topic, including a mutliplayer version of the multi-armed bandit problem. Two of the program organizers (S. Bubeck and G. Lugosi) independently pursued that thread and discovered a very fertile land at the intersection of learning, information theory, and game theory.

Workshop on Combinatorial Statistics
April 30–May 4, 2018, CRM

Organizers: Sébastien Bubeck (Microsoft), Luc Devroye (McGill), Gábor Lugosi (Pompeu Fabra)

Many new challenges in statistics and machine learning involve estimation, testing, or inference based on observing large random structures with nontrivial combinatorial properties. The aim of the workshop was to discuss new directions, techniques, and results in this rapidly developing area. Here are some highlights.

- Constantinos Daskalakis (recent Nevanlinna prize winner) talked about Generative Adversarial Networks, and how they connect to well-established objects such as Markov Random Fields.
- Andrea Montanari presented the first part of his work on using stochastic differential equations to understand stochastic gradient descent on neural networks. Since the original presentation, this work has greatly expanded and there has been a lot of follow-up from many different perspectives.
- Yuval Peres taught a minicourse consisting of four lectures on statistical reconstruction, in particular a lecture on reconstruction on trees and a lecture on the detection of a missing point in a perturbed lattice.

Joëlle Pineau

Closing Keynote Lecture:
"Data-Driven Dialogue Systems: Models, Algorithms, Evaluation, and Ethical Challenges"
Joëlle Pineau (McGill)
May 10, 2018, CRM

The use of dialogue systems as a medium for human-machine interaction is an increasingly prevalent paradigm. A growing number of dialogue systems use conversation strategies that are learned from large data sets. In this talk Joëlle Pineau reviewed several recent models and algorithms based on both discriminative and generative models, and discussed new results on the proper performance measures for such systems. Finally she highlighted potential ethical issues arising in dialogue systems research, including implicit biases, adversarial examples, privacy violations, and safety concerns.

Short Program on Probability in Number Theory May 14–June 1st, 2018

The appearance of Probability in Number Theory can be traced back to a famous collaboration of Erdős and Kac. Nowadays probabilistic techniques are routinely used in the study of integers and L-functions. Until recently, however, there had not been much room for modern and deep techniques of probability theory. During the past few years this has changed notably. Conversely number-theoretic techniques and heuristics have been proven effective in resolving standing problems in combinatorics and discrete probability theory. The goal of this month-long program was to bring together experts from Number Theory and Probability to highlight and facilitate the interactions between these two fields of mathematics. Finally we mention that four Simons CRM Scholars-in-Residence visited the CRM as part of this program: Adam Harper (Warwick), Kevin Ford (Illinois, Urbana-Champaign), Andrew Granville (University College London), and K. Soundararajan (Stanford).

School on Probability in Number Theory
May 14–18, 2018, CRM

Organizers: Andrew Granville (Montréal), Dimitrios Koukoulopoulos (Montréal), Maksym Radziwiłł (McGill)

Lecturers: Kevin Ford (Illinois), Adam Harper (Warwick), K. Soundararajan (Stanford)

The "probability in number theory" program got off to a good start with a one-week summer school addressed to advanced graduate students and early career post-doctoral researchers. There was great interest in the school, as evidenced by the tightly packed room at the CRM throughout the week. The main thrust of the summer school consisted of three lecture series given by leading experts of the field: Kevin Ford, Adam Harper, and K. Soundararajan. These lectures were followed by short presentations by researchers attending the school. The short presentations resulted in the showcasing of some impressive work by the young attendees and allowed the senior participants to interact with some of the younger mathematicians who were previously unknown to them.

Maksym Radziwiłł

Workshop on Probability in Number Theory
May 21–June 1st, 2018, CRM

Organizers: Andrew Granville (Montréal), Dimitrios Koukoulopoulos (Montréal), Maksym Radziwiłł (McGill)

The workshop following the school was more colloquial and addressed to seasoned researchers. The format was also designed to make collaborations easier. This meant that every day consisted of two lectures, followed by lunch and a free afternoon devoted to collaborative research. Each senior participant received an office at the CRM. There was a fair bit of collaborations, with the CRM rooms and corridors buzzing with mathematical conversations. Many participants continued their existing long-term projects while others started new ones.

In terms of its short-term impact the program will certainly result in several research papers by the participants. In the long term we hope that it will be one out of many more programs at the intersection of probability and number theory. This intersection has long been neglected in the past but currently the field seems starved for more programs in this direction, which is only now emerging as an important player in analytic number theory.

Andrew Granville

Aisenstadt Chair


Claudia Klüppelberg

The Aisenstadt Chair was endowed by Montréal philanthropist Dr. André Aisenstadt. Each year one or more distinguished mathematicians are invited to spend at least one week (ideally one or two months) at the CRM. During his or her stay a Chairholder delivers a series of lectures on a specialized topic and is also invited to prepare a monograph. At the request of Dr. Aisenstadt, the first lecture given by an Aisenstadt Chairholder should be accessible to a wide audience. Generally speaking the research fields of the Chairholders are closely related to the CRM thematic program for the current period. The Aisenstadt Chairholders for 2017–2018 were Claudia Klüppelberg and Alexander J. McNeil; their lectures were part of the thematic semester on risk.

Claudia Klüppelberg
(Technische Universität München)

After studying mathematics and receiving her doctorate in 1987 at the University of Mannheim, Claudia Klüppelberg held teaching and research positions in Mannheim, at ETH Zürich, and in Mainz until she was appointed Full Professor of Mathematical Statistics at the Technische Universität München in 1997. From 2008 to 2011 she also led the focus group on risk analysis and stochastic modelling at the Institute of Advanced Studies in Munich.

The research interests of Professor Klüppelberg cover a large spectrum of topics in statistics and applied probability. Much of her work has been concerned with risk analysis and its applications in economics, finance, and the environment. The methods that she designed, developed, and implemented through cooperation with industry have contributed to the improvement of risk management practices.

With several books and over 150 scientific articles, Professor Klüppelberg is not only a prolific author but also a co-editor of the *Springer Finance Series* and the *Lévy Matters* subseries of Springer's *Lecture Notes in Mathematics*. She is an elected Fellow of the Institute of Mathematical Statistics and held various offices in the Bernoulli Society.

Within the framework of her Aisenstadt Chair, Claudia Klüppelberg visited the CRM between August 21 and September 7, 2018, and gave three lectures: on August 24, September 5, and September 7, respectively. The reader will find a summary of her lectures in the Autumn 2017 edition of the *Bulletin du CRM*.

Alexander J. McNeil

Alexander J. McNeil
(University of York)

Alexander McNeil has been Professor of Actuarial Science at the University of York since September 2016. Educated at Imperial College London and Cambridge University, he was formerly Assistant Professor in the Department of Mathematics at ETH Zürich and Maxwell Professor of Mathematics in the Department of Actuarial Mathematics and Statistics at Heriot-Watt University, Edinburgh, where he founded and led the Scottish Financial Risk Academy (SFRA) between 2010 and 2016.

Professor McNeil's research interests lie in the development of quantitative methodology for financial risk management and include models for market, credit and insurance risks, financial time series analysis, models for extreme risks and correlated risks, and enterprise-wide models for solvency and capital adequacy.

Professor McNeil has published numerous papers in leading statistics, actuarial, econometrics, and financial mathematics journals. He is a regular speaker at international risk management conferences. He is an Honorary Fellow of the (British) Institute and Faculty of Actuaries and a Corresponding Member of the Swiss Association of Actuaries.

Within the framework of his Aisenstadt Chair, Alexander McNeil visited the CRM from September 13 to October 6, 2018, and gave three lectures: on September 22, September 29, and October 6, respectively. The reader will find a summary of these lectures in the Autumn 2017 edition of the *Bulletin du CRM*.

Previous Aisenstadt Chairholders

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, Craig Tracy, Stéphane Mallat, Claude Le Bris, Akshay Venkatesh, Alexander Razborov, Angus MacIntyre, Yuri Gurevich, Jamie Robins, Renato Renner, John Preskill, Richard M. Schoen, László Erdős, Elon Lindenstrauss, Fedor Bogomolov, Helmut Hofer, David Gabai, Gang Tian, Simon A. Levin, David Aldous, Martin Nowak, Masaki Kashiwara, Zeev Rudnick, Carl Pomerance, Sophie Morel, Pierre Colmez, Nikita Nekrasov, Bertrand Eynard, Selim Esedoğlu, Nalini Anantharaman, Scott Sheffield, Yuval Peres, Vic Reiner, Boris Adamczewski

Summer Schools

The CRM annually sponsors the *Séminaire de mathématiques supérieures* or SMS (a summer school that is the oldest continuous mathematical activity in Montréal). This year the SMS was held at the CRM and focused on Contemporary Dynamical Systems. The CRM also organized two summer schools held at the CRM itself (on Deep Learning and Reinforcement Learning, respectively) and a summer school held at the University of British Columbia. It also provided financial support for a summer school of the Atlantic Association for Research in the Mathematical Sciences (July 3–28, 2017) and for the 16th Summer School on Quantum Information and the 12th Canadian Student Conference QI (May 28–June 9, 2017), both organized by the Université de Sherbrooke.

PIMS–CRM Summer School in Probability June 5–30, 2017, University of British Columbia

Sponsored by PIMS, the CRM, the National Science Foundation, the UBC Mathematics Department, and the International Association of Mathematical Physics

Local Organizers: Omer Angel, Mathav Murugan, Edwin Perkins, and Gordon Slade (UBC)

Scientific Committee: Louigi Addario-Berry (McGill), Siva Athreya (Indian Statistical Institute, Bangalore), Maria Emilia Caballero (UNAM, Mexico), Dayue Chen (Peking University), Zhen-Qing Chen (University of Washington, Seattle), Takashi Kumagai (Kyoto University), Jean-François Le Gall (Université Paris-Sud), Jeremy Quastel (Toronto), Maria Eulalia Vares (UFRJ, Rio de Janeiro)

The Summer School was a major educational event with more than 120 participants, who were exposed to the cutting edge of several areas under active investigation in probability. It was also a major networking event, where the next generation of researchers spent four weeks living and hiking and studying together, making contacts that will be valuable for their future careers. There were two main courses consisting of 24 hours of lectures each, three mini-courses consisting of three hours of lectures each, and twenty-nine 30-minute lectures by participants.

The two main courses were given by Marek Biskup (UCLA) and Hugo Duminil-Copin (IHES and Université de Genève). Three mini-courses were given by Sandra Cerrai, Christina Goldschmidt, and Martin Hairer, respectively. The reader will find more information on the school web site (http://www.math.ubc.ca/Links/ssprob17/index.php).

2017 SMS Summer School Contemporary Dynamical Systems July 10–21, 2017, CRM

Sponsored by the CRM, the Fields Institute, PIMS, MSRI, the ISM, the CMS, and IMPA

Organizers: Sylvain Crovisier (Paris-Sud), Konstantin Khanin (Toronto), Andrés Navas Flores (Santiago de Chile), Christiane Rousseau (Montréal), Marcelo Viana (IMPA), Amie Wilkinson (Chicago)

Here are the names and affiliations of the instructors and the course titles.

Thomas Barthelmé (Queen's University)
Anosov Flows in Dimension 3

Sylvain Crovisier (Université Paris-Sud)
Partial Hyperbolicity Conservative and Dissipative

Konstantin Khanin (University of Toronto)
Renormalization

Patrice Le Calvez (Université Pierre et Marie Curie)
Maximal Isotopies, Transverse Foliations and Orbit Forcing Theory for Surface Homeomorphisms

Andrés Navas Flores
(Universidad de Santiago de Chile)
Groups and Dynamics

Enrique Pujals
(Instituto de Matemática Pura e Aplicada)
Dynamics of Smooth Volume-Contracting Surfaces Diffeomorphisms

Jean-François Quint (Université de Bordeaux)
Random Walks on Groups: Limit Theorems

Juan Rivera-Letelier (University of Rochester)
Thermodynamic Formalism of One-Dimensional Maps

Federico Rodriguez Hertz
(Pennsylvania State University)
Group Actions, Rigidity and Beyond

Christiane Rousseau (Université de Montréal)
Singularities of Analytic Dynamical Systems Depending on Parameters

Ferrán Valdez (Universidad Nacional Autónoma de México)
Geometry and Dynamics on Infinite Type Flat Surfaces

Marcelo Viana
(Instituto de Matemática Pura e Aplicada)
Lyapunov Exponents

Amie Wilkinson (University of Chicago)
The Ergodic Hypothesis and Its Sequelæ

Aaron Courville

2017 Deep Learning Summer School June 26–July 1st, 2017, CRM

Sponsored by the CRM and CIFAR

Organizers: Graham Taylor (Guelph), Aaron Courville (Montréal), Yoshua Bengio (Montréal)

Here are the names and affiliations of the instructors and the course titles.

Yoshua Bengio (Université de Montréal)
RNNs

Phil Blunsom (University of Oxford)
Natural Language Understanding I, II

Aaron Courville (Université de Montréal)
Generative Models II

Nando de Freitas
(University of Oxford & Google DeepMind)
Learning to Learn

Surya Ganguli (Stanford University)
Computational Neuroscience II and Deep Learning Theory

Ian Goodfellow (Google Brain)
Generative models I

Matthew C. Johnson (York University)
Automatic Differentiation
Combining Graphical Models and Deep Learning

Hugo Larochelle (Google Brain)
Neural Networks 1, 2

Michael Robert Osborne
(Australian National University)
Probabilistic Numerics for Deep Learning
AI Impact on Jobs

Doina Precup (McGill University)
Machine Learning

Blake Richards (University of Toronto Scarborough)
Computational Neuroscience

Raquel Urtasun (Uber ATG & University of Toronto)
Structured Models / Advanced Vision

Max Welling (Universiteit van Amsterdam)
Approximative Inference

Richard Zemel (University of Toronto & Vector Institute)
Introduction to CNNs

2017 Reinforcement Learning Summer School July 3–5, 2017, CRM

Sponsored by the CRM and CIFAR

Organizers: Joëlle Pineau (McGill), Doina Precup (McGill)

Here are the names and affiliations of the instructors and the course titles.

Pieter Abbeel (University of California, Berkeley)
Policy Search for RL

Nando de Freitas
(University of Oxford & Google DeepMind)
Deep Control

Nicolas Le Roux (Google Brain)
Applications of Bandits and Recommendation Systems

Joëlle Pineau (McGill University)
Reinforcement Learning

Satinder Singh (University of Michigan)
Reinforcement Learning

Richard S. Sutton (University of Alberta)
TD Learning

Csaba Szepesvári (University of Alberta)
Theory of RL

Philip S. Thomas (Carnegie Mellon University)
Safe RL

Hado van Hasselt (Google DeepMind)
Deep Reinforcement Learning

Other Activities

The CRM organizes and sponsors several other activities in various areas of mathematics. In particular they may fit into the general program for activities held at or outside the CRM or organized by other institutions. They may also be part of the interdisciplinary and industrial program; finally they may be organized by the laboratories.

In 2017–2018, five workshops were held at the CRM as part of the general program and 14 events were held elsewhere. The CRM held three workshops in the interdisciplinary or industrial program. The laboratories, meanwhile, held 10 workshops.

Finally, the CRM, in collaboration with the *Institut des sciences mathématiques* (ISM), organizes the *Colloque des sciences mathématiques du Québec*, a series of overview lectures given by mathematicians and statisticians of international renown on topics of current interest.

General Program

The general program is used to finance a variety of scientific events, from highly specialized workshops for a small number of researchers to congresses for hundreds of people. The general program aims to encourage the development of research in the mathematical sciences at all levels. The program is flexible and projects are reviewed as they are proposed.

Activities Held at the CRM

CRM-IMPA Joint Workshop
Challenges at the Interface of Optimization and Stochastic Processes
July 18–21, 2017, Université de Montréal

Organizers: Louigi Addario-Berry (McGill), Roberto Imbuzeiro Oliveira (IMPA), Prasad Tetali (Georgia Tech)

Gauge Theories, Monopoles, Moduli Spaces and Integrable Systems
A Conference Honouring Jacques Hurtubise on his 60th Birthday
August 21–25, 2017, CRM

Organizers: John Harnad (Concordia), Lisa Jeffrey (Toronto), Niky Kamran (McGill), Eyal Markman (UMass Amherst)

This workshop brought together a distinguished group of researchers who have made key contributions to research at the confluence of three of the most active domains of geometry and mathematical physics, namely gauge theories, moduli spaces, and integrable systems, all of which have been themes to which Jacques Hurtubise has made major contributions over the course of his research career.

Higgs bundles figured prominently in the scientific program, with talks by Hitchin, Andersen, García-Prada and Wentworth addressing fundamental issues related to the topology of their moduli spaces, including critical loci, Verlinde formulae, and singularities. Significant progress in non-reductive geometric invariant theory was reported by Kirwan, while character varieties and torus links in relation to BPS states were explored in the talk by Pantev. Recent progress in understanding the relation between Hilbert schemes, rational maps, and hyper-kaehler metrics was described in the talk by Bielawski. Integrable systems also figured prominently in the program of the conference, for instance in the talks by Boalch (who addressed the link between Hitchin systems and connections on curves, particularly in relation to integrable systems), Dancer (who reported on integrable geometric flows in Riemannian geometry), and Rains (who considered non-autonomous integrable systems arising from discrete connections).

Further links between Hitchin systems and the geometric Langlands correspondence were described by Donagi, while the connections between integrable systems and enumerative geometry were discussed in the lecture by Harnad. Important advances in Poisson geometry in relation to groupoids, *D*-modules, and Hamiltonian flows on spaces of flat connections were respectively featured in the talks by Gualtieri, Pym, and Goldman, with further aspects of the Goldman Poisson bracket being described in the talk by Bertola. Connections with logarithmic singularities on Riemann surfaces were studied in the talk by Biswas, while the geometry of the Stokes phenomenon in the analysis of irregular singular points was presented in the talk by Rousseau. Moduli spaces of instantons and other geometric and topological aspects of gauge theories were central to the talks by Charbonneau, Cherkis, and Jardim. The Kaehler geometry of Bott manifolds and moduli spaces of stable bundles over non-Kaehler manifolds were discussed by Boyer and Moraru, respectively.

In summary, the conference featured a wide range of talks describing some of the most exciting recent developments in this rich and vibrant area of research, and provided a special opportunity to honour Jacques Hurtubise for his distinguished research career.

Workshop
The Beauty of Discrete Mathematics
October 10–13, 2017, CRM

Organizers: Geňa Hahn (Montréal), Reza Naserasr (CNRS, IRIF), Ben Seamone (Dawson College)

Artificial Intelligence & Neuroscience (MAIN)
November 18–21, 2017, Université de Montréal

Sponsored by two CFREF programs (IVADO and HBHL), the RBIQ network, the Université de Montréal, the CRM, Mila, the PERFORM centre (Concordia University), and Facebook

Organizers: Pierre Bellec (Montréal), Karim Jerbi (Montréal), Jean-Marc Lina (ÉTS), Pascal Vincent (Montréal)

Artificial intelligence is used ever more often to tackle a large spectrum of questions in fundamental, cognitive, and clinical neuroscience. On the other hand, artificial intelligence takes some of its inspiration from the neurosciences. Given the connections between artificial intelligence and neuroscience, the organizers of MAIN thought that a forum should be created where researchers from these two scientific fields could meet and exchange ideas. The objective of MAIN (Montreal Artificial Intelligence and Neuroscience) is precisely to improve the synergy between the two communities.

MAIN 2017 was a tremendous success: the audience consisted of 242 students and researchers (with 100 persons on a waiting list), the lecturers were outstanding scientists, and the conference afforded many opportunities for exchanges and networking. Two days were devoted to lectures and the two days of hands-on work on open-source software were particularly appreciated by students. MAIN 2017 enabled the organizers to create a new community focused on artificial intelligence and neuroscience in Montreal. The comments made to the organizers showed that the participants were very pleased with the conference and that there was an important need for such an event. Several participants suggested that MAIN become an annual event and welcome more people.

24 heures de science (13th edition)
Math on the Move
May 11, 2018, Université de Montréal

Sponsored by the CRM, CIRRELT, GERAD, the rcm$_2$, CIRANO, and the ISM

Organizer: Christiane Rousseau (Montréal)

Activities Held Outside the CRM

Colloque du Groupe de didactique des mathématiques du Québec
May 31–June 2, 2017, McGill University

Organizer: Laura Broley (Concordia)

41st Annual Meeting of the Canadian Mathematics Education Study Group
June 2–6, 2017, McGill University

Organizer: Laura Broley (Concordia)

CanaDAM 2017
June 12–15, 2017, Ryerson University

Sponsored by AAMRS, the CRM, the Fields Institute, PIMS, the CMS, Ryerson University, and the Office of Naval Research

Program Committee: Peter Cameron (St. Andrews), Fritz Eisenbrand (EPFL), David Eppstein (UC Irvine), Ian Goulden (Waterloo), Catherine Greenhill (UNSW), Venkat Guruswami (CMU), Nick Harvey (UBC), Christine Heitsch (Georgia Tech), Nicole Immorlica (Microsoft), Daniel Král' (Warwick), Joy Morris (Lethbridge), Cheryl Praeger (UWA), Bruce Shepherd (McGill), József Solymosi (UBC)

Executive Committee: Shannon Fitzpatrick (PEI), Geňa Hahn (Montréal), Gary MacGillivray (Victoria), Marni Mishna (SFU), Joy Morris (Lethbridge), Brett Stevens (Carleton)

Local Arrangements Committee: Anthony Bonato (Ryerson), Peter Danziger (Ryerson), Dejan Delic (Ryerson), Shannon Fitzpatrick (PEI), Konstantinos Georgiou (Ryerson), Pawel Pralat (Ryerson)

2017 Mixed Integer Programming Workshop
June 19–22, 2017, HEC Montréal

Sponsored by the Canada Excellence Research Chair in Data Science for Real-Time Decision-Making, CIRRELT, the CRM, GERAD, the NSF, the ONR, IBM, ExxonMobil, Mosek, SAS, Tepper School of Business (Carnegie Mellon), Gurobi Optimization, MathWorks, the Canadian Operational Research Society, and GAMS

Program Committee: Merve Bodur (Toronto), Daniel Espinoza (Gurobi), Fatma Kılınç-Karzan (CMU), Andrea Lodi (Polytechnique Montréal), Giacomo Nannicini (IBM)

Local Committee: Miguel Anjos (Polytechnique Montréal), Jean-François Cordeau (HEC Montréal), Andrea Lodi (Polytechnique Montréal), Odile Marcotte (UQAM), Louis-Martin Rousseau (Polytechnique Montréal)

Mixed Integer Programming (MIP) refers to the class of mathematical programming models in which some variables must take integer values while the other variables are allowed to take fractional (or real) values. The objective function and the constraints of the model are often (but not always) linear. As such the field of mixed integer programming has links to linear programming, nonlinear programming, and combinatorial optimization. In 2003 several researchers in mixed integer programming initiated a series of workshops on MIP: the first workshop was held in New York City and followed by workshops in various North American cities (including Montreal in 2007). The program of each of the workshops is composed of 20 to 25 invited talks, organized in a single track. The organizers of these workshops encourage students and junior researchers to participate and the workshops feature poster sessions.

Andrea Lodi

The invited talks at the 2017 MIP workshop covered many different topics related to MIP: cutting planes (talks by Bill Cook, Hassan Hijazi, Sven Wiese, and Matthias Koeppe); artificial intelligence (talks by Dorit Hochbaum, Yoshua Bengio, and Pierre Bonami); graph theory (talks by Volker Kaibel, Thorsten Koch, and Pablo Parrilo); non-linear optimization and interior point algorithms (talks by David Bergman, Michael Perregaard, and Sercan Yıldız); optimization models and formulations (talks by Miguel Anjos, Maurice Queyranne, and Austin Buchanan); improvements in the solution of linear and integer programs (talks by Daniel Dadush, Philipp Christophel, and Louis-Martin Rousseau). There were also talks on MIP with PDE constraints (Christoph Buchheim), dynamic programming (Angelos Georghiou), an integer programming game in health care (Margarida Carvalho), primal heuristics for integer programs (Santanu Dey), distributed optimization (Vahab Mirrokni), and conic mixed integer programs (Burak Kocuk).

An extremely well-attended poster session took place on Monday June 19, with 35 poster presenters covering virtually all aspects of Mixed Integer Linear and Nonlinear Optimization. The Poster Award Committee (consisting of Claudia D'Ambrosio, Ricardo Fukasawa, Oktay Gunluk, and David Morton) nominated Gonzalo Munõz from Columbia University as a winner and awarded an honourable mention to each of Joey Huchette from MIT and Giulia Zarpellon from Polytechnique Montreal. Overall the 2017 MIP workshop was very successful (as successful as the 2007 workshop!) and was attended by 215 participants (from many countries). We believe none of the previous workshops had as many participants.

XXXVI Workshop on Geometric Methods in Physics S. Twareque Ali Memorial Session
July 6, 2017, Białowieża

Sponsored by the CRM and Uniwersytet w Białymstoku

Organizers: A. Odzijewicz (Białystok), G. Goldin (Rutgers), J.-P. Antoine (UCLouvain), T. Bhattacharyya (IISc), J.-P. Gazeau (Paris-Diderot), J. Harnad (Concordia), F. Schroeck (Denver)

11th International Conference on Monte Carlo Methods and Applications
July 3–7, 2017, HEC Montréal

Sponsored by the CRM, GERAD, and IVADO

Organizer: Pierre L'Écuyer (Montréal)

Canadian Undergraduate Mathematics Conference
July 19–23, 2017, UQAM

Sponsored by the ISM, the Fields Institute, the CMS, the CRM, the AMQ, the SSC, CAIMS, AARMS, PIMS, the FRQNT, MapleSoft, and four Montréal universities (Concordia, McGill, Université de Montréal, and UQAM, including the mathematics departments and student associations of these universities)

Mathematical Congress of the Americas
July 24–28, 2017, Montréal

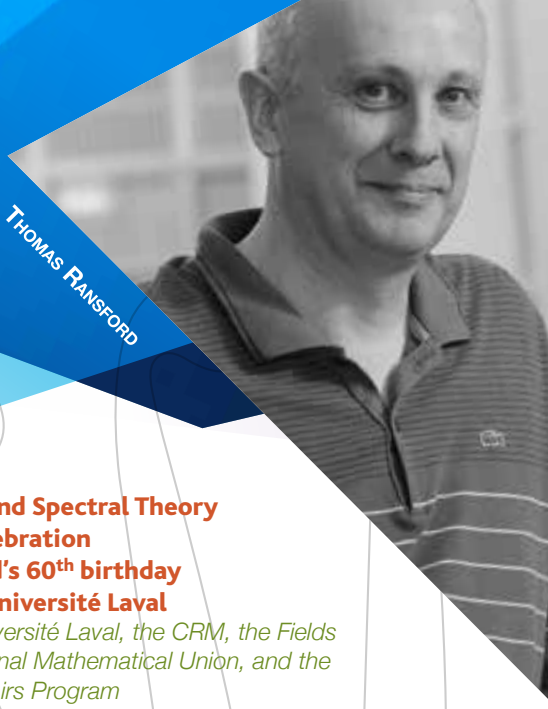
Sponsored by the CMS, PIMS, the Fields Institute, the CRM, AARMS, Tourisme Montréal, and the AMS

Program Committee: Noga Alon (Tel Aviv and IAS), Luis Caffarelli (Austin, Chair), Guillermo Cortiñas (Buenos Aires), Welington de Melo (IMPA), Mario Eudave (UNAM), Irene Fonseca (Carnegie Mellon), Servet Martinez (CMM, Chile), Kumar Murty (Toronto), Alfio Quarteroni (Lausanne), Yuri Tschinkel (NYU)

Organizing Committee: Brian Boe (University of Georgia and AMS), Steven Boyer (UQAM), Jacques Hurtubise (McGill), Christiane Rousseau (Montréal), Gantumur Tsogtgerel (McGill), Luc Vinet (Montréal and CRM)

Steering Committee: Alejandro Adem (MITACS), José Antonio de la Peña (CIMAT, Mexico), Susan Friedlander (USC), Jacques Hurtubise (McGill), Andrea Solotar (Buenos Aires), Marcelo Viana (IMPA)

The Mathematical Council of the Americas (MCofA) is a network of professional mathematical societies and research institutes based in the Americas, dedicated to promoting the development of mathematics, in all its aspects, throughout the continent. As a continental collaborative effort, special attention is given to cooperating with the Mathematical Union for Latin America and the Caribbean (UMALCA). The MCofA aims to highlight the excellence of mathematical achievements in the Americas within the context of the international arena and to foster the scientific integration of all mathematical communities in the continent.



The MCofA organizes a quadrennial Mathematical Congress of the Americas (MCA) that rotates host countries throughout the continent. The first MCA was organized by the *Centro de Investigación en Matemáticas* (CIMAT) and held in Guanajuato, Mexico, from August 5 to 9, 2013. This inaugural congress was well received and garnered the participation of about 1,000 mathematicians and students from all over the Americas and other parts of the world. The second MCA, held in Montréal and largely organized by CRM members, was also a big success (with almost 1,100 participants) and increased the visibility of the Québec mathematical community. For more information the reader is encouraged to peruse the congress site (https://mcs2017.org).

61e Congrès de l'Association mathématique du Québec
Les mathématiques au service de l'être humain
October 13–14, 2017, Cégep de l'Outaouais

Sponsored by the CRM, the ISM, and the CMS

Organizers: Olivier Rousseau, Andrée-Ann Pugin, Isabelle Goulet, Line Raymond, Pierre-Luc Ramier and Ousama Malouf (Cégep de l'Outaouais)

SUMM 2018 — Seminars in Undergraduate Mathematics in Montreal
January 12–14, 2018, Concordia University

Sponsored by the CRM, the ISM, the CMS Student Committee, and four Montréal universities (Concordia, McGill, Université de Montréal, and UQAM, including the mathematics departments and student associations of these universities)

Organizers: Kenzy Abdel-Malek (Concordia), Emilia Alvarez (Concordia), Raphaëlle Élément (Montréal), Alexis Langlois-Rémillard (Montréal), Véronique Marcotte (UQAM), David Marcil (McGill), Lycia Mameri (UQAM), Ben Sigman (Montréal), Daniel Zackon (McGill)

La Tempête des sciences
Partout la science!
April 11, 2018, Cégep Garneau

Event sponsored by Hydro-Québec, Syneos Health, Pearson ERPI, the Comité sectoriel de la main-d'oeuvre en transformation alimentaire, the Québec Government, the Faculty of Science and Engineering (Université Laval), and 27 adjunct partners (including the CRM)

Organizer: Nathalie Robitaille (Cégep Garneau)

Complex Analysis and Spectral Theory
A conference in celebration of Thomas Ransford's 60th birthday
May 21–25, 2017, Université Laval

Sponsored by the Université Laval, the CRM, the Fields Institute, the International Mathematical Union, and the Canada Research Chairs Program

Organizers: Line Baribeau, Alexandre Girouard, Frédéric Gourdeau, Damir Kinzebulatov, Javad Mashreghi, Jérémie Rostand (all from the Université Laval)

More than 50 participants from Canada, the United States, the United Kingdom, France, Morocco, Germany, Poland, Romania, Spain, Greece, and Ireland gathered to honour Professor Ransford, showing the extent of his network of collaborators. Mentors, past and present colleagues, and former students all expressed their appreciation of Thomas Ransford as a person and a mathematician and emphasized his talent as an expositor.

Altogether there were 35 talks. The scientific content illustrated the broad mathematical interests of Professor Ransford. His early career interests were addressed in talks on Banach algebras by Garth Dales and Jean Esterle; on classical complex analysis by Paul Gauthier and Richard Fournier; on several complex variables by Norm Levenberg and Lukasz Kosinski; and on potential theory by Dmitry Khavinson.

In a riveting talk, Isabelle Chalendar shared with the audience the story of her first collaboration with Thomas Ransford, when she was still a Ph.D. student and he was on sabbatical leave in Bordeaux, and showed recent applications of that work. It is during his time in Bordeaux that Ransford developed his interest in function spaces. This field was well represented at the conference, for instance with talks by co-author Omar El-Fallah, Emmanuel Fricain, and Catherine Bénéteau. Another visit to France, this time in Lille, was recalled by Laurent Marcoux and Mostafa Mbekhta.

The fourth day of the conference was entirely devoted to former students, who have branched out in a variety of subjects and places. Malik Younsi talked about conformal rigidity in circular domains, whereas Maxime Fortier Bourque talked about the local maxima of the systole function. Dominique Guillot discussed the problem of characterizing those functions that preserve positivity when applied entrywise to an $N \times N$ matrix and explained the relevance of such questions to data science. Constantin Costara presented results on spectral preservers and Mario Roy described recent advances on conformal graph directed Markov systems.

Workshop
Shimura Varieties and Hyperbolicity of Moduli Spaces
May 28–June 1st, 2018, UQAM

Sponsored by the IUF, the ANR, the CRM, CIRGET, and the UMI CRM

Organizers: Steven Lu (UQAM), Marc-Hubert Nicole (Aix–Marseille), Erwan Rousseau (Aix–Marseille)

Interdisciplinary and Industrial Program

The CRM has been organizing industrial problem solving workshops since 2007. In 2014 the three Canadian mathematics institutes (the CRM, the Fields Institute, and PIMS) were awarded an NSERC grant, called the Institutes Innovation Platform, to develop their industrial collaborations. This grant enabled the CRM to hire a Partnerships Development Officer, Dr. Stéphane Rouillon, and to organize more problem solving workshops. The CRM also decided to hold another kind of workshops, called networking industrial workshops. Such a workshop lasts for one day and consists of presentations by industrial partners, presentations by CRM laboratories, and exchanges between academic researchers and representatives from industry. Here are the workshops that were held in 2017–2018.

Eighth Montréal Industrial Problem Solving Workshop
August 7–11, 2017, CRM

Sponsored by the CRM, the Fields Institute, PIMS, CANSSI, and NSERC

Organizers: Thierry Duchesne (Laval), Michael Lamoureux (Calgary), Odile Marcotte (UQAM), Tom Salisbury (York), Stéphane Rouillon (CRM)

Team Coordinators: Farida Cheriet (Polytechnique Montréal), Pierre Duchesne (Montréal), Jean-Marc Frayret (Polytechnique Montréal), Bernard Gendron (Montréal), Huaxiong Huang (York), Philippe Langlais (Montréal), Manuel Morales (Montréal), Jean-François Plante (HEC Montréal), Bruno Rémillard (HEC Montréal), Louis-Martin Rousseau (Polytechnique Montréal)

Participating Companies: National Bank of Canada, National Research Council Canada, The Co-operators, CWP Energy, FPInnovations, Optina Diagnostics, Rio Tinto

In all 20 professors, 22 industrial representatives, and 65 students, postdoctoral fellows or research assistants took part in this workshop, which afforded the opportunity to study varied problems. These problems came from varied sources but also required tools from several mathematical disciplines: financial mathematics, combinatorial optimization, statistics, PDEs, etc. Six of the nine problems were proposed by companies that had submitted problems to previous workshops: the National Bank of Canada, Rio Tinto, The Co-operators (an insurance company), and FPInnovations (the research centre of the Canadian forestry industry). The Co-operators and FPInnovations each proposed two problems, a clear sign that they are enthusiastic about the CRM workshops! Optina Diagnostics and CWP Energy were proposing problems for the first time. Finally the workshop marked the beginning of a collaboration between the National Research Council of Canada (which proposed a problem) and the Canadian mathematics institutes.

The workshop gathered participants from all regions of Canada and from the United States and Europe (in particular a Polish student, three British students, and eight French students). The French students were welcomed within the framework of an exchange program between Canadian IPSWs and similar workshops held in France. For more information the reader may consult the workshop site (http://www.crm.umontreal.ca/probindustriels2017), where one can find the descriptions of the problems and the Monday and Friday presentations.

CRM Networking Industrial Workshop
Transportation
November 27, 2017, CRM

CRM Networking Industrial Workshop
Data Sciences
March 19, 2018, CRM

Activities Organized by the Laboratories

The members of the CRM laboratories organize not only activities within the thematic, general, and interdisciplinary CRM programs, but also activities that are supported by the laboratories themselves. Here are the activities organized by the laboratories in 2017–2018.

Translational-Oriented Quantitative Therapeutic Approaches: A Concerted Effort
June 12–14, 2017, Université de Montréal
Sponsored by the Faculty of Pharmacy of the Université de Montréal, in collaboration with the CRM, CAMBAM, and the GRUM

Organizer: Fahima Nekka (Montréal)

Workshop on Spatial Point Processes
June 22, 2017, UQAM
Sponsored by the Statistics Laboratory, CANSSI, the CRM, and UQAM

Organizer: Jean-François Cœurjolly (UQAM)

11th International Conference on Words
September 11–15, 2017, UQAM
Sponsored by LaCIM, UQAM, the CRM, and the Canada Research Chair in Algebra, Combinatorics and Computer Science

Organizers: Srečko Brlek (UQAM), Francesco Dolce (UQAM), Johanne Patoine (LaCIM), Élise Vandomme (UQAM)

The 2018 Montreal-Toronto Workshop in Number Theory
January 13–14, 2018, CRM
Sponsored by CICMA

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

Second Ruin Theory Day
February 22, 2018, UQAM
Sponsored by Quantact and the Canada Research Chair in Risk Management

Organizers: Hélène Cossette (Laval), David Landriault (Waterloo), Bin Li (Waterloo), Étienne Marceau (Laval), Jean-François Renaud (UQAM)

5th Workshop on Insurance Mathematics with a Special Session on Big-Data and Machine Learning in Risk Management
February 23, 2018, Université de Montréal
Sponsored by Quantact and IVADO

Organizers: Maciej Augustyniak and Manuel Morales (Montréal)

Quantact Workshop
Risk Management of Segregated Funds
March 9, 2018, Concordia University
Sponsored by Quantact, Concordia University, and the Autorité des marchés financiers

Organizers: Maciej Augustyniak (Montréal), Frédéric Godin (Concordia), Anne MacKay (UQAM)

1st Canadian Geometry and Topology Seminar
March 14–16, 2018, Fields Institute
Sponsored by the Fields Institute, PIMS, the CRM, CIRGET, NSERC, and the Ontario Government
Organizers: Steven Boyer (UQAM), Alejandro Adem (UBC), Ian Hambleton (McMaster)

North East Cosmology Workshop
March 16–18, 2018, McGill University
Sponsored by the Mathematical Physics Laboratory, the McGill High Energy Theory Group, the McGill Physics Department, and the McGill Space Institute
Organizers: Robert Brandenberger (McGill), Evan McDonough (McGill)

CRM–CANSSI Workshop
Statistical Inference for Complex Surveys
May 30–June 1st, 2018, CRM
Organizers: David Haziza (Montréal), Changbao Wu (Waterloo)

Colloque des sciences mathématiques du Québec

In 2017–2018, for Montréal, the colloquium was under the responsibility of Olivier Collin (UQAM), Henri Darmon (McGill), Dimitrios Koukoulopoulos (Montréal), Iosif Polterovich (Montréal), David A. Stephens (McGill), Hugh Thomas (UQAM), and Yang Yi (McGill). For Québec City the colloquium was under the responsibility of Ting-Hue Chen and Louis-Paul Rivest (both from the Université Laval).

September 15, 2017, UQAM
Siyuan Lu, Rutgers University
Isometric Embedding and Quasi-Local Type Inequality

September 29, 2017, Université de Montréal
John H. Conway, Princeton University
The First Field

October 13, 2017, Université de Montréal
Avi Soffer, Rutgers University
Supercritical Wave Equations

October 27, 2017, Université de Montréal
Justin Solomon, MIT
Beneath the Surface: Geometry Processing at the Intrinsic/Extrinsic Interface

November 17, 2017, UQAM
Jun-Cheng Wei, UBC
Recent Progress on De Giorgi Conjecture

November 24, 2017, McGill University
David R. Bellhouse, Western University
150 Years (and More) of Data Analysis in Canada

November 24, 2017, Université de Montréal
Stanislav Smirnov, Université de Genève & SkolTech
Complex Analysis and 2D Statistical Physics

December 8, 2017, UQAM
James Maynard, University of Oxford
Primes with Missing Digits

January 12, 2018, Université de Montréal
Semyon Dyatlov, UC Berkeley & MIT
What is Quantum Chaos

February 9, 2018, UQAM
Egor Shelukhin, Université de Montréal
Persistence Modules in Symplectic Topology

February 16, 2018, McGill University
Xiao-Li Meng, Harvard University
The Law of Large Populations: The Return of the Long-Ignored N and How It Can Affect Our 2020 Vision

February 16, 2018, Université de Montréal
Alexander Turbiner, UNAM
Quantum n-Body Problem: Generalized Euler Coordinates (from J-L Lagrange to Figure Eight by Moore and Ter-Martirosyan, Then and Today)

February 23, 2018, UQAM
Sabin Cautis, UBC
Cluster Theory of the Coherent Satake Category

April 13, 2018, UQAM
Eva Bayer, *EPFL*
Local-Global Principles in Number Theory

May 4, 2018, UQAM
Emmanuel Hebey, Université de Cergy–Pontoise
Klein–Gordon–Maxwell–Proca Systems in the Riemannian Setting

"Grandes Conférences du CRM"

In 2006 the CRM launched the *Grandes Conférences* lecture series in order to fulfill the expectations of a public wishing to understand important developments in the mathematical sciences. The *Grandes Conférences du CRM* feature outstanding lecturers whose presentations convey the power and beauty of mathematical research to a wide audience.

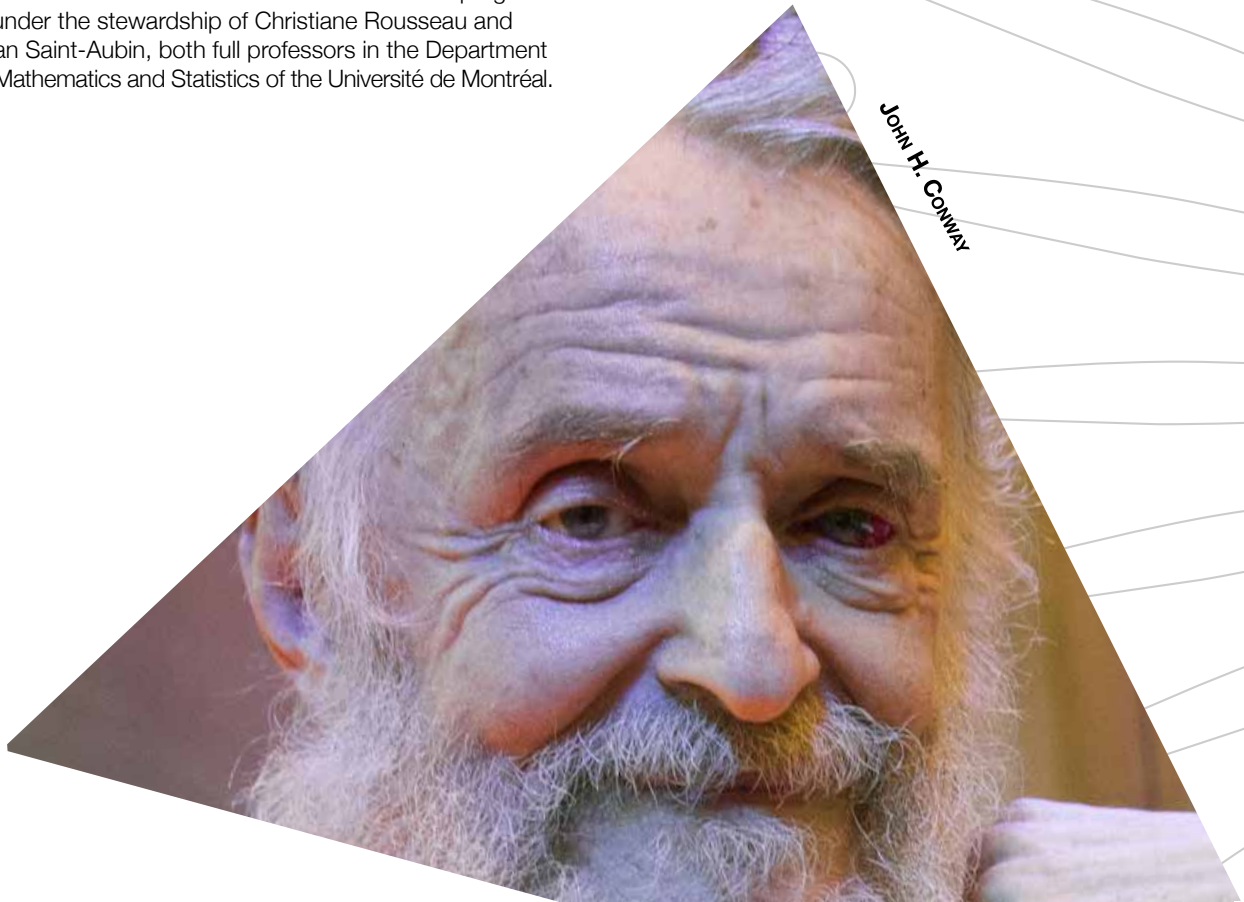
In 2017–2018 four lectures were delivered at the Université de Montréal: *The Faulhaber Triangle, the Bernoulli Numbers, and What They're Good For* by John H. Conway (September 27); *The Confidence Trap: Dysfunctional Dialogues about Climate* by Roger M. Cooke (October 18); *Le mouvement brownien, à quoi ça sert ?* by Stanislav Smirnov (November 23); and *Homer's Last Theorem — From Fermat to The Simpsons* by Simon Singh (March14). The reader will find below summaries inspired in part by texts published in *Le Bulletin du CRM* by Charles Alexandre Bédard, Christian Genest, Christiane Rousseau, and David Marcil.

Each of the lectures was attended by hundreds of participants of various ages. Receptions held after the lectures allowed members of the audience to ask questions, renew old acquaintances, and meet other attendees interested in science. The *Grandes Conférences* program is under the stewardship of Christiane Rousseau and Yvan Saint-Aubin, both full professors in the Department of Mathematics and Statistics of the Université de Montréal.

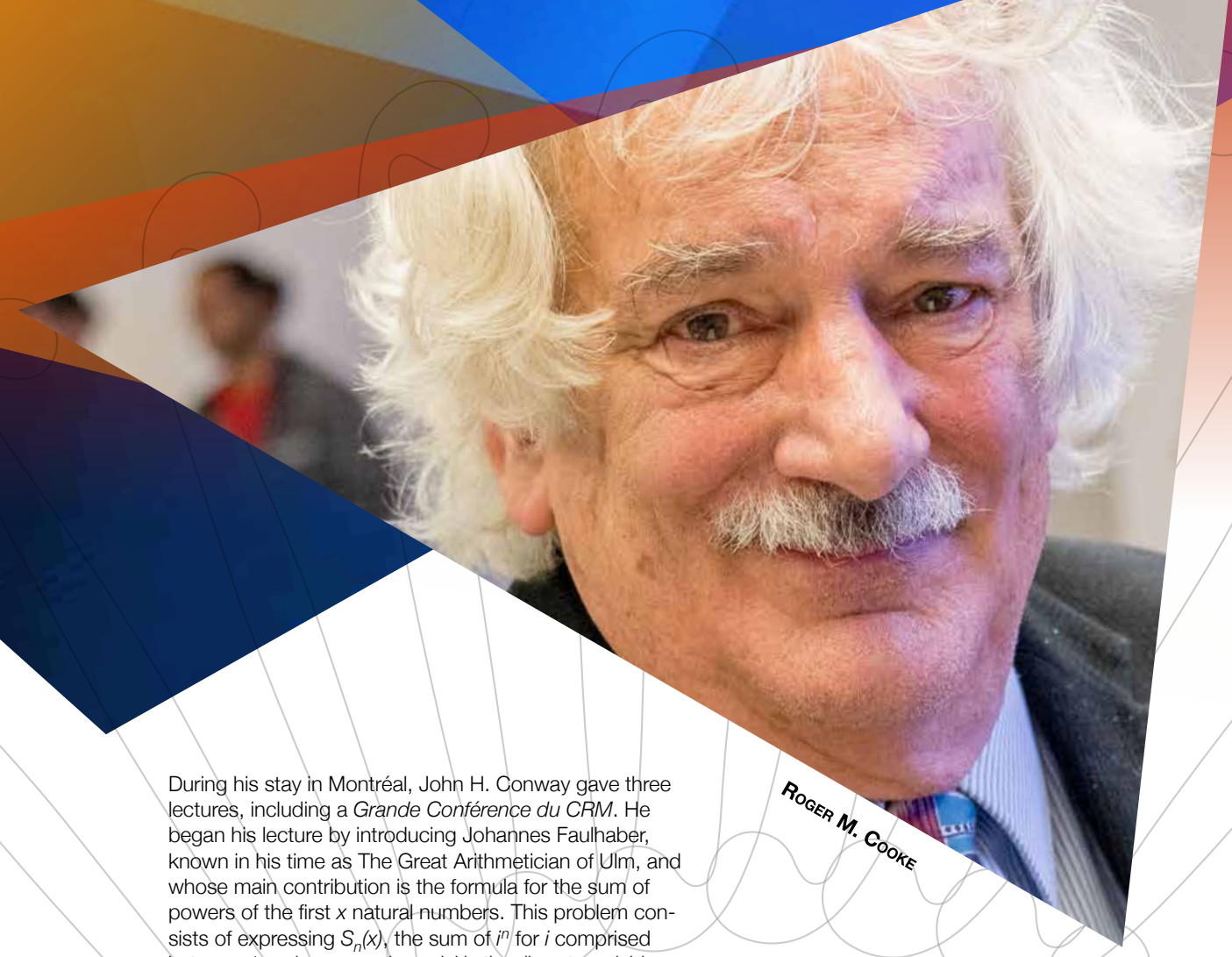
The Faulhaber Triangle, the Bernoulli Numbers, and What They're Good For

John H. Conway (Princeton University)

John H. Conway is an internationally known mathematician, famous also among amateur scientists for his invention of the Game of Life. This Game of Life was first introduced to the public in 1970 by Martin Gardner's column in the *Scientific American*, bringing instant celebrity to Conway. Even though many of his works start with playful considerations, his numerous deep results belong to classical domains of mathematics: analysis (through his surreal numbers), combinatorial game theory (through his theory of partisan games), algebra (through his Conway groups, his Moonshine conjectures, his work on the Atlas of finite groups), etc. Professor Conway received the Berwick Prize (1971), was elected a Fellow of the Royal Society (1981), was the first recipient of the Pólya Prize (1987), won the Nemmers Prize in Mathematics (1998), and received the Leroy P. Steele Prize for Mathematical Exposition (2000) awarded by the American Mathematical Society. He is now Professor Emeritus at Princeton University.



John H. Conway



Roger M. Cooke

During his stay in Montréal, John H. Conway gave three lectures, including a *Grande Conférence du CRM*. He began his lecture by introducing Johannes Faulhaber, known in his time as The Great Arithmetician of Ulm, and whose main contribution is the formula for the sum of powers of the first x natural numbers. This problem consists of expressing $S_n(x)$, the sum of i^n for i comprised between 1 and x, as a polynomial in the discrete variable x. The formulas for $S_0(x)$, $S_1(x)$, $S_2(x)$ are derived easily, and in a work entitled *Academia Algebrae* (1631), Faulhaber derived the first 17 polynomials of this type. To do this, he found algebraic relations between the sums of various powers and derived formulas for higher powers from those for smaller powers.

Professor Conway also introduced Faulhaber's triangle, whose $(n+1)^{st}$ row consists of the coefficients of powers of x in the polynomial $S_n(x)$. He then focused his attention on the coefficients of the x term in the different $S_n(x)$: these coefficients are called Bernoulli numbers because they were studied in detail by Jacob Bernoulli in the *Ars Conjectandi* (1713), although Bernoulli himself credits Faulhaber with their invention. Bernoulli made use of differential calculus to propose a general method for deriving $S_n(x)$ from $S_{n-1}(x)$.

At the end of his lecture Professor Conway gave a brief account of the links between methods developed for computing the Faulhaber coefficients and topics such as number theory, asymptotic series, and the Riemann zeta function. When leaving the lecture hall, several members of the audience asked John H. Conway to sign his book (*The Book of Numbers*): they were very pleased to have met the famous mathematician.

The Confidence Trap: Dysfunctional Dialogues about Climate

Roger M. Cooke (Resources for the Future)

Thanks to the Simons CRM Scholar-in-Residence Program, Professor Roger M. Cooke spent the month of October in Montréal and returned to Montréal in the Spring of 2018. On Wednesday evening, October 18, a packed audience at the Université de Montréal had the privilege of hearing him speak of the dysfunctional dialogues about climate that he has observed and, to an extent, helped to mend through his IPCC work.

The leitmotiv of Professor Cooke's presentation was that failure in communication about science often stems from a lack of appreciation for probabilistic thinking. In his view a cognitive illusion called the "Confidence Trap" is a major factor in explaining why the public climate debate currently runs the gamut from abysmal to bad. Some of the IPCC's poor uncertainty messaging, he says, has put it at a disadvantage in today's corrosive debate (the "climate wars"), characterized by a lopsided proof burden in which climate change deniers need not defend their positions but can win the public's support by merely instigating doubt about the scientific evidence. By arguing that "science isn't there yet," these sceptics are exploiting a politically and fiscally stressed environment to foster temporization. The stakes are so high, however, that delaying action until consensus is restored just won't be good enough, warned Professor Cooke; everyone will lose in the end. Statistical methods for integrating disparate sources of information can help us avoid the worst.

A confidence trap arises when deterministic reasoning is used in a probabilistic environment. To illustrate this point, think of a well-balanced die being cast *n* times. One can then be highly confident (with probability 5/6) in the statement "the result will not be a 6" on any given throw. Yet if the trials are mutually independent, the degree of confidence in the conjunction of events "for all *i = 1, 2, …, n* the result will not be a 6 on throw *i*" decreases rapidly with *n* (the probability that this statement is true is $(5/6)^n$). If the throws are dependent, however, the actual probability could lie anywhere between 0 and 5/6.

While most people can avoid this trap in a simple probabilistic context, they often fall right into it when they concatenate statements such as "The Earth is warming" or "Most of the warming over the last several decades can be attributed to human activities." IPCC reports express "high confidence" (i.e., about 8 chances out of 10 or higher) in these and each of its conclusions taken individually, but how should these assertions be combined? Professor Cooke contends that natural language is inadequate for communicating uncertainty and he has helped change IPCC practices in this regard. He also advocates greater care in accounting for uncertainty and dependence in reasoning about climate issues.

Professor Cooke emphasized that weather change projections under various physical and economic scenarios involve complex models for variables such as solar inputs, atmospheric composition and circulation, and that they depend on poorly understood interactions between the atmosphere, the biosphere, and the hydrosphere. While climatologists legitimately base their inferences on the most likely models, the degree of dependence between these models is unclear. Failure to account for these uncertainties can make experts unduly confident in their conclusions and expose them to unwelcome criticism.

In the last part of his talk, Professor Cooke delivered a vibrant plea in favour of the use of structured expert judgment in combining heterogeneous evidence and developing a rational consensus on uncertainty quantification. He described expert elicitation, calibration, and pooling techniques that enhance knowledge and encourage dialogue. His own work on Bayesian belief nets has shed light on several counterintuitive mechanisms related to probabilistic reasoning, such as negative learning (more data leads to greater uncertainty) and reduced uncertainty deriving from conflicting results or measurements.

Stanislas Smirnov

Le mouvement brownien, à quoi ça sert ?

Stanislas Smirnov
(Université de Genève & Skoltech)

On November 23, 2017, Stanislas Smirnov delivered a beautiful lecture in front of a packed room. He began by describing the first observations of Brownian motion by the Scottish botanist Robert Brown: a continuous and frantic motion of minuscule particles, whether pollen grains vacuoles or moss spores in water. Robert Brown first thought that the motion was biological in nature but quickly realized that it arose because of physical reasons. At the end of the XIXth century, more and more people were thinking that Brownian motion was due to the collision of particles with invisible molecules. Einstein adopted this idea to derive a theoretical model linking various physical parameters to the average distance travelled by particles. Einstein's model allowed Jean Perrin to compute the Avogadro number in a precise fashion, thus giving the first evidence for atomism!

This random walk can be modelled by forcing the particle to travel a distance σ in a random direction every ε seconds. Stanislas Smirnov gave an example of such a walk on the square lattice in the plane and showed that the standard deviation is of the order of σ multiplied by the square root of t/ε. The position X_n of the particle at time n tends towards a universal limit given by the Gaussian distribution. If one decreases the step size, the limit of the random walk is also universal: the limit is the Wiener process W_t, which has many applications. One of these is the modelling of the share prices by random walks, proposed by Louis Bachelier in the article entitled *Théorie de la spéculation*. Later Robert Merton and Myron Scholes were awarded the Nobel Prize for Economics for their work on the Black–Scholes model of options valuation (published in 1973).

Stanislas Smirnov then went back to the Brownian motion in two dimensions (2D) and presented Mandelbrot's conjecture, which states that the frontier of this motion is a fractal curve of dimension 4/3. This led him to define the notions of fractal curve and dimension of a fractal curve. Mandelbrot's conjecture was finally proved in 2001 by Gregory Lawler, Oded Schramm, and Wendelin Werner. These three authors and the lecturer himself showed that the frontier of the 2D Brownian motion coincides with the frontier of a sandpile percolation; they also made the conjecture that it coincides with a random polymer. Smirnov described briefly the percolation model, which enjoys much success because of its applications to forest fires, epidemics, erosion, etc.

Smirnov spoke about site percolation on the hexagonal lattice with critical value $p = 1/2$ and mentioned the numerical experiments carried out by Robert Langlands, Philippe Pouliot, and Yvan Saint-Aubin (described in their famous 1994 article). He also presented the formula for crossing probability proposed by Cardy in 1992, following a physical derivation: Smirnov gave a proof of this formula in 1991. Then he described the great idea of Oded Schramm on the frontiers of erosions: these frontiers are fractal curves whose evolution satisfies a stochastic differential equation, the Schramm-Loewner equation. This great idea led to the proof of Mandelbrot's conjecture. In practice, this means that for a box of dimensions 1000 x 1000, the length of a crossing is of the order of 10,000, making the crossing hard to observe... The dimension of the frontier equals 7/4 and the dimension of the eroded region equals 91/48.

Smirnov then focused on random polymers, of which an example is the DNA molecule (almost two-meter long!). How is it folded? Paul Flory, who was awarded the Nobel Prize for Chemistry in 1974, proposed a self-avoiding random walk model. If C_n denotes the number of random walks of length n, then C_n is of the order of $\mu^n n^{11/32}$, where μ depends upon the lattice. Bernard Nienhuis conjectured that 11/32 is a universal constant. Stanislas Smirnov, working with Hugo Duminil-Copin, proved in 2012 that μ equals the square root of "2 + square root of 2" on the hexagonal lattice.

Smirnov concluded his lecture by describing some applications, such as the partitions of rectangles into squares whose side lengths are integers and a cellular automaton in a reaction-diffusion equation for lizard skin patterns. The second topic led to a publication in *Nature* in 2017 (*A living mesoscopic cellular automaton made of skin scales*) by Stanislas Smirnov and biologists.

Homer's Last Theorem — From Fermat to The Simpsons

Simon Singh

The content of Simon Singh's lecture on March 14 can be summarized by the word "intuition." Singh stated that mathematics and science are important for society because they help us distinguish between reality and human intuition. To illustrate this claim, he first carried out an experiment with the audience. The song *Stairway to Heaven*, by Led Zeppelin, is often said to hide satanic messages within its lyrics, when played backwards. When the song was played backwards for the first time in the room, the audience did not notice anything special. When Singh, however, displayed the so-called satanic lyrics while playing the song for a second time, everybody was able to "hear" the displayed lyrics. These words did not appear magically in the song between the two hearings: the human brain, when reading the so-called satanic lyrics, can introduce the missing sounds and convince itself that it is hearing these lyrics. Singh explained that human intuition makes up a "reality" that does not exist, while science forces us to adopt logical thinking and avoid such traps.

SIMON SINGH

The goal of Simon Singh was to share the beauty of science and mathematics with his audience. He presented his book *Big Bang: The Origin of the Universe*, in which he shows how the attitude of the scientific community towards the Big Bang Theory evolved with time. The Big Bang Theory was first proposed by a priest, Georges Lemaître, and some people claimed that he was biased because of his religious opinions. To these critics Lemaître answered that "There exist two paths for reaching the truth. I followed both of them." This amounted to saying that his results were based on scientific experiments only (in spite of his beliefs). His model was eventually recognized as being valid by his fellow physicists: scientific reasoning had allowed cosmologists to discover a wonderful theory!

Finally Simon Singh spoke about his most famous work, *Fermat's Last Theorem*, in which he recounts the lives of Pierre de Fermat and Sir Andrew Wiles and discusses the influence both mathematicians had on the history of mathematics. The mathematical community is well aware of this story but Singh wishes to convey it to the general public. He also produced a documentary film on this topic, in which he interviews Sir Andrew Wiles himself. Singh is not the only one to try to popularize the topic: the famous television program *The Simpsons* "hides" references to Fermat's Last Theorem in several of its installments. For instance it includes "counterexamples" to the theorem such as $3987^{12} + 4365^{12} = 4472^{12}$. This equality is not valid but the numbers it contains are so large that it is difficult to show this. The presence of these "counterexamples" is not a coincidence: indeed several scriptwriters for *The Simpsons* have a good knowledge of mathematics and computer science. They wish to share their passion with the public, as does Simon Singh.

The lecture concluded with several examples of this kind. At the end of the lecture, members of the audience were able to meet the famous author and talk to him about the varied topics Singh addresses in his publications.

Laboratories

The CRM laboratories act as focal points for local research in mathematics and participate actively in the scientific programming of the CRM. Members of the laboratories organize thematic years or semesters, coordinate activities and seminars sponsored by the laboratories themselves, and train graduate students and postdoctoral fellows. The laboratories involve members from many universities and therefore greatly facilitate collaboration between researchers in Québec.

Mathematical Analysis

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. The laboratory includes regular and associate members working at more than ten different universities in Canada, the United Kingdom, France, and Austria. The members of the laboratory work in the following areas: harmonic analysis, complex analysis, several complex variables, potential theory, functional analysis, Banach algebras, microlocal analysis, analysis on manifolds, non-smooth analysis, spectral theory, partial differential equations, geometric analysis, ergodic theory and dynamical systems, control theory, mathematical physics, probability, non-linear analysis, non-linear differential equations, topological methods in differential equations, fluid dynamics, and turbulence.

The laboratory members organize (on their own or with other laboratories) several seminars that take place regularly in Montréal universities, at the Université Laval, and at the Université de Sherbrooke.

Highlights

In 2018, Professor Guillaume Poliquin (Cégep Ahuntsic) became an associate member of the Analysis Laboratory. His main mathematical interests are in spectral theory and he is working on various problems related to spectral and nodal geometry, including the study of nodal sets of eigenfunctions of the Laplacian and other linear and nonlinear differential operators on Riemannian manifolds. Professor Poliquin is also working on L_p bounds for eigenfunctions, isoperimetric inequalities for eigenvalues, and the shape optimization problem for the Laplacian in various settings.

Dmitry Jakobson

In 2017–2018, members of the Analysis Laboratory organized or co-organized activities mentioned elsewhere in this report. For instance, Christiane Rousseau co-organized the *Séminaire de mathématiques supérieures* on Contemporary Dynamical Systems (mentioned in the section on summer schools); members of the laboraroty organized five thematic sessions within the Mathematical Congress of the Americas (mentioned in the section on other activities); Pengfei Guan, Alina Stancu, and Jérôme Vétois were three of the organizers of the Workshop on Geometric Analysis (mentioned in the section on the 50th Anniversary Program); and Pengfei Guan, Dmitry Jakobson, Iosif Polterovich, and Alina Stancu co-organized the Nirenberg Lectures in Geometric Analysis (also mentioned in the section on the 50th Anniversary Program).

Students and Postdoctoral Fellows
In 2017–2018, the members of the Mathematical Analysis Laboratory supervised 36 M.Sc. students, 34 Ph.D. students, and 16 postdoctoral fellows.

Director
Dmitry Jakobson (McGill)

Regular Members
Marlène Frigon, Paul M. Gauthier, Iosif Polterovich, Christiane Rousseau, Dana Schlomiuk (Montréal)

Stephen W. Drury, Vojkan Jakšić, Paul Koosis, John A. Toth, Jérôme Vétois (McGill)

Abraham Boyarsky, Galia Dafni, Pawel Góra, Alexey Kokotov, Alexander Shnirelman, Alina Stancu, Ron J. Stern (Concordia)

Line Baribeau, Alexandre Girouard, Frédéric Gourdeau, Damir Kinzebulatov, Javad Mashreghi, Thomas J. Ransford, Jérémie Rostand (Laval)

Tomasz Kaczinski (Sherbrooke)

Dominic Rochon (UQTR)

Vadim Kaimanovich (Ottawa)

Richard Fournier (Dawson College)

Francis H. Clarke (Université Claude Bernard)

Robert Seiringer (IST Austria)

Associate Members
Octav Cornea, Richard Duncan, Samuel Zaidman (Montréal)

Kohur Gowrisankaran, Pengfei Guan, Niky Kamran, Ivo Klemes (McGill)

John Harnad, Dmitry Korotkin (Concordia)

Guillaume Poliquin (Cégep Ahuntsic)

Nilima Nigam (Simon Fraser)

Yiannis Petridis (University College London)

CAMBAM
Centre for Applied Mathematics in Bioscience and Medicine

The mission of CAMBAM is to be a leading institution in the application of mathematics to address challenges in bioscience and medicine through partnerships with industry, government, and other stakeholders in society. CAMBAM meets its objectives by promoting and fostering research, teaching, and training in applications of quantitative biology at all levels, ranging from the molecular/genetic through single-cell and whole-organ physiology and biology to population dynamics and broader ecological questions, on time scales from the present to the evolutionary; by honing the talents of students at all levels through unique training opportunities in academic and non-academic settings; and by conducting applied research of the highest scientific rigour, meeting existing industry and societal demands in clinical and public health settings.

CAMBAM organizes two seminar series. The first series, called Cutting Edge Lecture Series, is geared towards the general public and consists of one lecture per month, delivered at the Redpath Museum of McGill University. Each lecture draws more than 80 people. The second series is attended by CAMBAM members: it consists of lectures delivered by CAMBAM researchers and invited researchers, who present their work.

Highlights

CAMBAM and the NSERC-CREATE program in Complex Dynamics of Brain and Behavior jointly organized a summer school in nonlinear dynamics applied to the life sciences. Moreover, to support the summer school, CAMBAM received a 26,000 dollar grant from the William K. and Katherine W. Estes Foundation and the Psychonomic society. This international school took place at McGill University on June 18–29, 2018 and was attended by 18 invited speakers and more than 40 students. CAMBAM gave eight scholarships (whose total value amounted to 45,000 dollars) to graduate students and postdoctoral fellows, thus stimulating interdisciplinary research in biology and mathematics.

The 2017–2018 academic year featured an emerging partnership between CAMBAM and a new doctoral program in quantitative life sciences (QLS) at McGill University. CAMBAM and the QLS program jointly organized a series of lectures in quantitative biology that enabled them to invite 13 renowned external lecturers. This partnership also led to the creation of an annual symposium in quantitative biology during the Fall of 2018. CAMBAM is very proud to have participated in the Diamond Symposium organized in honour of Leon Glass and Michael Mackey, two pillars of CAMBAM. The Diamond Symposium took place on June 14–15, 2018, and included lectures by their former students and colleagues.

Students and Postdoctoral Fellows

In 2017–2018 the CAMBAM members supervised or cosupervised 14 M.Sc. students, 26 Ph.D. students, and 8 postdoctoral fellows.

Co-directors

Erik Cook and Frédéric Guichard (McGill)

Regular Members

Jacques Bélair, Alain Vinet (Montréal)

Mathieu Blanchette, David L. Buckeridge, Maurice Chacron, Vamsy Chodavarapu, Kathleen Cullen, Paul François, Gregor Fussman, Leon Glass, Michael Guevara, Anthony R. Humphries, Anmar Khadra, Svetlana V. Komarova, Brian Leung, Michael C. Mackey, Jacek Majewski, Sam Musallam, Christopher Pack (McGill)

André Longtin, Frithjof Lutscher (Ottawa)

Associate Members

Fahima Nekka (Montréal)

Juli Atherton (UQAM)

Lea Popovic (Concordia)

Claire de Mazancourt, Michel Loreau (CNRS)

Moisés Santillán Zerón (Cinvestav)

Vincent Lemaire (Pfizer)

Henri Darmon

CICMA
Centre interuniversitaire en calcul mathématique algébrique

CICMA includes researchers working in number theory, group theory, and algebraic geometry. Algebraic geometry is a broad discipline having close links with diverse fields from arithmetic to theoretical physics. Eyal Goren and Adrian Iovita are leaders in the application of techniques from algebraic geometry to problems arising in number theory, especially Shimura varieties and p-adic cohomology theories. John McKay is one of the instigators of the mooshine program, which ties together, in a surprising way, certain notions in the theory of modular forms, arithmetic geometry, and theoretical physics.

Number theory has developed over the last decades following two major trends: on one hand algebraic number theory, including such themes as the study of special values of L-functions attached to arithmetic objects, which originates in the work of Gauss and Dirichlet and leads to the modern conjectures of Deligne, Beilinson, and Bloch–Kato. Another theme of algebraic number theory, originating in the Langlands program, postulates a close link between arithmetic L-functions and automorphic representations.

On the other hand, analytic number theory addresses deep and subtle questions concerning the distribution of primes. It makes use of mathematical analysis techniques, especially functions of several complex variables and spectral theory. Number theory in all its different flavours is particularly well represented in the laboratory, with Darmon, Goren, Iovita, and Kassaei on the arithmetic and automorphic side, and David, Granville, Kisilevsky, Koukoulopoulos, and Lalín on the more analytic side of the subject.

The members of CICMA organize the Analytic Number Theory Seminar and the Quebec–Vermont Number Theory Seminar.

Highlights

The 2017–2018 academic year was a particularly active one for CICMA. In addition to its usual activities (Quebec–Vermont Number Theory Seminar, Quebec–Maine Conference, Montreal–Toronto Workshops, etc.), its members were also involved in the organization of the Short Program on Probability in Number Theory (described in the section on the 50th anniversary program). CICMA members were also involved in the preparation of a workshop celebrating CICMA's post-doctoral program, which was held in July 2018 and was also part of the 50th anniversary program. The success and influence of CICMA were underscored by the awarding of the Ribenboim Prize to Maksym Radziwiłł at the meeting of the Canadian Number Theory Association in July 2018, and the fact that two current members (Adrian Iovita and Maksym Radziwiłł) and three former postdocs (Fabrizio Andreatta, Kaisa Matomäki, and James Maynard) were invited to give 45-minute lectures in the number theory session of the ICM in Rio de Janeiro (in August 2018).

Students and Postdoctoral Fellows

In 2017–2018 the members of CICMA supervised or cosupervised one undergraduate student, 17 M.Sc. students, 39 Ph.D. students, and 21 postdoctoral fellows.

Director

Henri Darmon (McGill)

Regular Members

Andrew Granville, Dimitrios Koukoulopoulos, Matilde Lalín (Montréal)

Eyal Z. Goren, John Labute, Michael Makkai, Maksym Radziwiłł, Peter Russell (McGill)

Chris J. Cummins, Chantal David, Adrian Iovita, Hershy Kisilevsky, John McKay, Giovanni Rosso (Concordia)

Hugo Chapdelaine, Jean-Marie De Koninck, Antonio Lei, Claude Levesque (Laval)

Damien Roy (Ottawa)

M. Ram Murty (Queen's)

David S. Dummit (Vermont)

Associate Members

Daniel Fiorilli, Abdellah Sebbar (Ottawa)

Payman L. Kassaei (King's College London)

CIRGET
Centre interuniversitaire de recherches en géométrie et topologie

Topology and differential geometry are fundamental disciplines of mathematics whose richness and vitality, evident throughout history, reflect a deep link to our experience of the universe. They are a focal point of modern mathematics and indeed several domains of mathematics have recently shown a strong trend towards a geometrization of ideas and methods: two cases in point are mathematical physics and number theory.

CIRGET, based at UQAM, is composed of regular and associate members and a large number of postdoctoral fellows and graduate students working in this broad field. The main themes to be pursued in the coming years include the topological classification of 3-dimensional manifolds; the quantization of Hitchin systems and the geometric Langlands program; the classification of special Kähler metrics; the study of symplectic invariants, especially in dimension 4; non-linear partial differential equations in Riemannian geometry, convex geometry, and general relativity; and Hamiltonian dynamical systems. Two further domains are represented within CIRGET: algebraic geometry (through Steven Lu's and Peter Russell's work) and geometric group theory (through Daniel Wise's work).

The members of CIRGET organize several seminars in geometry and topology, symplectic topology, and geometric group theory, as well as the CIRGET Junior Seminar.

Highlights

During the 2017–2018 year, CIRGET had a flurry of scientific activity with the organization of five workshops and one summer school and a record number of visitors (ten in all), who stayed for periods ranging from one month to one year. UQAM's Faculty of Science gave a new working room to the Centre in September 2017, improving CIRGET's capacity to welcome visitors and hold more scientific events locally.

To celebrate CIRGET member Jacques Hurtubise's 60th birthday, the conference Gauge Theories, Monopoles, Moduli Spaces and Integrable Systems took place at the CRM on August 21–25, 2017, bringing together world leaders in the field as well as former students and postdoctoral fellows. Also this year, the 1st Canadian Geometry and Topology Seminar was officially launched. Held at the Fields Institute, the initiative was organized by Steven Boyer (CIRGET), Alejandro Adem (PIMS), and Ian Hambleton (Fields). We hope that this Canada-wide event will be held every two years.

CIRGET has benefited immensely from the different programs that fund long-term visitors. The CNRS Unité Mixte Internationale at the CRM (formally called CRM – UMI 3457) enabled the Centre to welcome six visitors (Stéphane Guillermou, Stéphane Lamy, Marc-Hubert Nicole, Yann Rollin, Georges Dloussky, and Paolo Ghiggini) and the new Simons CRM Scholar-in-Residence Program brought us two more visitors (Jacob Rasmussen and Sarah Rasmussen).

Students and Postdoctoral Fellows

In 2017–2018 the members of CIRGET supervised or cosupervised one undergraduate student, 24 M.Sc. students, 41 Ph.D. students, and 21 postdoctoral fellows.

Director

Steven Boyer (UQAM)

Regular Members

Abraham Broer, Octav Cornea, François Lalonde, Iosif Polterovich, Egor Shelukhin (Montréal)

Vestislav Apostolov, Olivier Collin, André Joyal, Steven Lu, Mark Powell, Frédéric Rochon (UQAM)

Pengfei Guan, Jacques Hurtubise, Niky Kamran, Mikaël Pichot, Piotr Przytycki, Peter Russell, Johannes Walcher, Daniel T. Wise (McGill)

Virginie Charette, Liam Watson (Sherbrooke)

Emmanuel Giroux (UMI CRM)

Associate Members

Dmitry Jakobson, Marcin Sabok, John A. Toth (McGill)

John Harnad (Concordia)

Maia Fraser (Ottawa)

Clément Hyvrier (Cégep de Saint-Laurent)

GIREF
Groupe Interdisciplinaire de Recherche en Éléments Finis

The recent advances in computer hardware and software allow researchers to model and simulate physical phenomena whose complexity is unheard of. These problems are characterized by non-linear laws, non-differentiable friction laws, large-deformation geometries, complex solid-solid or fluid-solid interactions, problems in multiphysics, etc. Such problems can be found everywhere in industrial environments, especially in the design and fabrication of high-technology products. Hence the members of GIREF (an acronym that means "Interdisciplinary Research Group in Finite Element Methods") aim to develop original numerical methods for solving cutting-edge industrial problems in non-linear mechanics. Their work concerns pure mathematics, computer science, software engineering, and engineering. The GIREF members propose general methods that can be used for diverse industrial applications.

GIREF organizes a regular seminar on the research areas of its members.

Highlights

In 2017–2018 two new industrial partnerships were initiated: one with Hydro-Québec and one with Bodycad. In the case of the partnership with Hydro-Québec, the first step consisted of a survey of the company's need for numerical simulation through finite elements. GIREF members decided to start working by modelling the cooling down of a transformer. This problem is very important in practice and requires a thermohydrodynamical model to simulate the oil flow in the transformer coupled with a thermal model (for the solid parts of the transformer).

As far as the partnership with Bodycad is concerned, GIREF members are developing custom-made biomedical prostheses, especially prostheses for knees and hips. Our MEF++ software will be integrated into the Bodycad design chain. To prevent the wear and tear of the prosthesis it is essential to simulate the deformable-rigid frictional contact between various parts of the prosthesis. GIREF members have also started a collaboration with the *Groupe de recherche en épidémiologie des zoonoses* (in Saint-Hyacinthe) on the interaction between birds, small mammals, deers, and ticks; the goal of this project is to model Lyme's disease in the south of Québec and GIREF members are hoping to extend this model to Canada as a whole.

Students and Postdoctoral Fellows

In 2017–2018 the members of GIREF supervised or cosupervised 16 M.Sc. students, 24 Ph.D. students, and 4 postdoctoral fellows.

Director

André Fortin (Laval)

Deputy Director

André Garon (Polytechnique Montréal)

Regular Members

Jean Deteix, Nicolas Doyon, Michel Fortin, Robert Guénette, Khader Khadraoui, René Therrien, José Urquiza (Laval)

Associate Members

Michel Delfour (Montréal)

Alain Cloutier, Marie-Laure Dano, Guy Dumas, Mathieu Olivier (Laval)

Stéphane Étienne, François Guibault, Dominique Pelletier (Polytechnique Montréal)

Yves Bourgault (Ottawa)

Mohamed Farhloul, Sophie Léger (Moncton)

Youssef Belhamadia (American University of Sharjah)

LaCIM
Laboratoire de combinatoire et d'informatique mathématique

LaCIM is a research centre gathering researchers in mathematics and mathematical computer science working in algebraic combinatorics, discrete mathematics, and the mathematical aspects of computer science. LaCIM was founded in 1989 and includes regular members, postdoctoral researchers, and associate researchers. The regular members of LaCIM supervise, on their own or with collaborators, Ph.D. and M.Sc. students and summer interns (who are undergraduate students). The research interests of LaCIM members have broadened considerably since 1989: it is considered as one of the main research groups worldwide in algebraic combinatorics, enumerative combinatorics, and word combinatorics. Some LaCIM researchers work in bioinformatics and analysis of algorithms. The laboratory welcomes many visitors and researchers who are leaders in the subjects studied at LaCIM. The laboratory also maintains numerous collaborations with most of the great centres in combinatorics, especially centres in France, the United States, and Canada. The combinatorics and mathematical computer science seminar takes place each Friday at LaCIM, from September to June.

Highlights

LaCIM members organized at the CRM the Thematic Semester on Algebra and Words in Combinatorics (March–June 2017), which concluded in June 2017 with the workshop on Algebraic and Geometric Combinatorics of Reflection Groups and the workshop on Equivariant Combinatorics. Members of LaCIM (in particular Srečko Brlek, Christophe Reutenauer, Sylvie Hamel, Ibrahim Assem, and Franco Saliola) co-organized two international conferences in 2017 (Words 2017 and CANCWiC 2017) and two annual meetings in 2017–2018 ("Advances in Representation Theory of Algebras VI" in September 2017 and "Combinatorial Algebra meets Algebraic Combinatorics" in January 2018). Recall that Hugh Thomas (a regular member of LaCIM) holds the Canada Research Chair in Algebra, Combinatorics and Computer Science, and that this CRC is associated with LaCIM. LaCIM is also the Canadian pole of the *Laboratoire International Franco-Québécois de Recherche en Combinatoire* (LiRCO), a CNRS International Laboratory.

Students and Postdoctoral Fellows

In 2017–2018 the members of LaCIM supervised or cosupervised 25 M.Sc. students, 33 Ph.D. students, and 9 postdoctoral fellows.

Director

Christophe Hohlweg (UQAM)

Regular Members

Sylvie Hamel (Montréal)

Anne Bergeron, François Bergeron, Alexandre Blondin Massé, Srečko Brlek, Gilbert Labelle, Vladimir Makarenkov, Christophe Reutenauer, Franco Saliola, Hugh Thomas (UQAM)

Ibrahim Assem, Thomas Brüstle, Shiping Liu (Sherbrooke)

Benoît Larose (Champlain Regional College)

Associate Members

Alain Goupil (UQTR)

Xavier Provençal, Laurent Vuillon (Savoie Mont Blanc)

Vincent Pilaud (LIX)

Adam Oberman

Applied Mathematics

The Applied Mathematics Laboratory is a research network of around 20 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 also 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.

Highlights

In 2017–2018 the Applied Mathematics Laboratory welcomed (and supported) three postdoctoral fellows: Xin Yang Lu, Evan DeCorte, and Maxime Laborde. Laboratory members received many honours. In particular Jean-Christophe Nave was awarded China's Yinzhi Fellowship (at Shanghai Jiaotong University) and the Carrie M. Derick Award for Graduate Supervision and Teaching (McGill's highest graduate supervision award); he was appointed a member of an NSERC Evaluation Group (EG1508) for the period 2018–2021. André Bandrauk had 20 publications in 2017–2018 and was invited at COFIL 2018, an international conference on laser filamentation. In recent articles published in *Journal of Physics B*, *Nature Communications*, and *Physical Review A*, he proposed and developed a new scientific direction, i.e., new ultrafast laser probing experimental methods for measuring ultrafast nuclear motions in molecules.

Jean-Philippe Lessard was awarded an NSERC Discovery Accelerator Supplement for the period 2018–2021; he was a plenary speaker in January 2018 at the Winter Workshop on Dynamics, Topology and Computations (Stefan Banach International Mathematical Center, Poland) and in August 2017 at The XI Americas Conference on Differential Equations and Nonlinear Analysis (University of Alberta). Adam Oberman gave invited lectures at Google Brain Montreal, Microsoft Research Montreal, Microsoft Research Redmond, and Facebook Artificial Intelligence Research Montreal. He also joined the Editorial Board of the *Journal of Dynamics and Games*. Rustum Choksi gave a series of lectures at the Ninth Summer School in Analysis and Applied Mathematics (Università di Roma La Sapienza, June 2017) and invited lectures on solid mechanics and mathematical analysis at the IHP (Paris, June 15–16, 2017).

Students and Postdoctoral Fellows
In 2017–2018 the members of the Applied Mathematics Laboratory supervised or cosupervised 2 undergraduate students, 11 M.Sc. students, 31 Ph.D. students, and 7 postdoctoral fellows.

Director
Adam Oberman (McGill)

Regular Members
Jacques Bélair, Robert G. Owens (Montréal)

Peter Bartello, Peter E. Caines, Xiao-Wen Chang, Rustum Choksi, Tim Hoheisel, Anthony R. Humphries, Jean-Philippe Lessard, Jessica Lin, Jean-Christophe Nave, Bruce Shepherd, Gantumur Tsogtgerel, Adrian Vetta (McGill)

Eusebius J. Doedel (Concordia)

André D. Bandrauk (Sherbrooke)

Emmanuel Lorin (Carleton)

Mila
Montreal Institute for Learning Algorithms

Mila was founded by Professor Yoshua Bengio (Department of computer science and operations research, Université de Montréal). It includes around 40 professors, almost 500 students, and around 50 full-time employees. The members of Mila have developed an impressive expertise in deep (discriminating or generative) networks and their applications in computer vision, speech modelling, and natural language processing. Mila has gained worldwide recognition for its numerous breakthroughs in the field of deep learning algorithms and their applications to many concrete problems (including, among others, the modelling of natural language, automatic translation, object recognition, generative models with structured output, and natural language recognition). The mission of Mila is to gather researchers in deep learning, to propose a platform for collaboration and student supervision, to pool human resources and computational clusters, and to facilitate technological transfer to companies wishing to benefit from machine learning algorithms.

The Mila seminars usually take place on Friday at the Université de Montréal. The seminars are given by Mila students or renowned researchers from other institutions or companies. The lecturers present their most recent discoveries. Each year Mila welcomes more than thirty invited lecturers.

Highlights
In 2017–2018 the development of Mila continued at breakneck speed. On March 31, 2018, the members of Mila were supervising at least 180 students enrolled in a master's or doctoral program at McGill or the Université de Montréal. They published at least 100 articles in 2017 (including 14 articles with industrial partners). Mila includes at least nine research teams, led respectively by Yoshua Bengio, Christopher Pal, Joëlle Pineau, Doina Precup, Pascal Vincent, Laurent Charlin, Aaron Courville, Simon Lacoste-Julien, and Jackie Cheung.

Yoshua Bengio, founder and scientific director of Mila, received further awards and distinctions for his exceptional scientific achievements. In 2017 he was awarded the Marie-Victorin Prize (the highest scientific award in Québec) and was named a member of the Royal Society of Canada and an Officer of the Order of Canada. In 2018 he was awarded the Lifetime Achievement Award by the Canadian AI Association and the Medal of the 50th Anniversary of the Ministry of International Relations and La Francophonie. Given his expertise, Professor Bengio is often invited to give lectures within the framework of international meetings, for instance the AI for Good Global Summit, UN (Geneva, June 2017) and the G7 ministerial meeting on Benefits and opportunities of AI (March 27, 2018).

In 2017 Joëlle Pineau became director of the Facebook AI Research Laboratory in Montréal and in 2018 she was awarded an E.W.R. Steacie Memorial Fellowship by NSERC. Doina Precup has led the DeepMind research team in Montreal since 2017. Pascal Vincent has been a Research Scientist at Facebook AI Research in Montreal since 2017.

Students and Postdoctoral Fellows
In 2017–2018 the members of Mila who are also CRM members supervised or cosupervised 26 M.Sc. students, 55 Ph.D. students, and 16 postdoctoral fellows.

Director
Yoshua Bengio (Montréal)

Regular Members
Aaron Courville, Simon Lacoste-Julien, Ioannis Mitliagkas, Pascal Vincent (Montréal)

Christopher Pal (Polytechnique Montréal)

Laurent Charlin (HEC Montréal)

Jackie Cheung, Doina Precup, Joëlle Pineau (McGill)

Associate Members
Alain Tapp, Emma Frejinger, Liam Paull (Montréal)

Andrea Lodi (Polytechnique Montréal)

Hugo Larochelle (Google)

Mathematical Physics

The mathematical physics group is one of the oldest and most active at the CRM. It consists of around twenty regular members, around ten local associate members (all full-time faculty members at one of the participating universities), and close to ten external associate members working permanently at universities and research laboratories in Europe, the U.S., and Mexico. The group carries out research in many of the most active areas of mathematical physics: coherent non-linear 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.

The laboratory organizes a regular mathematical physics seminar, held in general at the CRM on Tuesday afternoon.

Highlights
The laboratory welcomed Libor Snobl as an external associate member and Pierre Mathieu and Chris Cummins retired as members of the laboratory. Some of the events organized by laboratory members are mentioned elsewhere in this report, in particular: the 6th International Workshop on New Challenges in Quantum Mechanics: Integrability and Supersymmetry, organized in honour of Véronique Hussin (June 27–30, 2017, Valladolid); the Mathematical Congress of the Americas (July 24–28, 2017, Montreal); the conference on Gauge Theories, Monopoles, Moduli Spaces and Integrable Systems in honour of Jacques Hurtubise (August 21–25, 2017, CRM); and the North East Cosmology Workshop (March 16–18, 2018, McGill). Marco Bertola was one of the organizers of a workshop on the Geometry of Integrable Systems held at SISSA (June 7–9, 2017, Trieste) and Pavel Winternitz one of the organizers of SDEA III (August 14–17, 2017, Istanbul).

In November 2017 it was announced that Luc Vinet, director of the CRM, had been nominated Fellow of the 2018 Class of the American Mathematical Society. He gave a Tutte Colloquium (entitled *Spins Lattices, Graphs and Quantum State Revivals*) within the framework of a workshop on Algebraic Graph Theory and Quantum Walks at the University of Waterloo (April 23–27, 2018). William Witczak-Krempa gave an invited talk (entitled *Entanglement signatures of QED3 in the kagome spin liquid*) at the Aspen Winter Conference on Field Theory Dualities and Strongly Correlated Matter (March 19–23, 2018).

Students and Postdoctoral Fellows
In 2017–2018 the members of the Mathematical Physics Laboratory supervised or cosupervised 12 undergraduate students, 25 M.Sc. students, 43 Ph.D. students, and 20 postdoctoral fellows.

Director
John Harnad (Concordia)

Regular Members
Véronique Hussin, Manu B. Paranjape, Jiří Patera, Yvan Saint-Aubin, Luc Vinet, Pavel Winternitz, William Witczak-Krempa (Montréal)

Robert Brandenberger, Simon Caron-Huot, Keshav Dasgupta, Jacques Hurtubise, Alexander Maloney (McGill)

Marco Bertola, Richard L. Hall, Dmitry Korotkin (Concordia)

Vasilisa Shramchenko (Sherbrooke)

Alfred Michel Grundland (UQTR)

Associate Members
Alexander J. Hariton, François Lalonde, Igor Loutsenko (Montréal)

Sarah Harrison, Dmitry Jakobson, Vojkan Jakšić, Niky Kamran, John A. Toth (McGill)

Alexander Shnirelman (Concordia)

Ferenc Balogh (John Abbot College)

Stéphane Durand (Cégep Édouard-Montpetit)

Robert Conte, Bertrand Eynard (CEA-Saclay)

Jean-Pierre Gazeau (Paris Diderot)

Alexander R. Its (IUPUI)

Decio Levi (Roma Tre)

Robert Seiringer (IST Austria)

Libor Snobl (Czech Technical University)

Alexander Turbiner (UNAM, Mexico)

Johannes Walcher (Heidelberg)

Peter Zograf (Steklov Institute, St. Petersburg)

PhysNum

Applied mathematics now plays an important role in the biomedical field and especially the neurosciences. The research activity at PhysNum ("Numerical Physics") has two main themes: pharmacometrics and brain imaging. In particular Jean-Marc Lina and Habib Benali study the multimodal imaging of the spinal cord, Lina and Christophe Grova the multiresolution and multimodal imaging in magneto/electrophysiology, and Benali and Maxime Descoteaux models of the anatomical and functional connectivity of the brain. Grova also studies neurovascular models in epilepsy and Lina studies sparse representations, inverse problems, brain wave synchronization, and scale-invariant processes in electrophysiology.

Fahima Nekka and her team conduct research in pharmacometrics, a discipline whose goal is to interpret and describe pharmacological phenomena in a quantitative manner so as to support rational therapeutic decisions and improvement of patient health. They have developed a whole framework of probabilistic pharmacometrics in which different sources of variability and the non-linearity of the system are accounted for. The team is working on compliance metrics and ranking and on direct and inverse problems related to patient drug behaviour and the therapeutic effect of drugs. It is designing tools that shed new light on drug development and evaluation, revisiting classical concepts in pharmacology and developing models for drug interactions.

Highlights
Professor Habib Benali (Concordia University) was awarded a Tier 1 Canada Research Chair in November 2017. He is the scientific director of the Perform centre at Concordia University; Christophe Grova is also a member of this centre. In 2017, Frédéric Lesage, full professor in the Department of Electrical Engineering at Polytechnique Montréal, gave a lecture at the first Mexican symposium on near infrared spectroscopy. Jean-Marc Lina and Karim Jerbi (who holds the Canada Research Chair in Systems Neuroscience and Cognitive Neuroimaging) were two of the organizers of the MAIN 2017 conference, held in November 2017; this conference, described in the section on the other activities, was extremely successful and will be followed by other editions.

Jean-Marc Lina

In June 2017 Maxime Descoteaux and two co-authors published the article "Visualization, Interaction and Tractometry: Dealing with Millions of Streamlines from Diffusion MRI Tractography" in the journal *Frontiers in Neuroinformatics*. Fahima Nekka organized a workshop on translational-oriented quantitative therapeutic approaches in June 2017 at the Université de Montréal.

Students and Postdoctoral Fellows
In 2017–2018 the PhysNum members supervised or cosupervised 22 M.Sc. students, 35 Ph.D. students, and 14 postdoctoral fellows.

Director
Jean-Marc Lina (ÉTS)

Regular Members
Karim Jerbi, Fahima Nekka (Montréal)

Frédéric Lesage (Polytechnique Montréal)

Habib Benali, Christophe Grova (Concordia)

Maxime Descoteaux (Sherbrooke)

Alain Arnéodo (Laboratoire de physique, ENS Lyon)

Montréal Probability Group

In 2014 the CRM ratified the creation of a new CRM laboratory in probability: the Montréal Probability Group. The research interests of the group span theoretical and applied, continuous and discrete probability. One important stream of research within the laboratory is the development and analysis of probabilistic models for physical, biological, statistical, and computational systems. The creation of this laboratory highlights the quality of probability research in the Montréal region and the recent influx of researchers in this area.

Highlights
During the period from June 1st, 2017 to May 31, 2018 the probability lab, or Problab, had the pleasure to welcome a new member as Jessica Lin joined McGill University. She works at the intersection of probability theory and partial differential equations; she did her Ph.D. at the University of Chicago and her postdoc at the University of Wisconsin – Madison. Problab also recruited Sanchayan Sen as a CRM–ISM postdoc. During his time in Montréal he collaborated with Louigi Addario-Berry and they published a joint article on the geometry of the minimal spanning tree of a random 3-regular graph. Finally Problab hosted Pascal Maillard as a Simons CRM Scholar, which also led to publications during his visit.

The members of Problab organized several events during that period, including a workshop on probability and combinatorics at McGill's Bellairs institute in Barbados, a workshop on Mathematical Analysis of Biological Interaction Networks in Banff, as well as several sessions within larger events such as the AMS Northeastern Sectional and the 39th Conference on Stochastic Processes and their Applications in Moscow. The Problab members continue to benefit from an extraordinary international recognition, with conference invitations and collaborations in countries such as Australia, China, Chile, and several European countries (among others).

Students and Postdoctoral Fellows
In 2017–2018 the members of the Montréal Probability Group supervised or cosupervised one undergraduate student, 16 M.Sc. students, 27 Ph.D. students, and 13 postdoctoral fellows.

Director
Alexander Fribergh (Montréal)

Regular Members
Sabin Lessard (Montréal)

Janosch Ortmann (UQAM)

Louigi Addario-Berry, Linan Chen, Luc Devroye, Jessica Lin, Bruce A. Reed (McGill)

Lea Popovic, Wei Sun, Xiaowen Zhou (Concordia)

Raluca Balan, Aaron Smith (Ottawa)

Donald A. Dawson (Carleton)

Louis-Pierre Arguin (Baruch College, CUNY)

Associate Members
Andrew Granville (Montréal)

Jean-François Cœurjolly (UQAM)

Dmitry Jakobson, Vojkan Jakšić (McGill)

Marco Bertola (Concordia)

Quantact Actuarial and Financial Mathematics Laboratory

Quantact is the CRM Laboratory of Actuarial and Financial Mathematics, i.e., the area of mathematics concerned with problems in insurance and finance. The Laboratory members develop and use probabilistic and statistical methods to analyze issues having a financial impact on society. Quantact gathers professors from UQAM, Concordia University, the Université Laval, and the Université de Montréal.

The research interests of Quantact members include FADR insurance, actuarial statistics, actuarial finance, and mathematical finance, as well as the mathematics of risk and ruin theory. Here are a few of the themes studied by Quantact members: pricing and provisioning in FADR insurance; solvency of financial institutions; financial innovation in insurance (pricing and covering of variable annuities and market-linked insurance products); the modelling of longevity risk and mortality and its impacts on life insurance and pension schemes; the quantification of the impact of natural disasters and other extreme events; dependency models; measures of risk; models for the frequency and severity of disasters; stochastic control of risk processes and stochastic optimization; and the statistical analysis of big data in insurance.

Highlights
In 2017–2018 Quantact decided to focus on thematic workshops lasting one day each. Four such workshops were held during the academic year: the Second Ruin Theory Day (in February 2018), the 5th Workshop on Insurance Mathematics With a Special Session on Big Data and Machine Learning in Risk Management (also in February 2018), the Quantact Workshop on Risk Management of Segregated Funds (in March 2018), and the Non-life Insurance Workshop (in April 2018). In 2017–2018 Quantact also invited four researchers to give research seminars.

Students and Postdoctoral Fellows
In 2017–2018 the members of Quantact supervised or cosupervised one undergraduate student, 47 M.Sc. students, 18 Ph.D. students, and 2 postdoctoral fellows.

Director
Mathieu Boudreault (UQAM)

Regular Members
Maciej Augustyniak, Manuel Morales (Montréal)

Jean-Philippe Boucher, Arthur Charpentier, Anne MacKay, Mathieu Pigeon, Jean-François Renaud, Alexandre F. Roch (UQAM)

Patrice Gaillardetz, José Garrido, Frédéric Godin, Cody Hyndman, Mélina Mailhot (Concordia)

Hélène Cossette, Étienne Marceau (Laval)

Chantal Labbé (HEC Montréal)

Statistics

Statistical methods and reasoning play an important role in the advancement of knowledge. Be it through surveys from sampling, the measure of socio-economic indicators, clinical trials to compare various biomedical treatments, or the study of the survival of an animal population in ecology, statistical methodology can be found everywhere in the sciences. 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. Statistical methodology is now addressing problems whose structure is very complex, such as the analysis of brain images or genome data, and new methodology (such as data mining) is being developed for large data sets. The computational aspect of statistics is thus becoming more and more important, but of course mathematics continues to be the foundation of statistics.

Statistics has many application areas and in particular the laboratory includes several researchers in biostatistics. One of the aims of the laboratory is to structure the Québec statistical community so that it can participate in the revolution mentioned above at a time when an important renewal of academic personnel is taking place. This structure allows the Québec community to participate in Canada-wide programs organized by the three Canadian mathematics institutes, as well as the newly created Canadian Statistical Sciences Institute (CANSSI). 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.

The members of the Statistics Laboratory organize four regular seminars: the Statistics Seminars at McGill, Laval, and Sherbrooke, respectively, and the Biostatistics Seminar at the Université de Montréal.

Highlights

Several members of the Statistics Laboratory have organized or co-organized large scientific meetings, several of which were supported financially by the CRM and the laboratory itself. For instance Christian Genest was the coordinator of the Thematic Semester on Risk in Complex Systems, described in the section on the CRM thematic program. Erica Moodie, David Stephens, Bruno Rémillard, Johanna Nešhelová, and Debbie Dupuis co-organized various workshops within this semester. Russell Steele was the main organizer of the 2018 Annual Meeting of the Statistical Society of Canada held at McGill University in June 2018.

Many members of the Statistics Laboratory received honours or appointments demonstrating their competence and influence on the national and international scenes. For instance David Haziza received the CRM–SSC Prize in 2018 and the Gertrude Cox Award of the ASA in the same year; Christian Genest has just completed a four-year term as editor-in-chief of the *Journal of Multivariate Analysis*; Yoshua Bengio's articles have been cited more often than those of any other computer scientist according to Google Scholar; Erica Moodie was one of the leaders of the PMED program on Statistical, Mathematical, and Computational Methods for Precision Medicine (organized by SAMSI); and in 2017 Alexandra Schmidt was awarded the Distinguished Achievement Medal of the ASA Section on Statistics and the Environment.

Altogether, in the academic year 2017–2018, more than 100 researchers gave presentations within the framework of the five seminar series mentioned above.

Students and Postdoctoral Fellows

In 2017–2018 the members of the Statistics Laboratory supervised or cosupervised 126 M.Sc. students, 127 Ph.D. students, and 29 postdoctoral fellows.

Director

Éric Marchand (Sherbrooke)

Regular Members

Jean-François Angers, Mylène Bédard, Yoshua Bengio, Martin Bilodeau, Pierre Duchesne, David Haziza, Christian Léger, Alejandro Murua, François Perron, Mireille Schnitzer (Montréal)

Juli Atherton, Jean-François Cœurjolly, Sorana Froda, Simon Guillotte, Fabrice Larribe, Geneviève Lefebvre, Brenda MacGibbon, Karim Oualkacha (UQAM)

Masoud Asgharian, Christian Genest, Abbas Khalili, Erica E. M. Moodie, Johanna Nešlehová, Robert W. Platt, James O. Ramsay, Paramita Saha Chaudhuri, Alexandra M. Schmidt, Russell Steele, David A. Stephens, David B. Wolfson, Yi Yang (McGill)

Yogendra P. Chaubey, Arusharka Sen (Concordia)

Belkacem Abdous, Anne-Sophie Charest, Ting-Huei Chen, Thierry Duchesne, Lajmi Lakhal Chaieb, Khader Khadraoui, Louis-Paul Rivest, Denis Talbot (Laval)

Taoufik Bouezmarni (Sherbrooke)

Debbie J. Dupuis, Aurélie Labbe, Bruno Rémillard (HEC Montréal)

Associate Members

Fateh Chebana (INRS-ETE)

Nadia Ghazzali (UQTR)

Vahid Partovi Nia (Polytechnique Montréal)

CRM Prizes

Jeremy Quastel

Each year the CRM awards four prizes (among the eight important national prizes in the mathematical sciences): the CRM–Fields–PIMS Prize (awarded jointly by the three Canadian mathematics institutes); the André Aisenstadt Prize, awarded by the CRM to a rising young Canadian star selected by the CRM International Scientific Advisory Committee; the Theoretical Physics Prize awarded jointly by the CRM and the Canadian Association of Physicists; and the CRM–SSC Prize, awarded jointly by the CRM and the Statistical Society of Canada to a researcher at the beginning of his or her career. The 2018 winners are, respectively: Jeremy Quastel (Toronto), Benjamin Rossman (Toronto), Ariel Zhitnitsky (UBC), and David Haziza (Montréal).

The 2018 CRM–Fields–PIMS Prize Awarded to Jeremy Quastel

Jeremy Quastel is widely recognized as one of the top probabilists in the world, having made major advances in the fields of hydrodynamic theory, stochastic partial differential equations, and integrable probability. He is particularly recognized for a series of groundbreaking works during the last ten years related to the Kardar-Parisi-Zhang (KPZ) equation and the wider class of random growth models conjectured to share the same long-time, large-scale limit (the so-called KPZ universality class). He proved a 25-year-old conjecture from physics about the scaling exponents for the KPZ equation, as well as computing an exact formula for its one-point distribution. He demonstrated that the KPZ equation is universal in that it arises as a scaling limit of a wide variety of nonlinear stochastic partial differential equations of Hamilton-Jacobi type. Most recently he constructed and computed transition probabilities for the “KPZ fixed point” Markov process, which should be the universal long-time limit of all models in the KPZ universality class. Among his earlier contributions, Quastel derived the incompressible Navier-Stokes equation from a class of interacting particle systems, derived equations for the behaviour of the “internal diffusion limited aggregation” model, and proved a conjecture about the speed of the travelling front for the stochastic Fisher-Kolmogorov-Petrovsky-Piskunov equation, which models branching diffusion processes.

Benjamin Rossman

For the profound impact of his work, Quastel was named a Fellow of the Royal Society of Canada (2016) and received a Killam Research Fellowship (2013). He delivered an invited address at the 2010 International Congress of Mathematicians in Hyderabad (India). Jeremy Quastel received his undergraduate degree from McGill University and his Ph.D. from the Courant Institute in 1990 (under the direction of S.R.S. Varadhan). He is Chair of the Department of Mathematics at the University of Toronto, where he has taught since 1998.

The CRM–Fields–PIMS Prize

This prize was established in 1994 as the CRM–Fields Prize to recognize exceptional research in the mathematical sciences. In 2005 PIMS became an equal partner in the awarding of the prize and its name was changed to the CRM–Fields–PIMS Prize. A committee appointed by the three institutes chooses the recipient.

The previous recipients of the prize are H.S.M. (Donald) Coxeter (1995), George A. Elliott (1996), James Arthur (1997), Robert V. Moody (1998), Stephen A. Cook (1999), Israel Michael Sigal (2000), William T. Tutte (2001), John B. Friedlander (2002), John McKay (2003), Edwin Perkins (2003), Donald A. Dawson (2004), David Boyd (2005), Nicole Tomczak-Jaegermann (2006), Joel S. Feldman (2007), Allan Borodin (2008), Martin Barlow (2009), Gordon Slade (2010), Marc Lewis (2011), Stevo Todorčević (2012), Bruce Reed (2013), Niky Kamran (2014), Kai Behrend (2015), Daniel Wise (2016), and Henri Darmon (2017).

The 2018 André Aisenstadt Prize Awarded to Benjamin Rossman

Benjamin Rossman received his Ph.D. in 2010 at MIT under Madhu Sudan and held postdocs at the Tokyo Institute of Technology, the Simons Institute for the Theory of Computing at Berkeley, and the National Institute of Informatics in Tokyo before joining the University of Toronto in 2016. He is a Sloan Fellow (2017) and an invited speaker at the International Congress of Mathematicians in Rio de Janeiro (2018).

Professor Rossman works in computational complexity theory, a branch of theoretical computer science that classifies problems according to their relative difficulty. His research seeks to quantify the minimum resources required to solve basic problems in combinatorial models such as Boolean circuits. Through creative techniques based on logic and the probabilistic method, Rossman has derived groundbreaking lower bounds on the complexity of detecting cliques and determining connectivity in random graphs. His other notable results include size and depth hierarchy theorems for bounded-depth circuits, which answered longstanding questions. This work has contributed to a reemergence of interest in circuit complexity, a concrete approach to the famous P vs NP problem that had seen little progress since the breakthroughs of the 1980s.

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 monetary 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 mathematician who is awarded this prize is invited to give a lecture at the CRM and present a summary of his or her work for publication in the *Bulletin du CRM*.

The previous recipients of the André Aisenstadt Prize are Niky Kamran (1992), Ian Putnam (1993), Michael Ward (1995), Nigel Higson (1995), Adrian S. Lewis (1996), Lisa Jeffrey (1997), Henri Darmon (1997), Boris Khesin (1998), John Toth (1999), Changfeng Gui (2000), Eckhard Meinrenken (2001), Jinyi Chen (2002), Alexander Brudnyi (2003), Vinayak Vatsal (2004), Ravi Vakil (2005), Iosif Polterovich (2006), Tai-Peng Tsai (2006), Alexander E. Holroyd (2007), Gregory G. Smith (2007), József Solymosi (2008), Jonathan Taylor (2008), Valentin Blomer (2009), Omer Angel (2010), Joel Kamnitzer (2011), Marco Gualtieri (2012), Young-Heon Kim (2012), Spyros Alexakis (2013), Sabin Cautis (2014), Louis-Pierre Arguin (2015), Anne Broadbent (2016), and Jacob Tsimerman (2017).


Ariel Zhitnitsky

The 2018 CAP–CRM Prize Awarded to Ariel Zhitnitsky

Ariel Zhitnitsky is a Professor in the Department of Physics and Astronomy at UBC. He has made several highly innovative contributions to theoretical physics. One of Zhitnitsky's most influential ideas was published shortly after he finished his Ph.D., when he proposed that the Strong CP problem in the Standard Model could be resolved by a nearly invisible axion. This paper has over 1000 citations and has influenced experimental searches; the proposed axions are a candidate for cosmological cold dark matter.

Another influential work was accomplished with V. Chernyak, providing a set of wavefunctions that allow computation of exclusive amplitudes at high energies, such as form-factors or two-particle decays of heavy mesons. A series of papers with D. Son analyzed anomalous topological non-dissipating currents in dense matter using an effective Lagrangian approach. Zhitnitsky later investigated the roles of these topological currents in neutron stars as a model for kicks and superconductivity. With D. Kharzeev, he further used these results to explain the CP-odd asymmetries observed at the Relativistic Heavy Ion Collider, and proposed that the bulk of dark matter is anti-baryonic so that the Universe as a whole could be baryon-symmetric.

Professor Zhitnitsky has made key contributions to our understanding of the QCD phase transition, hadron physics, dark matter, QCD axions, and neutron stars.

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 in recognition of exceptional achievements in theoretical and mathematical physics. The prize consists of a monetary award and a medal.

The previous recipients of the ACP–CRM Prize are Werner Israel (1995), William G. Unruh (1996), Ian Affleck (1997), J. Richard Bond (1998), David J. Rowe (1999), Gordon W. Semenoff (2000), André-Marie Tremblay (2001), Pavel Winternitz (2002), Matthew Choptuik (2003), Jiří Patera (2004), Robert Myers (2005), John Harnad (2006), Joel S. Feldman (2007), Richard Cleve (2008), Hong Guo (2009), Clifford Burgess (2010), Robert Brandenberger (2011), Luc Vinet (2013), Mark Van Raamsdonk (2014), Charles Gale (2015), Freddy Cachazo (2016), and Raymond Laflamme (2017).

David Haziza

The 2018 CRM–SSC Prize Awarded to David Haziza

David Haziza obtained his B.Sc. and M.Sc. from the Université du Québec à Montréal before starting his Ph.D. studies in survey sampling at Carleton University under the supervision of J. N. K. Rao. He works in several areas of survey sampling, including variance estimation, survey sampling methods robust with respect to influential observations, calibration, small area estimation, and design. He is recognized as "one of the leading researchers in survey statistics worldwide, continuing a traditional strength of statistical research in Canada." He became an ASA Fellow in 2016 and received the Cox Award in 2018.

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 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. The previous recipients of the CRM–SSC Prize are Christian Genest (1999), Robert J. Tibshirani (2000), Colleen D. Cutler (2001), Larry A. Wasserman (2002), Charmaine B. Dean (2003), Randy Sitter (2004), Jiahua Chen (2005), Jeffrey Rosenthal (2006), Richard Cook (2007), Paul Gustafson (2008), Hugh Chipman (2009), Grace Y. Yi (2010), Edward Susko (2011), Changbao Wu (2012), Derek Bingham (2013), Fang Yao (2014), Matías Salibián-Barrera (2015), Radu Craiu (2016), and Lei Sun (2017).

Education

As part of its mandate, the CRM encourages research in mathematics at all levels. It is thus involved in the training of young researchers, the fostering of research, and the development of mathematical education. A substantial part of these activities are carried out in collaboration with the *Institut des sciences mathématiques* (ISM), which was created in 1991 and has eight academic partners: Bishop's, Concordia, McGill, Université de Montréal, UQAM, UQTR, Université de Sherbrooke, and Université Laval. The ISM is financed by its partners and the Québec Ministry of Education. The ISM mission consists of: coordinating and harmonizing the mathematics graduate programs of Québec universities; fostering excellence in training; supporting research through scholarships and prizes; and stimulating the interest of young people for the mathematical sciences, in particular through the dissemination of mathematical knowledge among teachers, young people, and the general public. In 2017–2018 the director of the ISM was Professor Alina Stancu (Concordia University).

CRM–ISM Postdoctoral Fellowships

The CRM–ISM Postdoctoral Fellowships allow promising young researchers to devote most of their time to research within the CRM and its partner institutions. The program is very competitive. Postdoctoral fellows collaborate with mature researchers, bringing new ideas from other great centres of mathematical research and organizing working groups on cutting-edge topics.

Here is the list of fellows, along with the institution and year of their PhD. We also give their research areas and the names of the mathematicians who supervised them at the CRM.

Jonah Gaster
PhD: University of Illinois at Chicago (2014)
Supervisors: Piotr Przytycki and Daniel Wise (McGill)
Research Area: Geometry and Topology

Siran Li
PhD: University of Oxford (2017)
Supervisors: Galia Dafni and Alexander Shnirelman (Concordia), Pengfei Guan, Dmitry Jakobson, and Adam Oberman (McGill)
Research Area: Mathematical Analysis and Applied Mathematics

Abbas Mehrabian
PhD: University of Waterloo (2015)
Supervisors: Louigi Addario-Berry and Luc Devroye (McGill)
Research Area: Probability

Corentin Perret-Gentil
PhD: ETH Zürich (2016)
Supervisors: Henri Darmon and Maksym Radziwiłł (McGill), Chantal David (Concordia), Dimitrios Koukoulopoulos (Montréal)
Research Area: Algebra and Number Theory

Undergraduate Summer Scholarships

In collaboration with the CRM and 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. In most cases these undergraduates are supervised by postdoctoral fellows or young professors.

Here is the list of undergraduate scholars for the summer of 2017.

Antoine Abram (UQAM)
Junior Supervisor: Alexander Garver (postdoctoral fellow)
Supervisor: Hugh Thomas
Project: Groupes de Coxeter, pavages et automates

Philippe Boileau (Concordia)
Junior Supervisor: Lisa Kakinami
Supervisor: Léa Popovic
Project: Exploration of Multi-Network Data with Heatmaps

Samuel Desrochers (McGill)
Junior Supervisor: Rohit Jain (postdoctoral fellow)
Supervisor: Jérôme Vétois
Project: Derivation of Gradient Bounds of Elliptic PDEs

Cédric Dion (Laval)
Supervisor: Antonio Lei
Project: Arithmetic Properties of the *p*-adic Logarithm

Courtney Drew (Bishop's)
Supervisors: Trevor Jones and Brad Willms
Project: Peak Oil Models

Jean-Pascal Guévin (Université de Montréal)
Junior Supervisor: Poclaire Kenmogne (Ph.D. student)
Supervisor: Manuel Morales
Project: De l'application des réseaux de neurones profonds au cours de devises transigées sur le FOREX

Daniel Hutama (McGill)
Junior Supervisor: Daniel Fiorilli
Supervisors: Henri Darmon and Andrew Granville
Project: Primes in Arithmetic Progressions and Eisenstein Primes

Jacqueline Lefèvre Lopéz (McGill)
Junior Supervisor: Amit Sharma (postdoctoral fellow)
Supervisor: Mikaël Pichot
Project: Random Groups of Aut(F2)

Florence Maas-Gariépy (UQAM)
Junior Supervisor: Rebecca Patrias (postdoctoral fellow)
Supervisor: Hugh Thomas
Project: Fonctions de Schur et généralisations à la K-théorie

Ndiamé Gueye Ndiaye (McGill)
Junior Supervisor: Evan DeCorte (postdoctoral fellow)
Supervisor: Bruce Shepherd
Project: Circular Chromatic Number of the Orthogonality Graph

Promotion of the Mathematical Sciences

The Accromαth magazine is produced by the ISM and its production costs are defrayed in part by the CRM. There are two issues of the magazine every year and they are distributed free of charge in all Québec high schools and cégeps. The goal of Accromαth is to stimulate the high school and cégep teachers by providing them with material that is topical and up-to-date. Accromαth consists of articles on the most recent developments in mathematics and its applications, as well as articles on the history of mathematics or links between mathematics and the arts. Accromαth has been awarded several prizes (both for its contents and graphic design).

The CRM and the ISM jointly support the “Sciences et mathématiques en action” program (created by Professor Jean-Marie De Koninck) and the “Association québécoise des jeux mathématiques.”

Graduate Student Supersivion

The CRM members supervise a large number of graduate students. We now give information on the students supervised by CRM members who graduated in 2017–2018. The name of the student is followed by the name of his or her supervisor (or names of his or her supervisors). Some names may be missing from this list, because we have only included those that have been brought to our attention.

Students Who Obtained Their Ph.D. in 2017–2018

Bilal Abbasi (Adam M. Oberman)

Adjobo Folly Dzigbodi Adjogou (Alejandro Murua)

Ludovic Alarie-Vézina (Pierre Mathieu)

Adam Rafael Alcolado
(Dmitry Jakobson, Johannes Walcher)

Hossein Amini Kafiabad (Peter Bartello)

Olivier Asselin (Peter Bartello)

Tarik Bahraoui (Taoufik Bouezmarni)

Ridouan Bani (Frédéric Guichard)

Hossein Bazrafshan Moghaddam
(Robert Brandenberger)

Sébastien Bertrand (Alfred Michel Grundland)

Sahir R. Bhatnagar (Yi Yang)

Loïs Boullu (Jacques Bélair)

Maxime Breden (Jean-Philippe Lessard, Laurent Desvillettes)

Thomas Briffard (André Fortin, José Manuel Urquiza)

Almaz Butaev (Galia Dafni, Ming Mei)

Sisi Chen (Peter Bartello, M.K. (Peter) Yau)

Achmad Choiruddin (Jean-François Cœurjolly)

Junyoung Chung (Yoshua Bengio)

Maurice-Étienne Cloutier
(Jean-Marie De Koninck, Nicolas Doyon)

Mohamad Elmasri (David A. Stephens)

Veronica Errasti-Diez (Keshav Dasgupta)

Nicolas Essis Breton (Patrice Gaillardetz)

Elisa G. M. Ferreira (Robert Brandenberger)
Philippe Gagnon (Mylène Bédard, Alain Desgagné)
Brigitte Gelein (David Haziza)
Elnaz Ghadimi (Yogendra P. Chaubey, Arusharka Sen)
Çaglar Gülçehre (Yoshua Bengio)
Emmanuel Hamel (Ghislain Léveillé)
Xiao He (Michael Lau)
Omidali Aghababaei Jazi (Masoud Asgharian, Abbas Khalili)
Romain Kadje Kenmogne (François Perron)
Oleksiy Klurman (Andrew Granville)
Anastasis Kratsios (Alina Stancu, Cody Hyndman)
Tao Lei (Louigi Addario-Berry)
Marianna Lytova (André D. Bandrauk, Emmanuel Lorin)
Marzieh Mehdizadeh (Andrew Granville, Dimitrios Koukoulopoulos)
Mehdi Mirza (Yoshua Bengio)
Itre Mtalai (Étienne Marceau, Hélène Cossette)
Bruno Oliveira Ferreira de Souza (Frédéric Lesage)
Nabila Parveen (Erica E. M. Moodie)
Benoît Pouliot (André Fortin, José Manuel Urquiza)
Alice Pozzi (Eyal Z. Goren, Henri Darmon, Adrian Iovita, Payman L. Kassaei)
Louis-Xavier Proulx (Anne Bourlioux)
Paul Raymond-Robichaud (Gert Sabidussi, Gilles Brassard)
Syed Ahsan Raza (Mireille Schnitzer)
Geoffroy Rouget (Javad Mashreghi)
Abdolnasser Sadeghkhani (Éric Marchand)
Tiago Miguel Saldanha Salvador (Adam M. Oberman)
Sam Selmani (Johannes Walcher, Alexander Maloney)
Fatemeh Sharifi (Paul M. Gauthier, Gordon Sinnamon)
Nicolas Simard (Henri Darmon)
Hipolito J. Treffinger Cienfuegos (Ibrahim Assem, David Smith)
Bart van Merriënboer (Yoshua Bengio)
Luc Villandré (David A. Stephens, Aurélie Labbe)
Renjie Wang (Wei Sun, Cody Hyndman)
Joseline Zafack Guetsop (Alexandre Bureau)
Jiayu Zheng (Xiaowen Zhou)

Students Who Obtained Their M.Sc. in 2017–2018

Zahra Abbas (Alina Stancu)
Brahim Abdenbi (Daniel T. Wise)
Ismail Abouamal (Pavel Winternitz)
Gabriel Alepin (Jean-Philippe Boucher)
Chahira Imène Allab (René Ferland)
Abeer Alzahrani (Wei Sun)
Atousa Assadi (Christophe Grova)
Kpedetin Tatiana Lorelle Avissoudo (Geneviève Gauthier)
Salik Bahar (Chantal David)
Jean-Thomas Baillargeon (Étienne Marceau, Hélène Cossette)
Roba Bairakdar (Mélina Mailhot)
Maryam Baradaran Kashani (Maciej Augustyniak)
Mélissa Barbe Marcoux (Ibrahim Assem)
Alexandre Beausoleil (Frédéric Lesage, Geneviève Lefebvre)
Thierry P. Beausoleil (Frédéric Lesage)
Étienne Bégin (Taoufik Bouezmarni)
Olexa Bilaniuk (Yoshua Bengio, Roland Memisevic)
Alexandre Bizeau (Maxime Descoteaux)
Frank Boahen (Javad Mashreghi, Nicolas Doyon)
Florian Bordes (Pascal Vincent)
Lotfi Bouallagui (Alexandre Blondin Massé, Halima Elbiaze)
Alexandre Brandts-Longtin (Louigi Addario-Berry)
Lu Cao (Mélina Mailhot)
Alexandre Carbonneau (Maciej Augustyniak)
Rebecca Carrington (Adam M. Oberman)
Miguel Caubet-Fernandez (Sorana Froda, Geneviève Lefebvre, Maja Krajinovic)
Iakovos Chinis (Chantal David)
Cherry Chu (Erica E. M. Moodie)
Émilie Cyrenne (Alina Stancu)
Laurence Desbois-Bédard (Louis-Paul Rivest, Anne-Sophie Charest)
Fanny Desjardins (Olivier Collin)
Awa Diop (Anne-Sophie Charest)
Fatiha Djermane (Christophe Reutenauer)
Sami Douba (Eyal Z. Goren, Payman L. Kassaei)
Ortéga Wanignon Dovoedo (Pierre Duchesne, David Haziza)

Daniel Kokou Enam Edoh-Bedi (Pascal Vincent, Roland Memisevic)
Hicham El Kimakh (Frédéric Godin)
Thomas Enoh (Ron J. Stern)
Sergio Ewane Ebouele (Louis-Paul Rivest)
Victor Fardel (François Perron)
Farnoush Farhadi (Vahid Partovi Nia)
Julien Gaboriaud (Luc Vinet)
N'vyssan Samuella Germaine Bonou (Alexandre Bureau)
Kévin Gervais (Abraham Broer)
Zahra Ghasemivanani (Mathieu Pigeon)
Daniela-Neriman Ghete (Jean-François Angers)
Guillermo Gimenez-Monteiro (Andrew Granville)
Vincent Girard (Abraham Broer)
Sara Golyari (Robert G. Owens)
Herman Goulet-Ouellet (Franco Valentino Saliola)
Pascale Gourdeau (Prakash Panangaden)
Steve Guerra Ferreira (Mireille Schnitzer)
Alvaro Guillen-Cuevas (Lea Popovic)
Samuel Guy-Plourde (Pierre Blanchet)
Chaima Hamdi (Tomasz Kaczynski)
Fatemeh Hosseininasabnajar (Yogendra P. Chaubey, Lisa Kakinami)
Léonard Houde Therrien (Yvan Saint-Aubin, Luc Vinet)
Jean Hounkpe (Pierre Duchesne, Maciej Augustyniak)
Harrison Humphrey (Prakash Panangaden)
Francis Huot-Chantal (Michel C. Delfour)
Aude Jegou (Christophe Grova)
Clovis Kari (Steven Patrick Boyer)
Christopher Keefe (Pawel Góra, Abraham Boyarsky)
Jafar Khezri (Étienne Marceau, Hélène Cossette)
Justin Le Sauteur-Robitaille (Jacques Bélair)
Marie Lafrance (Véronique Hussin)
Michaël Lalancette (Mylène Bédard)
Nicolas Laliberté (Alexander Fribergh)
Alex Lamb (Aaron Courville)
Louis-Philippe Ledoux (Maxime Descoteaux)
Nadège Octavie Lenkeu Lenkeu (Alexandre Girouard, Nicolas Doyon)
Alexander Levis (Robert W. Platt)
Zhaoyang Li (Xiaowen Zhou)
Abdelilah Mahfoud (Simon Guillotte)
Ana Mamaliga (Manuel Morales)
Joanie Martineau (Iosif Polterovich)
Olivier Mastropietro (Aaron Courville)
James Hugh McVittie (David B. Wolfson, David A. Stephens)
Eric Morenz (Russell Steele)
Erfan Nazari Zahraei Motlagh (Niky Kamran)
Isabella Negrini (Adrian Iovita)
Pierre-Olivier Parisé (Dominic Rochon)
Alexandre Piché (Russell Steele)
Manuela Pineros-Rodriguez (Michael C. Mackey, Anmar Khadra)
Renaud Raquépas (Vojkan Jakšić, Jacques Hurtubise)
Dominique Rathel-Fournier (François Lalonde)
Annabelle Redelmeier (David B. Wolfson, Russell Steele, Johanna Nešlehová)
Damien Rioux Lavoie (Robert G. Owens)
Marie-Christine Robitaille-Grou (David Haziza, Mireille Schnitzer)
Jeremy Rothschild (Paul François)
Maxime Roussakov (Manuel Morales)
Tanna Sanchez McMillan (Ibrahim Assem)
Erick Schulz (Gantumur Tsogtgerel)
Joanie Simard (Taoufik Bouezmarni)
Sara Soufsaf (Jun Li)
Ervin Thiagalingam (Henri Darmon)
Natalia Vasilyeva (Pawel Góra, Abraham Boyarsky)
Edith Viau (Michèle Breton, Frédéric Godin)
Nancy Wallace (François Bergeron)
Guanbo Wang (Mireille Schnitzer)
Chengrong Xie (Patrice Gaillardetz)
Juan-Sebastian Yanez (Mathieu Pigeon)
Mahmoud Yassin (Hershy Kisilevsky)
Maria Alejandra Yepez (Debbie J. Dupuis)
Ebrahim Zare (Louise Laforest, Geňa Hahn)
Peter Zenz (Dimitrios Koukoulopoulos, Maksym Radziwiłł)
Myriam Ziou (Fabrice Larribe)
Giovanni Zoroddu (Lea Popovic)

Partnerships

Although the CRM is primarily concerned with mathematical research and training taking place within Québec, its activities are part of a broad framework and it collaborates with many partners to fulfill its mission and ensure that the research carried out in Québec is of international calibre.

Canadian Partnerships

On the Canadian scene the most important partnership of the CRM is the one with the two other Canadian mathematics institutes, i.e., the Fields Institute for Research in Mathematical Sciences (FI), based in Toronto, and the Pacific Institute for the Mathematical Sciences (PIMS) in the West. The three institutes coordinate their scientific activities (particularly their thematic programs) and have carried out several projects together, including the creation of networks such as Mitacs (see below) and the creation of the CRM–Fields–PIMS Prize. The three institutes also support some activities of the professional associations in the mathematical sciences and give some financial support to the Atlantic Association for Research in the Mathematical Sciences (AARMS), founded in 1996 to encourage and promote research in the mathematical sciences in the Atlantic provinces. The three institutes also support the Canadian Statistical Sciences Institute (CANSSI), whose aim is to develop statistical sciences in Canada through attracting new researchers to the field, increasing the points of contact among researchers nationally and internationally, and fostering collaborations with other disciplines and organizations. Finally the CRM is a partner of the Banff International Research Station (BIRS), which organizes workshops in mathematics all year round.

International Partnerships

The CRM members have many fruitful collaborations with French researchers, in particular those working at the *Centre national de la recherche scientifique* (CNRS), the *Institut national de recherche en informatique et automatique* (INRIA), and the *Institut national de la santé et de la recherche médicale* (INSERM). In March 2015 the CRM signed agreements with two prestigious French institutes: IHÉS (*Institut des Hautes Études Scientifiques*) and IHP (*Institut Henri Poincaré*). The CRM has signed a formal agreement with the ALGANT consortium (Algebra, Geometry, Number Theory) within the Erasmus Mundus network of the European Union. This agreement stimulates exchanges and joint supervision of graduate students.

The CRM also signed an agreement in 2014 with the *Agencia Estatal Consejo Superior de Investigaciones Científicas* (Spain) and agreements in 2016 with the Czech Technological University and the *Instituto Nacional de Matematica Pura e Aplicada* (Brazil). Finally we mention that the National Science Foundation (NSF) of the United States provides some financial support for almost every thematic program organized by the CRM.

The CNRS Unité Mixte Internationale at the CRM

A few years ago the *Centre National de la Recherche Scientifique* (CNRS) in France decided to create at the CRM a so-called UMI (i.e., a research unit outside of France), within the framework of a formal agreement between the CNRS and the Université de Montréal. The official name of this UMI is “Centre de recherches mathématiques – UMI 3457” and it was inaugurated in October 2011. This UMI is extremely successful, thanks to the outstanding work of its first director, Laurent Habsieger, and its current director, Professor Emmanuel Giroux (CNRS Research Director). The UMI gives financial support to French researchers so that they can visit the CRM for long or short periods of time. It also supports visits to France by Québec researchers who

spend a few weeks in France or are given temporary positions. The UMI also provides financial support for the organization of meetings and workshops, either directly or through the reimbursement of lecturers' expenses (for instance). In this manner the UMI supports the activities of the CRM thematic programs and other activities. The agreement between the CNRS and the Université de Montréal was renewed for five years in 2015.

When the President of France visited Québec in November 2014, the CNRS and the FRQNT signed an agreement providing for the financial support (by Québec) of Québec researchers visiting French laboratories (called *sites miroirs*) for periods of two to six months. The Québec researchers in question must be affiliated with one of the three UMIs located in Québec universities. In particular this agreement allows members of the CRM to visit France in order to work with their French colleagues.

Academic Partners

Legally speaking the CRM is a Université de Montréal research centre and has six university partners: the Université de Montréal, McGill University, UQAM, Concordia University, the Université Laval, and the Université de Sherbrooke. The Université de Montréal provides the CRM with its office space and an operating grant and the support of the other partner universities consists mainly of a support to the CRM laboratories. The Department of Mathematics and Statistics of the University of Ottawa became a partner of the CRM in 2003. The CRM finances teaching releases so that University of Ottawa researchers can work in the CRM laboratories and take part in its scientific activities. The CRM also supports postdoctoral fellows at the University of Ottawa and finances the CRM–University of Ottawa Distinguished Lecture Series, featuring talks by prominent mathematicians from Canada and abroad on topics at the forefront of mathematical research.

Collaborations with Research Networks

The CRM has created, on its own or with other institutes, research networks that promote collaborations in the mathematical sciences between universities and industry. In 1997 the CRM (whose director was Luc Vinet) created the Network for Computing and Mathematical Modeling (ncm_2), a consortium of research centres in the Montréal area. The ncm_2, which was funded by NSERC, was able to respond to the needs of industry in a wide variety of fields related to computing and mathematical modelling. At the present time it allows four research centres (the CRM, GERAD, CIRRELT, and CIRANO) to fund joint projects in the mathematical sciences.

The three Canadian mathematics institutes (the CRM, the Fields Institute, and PIMS) launched the Mitacs network in 1999, thanks to a grant from the Canadian government. The objective of Mitacs, the only network of centres of excellence in the mathematical sciences, was to channel Canadian efforts in designing, applying, and commercializing new mathematical tools and methodologies within the framework of a world-class research program. Mitacs was extremely successful: in particular it has involved up to 300 researchers and 600 students in around 50 Canadian universities. In 2011 Mitacs broadened the scope of its activities and the "mathematics" section of Mitacs was taken over by the Mprime network (from 2011 to 2014). Since Mprime does not exist anymore, the creation and fostering of CRM/industry partnerships is now taking place within the framework of the Institutes Innovation Platform (IIP), a project of the three Canadian mathematics institutes funded by NSERC and mentioned elsewhere in this report.

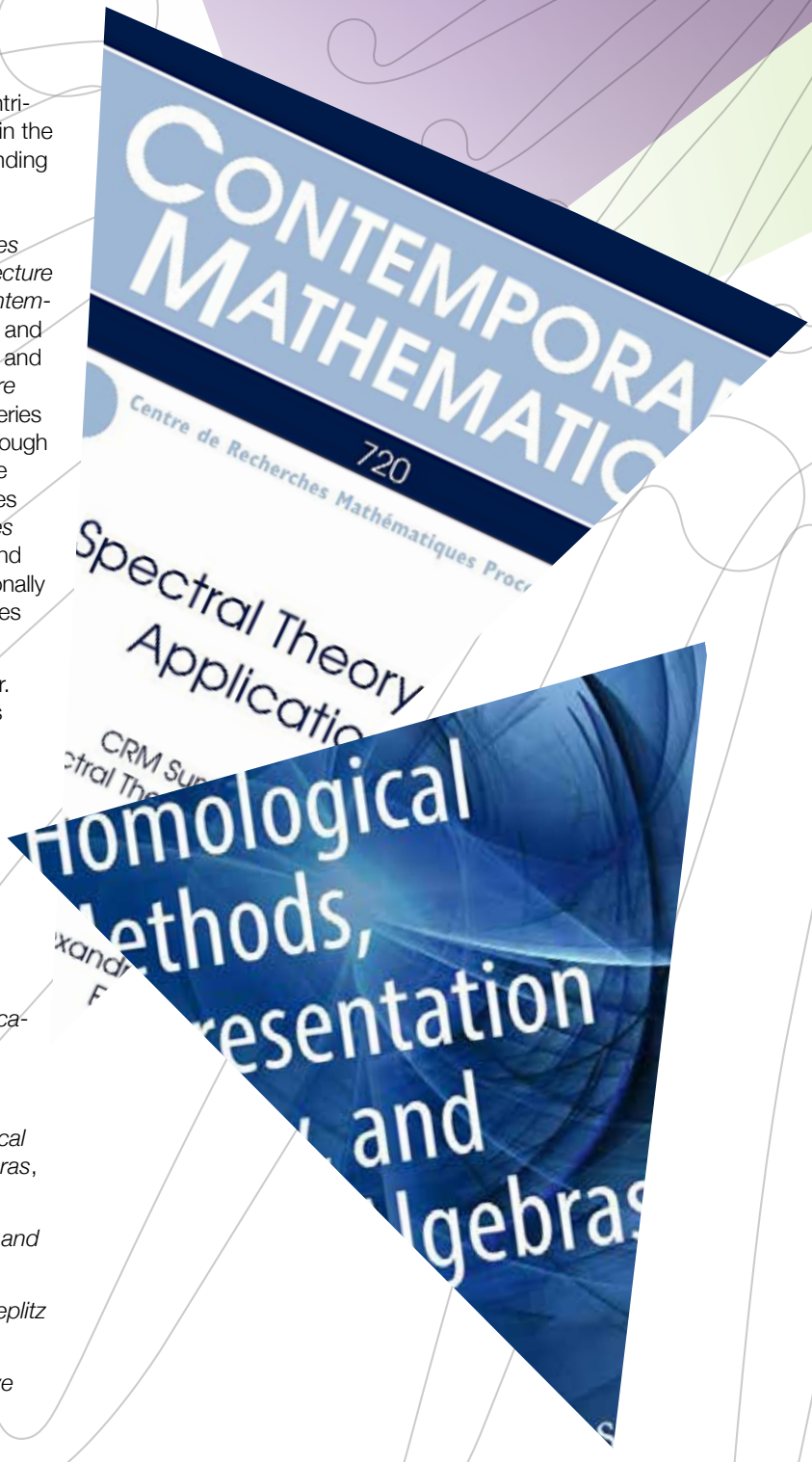
Collaborations with Professional Societies

The CRM and the other Canadian mathematics institutes extend some financial support for the organization of the meetings of Canadian societies in the mathematical sciences. In particular, in 2017–2018, the CRM supported the Mathematical Congress of the Americas (already mentioned in the section on other activities), the Winter Meeting of the CMS (Waterloo, December 9–11, 2017), the Annual Meeting of the Statistical Society of Canada (Winnipeg, June 11–14, 2017), and the Annual meeting of the Canadian Applied and Industrial Mathematics Society (Halifax, June 17–21, 2017).

CRM Publications

Publications are an important component of the contribution of the CRM to the dissemination of research in the mathematical sciences. The CRM has two long-standing series published in collaboration with the American Mathematical Society (AMS): the *CRM Monograph Series* and the *Centre de Recherches Mathématiques Proceedings* (formerly the *CRM Proceedings and Lecture Notes*). The second series has been included in *Contemporary Mathematics* since 2013. Springer publishes and distributes the *CRM Series in Mathematical Physics* and a few titles from the CRM were included in its *Lecture Notes in Statistics* series. The first volume of a new series (entitled *CRM Short Courses*) appeared in 2017. Although most of the books issued by the CRM are now to be found in these various series, the CRM also publishes and distributes, in French and in English, through *Les Publications du CRM*, monographs, proceedings, and lecture notes. In addition the CRM takes part occasionally in joint projects with various publishers and distributes preprints of articles authored by its researchers.

The CRM publishes *Le Bulletin du CRM* twice a year. This newsletter (20- to 30-page-long) includes news from the CRM and articles on its activities and the research of its members and prize winners.



2017–2018 Publications

Contemporary Mathematics — American Mathematical Society Centre de Recherches Mathématiques Proceedings

Alexandre Girouard (ed.), *Spectral Theory and Applications*, 2018

CRM Short Courses — Springer

Ibrahim Assem and Sonia Trepode (eds.), *Homological Methods, Representation Theory, and Cluster Algebras*, 2018

Daniel W. Stroock, *Elements of Stochastic Calculus and Analysis*, 2018

Yohann Le Floch, *A Brief Introduction to Berezin–Toeplitz Operators on Compact Kähler Manifolds,* 2018

Yuri I. Manin, *Quantum Groups and Noncommutative Geometry*, 2018

Véronique Hussin

CRM Committees

Governance & Scientific Guidance

The CRM structure consists of a Board of Directors, an Assembly of Members, an International Scientific Advisory Committee, a Local Scientific Committee, a Management Committee, a Committee of Laboratory Directors, and an Industrial Committee. Here are the members of these committees in 2017–2018 (except for the directors of laboratories, already mentioned in a previous section).

Board of Directors

The Board of Directors is composed of:

- The Director (ex officio);
- A member of the Management 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 Laboratory Directors for a two-year mandate, normally renewable once;
- The Chair of the International Scientific Advisory Committee;
- A postdoctoral member;
- The Vice-principals, Research, of the six partner universities of the CRM;
- Additional members nominated by the Board of Directors, with or without the right to vote, chosen within any relevant sector: business, industry, major Canadian or foreign research institutes, and public service.

In 2017–2018, the Board members were Luc Vinet (Director of the CRM), Véronique Hussin (Deputy Director of the CRM), Christiane Rousseau and Jacques Bélair (both from the Université de Montréal), Steven Boyer (Director of CIRGET), Gérard Ben Arous (Chair of the International Scientific Advisory Committee), Rebecca Patrias (postdoctoral fellow), Marie-Josée Hébert (Vice-Principal, Research, Université de Montréal), Christophe Guy (Vice-Principal, Research, Concordia), Martha Crago (Vice-Principal, Research, McGill), Catherine Mounier (Vice-Principal, Research, UQAM), Angelo Tremblay (Vice-Principal, Research, Université Laval), Vincent Aimez (Vice-Principal, Research, Université de Sherbrooke), Alina Stancu (Director of the ISM), Hélène Desmarais (*Centre d'entreprises et d'innovation de Montréal*), and Luis Seco (University of Toronto and Sigma Analysis and Management).

Louigi Addario-Berry (McGill) and Odile Marcotte (UQAM and GERAD), Deputy Directors of the CRM, were invited members of the Board of Directors.

International Scientific Advisory Committee

The International Scientific Advisory Committee (ISAC) consists of outstanding Canadian or foreign researchers who are either mathematicians or scientists with close links to the mathematical sciences. The main task of the Committee is to make recommendations on the general scientific orientations of the CRM and give advice on proposed scientific activities.

In 2017–2018 this committee was chaired by Gérard Ben Arous (Courant Institute) and also included Michael Bennett (University of British Columbia), Ruth Charney (Brandeis University), Emmanuel Giroux (CNRS), Claude Le Bris (École des Ponts ParisTech), Dusa McDuff (Columbia University), Robert Pego (Carnegie Mellon University), Duong Phong (Columbia University), Dana Randall (Georgia Institute of Technology), Nicolai Reshetikhin (University of California, Berkeley), Emmanuel Ullmo (*Institut des hautes études scientifiques*), and Luc Vinet (Director of the CRM).

Louigi Addario-Berry, Véronique Hussin, and Odile Marcotte (Deputy Directors of the CRM) were invited members of ISAC.

Local Scientific Committee

In 2017–2018 the Local Scientific Committee included Louigi Addario-Berry (McGill), Rustum Choksi (McGill), Octav Cornea (Montréal), Chantal David (Concordia), Alexandre Girouard (Laval), Erica E. M. Moodie (McGill), Hugh Thomas (UQAM), and Luc Vinet (Director of the CRM).

Management Committee

The Management Committee of the CRM consisted of Luc Vinet (Montréal), Director of the CRM; Louigi Addario-Berry (McGill), Deputy Director, Scientific Programming; Véronique Hussin (Montréal), Deputy Director, Publications and Communications; and Odile Marcotte (UQAM and GERAD), Deputy Director, Partnerships.

Industrial Committee

The Industrial Committee of the CRM consisted of Luc Vinet (Director of the CRM), Odile Marcotte (Deputy Director, Partnerships), Michel Carreau (Hatch), Denis Faubert (CRIAQ), Pierre Trudeau (GIRO), and Roxana Zangor (Pratt & Whitney Canada).

THE CRM IN NUMBERS

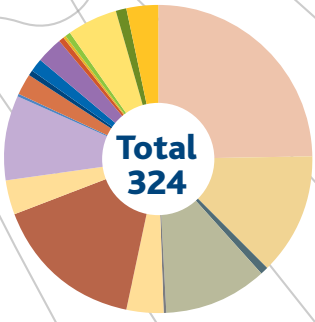
Sources of funding in 2017-2018
in thousands of $

FRQNT	**610**
NSERC	**1,178**
Universities (funding)	**901**
Universities (in-kind)	**1,350**
Endowments	**75**
Sales and registration fees	**171**
Simons Foundation	**216**
Partner organizations	**126**
	4,627

Use of funds
in thousands of $

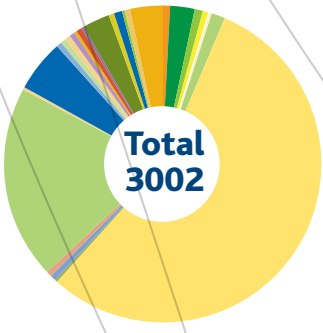
Laboratories	**871**
Programs	**1,108**
Postdoctoral fellows	**210**
Management and staff	**959**
Spaces and services (universities)	**1,350**
Communications	**27**
Operating costs	**102**
	4,627

Affiliation of the regular and associate members (researchers) of the CRM and its laboratories



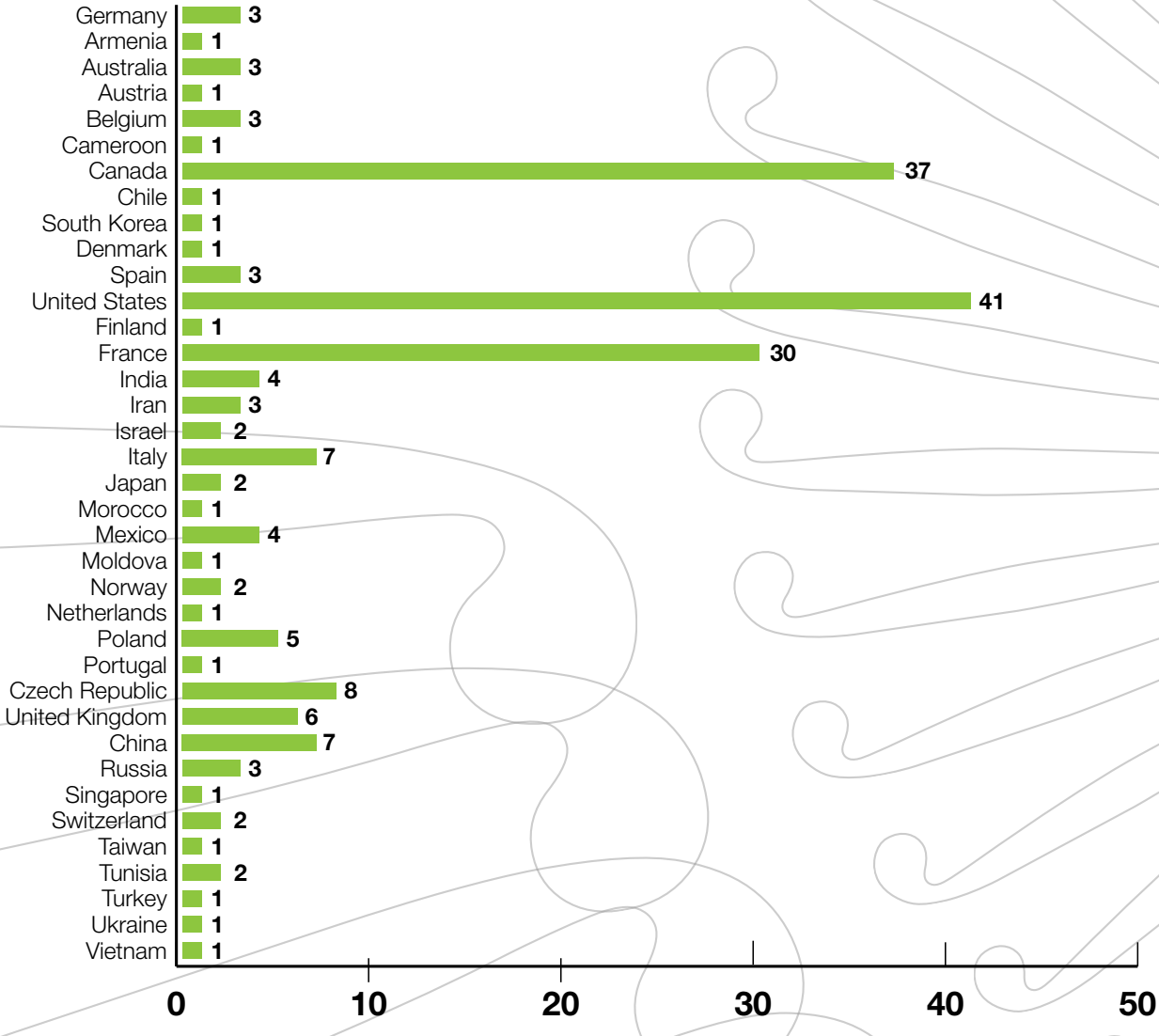
McGill University	80	Québec, Colleges	7
Université Laval	41	INRS	2
Université du Québec à Trois-Rivières	3	HEC Montréal	5
Université du Québec à Montréal	35	École Polytechnique de Montréal	9
Université du Québec à Chicoutimi	1	École de Technologie Supérieure	1
Université de Sherbrooke	12	Conseil National de Recherches du Canada	1
Université de Montréal	52	Mexico	2
University of Ottawa	11	Others, Europe	17
Concordia University	29	United States	4
Québec, Industry	1	Others, Canada	11

Country of origin of participants in CRM activities



Africa	18	India	14
Germany	79	Israel	15
Australia	22	Italy	24
Austria	15	Japan	14
Belgium	14	Mexico	10
Brazil	38	Middle East	13
Canada	1,660	Netherlands	13
Chile	11	United Kingdom	77
South Korea	14	China	18
Spain	16	Swizerland	23
United States	591	Other, Americas	14
Finland	14	Other, Asia	12
France	156	Other, Europe	107

Country of origin of visiting and postdoctoral researchers (193)



CRM Administrative and Support Staff

Direction

Luc Vinet	Université de Montréal Director
Louigi Addario-Berry	McGill University Deputy Director – Scientific Programming
Véronique Hussin	Université de Montréal Deputy Director – Publications and Communications
Odile Marcotte	UQAM and GERAD Deputy Director – Partnerships

Administration and Research Support

Vincent Masciotra	Head of Administration
Guillermo Martinez-Zalce	Research Laboratories Coordinator
Diane Brulé-De Filippis	Administrative Assistant
Lucie Vincent	Secretary
Wendy Barrientos	Administrative Assistant

Scientific Activities

Louis Pelletier	Coordinator
Louise Letendre	Administrative Assistant
Chantal Thibodeau	Administrative Assistant
Sakina Benhima	Project Manager
Guillermo Martinez-Zalce	Research Laboratories Coordinator

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

Special Projects

Stéphane Rouillon	Partnerships Development Officer

CENTRE
DE RECHERCHES
MATHÉMATIQUES

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