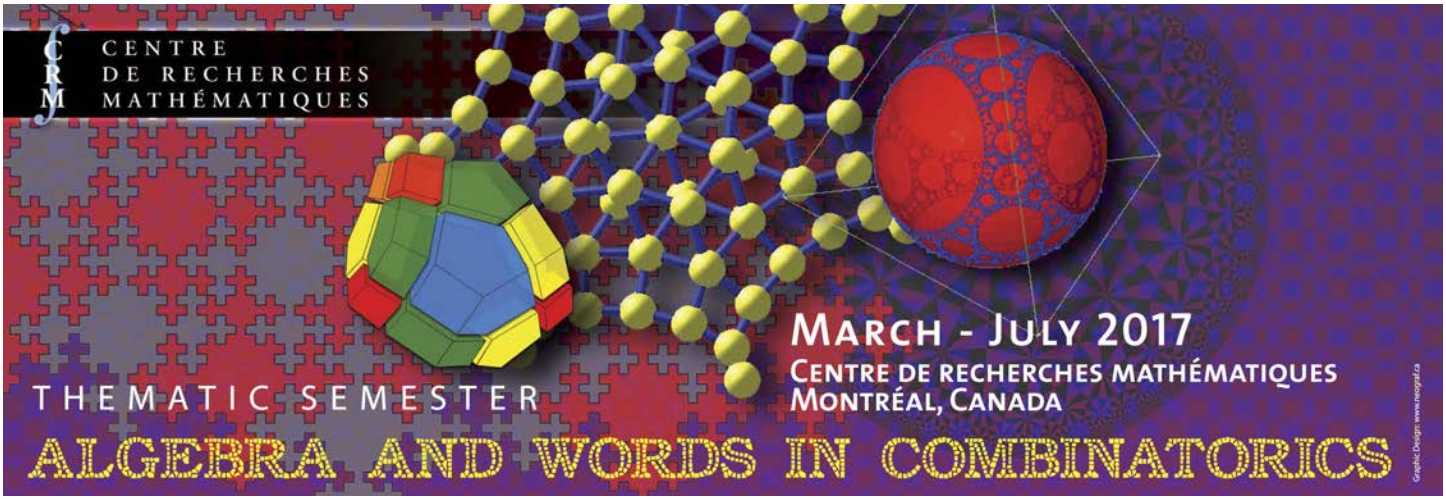
CENTRE DE RECHERCHES MATHÉMATIQUES

Le Bulletin

Automne/Fall 2016 — Volume 22, N° 2 — Le Centre de recherches mathématiques



Overview

The thematic semester will explore the close interactions between algebra, the theory of formal languages, and combinatorics, as well as a variety of fundamental questions that appear naturally when one interleaves principal threads from combinatorics, algebra, geometry, representation theory, and number theory.

Combinatorics has a strong tradition of fruitful interactions with other domains of mathematics, some of which are emerging. The program will be centred on the exploration of the various links: between automata, automatic sequences, algebra and number theory; between combinatorics on words and discrete geometry; between group representation theory, reflection groups and combinatorics; as well as several questions from algebraic geometry and knot theory linked to intriguing combinatorial considerations.

The aim of the workshops is to bring together junior and senior mathematicians working in these exciting areas to discuss their research and to foster collaborations. In total, there will be four major workshops; each workshop is preceded by a week-long school to introduce junior mathematicians to the most recent developments in these areas.

A central aspect of the program will be a focus on scientific computation and experimental mathematics as prominent research tools. There will be introductory sessions dedicated to presenting the cutting-edge research tools in the various research areas.

Aisenstadt Chairs

Vic Reiner (University of Minnesota), March–April 2017
Boris Adamczewski (CNRS, Institut Camille Jordan), April–May 2017

School and Workshops

Combinatorics on Words and Tilings
School: March 27–31, 2017
Workshop: April 3–7, 2017
Organizers: Alexandre Blondin Massé (UQAM), Srečko Brlek (UQAM), Xavier Provençal (Université Savoie Mont Blanc)

Bridges between Automatic Sequences, Algebra and Number Theory
School: April 24–28, 2017
Workshop: May 1–5, 2017
Organizers: Boris Adamczewski, Jason Bell (University of Waterloo), Valérie Berthé (CNRS, Institut de recherche en informatique fondamentale), Sébastien Labbé (CNRS, Laboratoire bordelais de recherche en informatique)

Algebraic and Geometric Combinatorics of Reflection Groups
School: May 29–June 2, 2017
Workshop: June 5–9, 2017
Organizers: Mathieu Dyer (University of Notre Dame), Christophe Hohlweg (UQAM), Vincent Pilaud (CNRS, Laboratoire d'informatique de l'école polytechnique), Hugh R. Thomas (UQAM)

Equivariant Combinatorics
School: June 12–16, 2017
Workshop: June 19–23, 2017
Organizers: François Bergeron (UQAM), Luc Lapointe (Universidad de Talca), Jennifer Morse (Drexel University), Franco Saliola (UQAM)

Related Activities

Combinatorial Algebra Meets Algebraic Combinatorics
Dates: January 27–29, 2017
Organizers: Alexander Garver (UQAM), Christophe Hohlweg, Rebecca Patrias (UQAM), Franco Saliola, Hugh R. Thomas

Sage Days
Dates: May 8–12, 2017
Organizers: Sébastien Labbé, Nicolas M. Thiéry (Université Paris-Sud)

International Scientific Advisory Committee

Jason Bell, Mireille Bousquet-Mélou (CNRS, Laboratoire bordelais de recherche en informatique), Jennifer Morse, Christophe Reutenauer (UQAM), Anne Schilling (University of California, Davis), Nicolas M. Thiéry, Hugh R.Thomas

Sponsors

This thematic program is funded by the following organizations: NSERC (Canada), FRQNT (Québec), Université de Montréal (where the CRM is located), McGill University, UQAM, Concordia University, Université Laval, University of Ottawa, Université de Sherbrooke, European Research Council, Horizon 2020, and CNRS (France).

2016 CRM–SSC Prize Recipient

V. Radu Craiu (University of Toronto)

V. Radu Craiu

The 2016 CRM–SSC Prize in Statistics is awarded to Virgil Radu Craiu of the University of Toronto. The CRM–SSC Prize in Statistics is awarded annually by the CRM and the Statistical Society of Canada (SSC). It is awarded in recognition of a statistical scientist's professional accomplishments in research during the first fifteen years after having received a doctorate.

Radu Craiu grew up in Bucharest, Romania, where he received his B.Sc. and M.Sc. degrees in mathematics. After a brief stage in Paris, where he developed both statistical knowledge and conversational French under the supervision of Christian Robert, he enrolled in the Ph.D. program of the Statistics Department at the University of Chicago. Five years later, in 2001, he completed his doctoral dissertation, *Multivalent Framework for Approximate and Exact Sampling and Resampling*, under the direction of Xiao-Li Meng, including research about antithetic coupling schemes for Markov chain Monte Carlo (MCMC) algorithms, which was later published in *The Annals of Statistics*.

Upon graduation, Dr. Craiu received a number of job offers. He settled on the University of Toronto, where he has been a professor of statistics ever since. In that time, he has published several dozen research papers, in such leading journals as *The Annals of Statistics*, *Journal of the American Statistical Association*, *The Annals of Applied Statistics*, *Journal of Computational and Graphical Statistics*, *Statistics and Computing*, *Biometrika*, and more. And at last check, he has already submitted three new research papers during the first three months of 2016—so he won't be slowing down any time soon!

Most striking is the breadth of Prof. Craiu's research. He has published papers about such important and diverse topics as statistical computation, MCMC methodology, copula applications, and competing risk models. In addition, he joined forces with the biostatistician Lei Sun, not only to get married and raise two delightful children, but also to publish several important papers about statistical genetics, including its relation to winner's curse and false discovery rates.

In assessing Prof. Craiu's research, leading experts have written such praise as: "Radu is doing excellent and highly original work in several areas of modern statistical science; he has a broad range of interests and signifiant achievements", "I am struck especially by the fact that Radu has made substantial contributions across a number of topic areas—his combination of breadth and depth is really impressive... Radu's record of leadership is exemplary", "Professor Craiu has produced an amazing array of high quality papers in diverse areas ranging from statistical genetics to Markov chain Monte Carlo... One thing that has always impressed me is how impeccably well-written his papers are", and that he "deeply contributes to shaping computational and applied Statistics with... many clever advances in Monte Carlo methods" which are "deep and at the forefront", and "Many highly distinguished researchers finish their careers without reaching anything like the diversity that Dr. Craiu has already achieved."

Prof. Craiu's deep and influential research contributions, the breadth of his research topics, the impressiveness of his publication record, and his many deep research ideas, all clearly demonstrate great distinction in research in statistics. He is a powerful and gifted researcher, and will continue to produce new ideas at a very high level for many years to come.

Radu Craiu will give his prize lecture at the CRM on January 27, 2017.

2016 Aisenstadt Chair

Selim Esedoḡlu (University of Michigan)

April 4 and 7, 2016

Rustum Choksi and Adam Oberman (McGill University)

Selim Esedoḡlu

The Aisenstadt Chair during the "Thematic Semester on Computational Mathematics in Emerging Applications" was held by Selim Esedoḡlu, Professor of Mathematics at the University of Michigan, Ann Arbor. Selim Esedoḡlu received his Ph.D. from the Courant Institute under the supervision of Robert Kohn in 2000. After postdoctoral positions at the IMA (Minnesota) and UCLA, he joined the faculty at Ann Arbor. He has been the recipient of both a Sloan Foundation Fellowship and an NSF Early Career award. Selim Esedoḡlu is an expert at using tools from the modern calculus of variations and nonlinear partial differential equations to develop state of the art numerical methods for addressing contemporary problems in image processing and in the material sciences.

Selim Esedoḡlu delivered a series of three lectures titled:

- *Algorithms for Motion by Mean Curvature of Networks of Surfaces, and Applications*;
- *Threshold Dynamics for Networks with Arbitrary Surface Tensions*;
- *Threshold Dynamics for Anisotropic Surface Energies.*

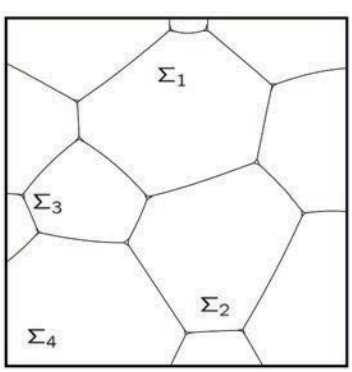
Motion by mean curvature for networks of surfaces arises in many scientific contexts. This evolution describes gradient descent, in an appropriate sense, for a variational model that penalizes surface area of interfaces that partition a domain D, say in $\mathbb{R}^d$, into disjoint regions. A typical cost function is the following:

$$E(\Sigma_1, \ldots, \Sigma_N) = \sum_{\substack{i,j=1 \\ i<j}}^{N} \text{Area}(\partial\Sigma_i \cap \partial\Sigma_j) \tag{1}$$

which is to be minimized over subsets $\Sigma_1, \ldots, \Sigma_N$ of D that are subject to the constraints:

$$\Sigma_i \cap \Sigma_j = \partial\Sigma_i \cap \partial\Sigma_j \text{ for } i \neq j, \quad \text{and} \quad \bigcup_{i=1}^{N} \Sigma_i = D. \tag{2}$$

Variational model (1) & (2) appears often in applications. For example, in the context of computer vision, it appears in the image segmentation model of Mumford & Shah [8], where the regions Σ_i correspond to distinct objects contained in a given image. In the context of materials science, it appears prominently in Mullins' [7] model for grain boundary motion, where the regions Σ_i correspond to single crystal pieces, known as grains, that make up a polycrystalline material: when heated, the grain boundaries $\partial\Sigma_i$ in such a material are believed to move in order to dissipate the internal energy (1) of the system. More recently, cost function (1) has also proved useful in the context of machine learning [3], where the domain D is now a graph, Σ_i are disjoint collections of its vertices, and the surface area of $\partial\Sigma_i$ is the sum of the weights of edges severed in separating Σ_i from Σ_i^c.



A domain D and its partition into regions Σ_i.

The simplest case is with $D = \mathbb{R}^d$ and $N = 2$, where the energy becomes

$$E(\Sigma) = \text{Area}(\partial\Sigma). \tag{3}$$

In this case, L^2 gradient descent on $\partial\Sigma$ leads to motion by mean curvature

$$v_\perp(x) = H(x) \tag{4}$$

where each point $x \in \partial\Sigma$ moves with normal speed $v_\perp(x)$ given by the mean curvature $H(x)$ at that point. Even in this simplest setting, computing the flow $\Sigma(t)$ is challenging since $\partial\Sigma(t)$ can change topology during the evolution. This challenge can be met with many famous modern numerical methods, such as the level set [9] and phase field methods. An important property of evolution (4) is monotonicity: if $\Sigma(0) \subset \Omega(0)$ are both evolved under this flow, their inclusion relation is preserved for all time: $\Sigma(t) \subset \Omega(t)$. No such simple comparison principle exists in the *multi-phase* situation, $N > 2$.

The Aisenstadt lectures focused on an almost miraculously simple and efficient class of numerical algorithms, known as threshold dynamics, that was proposed originally by Merriman, Bence, and Osher [5, 6] for evolutions such as (4) that result from variational models such as (3). In the simplest two-phase setting of (4), given a time step size $\delta t > 0$, a

discrete-in-time approximation to the flow $\Sigma(t)$ is generated by alternating the following steps to advance from approximate solution Σ^k at time $t = k\delta t$ to Σ^{k+1} at time $t = (k+1)\delta t$:

(A1.1) Convolution: $u = K_{\delta t} * \mathbf{1}_{\Sigma^k}$, followed by
(A1.2) Thresholding: $\Sigma^{k+1} = \{x : u(x) \geq \frac{1}{2}\}$.

Here, the convolution kernel $K_{\delta t}$ is obtained by scaling a given kernel K: $K_{\delta t}(x) = 1/(\delta t)^d K\big(x/(\delta t)\big)$. In the original paper [6], K is taken to be the Gaussian, thus radially symmetric. Since $K \geq 0$ in that case, the scheme respects the monotonicity of flow (4) regardless of the size δt of the time step, resulting in unconditional stability. The scheme is easy and efficient to implement on a uniform grid, since then the fast Fourier transform can be used to do the convolution, while the pointwise thresholding step is entirely trivial. Simulations show the scheme moves past topological changes effortlessly, as in level set and phase field methods.

An extension of this elegant scheme to the multiphase setting of (3) appears in the original paper [6]. To obtain the phases Σ_i^{k+1}, $i = 1, 2, \ldots, N$, at time $t = (k+1)\delta t$ from those at time $t = k\delta t$ requires merely the following steps:

(A2.1) Convolution: $u_i = K_{\delta t} * \mathbf{1}_{\Sigma_i^k}$, followed by
(A2.2) Thresholding: $\Sigma_i^{k+1} = \{x : u_i(x) \geq \max_{j \neq i} u_j(x)\}$.

In words, the phases compete for each point $x \in D$ based on their local density around x at the current time step. Whichever has the largest density claims the point x for itself at the next time step. Astonishingly, even the boundary condition known as the Herring angle condition that needs to be imposed along free boundaries known as triple junctions (which are curves formed as the intersection of three of the interfaces in the network) is automatically satisfied by these two simple steps.

The lectures addressed the following questions about threshold dynamics that had remained unanswered despite a number of previous attempts:

1. Can the multi-phase algorithm (A2.1) & (A2.2) be extended, while preserving its elegance and efficiency, to energies such as

$$E(\Sigma_1, \ldots, \Sigma_N) = \sum_{\substack{i,j=1 \\ i<j}}^{N} \sigma_{i,j} \operatorname{Area}(\partial\Sigma_i \cap \partial\Sigma_i) \tag{5}$$

that are of greater interest to, e.g., materials scientists? Here, $\sigma_{i,j}$ are positive, possibly distinct constants. In the context of polycrystalline materials, they represent the *surface tension* associated with the interface between any two neighbouring grains, which is known to depend on the mismatch between crystallographic orientations of the two single crystal pieces.

2. Previous studies, e.g., [1, 4, 10], indicated that using convolution kernels K other than the Gaussian in (A1.1) & (A1.2) may yield gradient descent for the following *anisotropic* version of energy (3):

$$E(\Sigma) = \int_{\partial\Sigma} \sigma\big(n(x)\big)\, \mathrm{d}S(x) \tag{6}$$

where $\mathrm{d}S$ denotes the surface area element, $n(x)$ is the unit normal at $x \in \partial\Sigma$, and $\sigma\colon \mathbb{S}^{d-1} \to \mathbb{R}^+$ is an even function. Whether a convolution kernel K can be found for any given anisotropy σ had remained incompletely understood. Whether it can be chosen to be positive, so that the scheme preserves monotonicity, was even less understood.

3. Finally, can the multi-phase algorithm (A2.1) & (A2.2) be extended to the even more general multi-phase, anisotropic setting of the variational model

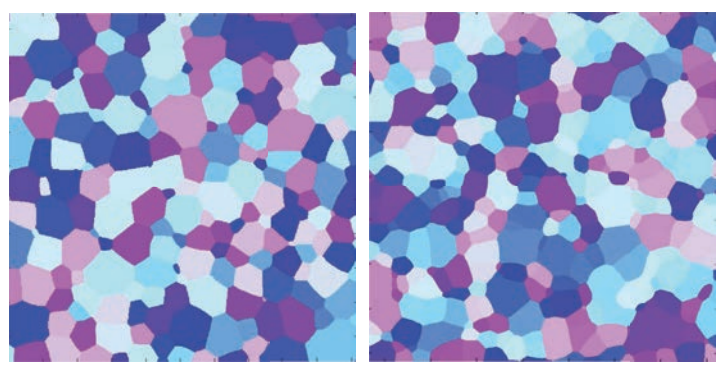
$$E(\Sigma_1, \ldots, \Sigma_N) = \sum_{\substack{i,j=1 \\ i<j}}^{N} \int_{\partial\Sigma_i \cap \partial\Sigma_j} \sigma_{i,j}\big(n(x)\big)\, \mathrm{d}S(x) \tag{7}$$

where each surface tension $\sigma_{i,j}\colon \mathbb{S}^{d-1} \to \mathbb{R}^+$ can be a distinct even function?

The answers the lectures provided were based on a new, variational interpretation for threshold dynamics algorithms (A1.1) & (A1.2) and (A2.1) & (A2.2) obtained in joint work [2] with Felix Otto. This new formulation shows that threshold dynamics type algorithms can be derived from nonlocal approximations to energies such as (3) by a systematic procedure. For example, in the case of energy (5), the non-local approximation reads

$$E_t(\Sigma_1, \ldots, \Sigma_N) = \sum_{\substack{i,j=1 \\ i<j}}^{N} \sigma_{i,j} \int_{\Sigma_i} K_t * \mathbf{1}_{\Sigma_j}\, \mathrm{d}x. \tag{8}$$

The systematic procedure then yields a threshold dynamics algorithm for model (5) that is just as elegant as (A2.1) & (A2.2). The lectures discussed how the same variational interpretation of threshold dynamics also allows one to easily



Left: A grain boundary network after evolution by model (1) computed using original threshold dynamics algorithm (A2.1) & (A2.2). Right: Same network after evolution by model (5) computed using the extension of threshold dynamics algorithm that results from the variational interpretation discussed in the lectures. The colours represent crystallographic orientation of the grains. Surface tensions $\sigma_{i,j}$ for the interfaces in model (5) were determined in terms of these orientations using a well-known surface tension model in materials science literature.

(*continued on page 6*)

2016 Aisenstadt Chair

Nalini Anantharaman (Université de Strasbourg)

August 22–24, 2016

Dmitry Jakobson (McGill University)

Nalini Anantharaman

Nalini Anantharaman received her Ph.D. in 2000 *under the supervision of François Ledrappier at the Université Pierre et Marie Curie. She worked at the ENS Lyon and at the École polytechnique before becoming a full Professor at the Université Paris-Sud in* 2009*. She is now a Professor at the Université de Strasbourg. Professor Anantharaman held visiting positions at UC Berkeley* (*where she was a Visiting Miller Professor in* 2009) *and at IAS, Princeton in* 2013*.*

In 2011*, Nalini Anantharaman received the Jacques Herbrand Prize from the French Academy of Sciences. In* 2011*, she also won the Salem Prize. In* 2012 *she won the Henri Poincaré Prize for mathematical physics. In* 2013 *she was awarded the Médaille d'argent of the CNRS. She served as Vice-President of the Société Mathématique de France.*

Nalini Anantharaman gave her Aisenstadt lectures on August 22, 23 and 24, 2016, during the workshop "Probabilistic Methods in Spectral Geometry and PDE" held at the CRM on August 22–26, 2016.

In her first lecture, Professor Anantharaman gave a survey of the classical results due to Shnirelman, Zelditch and Colin de Verdière on delocalization (equidistribution) of eigenfunctions at high energy, or the so-called quantum ergodicity. She presented a new proof, that was later generalized to the case of operators on graphs, and described a probabilistic version of the quantum ergodicity theorem (due to Zelditch, VanderKam et al.). She also discussed eigenfunction localization on the sphere and on arithmetic tori (results due to Jakobson, Bourgain, Anantharaman, Macia et al.). Nalini then stated the quantum unique ergodicity conjecture of Rudnick and Sarnak. Next, she described several further developments, including the proof of the conjecture for arithmetic hyperbolic manifolds by Lindenstrauss, Holowinsky and Soundararajan, and counterexamples for the Bunimovich stadium due to Hassell et al. She also described her own work (together with Nonnenmacher and Koch) on the entropy of quantum limits and consequences to equidistribution of eigenfunctions. She next discussed "local" (small scale) equidistribution of eigenfunctions, including Berry's "semiclassical eigenfunction hypothesis," as well as recent work of Hezari, Rivière, Han, Lester, Rudnick et al.

In her second lecture, Nalini Anantharaman talked about quantum ergodicity on regular graphs. She considered finite regular graphs whose size grows to infinity, and discussed some delocalization results for eigenfunctions of the adjacency matrix (joint with Le Masson), as well as connections between quantum ergodicity on graphs and that on manifolds, mostly through the work of Lindenstrauss and collaborators on arithmetic quantum ergodicity. Eigenvalue spacings for random graphs were first studied by Jakobson–Miller–Rivin–Rudnick and by Lafferty–Rockmore; eigenvector localization was considered by Smilansky, Kottos, Elon, Bogomolny, Keating, Berkolaiko, Winn, Piotet, Marklof, Gnutzmann and others. For a fixed metric graph, it is known that quantum ergodicity does not hold in the high energy limit (Tanner, Colin de Verdière). She discussed graph sequences converging to a regular tree in the sense of Benjamini–Schramm (e.g., few short cycles compared to the graph size). It follows from the work of Kesten–McKay that eigenvalue density converges to the spectral measure for the random walk on a tree. The lecture also covered eigenvector delocalization results due to Brooks–Lindenstrauss (in the L^p sense). She next formulated her joint result with Le Masson on eigenvector delocalization for graph sequences (with few short cycles and a uniform spectral gap) in the sense that is closer to the definition of QE on manifolds (inner product observables of eigenvectors with "observables"). The hypotheses are satisfied for random graphs, and for numerous explicit graph families. A probabilistic proof of a related result was given by Geisinger in 2013. She also stated a more general "operator" version of her result with Le Masson. The proof proceeds by the phase space analysis (à la Helgason) on regular graphs, and use of geodesic dynamics to study eigenfunctions of the Laplacian. The proof was reminiscent of the proof in the continuous case described in the first lecture. Nalini finished the lecture by stating a continuous analogue of those results by Le Masson–Sahlsten (explained in more detail by Le Masson later in the conference). She also stated a related result (due to Brooks, Le Masson and Lindenstrauss) on delocalization of spherical harmonics that are eigenfunctions of Hecke operators.

In her last lecture, Nalini Anantharaman discussed possible extensions of quantum ergodicity results from the case of regular graphs to other models: Anderson model on regular graphs (work in progress with Mostafa Sabri), percolation graphs on regular graphs. She also compared her recent results to recent results on eigenvectors of random matrices.

Nalini's lectures were well attended and were a great success.

Computational Optimal Transportation

July 18–22, 2016

Organizers: Adam M. Oberman (McGill), Jean-David Benamou (INRIA)

Computational Optimal Transportation is a field which barely existed in 2012. It has grown immensely, in large part due to a productive collaboration between the French group, largely based in INRIA and Paris-Dauphine, and the north American group, spread across several universities in Canada. This workshop started as a working group of eight people in Banff four years ago, and has grown to a workshop attended by 50 people, in a growing number of topics.

The mathematical theory of Optimal Transportation has seen a great deal of activity in the last fifteen years. However, applications require numerical methods, and this has been lacking, due to the apparently intractable nature of the computations involved. Progress in PDE and linear programming method led to substantial gains in the complexity of problems which could be solved. A recent breakthrough by Cuturi–Peyre and collaborators was the entropic regularization method, which is a modification of the OT problem, adding entropy to the measures involved.

The workshop was notable in that the majority of speakers were early career researchers and postdocs. Since the field is growing so fast, significant and novel contributions are being made by young researchers. The excitement of working in an emerging field with lots of opportunities was palpable. The talks were notable in that each half day session was organized thematically, and the topics were on new subjects. This made the talks interesting with a focus on ideas and methods rather than technical detail.

This has led to new progress in machine learning and big data applications. In particular the Gromov–Wasserstein model, discussed by Peyre, uses intrinsic metrics to compare shapes. Solomon compares distances on graph where computing the geodesic distance directly would be intractable. The Wasserstein metric has natural applications to statistics. Novel approaches to nonlinear nonparametric regression were discussed by Cuturi. These approaches have also been used to explain variability in spatially distributed or biased data by Triglia.

The workshop included half days on: PDE Methods by Mirebeau, Froese and Duval, which was impressive in the depth and power of the state of the techniques; Economic and Finance Applications, by Carlier, Kim, and Dupuis, which showcased the impact of the field in matching problems and robust risk management; and Reflector Problems by Guitierrez and Levy, where the OT problem can be used to solve a reflector design problem leading to custom-designed reflectors found by solving nonlinear PDEs, used in modern lighting applications; Numerical Methods including further advances in the entropic regularization method, applications to weak solutions of the Euler PDE for incompressible fluids, an implementation of a weak solution developed by Brenier.

Selim Esedoḡlu

(*continued from page 4*)

answer some of the questions regarding anisotropic models (6) and (7). For example, it turns out that in two dimensions, a monotone two-phase threshold dynamics algorithm of the form (A1.1) & (A1.2) can be devised, by constructing a positive convolution kernel K, for essentially any given anisotropy σ, but this is no longer the case in three dimensions: there exist smooth, strictly convex anisotropies σ for which no monotone threshold dynamics scheme can be found.

[1] E. Bonnetier, E. Bretin, and A. Chambolle. "Consistency result for a non monotone scheme for anisotropic mean curvature flow". *Interfaces Free Bound.* 14:1 (2012), 1–35.

[2] S. Esedoḡlu and F. Otto. "Threshold dynamics for networks with arbitrary surface tensions". *Comm. Pure Appl. Math.* 68:5 (2015), 808–864.

[3] C. Garcia-Cardona, E. Merkurjev, A.L. Bertozzi, A. Flenner, and A.G. Percus. "Multiclass data segmentation using diffuse interface methods on graphs". *IEEE Trans. Pattern Anal. Mach. Intell.* 36:8 (2014), 1600–1613.

[4] H. Ishii, G.E. Pires, and P.E. Souganidis. "Threshold dynamics type approximation schemes for propagating fronts". *J. Math. Soc. Japan* 51:2 (1999), 267–308.

[5] B. Merriman, J.K. Bence, and S.J. Osher. "Diffusion generated motion by mean curvature". *Computational Crystal Growers Workshop*. Ed. by J.E. Taylor. 1992, 73–83.

[6] B. Merriman, J.K. Bence, and S.J. Osher. "Motion of multiple functions: a level set approach". *J. Comput. Phys.* 112:2 (1994), 334–363.

[7] W.W. Mullins. "Two-dimensional motion of idealized grain boundaries". *J. Appl. Phys.* 27 (1956), 900–904.

[8] D. Mumford and J. Shah. "Optimal approximations by piecewise smooth functions and associated variational problems". *Comm. Pure Appl. Math.* 42:5 (1989), 577–685.

[9] S. Osher and J.A. Sethian. "Fronts propagating with curvature-dependent speed: Algorithms based on Hamilton–Jacobi formulations". *J. Comput. Phys.* 79:1 (1988), 12–49.

[10] S.J. Ruuth and B. Merriman. "Convolution-generated motion and generalized Huygens' principles for interface motion". *SIAM J. Appl. Math.* 60:3 (2000), 868–890.

2016 André Aisenstadt Prize

Anne Broadbent (University of Ottawa)

Anne Broadbent earned her Ph.D. from the Université de Montréal in 2008, *under the joint supervision of Alain Tapp and Gilles Brassard. Her thesis* Quantum Nonlocality, Cryptography and Complexity *was distinguished by several prizes, including an NSERC Doctoral Prize. She went on to win the prestigious John Charles Polanyi Prize in Physics in* 2010. *Dr. Broadbent continued her research at the Institute for Quantum Computing of the University of Waterloo, first as an NSERC postdoctoral fellow, and then as a CIFAR Global Scholar* (2011–2013). *In January* 2014, *she joined the Department of Mathematics and Statistics at the University of Ottawa, where she holds the University Research Chair in Quantum Information.*

Anne Broadbent

Prof. Broadbent presented her prize lecture on September 23, 2016. *She wrote the following description of her research for the Bulletin.*

Introduction

Quantum cryptography is the art and science of exploiting quantum mechanical effects in order to perform cryptographic tasks. *Quantum key distribution* (QKD) is one of the first and undeniably the most well-known example of this discipline. In a nutshell, QKD exploits quantum mechanical effects such as Heisenberg's uncertainty principle to ensure that two parties, Alice and Bob, can communicate in perfect secrecy, assuming only that they share an initial short secret (thus, QKD is more accurately described as a *key expansion* primitive). The amazing feature of quantum mechanics is that it allows such a primitive without introducing any extra assumptions—in contrast, such a feat is known to be impossible using classical (non-quantum) information alone. First-generation technologies for quantum key distribution are well understood and already commercially available.

While QKD has taken the spotlight in terms of applications of quantum information to cryptography, there are many areas where quantum information offers a new perspective to cryptography—as well as many more new areas to explore! (For a survey, please see [11]).

Delegated Quantum Computation

My research focuses on the benefits and challenges of cryptography in a quantum world. One important area of interest is *Delegated Quantum Computation*, which I now describe.

Quantum computers are known to enable extraordinary computational feats unachievable by today's devices: without a doubt, the most outstanding being Shor's algorithm for factoring integers and computing discrete logarithms [17] (the consequence of this being that the ubiquious RSA cryptosystem [16] is insecure in the presence of quantum computers!). However, technologies to build quantum computers are currently in their infancy; the current state-of-the-art suggests that, when quantum computers become a reality, these devices are likely to be available at a few location only. In this context, we envisage the outsourcing of quantum computations from quantum computationally weak clients to powerful quantum computers (a type of *quantum cloud* architecture). From the cryptographic point of view, this scenario raises many questions in terms of the possibility of privacy in delegated quantum computation.

Together with Fitzsimons and Kashefi [7], I gave the first practical and universal protocol for private delegated quantum computation, called "blind quantum computation" (BQC). In BQC, the client only needs to be able to prepare random single-qubit auxiliary states (the client requires no quantum memory or quantum processor). Via a classical interaction phase, the client remotely drives a quantum computation of her choice, such that the quantum server cannot learn any information about the computation that is performed—with only the client learning the output. The BQC protocol has been the object of a photonic experimental demonstration [3].

Remarkably, in BQC, the technology required on the client's side is very similar to what is required in QKD. However, for the first time, in BQC this technology is used to directly achieve a *computational* cryptographic task (in prior protocols, states are directly measured in order to extract classical information). This feature is more clearly apparent in a related protocol called "quantum computing on encrypted data" (QCED) [5, 13]. Here, the computation (as given by a quantum circuit) is public, but is executed remotely on an *encrypted* version of the data (reminiscent of the work on classical *fully homomorphic encryption* [15]). In this situation, QCED shows that it is possible to achieve delegated quantum computation where the client only needs to send random states in $\{|\nwarrow\rangle, |\nearrow\rangle, |\circlearrowleft\rangle, |\circlearrowright\rangle\}$ (the arrow symbols represent the polarization of light particles, and are more abstractly represented as quantum states in $\{(|0\rangle + |1\rangle)/\sqrt{2}, (|0\rangle - |1\rangle)/\sqrt{2}, (|0\rangle + \mathrm{i}\,|1\rangle)/\sqrt{2}, (|0\rangle - \mathrm{i}\,|1\rangle)/\sqrt{2}\}$.

I now give further details on the QCED protocol. Let $\mathsf{X}\colon |j\rangle \mapsto |j \oplus 1\rangle$, $\mathsf{Z}\colon |j\rangle \mapsto (-1)^j\,|j\rangle$ and $\mathsf{Y} = -\mathrm{i}\mathsf{XZ}$ (together with the identity, these are the single-qubit *Pauli operators*), and define the single-qubit gates $\mathsf{H}\colon |j\rangle \mapsto (|0\rangle + (-1)^j\,|1\rangle)/\sqrt{2}$,

$\mathsf{P}\colon |j\rangle \mapsto (\mathrm{i})^j |j\rangle$ and $\mathsf{T}\colon |j\rangle \mapsto \mathrm{e}^{\mathrm{i}j\pi/4} |j\rangle$. Recall also the two-qubit gate $\mathsf{CNOT}\colon |j\rangle |k\rangle \mapsto |j\rangle |j \oplus k\rangle$.

In order to encrypt an n-qubit state, we apply to each qubit a uniformly random Pauli operator, as given by a randomly chosen *key*; this is known as the *quantum one-time pad* [2]. The n-qubit *Clifford group* is defined as the set of n-qubit operators that conjugate n-qubit Pauli operators into n-qubit Pauli operators; a universal gate set for *Clifford group circuits* consists of the Pauli gates themselves, together with H, P and CNOT. Therefore, it is clear that applying a Clifford group circuit to encrypted quantum data is equivalent to applying the same Clifford group circuit to the unencrypted data *up to a change in the encryption key*. In order to perform *universal* quantum computations, we must add another gate not in the Clifford group, which we choose to be the T-gate. Note that $\mathsf{TX} = \mathsf{XZPT}$, and so we can no longer simply apply the T on encrypted data and re-interpret the key, because the output may pick up an undesirable P gate, which cannot be corrected by applying a Pauli operator. We solve this problem using classical interaction and a single forward auxiliary qubit randomly chosen out of four possibilities. See Figure 1. The reader is referred to [5, 13] for a more complete description, formal definitions and proofs.

Related Problems

The possibility of outsourcing private quantum computations raises a myriad of related paradigms and questions. We now list a few.

- *Quantum Fully Homomorphic Encryption.* Would it be possible to efficiently outsource *any* quantum computation on encrypted quantum data (as chosen by the Server)? In the classical world, this is known as *Fully Homomorphic Encryption* (FHE), and its achievability was the object of a recent breakthrough [15]. In the quantum world, together with Jeffery, I was the first to formally define the paradigm and to provide a scheme for a large, yet restricted family of circuits [9]. This was recently improved to the class of all polynomial-sized quantum circuits [12].

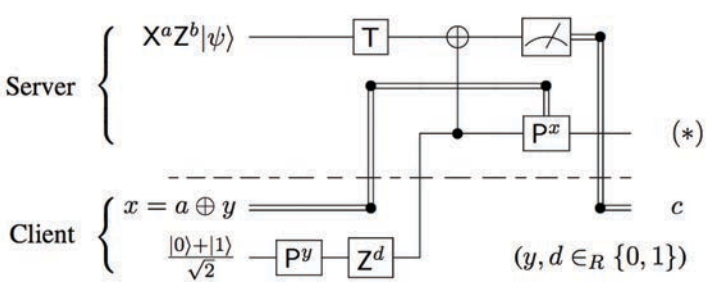


Figure 1. Interactive protocol for a T-gate. At the beginning of the protocol, the Server holds an encrypted input $\mathsf{X}^a\mathsf{Z}^b|\psi\rangle$, and receives from the Client a classical bit $x = a \oplus y$ and an auxiliary qubit $\mathsf{Z}^d\mathsf{P}^y\big((|0\rangle + |1\rangle)/\sqrt{2}\big)$ (y and d are chosen uniformly at random). Next, the server applies a CNOT, measures the top wire in the computational basis and returns the result c to the Client. The Server applies P^x (a gate conditioned on the value x). Finally, the Client updates her value for the key on the output wire, using $(*) = \mathsf{X}^{a\oplus c}\mathsf{Z}^{a(c\oplus y\oplus 1)\oplus b\oplus d\oplus y}\mathsf{T}|\psi\rangle$.

- *Verifiable Quantum Computation.* The possibility of outsourcing of quantum computations raises a fundamental question: *how can the Client be confident that the outcome of the computation is correct*? Some computations (such as factoring) clearly admit an efficient verification procedure, but this is not the case for the most general quantum computations. In [6], I propose a solution to this conundrum, based on the *interaction* and single-qubit preparation that is present in QCED (see also related work [1, 14]). In a nutshell, the idea is for the verifier to randomly choose between two types of runs: a test run or a computation run. In a test run, the transcript of the interaction is easily predictable (and thus can be used as a test); however, in a computation run, the target computation is performed. As in QCED, we use the cryptographic technique of the quantum one-time pad to make the prover oblivious to the type of run that is executed. Thus, by repeating the protocol many times, the verifier can increase her confidence on the correctness of the outcome, without ever having to compute the outcome of the computation herself!

- *Uses of Verifiable Quantum Computation.* As a cryptographic primitive, the verification of quantum computations unleashes a host of new functionalities. This has already been exploited in *multi-party quantum computation* [4], as well as in work that I performed with collaborators on quantum one-time programs [8] and quantum zero-knowledge proofs [10].

Future Directions

The capacity for privacy and verifiability in delegated quantum computation has opened up many new avenues of research, but many more remain to be explored. Some of the outstanding questions are:

- Could we delegate quantum computations between a purely classical Client and a quantum Server?
- Can we make these protocols even more efficient and implementable in the lab?
- What are the other uses of privacy and verifiability in delegated quantum computation?

[1] D. Aharonov, M. Ben-Or, and E. Eban. "Interactive proofs for quantum computations". *Innovations in Computer Science — ICS 2010*. 2010, 453–469.

[2] A. Ambainis, M. Mosca, A. Tapp, and R. de Wolf. "Private quantum channels". *41st Annual Symposium on Foundations of Computer Science*. 2000, 547–553. DOI: 10.1109/SFCS.2000.892142.

[3] S. Barz, E. Kashefi, A. Broadbent, J.F. Fitzsimons, A. Zeilinger, and P. Walther. "Demonstration of blind quantum computing". *Science* 335:6066 (2012), 303–308. DOI: 10.1126/science.1214707.

[4] M. Ben-Or, C. Crépeau, D. Gottesman, A. Hassidim, and A. Smith. "Secure multiparty quantum computation with (only) a strict honest majority". *47th Annual Symposium on Foundations of Computer Science — FOCS 2006*. 2006, 249–260. DOI: 10.1109/FOCS.2006.68.

(*continued on page* 10)

Two Linked Conferences in Canada to Celebrate Barry Simon's 70th Birthday

Percy Deift (Courant Institute), Andrei Martínez-Finkelshtein (Universidad de Almería)

Barry Simon

Two consecutive events took place in Canada in the second half of August 2016, as part of Barry Simon's 70th birthday celebration. Barry is one of the founding fathers of modern mathematical physics. His interests span a vast number of topics and his influence, through research papers, books and mentoring skills, is felt in many areas of mathematics. He has made significant contributions over the years to quantum field theory, statistical mechanics, Schrödinger operators, to the theory of orthogonal polynomials, and the list is not complete.

First, honouring his remarkable dedication to the advancement of young mathematical physicists, a Young Researchers Symposium "Methods of Modern Mathematical Physics" covering several areas of mathematical physics took place at the Fields Institute in Toronto, August, 22–26, 2016. There were 120 registered participants, most of whom were students, postdocs and junior faculty members from all over the world.

Distinct topics were covered in five days; the opening talks were given by scientific leaders, who also acted as moderators, and were mostly of an introductory character. The topics and moderators (Monday to Friday schedule) matched some of the fields of interest of Barry Simon, mentioned above:

- Robert Seiringer (IST Austria), Bose–Einstein condensation;
- Rupert Frank (Caltech), Many-body quantum mechanics;
- László Erdős (IST Austria), Random matrices and random Schrödinger operators;
- Jacob S. Christiansen (Lund), Orthogonal polynomials;
- Svetlana Jitomirskaya (UC Irvine), Spectral theory of quasi-periodic operators.

There were two one-hour lectures on Mathematical Methods in Many-Body Quantum Mechanics (I & II) by Mathieu Lewin (CNRS, CEREMADE), and three "short introductions": to random matrices, by László Erdős; to orthogonal polynomials, by Jacob S. Christiansen; and finally, to the quasi-periodic session, by Svetlana Jitomirskaya. These opening lectures were especially helpful for non-specialists to be able to follow the approximately 40 talks of junior researchers and a discussion of open problems.

Many of the participants at the Toronto meeting also attended the second event, conference on "Frontiers in Mathematical Physics" that took place at the CRM in Montréal the following week. This time the goal was to bring together leading researchers in mathematical physics, with the purpose of outlining recent advances and new directions of research. There were a total of 160 registered participants. Some of the moderators at the Toronto meeting gave talks, together with other researchers representing several fields, for a total of 19 invited speakers. Many of them took advantage of their talks to tell some stories featuring Barry. More stories were told during the conference banquet.

The talks spanned again the broad spectrum (pun intended) of Barry's interests. There was some mathematical physics (Jürg Fröhlich, Israel Michael Sigal, Abel Klein, Rupert Frank, Elliott Lieb, and Robert Seiringer), random matrices and stochastic processes (Horng-Tzer Yau, László Erdős, Martin Hairer, Alexei Borodin, Herbert Spohn, Percy Deift and Thomas Spencer), spectral theory (Fritz Gesztesy, Svetlana Jitomirskaya) and orthogonal polynomials (Doron Lubinsky, Andrei Martínez-Finkelshtein).

The organization of both events and the facilities at the venues were superb. Although the schedule of lectures was dense, there were no parallel sessions, which allowed the participants to attend any lecture they wished. Those of us who know Barry Simon were not surprised that he attended all the lectures from both conferences, actively contributing with questions and remarks.

The conferences were sponsored by several organizations. George Hagedorn, from Virginia Tech, did a great job coordinating the application for an AMS grant, which was used to support junior people from the USA.

The local organizers, whose hard work and dedication were essential to the flawless running of the events, deserve special mention, in particular, Vojkan Jakšić, from McGill University, who was the driving force behind the meetings. On behalf of all of the participants we thank them for all the work they have put into making the meetings such a success.

Conférence internationale

Developments in Language Theory

25 au 28 juillet 2016

Srečko Brlek, Alexandre Blondin Massé (UQAM)

La vingtième édition de la conférence internationale « Developments in Language Theory » (DLT 2016) a été tenue à Montréal, du 25 au 28 juillet 2016. L'évènement fut organisé par le Laboratoire de Combinatoire et d'Informatique Mathématique (LaCIM) au Complexe des sciences Pierre-Dansereau, de l'Université du Québec à Montréal (UQAM), près de la Place des Arts.

Cette série de conférences fut initiée en 1993 par Grzegorz Rozenberg et Arto Salomaa à Turku (Finlande). Les premières éditions de ces conférences furent biennales : Magdebourg, Allemagne (1995), Thessalonique, Grèce (1997), Aix-la-Chapelle, Allemagne (1999), et Vienne, Autriche (2001). Par la suite, l'évènement prit place en Europe chaque année impaire et en dehors de l'Europe chaque année paire. Les lieux des conférences DLT depuis 2002 ont été : Kyoto, Japon (2002), Szeged, Hongrie (2003), Auckland, Nouvelle-Zélande (2004), Palerme, Italie (2005), Santa Barbara, USA (2006), Turku, Finlande (2007), Kyoto, Japon (2008), Stuttgart, Allemagne (2009), London, Canada (2010), Milan, Italie (2011), Taipei, Taiwan (2012), Marne-la-Vallée, France (2013), Ekaterinbourg, Russia (2014), Liverpool, UK (2015).

Cette série de conférences sur les développements en théorie des langages constitue un forum privilégié d'échange pour les membres des milieux académique, de la recherche et du monde industriel intéressés aux langages formels, à la théorie des automates et les domaines connexes. Les sujets comprennent, sans y être limités, les grammaires, accepteurs et transducteurs de mots, les arbres et les graphes ; la théorie algébrique des automates ; propriétés algébriques et combinatoires des mots et des langages ; codes à longueur variable ; dynamique symbolique ; automates cellulaires ; polycopions et motifs en dimension supérieure ; problèmes de décidabilité ; traitement d'images et compression ; algorithmes efficaces de traitement de textes ; relations avec la cryptographie, parallélisme, théorie de la complexité et logique ; informatique biologique et quantique.

Le comité de programme a procédé à la sélection de 32 communications sur un total de 48 propositions. Chaque article a été évalué par au moins trois spécialiste du domaine et les articles choisis sont rassemblés dans le volume 9840 des *Lecture Notes in Computer Science* de Springer.

Une édition spéciale contenant une sélection des meilleurs articles paraîtra dans le *International Journal of Foundations of Computer Science* (IJFCS) en accord avec Oscar H. Ibarra (rédacteur en chef).

Un total de 51 participants provenant de tous les continents ont suivi les exposés et discussions.

Anne Broadbent

(*continued from page* 8)

[5] A. Broadbent. "Delegating private quantum computations". *Canad. J. Phys.* 93:9 (2015), 941–946. DOI: 10.1139/cjp-2015-0030.

[6] A. Broadbent. *How to verify a quantum computation.* 2015. arXiv: 1509.09180.

[7] A. Broadbent, J. Fitzsimons, and E. Kashefi. "Universal blind quantum computation". *2009 50th Annual IEEE Symposium on Foundations of Computer Science (FOCS 2009).* 2009, 517–526. DOI: 10.1109/FOCS.2009.36.

[8] A. Broadbent, G. Gutoski, and D. Stebila. "Quantum one-time programs (extended abstract)". *Advances in Cryptology — CRYPTO 2013. Part II.* 2013, 344–360. DOI: 10.1007/978-3-642-40084-1_20.

[9] A. Broadbent and S. Jeffery. "Quantum homomorphic encryption for circuits of low T-gate complexity". *Advances in Cryptology — CRYPTO 2015. Part II*, 609–629. DOI: 10.1007/978-3-662-48000-7_30.

[10] A. Broadbent, Z. Ji, F. Song, and J. Watrous. *Zero-knowledge proof systems for QMA.* 2016. arXiv: 1604.02804.

[11] A. Broadbent and C. Schaffner. "Quantum cryptography beyond quantum key distribution". *Designs, Codes and Cryptography* 78:1 (2016), 351–382. DOI: 10.1007/s10623-015-0157-4.

[12] Y. Dulek, C. Schaffner, and F. Speelman. "Quantum homomorphic encryption for polynomial-sized circuits". *Advances in Cryptology — CRYPTO 2016.* 2016, 3–32. DOI: 10.1007/978-3-662-53015-3_1.

[13] K.A.G. Fisher, A. Broadbent, L.K. Shalm, Z. Yan, J. Lavoie, R. Prevedel, T. Jennewein, and K.J. Resch. "Quantum computing on encrypted data". *Nature Communications* 5 (Jan. 2014), 3074. DOI: 10.1038/ncomms4074.

[14] J.F. Fitzsimons and E. Kashefi. *Unconditionally verifiable blind computation.* 2012. arXiv: 1203.5217.

[15] C. Gentry. "Fully homomorphic encryption using ideal lattices". *STOC'09 — Proceedings of the 2009 ACM International Symposium on Theory of Computing.* 2009, 169–178. DOI: 10.1145/1536414.1536440.

[16] R.L. Rivest, A. Shamir, and L. Adleman. "A method for obtaining digital signatures and public-key cryptosystems". *Communications of the ACM* 21:2 (1978), 120–126. DOI: 10.1145/359340.359342.

[17] P.W. Shor. "Algorithms for quantum computation: discrete logarithms and factoring". *35th Annual Symposium on Foundations of Computer Science.* 1994, 124–134. DOI: 10.1109/SFCS.1994.365700.

Conference on Differential Geometry

in Honour of Claude LeBrun, July 5–9, 2016

Vestislav Apostolov (UQAM)

The Conference on Differential Geometry, held at the UQAM campus of the CRM from July 5 to 9, 2016, was the occasion for a broad overview of the most recent advances and active interactions in the following central topics of current research:

Claude LeBrun

- Complex methods in conformal geometry and twistor theory;
- Special structures in geometry and physics;
- Kähler geometry.

It gave us an ideal opportunity to highlight the broader aspects and deep influence of Claude LeBrun's scientific career, and the mathematics avenues it has opened.

The conference put together more than 80 participants, most of them recognized international experts in the mentioned fields, varying from algebraic geometers through differential geometers to experts in PDE to mathematical physicists. The speakers presented recent results on all of the above mentioned topics. There were two featured talks, by Sir Roger Penrose (Twistor Theory) and Sir Simon Donaldson (manifolds with holonomy G_2 and Spin(7)), which provided excellent introductions to the respective fields and were very useful for the 20 Ph.D. students who attended the talks. There were many fruitful discussions across boundaries, the conference succeeded in tying together most of the new results in the subject, and a variety of new projects were discussed. There was a special effort of informal tutoring of the Ph.D. students attending the conference. The participants affirmed frequently and spontaneously that the program was a great success.

We now review in more detail the 22 one-hour talks that were given during the workshop.

Twistor theory was first introduced by Sir Roger Penrose in 1967 as a correspondence in mathematical physics which maps the geometric objects of 4-dimensional Lorentzian space-time into holomorphic objects of a 4-dimensional complex manifold with a Hermitian form of signature $(2,2)$, called twistor space, and its complex valued coordinates are called "twistors." Almost 50 years later, this theory is much alive and produces far reaching results both in mathematics and mathematical physics.

Sir Roger Penrose

In his opening lecture (attended by much more than the registered participants of the conference), Sir Richard Penrose (Oxford) gave a panoramic review of basic ideas behind twistors. He then introduced the new notion of palatial twistor theory as a tool for encoding 4-dimensional Lorentzian space-time geometry into a twistor framework. He explained how this notion encodes Einstein spaces.

Lionel Mason (Oxford) presented his joint work with LeBrun on holomorphic discs and on ambi-twistors (i.e., spaces of complex null geodesics). He described how some recent developments in the study of ambit-twistors can be used to solve for the scattering of gravitational waves.

In pure mathematics, the Penrose twistor correspondence was used in a seminal work by Atiyah, Hitchin and Singer from 1978, who established a one-to-one correspondence between anti-self-dual conformal structures on a 4-manifold and the corresponding twistor spaces, which are complex 3-manifolds fibered over the 4-manifold by smooth rational curves. The twistor spaces turned out to be of great importance to complex algebraic geometry and have been extensively studied in the late part of the last century.

In his lecture, Nobuhiro Honda (Tokyo Institute of Technology) presented an overview of the development of twistor algebraic geometry over the last 10 years and gave an exhaustive account of the current status of knowledge on the structure of twistor spaces.

In 1982, Claude LeBrun showed how to use the Penrose twistor correspondence in order to obtain self-dual Einstein metrics from conformal 3-manifolds. Nearly 20 years later, Birte Feix and Dimitry Kaledin independently obtained a general existence result for hyper-Kähler metrics on cotangent bundles, using a similar idea. In his talk, D. Calderbank (Bath) showed how to extend all these constructions to a general correspondence between U(1)-invariant quaternionic manifolds with a fixed maximal totally complex sub-manifold, and complex manifolds with a so-called c-projective structure.

Simon Salamon (Kings College, London) presented a yet another use of twistor spaces, lecturing on a fascinating correspondence between orthogonal complex structures on the spheres S^4 and S^6 and special algebraic sub-varieties in the projective space $\mathbf{CP}^3$.

Manifolds with special holonomy, $SU(n)$, G_2, Spin(7) are important classes of Ricci-flat Riemannian manifolds. The case

of holonomy G_2 became of great importance in string theory after Dominic Joyce constructed the first compact examples in 1994. Since then, the mathematical theory of G_2 manifolds represents a most vibrant field of current research.

Sir Simon Donaldson (Imperial College) lectured on adiabatic limits of G_2 manifolds. In the first part of his talk, he reviewed background in the theory of metrics of exceptional holonomy G_2 on 7-dimensional manifolds, and in particular a variational point of view, due to Hitchin. He then defined the notion of "Kovalev–Lefschetz" fibration by K3 surfaces and explained that there is an adiabatic limit of G_2 holonomy condition which, locally, takes the form of the maximal sub-manifold equation in a space of indefinite signature. He then discussed boundary value problems and their relevance to uniqueness questions.

In his talk, Michael Eastwood (Adelaide) showed how to use a symplectic form to construct an elliptic complex replacing the de Rham complex. Under suitable curvature conditions, he introduced coupled versions of this complex and showed that on the complex projective space, his constructions give rise to a series of elliptic complexes with geometric consequences for the Fubini–Study metric and its X-ray transform.

Robin Graham (University of Washington) described in his talk a derivation of a conformally invariant energy for an even-dimensional submanifold of a Riemannian manifold, generalizing the Willmore energy of a surface. He used this notion for studying the asymptotics of minimal submanifolds in asymptotically Poincaré–Einstein spaces associated to a conformal manifold.

The Seiberg–Witten theory provides a smooth invariant, which can be used to distinguish homeomorphic, non-diffeomorphic, smooth structures. Fundamental work of LeBrun showed that it also has a deep impact on the metric properties of 4-manifolds, notably on the existence of Einstein metrics and the Yamabe invariant of the manifold.

Ioana Suvaina (Vanderbilt) reported on her results concerning the use of Seiberg–Witten theory to obtain new obstructions to the existence of Einstein metrics, and to compute the Yamabe invariant for Kähler surfaces and symplectic 4-manifolds.

Masashi Ishida (Tohuko) linked Seiberg–Witten theory with the long time existence of the normalized Ricci flow on a compact oriented 4-manifold.

Jimmy Petean (CIMAT) lectured on non-uniqueness of Yamabe minimizers obtained using topological methods.

Matthew Gursky (Notre Dame) presented his recent results with J. Streets (UC Irvine), in which they define a formal Riemannian metric on the set of metrics in a conformal class with positive (or negative) curvature. It allowed them, by analogy with metric defined in the Kähler setting, to extend some two-dimensional results to higher dimensions, especially 4-d, in which this construction has some interesting applications to the fully nonlinear Yamabe problem.

Asymptotically locally Euclidean (ALE) and asymptotically conical (AC) scalar-flat Kähler metrics appear naturally as 'bubbles' at the boundary of the moduli spaces of constant scalar curvature Kähler metrics involved in the Yau–Tian–Donaldson conjecture, and they can also be used as building blocks for the gluing techniques of Arezzo–Pacard. They have been of greatest interest to mathematical physics, as earlier work of LeBrun produced counter-examples to the zero mass conjecture. In recent times, a work of Hein and LeBrun showed how the mass of ALE Kähler spaces is linked to the underlying holomorphic structure of the manifold.

Claudio Arezzo (ICTP) lectured on his new results with C. Spotti concerning ALE and AC scalar-flat Kähler metrics and their use in solving singularities of singular constant scalar curvature Kähler spaces.

Song Sun (Stony Brook) presented his recent work with Hein on the development of singularities in the limit of a sequence of volume non-collapsed Kähler–Einstein metrics. He described in detail the first known examples of compact Ricci-flat Kähler manifolds with non-orbifold isolated conical singularities.

Jeff Viaklovsky (Wisconsin) lectured on Kuranishi-type theorems for deformations of complex structure on ALE Kähler surfaces, proving that for any scalar-flat Kähler ALE surface, all small deformations of complex structure also admit scalar-flat Kähler ALE metrics. He presented a construction of a local moduli space of scalar-flat Kähler ALE metrics and showed that it is universal up to small diffeomorphisms.

Christina Tønnesen-Friedman (Union College) and Gideon Maschler (Clark) spoke about their recent results regarding a Riemannian analogue of the Einstein–Maxwell equations in general relativity, arising in the framework of Kähler geometry and extending the notion of Kähler metrics of constant scalar curvature.

Fabrizio Catanese (Bayreuth) spoke about Kodaira fibered surfaces, the many intriguing open questions concerning them, especially the slope question raised by LeBrun, and the existence of metrics of negative curvature on them. He described the construction of double Kodaira fibred surfaces leading to the highest known slope, and to rigid Kodaira fibrations. He then described examples which give counterexamples to an old question by Fujita concerning variation of Hodge structures.

Luca Di Cerbo (ICTP) lectured on Seshadri constants of holomorphic line bundles over a smooth projective variety. These constants are notorious for being hard to compute or estimate. In his talk, he presented estimates in the case when the fundamental group of the underlying variety is "large."

Two Weeks in Vancouver

A Summer School for Women in Math, August 15–25, 2016

Malabika Pramanik (UBC)

The summer school at PIMS–UBC, held during August 15–25, 2016, was a highly selective program, aimed at top undergraduate women from across the country and the northwest United States, specializing in mathematics or in the closely related fields of computer science, physics and statistics. The program exposed them to the many facets of mathematics and related fields as a career, in an intense two-week immersion. The hope is to encourage these gifted young women to continue on to graduate work. The program will teach them topics in mathematics that lie beyond the undergraduate curriculum, offer a glimpse into the life of a graduate student by introducing a research component, and reveal a wide range of resulting career options, all in a collaborative environment.

Photo: *Ruth Situma*

Although the number of women studying mathematics and basic sciences at the undergraduate level in Canada is similar to that of men, the percentage drops sharply for women continuing on to graduate school. Certainly in high school and even in the early years at college, students often do not understand what research-level mathematics involves, and what connections exist between advanced mathematics and the real world. Undergraduate women are often unaware of the many interesting career opportunities, both in academia and in industry, that require graduate level mathematics and yet have tangible real-world applications. Some may have never encountered a woman in such a position or been encouraged to consider whether such a career might be of interest to them, and hence are unable to visualize themselves in such positions. This often results in a reluctance to pursue higher studies or a career in competitive, challenging and intellectually stimulating fields, even though the person may have great potential for success according to her teachers and peers. On the other hand, it has been established that women undergraduates are far more likely to become actively engaged and adventurous in their studies, focus their ambitions, and demonstrate leadership in a female-only environment that encourages cooperation, rather than competition. An event that promotes such an environment is a demonstrated successful strategy for alleviating some common issues which hold women back, such as isolation within their program and lack of role models, which in turn can cause loss of confidence. Such programs are particularly effective when many (though not necessarily all) of the leaders are women, who can serve in the combined capacity of mentors, resources and role models.

The program was hosted by PIMS, with generous support from PIMS, Fields Institute (Toronto), CRM (Montréal), Goldcorp Foundation, Faculty of Science (UBC) and Faculty of Applied Science (UBC).

The organizing committee consisted of Shawn Desaulniers, Fok-Shuen Leung, Rachek Kuske and Malabika Pramanik, all from the Department of Mathematics at UBC. The student participants were selected based on an application process starting in early 2016. Highlights of the program included:

(1) Two week-long minicourses, one in stochastic dynamics led by Prof. Rachel Kuske (UBC) and the second in knot theory by Laura Schaposnik (University of Illinois at Chicago). Students worked on group projects which they presented at the end of the summer school. Course material and group presentations have been posted online.

(2) A public lecture on "Mathematics of Quilting" by Prof. Gerda de Vries (University of Alberta) who won the 2014 CMS Excellence in Teaching Award.

(3) Field trips to 1Qbit Technologies (downtown Vancouver) and DWave Systems (Burnaby).

(4) Guest speakers from industry (Fincaid, BC Safety Authority) and academia (UBC Math, Faculty of Applied Science). The presentations were interactive, with passionate discussions and question-answer period following the talks.

(5) Panel discussion with women mathematicians at various levels of seniority. There was a banquet after the panel discussion to allow time for informal interaction with the panelists.

The feedback so far has been fantastic. A number of participants who were undecided whether or not to join grad school have now written to say that they intend to pursue a Ph.D. Some of them have been able to find a specialization of interest. The students have set up a Facebook page that they are using now for networking purposes. We hope that this will continue as a nationwide program, and look forward to hosting a similar event at UBC at a future date.

In Memory of André Boivin (1954–2014)

Paul M. Gauthier (Université de Montréal), Myrto Manolaki (University of South Florida), Javad Mashreghi (Université Laval)

The Life and Academic Career of André Boivin

André Boivin was born on August 7, 1954 in Montréal, where he obtained his B.Sc. degree in Mathematics in 1977 from Université de Montréal. After completing his M.Sc. degree at the University of Toronto in 1979, he returned to Université de Montréal to pursue his doctoral studies under the supervision of Paul M. Gauthier, with whom he developed a beautiful friendship and fruitful lifelong collaboration. He obtained his Ph.D. degree in 1984 for his thesis entitled *Approximation uniforme harmonique et tangentielle holomorphe ou méromorphe sur les surfaces de Riemann*. After his Ph.D., he was awarded a two-year NSERC postdoctoral fellowship, which was held at the University of California, Los Angeles (1984–1985) and at University College, London (1985–1986). During his postdoctoral studies he had the opportunity to interact with leading experts in Complex Analysis such as Theodore Gamelin and J. Milne Anderson. After one year in London, UK, he was hired in London, Ontario (!) as an Assistant Professor in the Department of Mathematics at the University of Western Ontario. Except for two years when he was on sabbatical leave (as Visiting Researcher at the CRM, Université de Montréal, during 1999–2000 and as Visiting Professor at CeReMaB, Université Bordeaux 1, during 1992–1993), André Boivin spent the rest of his life in London, Ontario, together with his wife Yinghui, his daughter Melanie, his son Alex and his step son JP. He was promoted to Associate Professor in 1991 and to Professor in 2004.

Throughout his career, André Boivin gave his very best to creating the most positive and creative atmosphere in the department, looking after every single detail. One of his "invisible" contributions was in the departmental Analysis Seminar; despite the small number of Analysis members of the department, André Boivin managed to keep the Analysis seminar series alive and of high quality, by inviting some of the most prominent experts (and as always, being an excellent host). André was one of the most dedicated and influential lecturers. This was reflected in the great number of graduate students he successfully supervised. In particular, he supervised more than 12 Master's students, 5 Ph.D. students and two postdoctoral fellows. Moreover, he served with distinction as Graduate Student Chair and in 2011 he was appointed as the Chair of the Department of Mathematics, a post that he served with remarkable devotion until the very last days of his life. He was deservedly characterized by his colleagues as the heart and soul of the department.

Apart from his intense mathematical action at the University of Western Ontario, André Boivin gave tireless service in various Canadian committees. For example he was a member of the Grant Selection Committee in the program "Grants to Research Teams," Fonds québécois de la recherche sur la nature et les technologies. Moreover, in December 2009, he organized (with Tatyana Foth) a Session on Complex Analysis at the Winter Meeting of the Canadian Mathematical Society in Windsor. In June 2011, together with Javad Mashreghi, he organized the international conference "Complex Analysis and Potential Theory" (in honour of Paul M. Gauthier and K. N. GowriSankaran) which took place at the CRM, Montréal. The last conference that André (co)organized was the 16th Annual Meeting of Chairs of Canadian Mathematics Departments, which took place at the University of Western Ontario, two weeks after he suddenly passed away in October 2014. In July 2016 a conference was held in memory of André Boivin at the Fields Institute in Toronto.

André Boivin

The work of André Boivin on Complex Analysis and Approximation Theory

Boivin's research interests were in Complex Analysis and Approximation Theory. In particular, his main topics of investigation were approximation by holomorphic functions of one or several variables, approximation by harmonic functions, and by solutions of elliptic partial differential equations. He has written several influential papers in these areas and he had collaborators in North America, Russia, Spain and Germany. Some of his main collaborators were Paul M. Gauthier, Petr Paramonov, Chang Zhong Zhu, Roman Dwilewicz and Joan Verdera.

One important component of the work of André Boivin concerns Carleman approximation by holomorphic and meromorphic functions. A closed subset E of a non-compact Riemann surface R is called a set of holomorphic (respectively meromorphic) Carleman approximation if whenever f is continuous on E and holomorphic on the interior of E and ε is a continuous positive error function on E, there exists a holomorphic (respectively meromorphic) function g on R such that $|f(p) - g(p)| < \varepsilon(p)$, for all p in E.

In 1927 Carleman showed that the real line is a Carleman set of approximation by holomorphic functions in the complex plane. Later, in 1971, Nersesjan gave a complete characterization of sets of holomorphic Carleman approximation in the case of the complex plane, based on previous work of Gauthier. In 1986, in his paper in *Math. Ann.*, Boivin provided a complete characterization of the sets of holomorphic Carleman approximation on an arbitrary open Riemann surface.

The problem of characterizing the sets of meromorphic Carleman approximation still remains open (even in the case of the complex plane). Boivin's work has shed considerable light on this problem. For example, he showed that the meromorphic analogue of the sufficient condition that appears in Nersesjan's characterization of holomorphic Carleman approximation is not sufficient to characterize the sets of meromorphic Carleman approximation. He also provided a new sufficient condition (in terms of the Gleason parts) and one necessary condition (in terms of the fine topology) for sets to be sets of meromorphic Carleman approximation. Later, in a coauthored paper with Nersesjan, he showed that the sufficient condition in terms of the Gleason parts fails to be necessary for this kind of approximation.

André Boivin also worked on many other classical problems in approximation theory on Riemann surfaces (such as Arakelian and Vitushkin type theorems), and in various function spaces. For example he developed the theory of T-invariant algebras on Riemann surfaces (following the work of Gamelin in the complex plane). Together with his coauthor Paramanov, he developed an axiomatic theory which gave a set of natural conditions on a space of functions X and a subspace Y for a local to global principle for approximation of functions in X by functions in Y. Examples of this theory include approximation theorems for solutions of elliptic partial differential equations.

Finally, another component of his work concerns non-harmonic Fourier series. Namely, he obtained results on the approximation properties of systems of exponentials. Several results in this area have considerable contemporary importance in view of the connections with control theory and signal processing.

André Boivin was known, not only for his important mathematical contributions and his tireless academic service, but also for his unique generous, warm and colourful personality. André will be fondly remembered for his honesty and openness, for his endless positive energy and clever sense of humour, for his progressive and humanistic spirit, for being an influential teacher, a passionate mathematician, and, above all, for being a wonderful person and friend who appreciated life in all its dimensions. It is impossible to describe with words the impact he had in our lives and how big is the gap he has left behind.

Très cher André, ceux de nous qui avons eu l'immense privilège de faire un bout de chemin avec toi et d'en tirer une profonde reconnaissance et admiration, t'exprimons nos sentiments « beaucoup plus qu'amicaux ».

A Conference in Memory of André Boivin

New Trends in Approximation Theory

July 25–29, 2016

Organizers: Paul Gauthier, Myrto Manolaki, Javad Mashreghi

The international conference entitled "New Trends in Approximation Theory" was held at the Fields Institute, in Toronto, from July 25 until July 29, 2016. The conference (which received financial support from the Fields Institute and the CRM) was fondly dedicated to the memory of our unique friend and colleague André Boivin. The impact of his warm personality and his fine work on Complex Approximation Theory was reflected by the mathematical excellence and the wide research range of the 37 participants. In total there were 27 talks, delivered by well-established mathematicians and young researchers. In particular, 19 invited lectures were delivered by leading experts of the field, from eight different countries (USA, France, Canada, Ireland, Greece, Spain, Israel, Germany).

The wide variety of presentations composed a mosaic of multiple aspects of Approximation Theory and highlighted interesting connections with important contemporary areas of Analysis. In particular, the main topics that were discussed include the following:

1. Applications of Approximation Theory (isoperimetric inequalities, construction of entire order-isomorphisms, dynamical sampling);
2. Approximation by harmonic and holomorphic functions (and especially uniform and tangential approximation);
3. Polynomial and rational approximation;
4. Zeros of approximants and zero-free approximation;
5. Tools used in Approximation Theory (analytic capacities, Fourier and Markov Inequalities);
6. Approximation on complex manifolds (Riemann surfaces), and approximation in product domains;
7. Approximation in function spaces (Hardy and Bergman spaces, disc algebra, de Branges–Rovnyak spaces);
8. Boundary behaviour and universality properties of Taylor and Dirichlet series.

The last talks of the conference were devoted in the main contributions of André Boivin in Approximation Theory and his collaborations (ranging from the work in his Ph.D. thesis until his recent work with his last doctoral student).

Throughout the conference there was a very creative and friendly atmosphere, with many interesting discussions and mathematical interactions which, hopefully, will lead to future collaborations.

Videos and slides of the presentations can be found at the following link:
https://www.fields.utoronto.ca/video-archive/event/1996

Spectral Theory and Applications

CRM Summer School in Québec City, July 4–14, 2016

Alexandre Girouard, Javad Mashreghi, and Thomas Ransford (Laval), Catherine Bénéteau and Dmitry Khavinson (South Florida)

This 2016 CRM summer school in Québec City was a great success. The goal of the first instalment of this biennial event was to prepare advanced undergraduate and beginning graduate students for research involving spectral theory by giving an overview of a selection of topics from the subject. There were six mini-courses, complemented by supervised computer labs and exercise sessions. In addition, five invited speakers gave hour-long specialized talks. The school brought together over fifty undergraduates, graduates and postdocs, hailing from Canada, France, Israel, Italy, Mexico, Russia, Sweden, Switzerland, Turkey, the United Kingdom and the USA.

The school kicked off with a mini-course on the "Fundamentals of Spectral Theory," given by Thomas Ransford (Laval). The course covered the basic background in functional analysis needed for the other lectures: normed spaces, Hilbert spaces, operators, spectrum, compact operators and the spectral theorem. It was also shown how to use these ideas to analyze a one-dimensional boundary-value problem, namely the Sturm–Liouville equation.

Felix Kwok (Hong Kong Baptist University) gave a mini-course on "Numerical Methods for Spectral Theory." The course treated both finite-difference methods and finite-element methods for calculating eigenvalues and eigenfunctions of the Laplacian. The practical implementation of these methods involves the numerical solution of matrix eigenvalue problems, and the course contained an extensive discussion of the methods used for solving these problems, including the power method, the QR method and the Lanczos method. The lectures were supplemented by practical exercises in the computer lab.

The third and final mini-course of the first week, given by Richard Froese (UBC), was entitled *From Classical to Quantum Mechanics*. After an introduction to the Hamiltonian formulation of classical mechanics, the lectures moved on to the basics of quantum mechanics, emphasizing the analogy with the classical theory and at the same time making the link with spectral theory. These ideas were illustrated by a number of examples. The course concluded with some strange properties of quantum systems, notably Hardy's paradox, which shows that a purely random-variable description of a quantum mechanical system is not always possible.

The second week began with a mini-course on the *Spectrum of Elliptic Operators* by Richard Laugesen (Illinois). The main theme of the course was how to reformulate Dirichlet and Neumann problems for the Laplacian on a bounded Euclidean domain in terms of so-called weak solutions in appropriate Sobolev spaces, and then how to exploit the spectral theorem to show that there is an orthonormal basis of eigenfunctions for these problems. There was also an extensive discussion of the Rayleigh principle and its use in establishing a number of qualitative properties of the eigenvalues.

The extension of these ideas to manifolds was the main theme of the mini-course on *Spectral Geometry*, delivered by Yaiza Canzani (Harvard). It was shown how to define the Laplacian on a Riemannian manifold (this included an introduction to Riemannian geometry for the uninitiated). There followed an account of the spectral theory of the Laplacian in this context, including some beautiful computer-animated examples of eigenfunctions. The course concluded with a discussion of the isospectral problem: what properties of the manifold can one deduce from a knowledge of the spectrum of the Laplacian ("Can you hear the shape of a manifold?").

The remaining mini-course, by Ram Band (Technion), was an introduction to a relatively new topic, that of *Quantum Graphs*. The course opened with a careful introduction to metric graphs and the formulation of several vertex conditions on these graphs. This was followed by a presentation of the scattering approach to quantum graphs and of trace formulas which related the spectrum to periodic orbits on the graph.

In addition to the mini-courses, there were also some individual lectures on themes related to spectral theory, both pure and applied. On the pure side, Catherine Bénéteau gave a talk entitled *Zeros of Optimal Approximants, Norms of Jacobi Matrices, and Jentzsch-Type Theorems*, and Dmitry Khavinson spoke on *The Spectral Properties of Several Classical Function-Theoretic Operators and Geometry*. On the applied side, there were three speakers: Geoff Sanders (Lawrence Livermore Lab) on *Numerical analysis for practical spectral graph embedding algorithms*, Jean-Gabriel Young (Laval) on *Spectral Clustering of Graphs*, and Patrick Desrosiers (Laval) on *The Spectra of Random Matrices*.

A volume of lectures from this summer school is being prepared for the *CRM Proceedings*, part of the *Contemporary Mathematics* series from the AMS.

Doppler Institute–CRM Workshop on the Occasion of the 80th Birthdays of Jiří Patera and Pavel Winternitz

May 30–June 3, 2016

Sarah Post (University of Hawai'i at Mānoa)

This May, a joint Doppler Institute–CRM workshop was held celebrating the 80th birthdays of professors Jiří Patera and Pavel Winternitz. This workshop comes as we approach the 20th anniversary of the symposium on Algebraic Method in Physics, held in January 1997 at the CRM celebrating the 60th birthdays of Jiří and Pavel. In the introduction of the proceedings for that conference, Yvan Saint-Aubin and Luc Vinet (both of Université de Montréal and the CRM) wrote about numerous seminal results published by Jiří and Pavel, both together, with other collaborators and individually, in fields such as scattering theory, symmetries and separation of variables, Lie groups and algebras, orbit functions and quasicrystals, integrable systems and Painlevé equations. Luckily for all of us working with and around them, their productivity has not slowed down in the past 20 years. Since 1997 they have published a total of 170 papers, graduated over 19 M.Sc. and 17 Ph.D. students, have mentored 22 postdocs, published one book and have two patents!

The breadth and depth of the influence of Jiří and Pavel was on full display during the course of this one week workshop with over 40 participants, most of whom were either (ex-)students or (ex-)postdocs of Jiří or Pavel. The conference started with a day of plenary lectures at the Czech Technical University (CTU), with an opening address by the Dean of the Faculty of Nuclear Sciences and Physical Engineering (FNSPE). On this occasion, Pavel and Jiří were awarded Medals of FNSPE. During the first day, Luc Vinet gave a talk on spin chains with applications to quantum computing. Willard Miller Jr. (Minnesota) discussed conformal superintegrable systems and their contractions. Sasha Turbiner (UNAM) gave a talk on polynomial integrable systems. Jiří Tolar (CTU) again brought up the topic of quantum computing but this time with regards to Clifford groups and their contractions. Anatoly Nikitin (National Academy of Science Ukraine) gave a talk on superintegrable and supersymmetric systems with position dependent mass. Zuzana Masáková (CTU) finished the day speaking about Pisot-cyclotomic numbers and their spectra.

The remaining four days of the conference were held at the beautiful Villa Lana, the representative residence of the Academy of Sciences of the Czech Republic, which also provided accommodation to visiting participants. Throughout the week, the interplay between different aspects of algebraic systems and mathematical physics came up continually with talks on sigma models, integrable and superintegrable systems, symmetry reduction, quantum state transfer, orbit functions, symmetries of difference equations, etc.

Villa Lana also hosted a splendid conference dinner where the two honourees were celebrated. Speeches and toasts throughout the night reminded the participants of how the two came to Montréal just as the CRM was being established and helped make the Mathematical Physics group at the CRM so well renowned. After the Velvet Revolution in 1989, Jiří and Pavel again lent their expertise and support to another newly founded institution, the Doppler Institute of FNSPE CTU, the other co-sponsor of the event. The continuing collaboration and close ties that these two have established between Prague and Montréal were recognized during the conference dinner by signing a memorandum of understanding between the CRM and FNSPE CTU.

The conference was well organized and ran smoothly, largely due to the tireless efforts of the chair of the organizing committee Libor Šnobl, a former postdoc of Pavel and frequent visitor to the CRM. It was due to his remarkable effort that the proceedings were published in *Acta Polytechnica* in advance of the conference. The special issue was given to all participants on arrival, including the honourees for which it was a surprise.

Happy birthday Jiří and Pavel! We look forward to many more years of research and friendship.

Conférence de Théorie des nombres Québec–Maine

8 et 9 octobre 2016

Hugo Chapdelaine, Antonio Lei, Claude Levesque (Université Laval)

Les 8 et 9 octobre 2016 se tenait à l'Université Laval la « Conférence de Théorie des nombres Québec–Maine ». Le congrès était dédié à David Dummit (à l'occasion de son départ à la retraite) et à Kumar Murty (pour souligner ses 60 ans). Rappelons pour la petite histoire que ces deux mathématiciens ont déjà été membres du corps professoral de l'Université Concordia et ont grandement contribué à la naissance et au développement du CICMA. Le congrès Québec-Maine est une rencontre qui, depuis 1998, alterne d'année en année entre la University of Maine et l'Université Laval. Cette année, il y avait près d'une centaine de participants. Cinquante-deux exposés ont été présentés, la plupart dans un cadre de trois sessions en parallèle.

Nous avons eu l'insigne honneur d'avoir comme conférencier plénier distingué Laurent Lafforgue (IHéS, médaille Fields en 2002). Le titre de son exposé était : *Le principe de fonctorialité de Langlands comme problème de généralisation de la loi d'addition.* Ce fut le seul exposé en français. Henri Darmon n'avait qu'un mot pour qualifier son exposé : « Excellent ! » Nous nous permettons de reproduire le commentaire de Hershy Kisilevsky qui décrit bien cet exposé : « Lafforgue's lecture was brilliant—and surprisingly accessible. He made a real effort to engage the audience ».

Ce fut aussi un plaisir pour tous d'écouter Joseph Oesterlé (professeur émérite à l'Université Pierre et Marie Curie et ancien directeur de l'Institut Henri Poincaré) : *Doubles restes des nombres multizêtas.* Une fois de plus, Hershy en donne une description on ne peut mieux appropriée : « And Oesterlé was Oesterlé—perfection! »

Le dernier exposé était historique (Dedekind, Hensel) et fut donné par Fernando Gouvêa : *The mystery of the extra divisors.*

Malheureusement, les circonstances nous ont forcés à mettre beaucoup d'exposés en parallèle et nous nous excusons auprès de tous et chacun pour les inconvénients générés et pour les choix cornéliens que cette situation a pu occasionner.

Nous avons le plaisir de souligner que seize chercheurs postdoctoraux (l'élite de demain) ont fait état de leurs travaux. Aussi sept étudiants au niveau du doctorat. On a même eu un étudiant de seize ans du « high school », Myank Pandey : *On Eisenstein primes.* Il a utilisé des méthodes de Friedlander et Iwaniec et son mentor est Daniel Goldston. C'était époustouflant d'entendre un adolescent avec une telle maturité.

Ce congrès fut rendu possible grâce aux soutiens financiers des organismes suivants : CRM (Centre de recherches mathématiques), CICMA (Centre interuniversitaire en calcul mathématique algébrique), NTF (Number Theory Foundation), NSF (National Science Foundation) via la collaboration de Andy Knightly d'une part, et de Carl Pomerance et John Voight d'autre part.

Pour plus de détails voir : http://www.math.umaine.edu/numbertheory/mainequebec.html

Henri Darmon recevra le prix Cole en théorie des nombres

Henri Darmon

Décerné tous les trois ans, le prix Cole en théorie des nombres de l'American Mathematical Society reconnaît un travail remarquable en théorie des nombres publié au cours des six années précédentes. Henri Darmon (McGill, Directeur du Laboratoire CICMA) sera le lauréat du prix de l'année 2017, pour ses contributions à l'arithmétique des courbes elliptiques et des formes modulaires. Les travaux d'Henri Darmon tournent autour de la conjecture de Birch et Swinnerton-Dyer, un des sept problèmes du « Millennium Prize », dont les solutions font l'objet de prix de 1 million de dollars offert par le Clay Mathematics Institute, http://www.claymath.org/millennium-problems/birch-and-swinnerton-dyer-conjecture

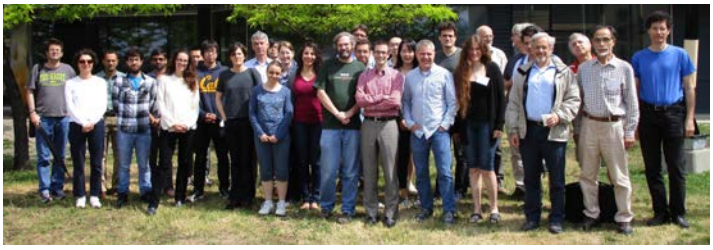
Le prix Cole honore deux articles que Darmon a écrits avec des co-auteurs : *Generalized Heegner cycles and p-adic Rankin L-series* (avec Massimo Bertolini et Kartik Prasanna et avec une annexe de Brian Conrad), Duke Mathematical Journal, 2013 ; et *Diagonal cycles and Euler systems.* II: *The Birch and Swinnerton-Dyer conjecture for Hasse–Weil–Artin L-functions* (avec Victor Rotger), Journal of the AMS, 2016. Les deux articles jettent une nouvelle lumière sur la conjecture de Birch et Swinnerton-Dyer et sur les extensions éventuelles de la théorie de la multiplication complexe. Cette théorie a été développée par des mathématiciens tels que Gauss, Eisenstein et Kronecker et est un ingrédient clé dans beaucoup des percées les plus importantes sur la conjecture de Birch et Swinnerton-Dyer, y compris le travail de Coates et Wiles du milieu des années 1970 et de Gross–Zagier et Kolyvagin de la fin des années 1980. Le communiqué de presse de l'AMS note que Darmon est l'un des chefs de file mondiaux de la théorie des nombres, et les deux articles qui sont honorés ne sont que quelques points forts d'une longue série d'articles influents de Darmon.

Pour plus d'informations sur ce prix, rendez-vous à l'adresse suivante : http://www.ams.org/news?news_id=3220

Algebraic Cycles and Moduli

June 2–8, 2016

Matt Kerr (Washington University in St. Louis)



The workshop drew together 25 seasoned researchers in number theory and algebraic (and differential) geometry, and around 20 students and postdocs, around the common theme of Hodge-theoretic invariants: their use to parametrize and compactify moduli, and to describe cohomology classes (or predict the presence) of algebraic cycles. While the topics were diverse, ranging from the minimal model program to special values of L-functions, this common language made for robust interaction and general accessibility.

Many of the speakers explored the use of limiting mixed Hodge structures to construct and parametrize boundary components for moduli problems: Green and Robles spoke on their recent work with Laza and Griffiths to Hodge-theoreticaly interpret the KSBA boundary strata for H-surfaces, while a new link between the KSBA strata and mirror symmetry (for K3 surfaces, involving generalized theta functions) was described by Paul Hacking. Mirror symmetry in relation to degenerations (of Calabi–Yau threefolds) was also explored by Doran. Izadi described her exciting work on the use of Prym–Tyurin varieties to (finally) give a uniformization of A_6 via moduli of curves (and the relationship between their compactifications, which is widely hoped to settle the question of whether A_6 has general type). Laza and Sacca gave back-to-back talks on degenerations of intermediate Jacobians of cubic threefolds, relating these to toroidal compactifications and hyperkähler geometry.

The hyperkähler theme was picked up by Markman in his lecture on a recent breakthrough of his student Buskin, giving the proof of a case of the Hodge conjecture for self-products of K3 surfaces using twistor deformations of (analytic) K3s. Prasanna used a special case of Langlands functoriality to construct new Hodge classes on products of quaternionic Shimura varieties, giving evidence for a new case of the Tate conjecture. For certain varieties with $h^{2,0} = 1$, Moonen gave a riveting lecture presenting a proof of this conjecture.

The use of Hodge-theoretic extension classes in relation to algebraic cycles also received some attention: Looijenga and Nair gave lectures on their closely related results on classes (related to the Beilinson conjectures) arising from extensions of automorphic vector bundles over the Baily–Borel compactification of A_g. The Beilinson conjectures also showed up in Lalin's talk on Mahler measure, Lewis's talk on generalized height pairings, and Deninger's visionary lecture proposing a conjectural framework unifying the Riemann hypothesis and positivity conditions for height pairings.

Mumford–Tate groups and representation theory were another common thread running through several of the lectures, including Green, Robles, Peters, Oblomkov, and the back-to-back talks by Belkale and Gibney on conformal blocks.

The overall mood of the workshop was quite buoyant, considering that several of the talks presented proofs of long-standing conjectures (Sacca, Moonen, Markman) and deep new evidence for others (Deninger, Prasanna, Izadi). One of the participants remarked that there was a large proportion of women compared to similar workshops. The coffee breaks provided by the CRM were extremely beneficial for new mathematical interactions.

Maksym Radziwill to Receive 2016 SASTRA Ramanujan Prize

Maksym Radziwill, a new faculty member at McGill University and member of CICMA, has been awarded the 2016 SASTRA Ramanujan Prize. The SASTRA Ramanujan Prize was established in 2005 and is awarded annually for outstanding contributions by young mathematicians to areas influenced by Srinivasa Ramanujan. The age limit for the prize has been set at 32 because Ramanujan achieved so much in his brief life of 32 years.

Dr. Radziwill will share the $10,000 prize with Kaisa Matomaki (University of Turku, Finland) for their extraordinary joint work which was carried out largely while both were visiting Montréal as guests of the CRM and the Laboratoire CICMA. According to the prize announcement: "Their recent revolutionary collaborative work on multiplicative functions in short intervals has shocked the mathematical community by going well beyond what could be proved previously even assuming the Riemann hypothesis, and has opened the door to a series of breakthroughs on some notoriously difficult questions such as the Erdős discrepancy problem and Chowla's conjecture, previously believed to be well beyond reach. They are especially recognized for their spectacular collaboration, and also for their very significant individual contributions."

The prize will be awarded during December 21–22, 2016, at the International Conference on Number Theory at SASTRA University in Kumbakonam (Ramanujan's hometown) where the prize has been given annually.

Colloque panquébécois des étudiants en mathématiques de l'ISM

De belles rencontres pour élargir ses horizons mathématiques

Nadia Lafrenière (UQAM)

Le Colloque panquébécois est une occasion de réunir des étudiantes et étudiants de toutes les universités québécoises et de tous les secteurs des sciences mathématiques. Pour la 19e édition, il a eu lieu au pavillon Sherbrooke de l'UQAM, du 13 au 15 mai. Les participantes et participants ont pu y présenter leurs résultats de recherche et découvrir le fruit du travail des autres. Elles et ils ont également été invités à écouter des présentations de chercheurs et chercheuse d'influence qui ont obtenu leur doctorat dans une université québécoise. La qualité des conférenciers et conférencière invités a d'ailleurs été soulignée par plusieurs.

Tout au cours de la fin de semaine, les activités ont été réparties entre 24 conférences étudiantes, cinq conférences plénières, deux activités sociales et plusieurs pauses dans l'accueillant Café Sain Fractal.

L'événement, organisé en grand pour le 25e anniversaire de l'ISM, souhaitait souligner les talents d'ici. Les conférenciers et conférencière invités ont donc été des chercheurs que les universités québécoises ont vu émerger, puisque tous ont obtenu leur doctorat dans les universités membres de l'ISM. Les participantes et participants ont donc pu écouter Marni Mishna (Simon Fraser University) présenter la combinatoire systématique, Baptiste Chantraine (Université de Nantes) nous parler de la trajectoire d'une bicyclette, Daniel Fiorilli (Université d'Ottawa) révéler certains mystères des nombres premiers et Alexandre Girouard (Université Laval) nous faire écouter la forme des objets à travers le prisme de la géométrie spectrale.

Enfin, le colloque était l'occasion pour l'ISM de décerner le prix Carl-Herz, remis à un étudiant dont la contribution en recherche a été remarquable. Cette année, Jonathan Belletête (Université de Montréal) a remporté cette prestigieuse récompense. Il nous a donc exposé le sujet de sa thèse, les règles de fusion dans les algèbres de Temperley–Lieb. Ses recherches répondent à des questions de convergence pour des suites issues de données d'expériences en physique.

Du côté des séances de conférences étudiantes, elles allaient de la combinatoire aux mathématiques financières, en passant par l'analyse, la didactique des mathématiques, la statistique, la géométrie, l'algèbre et les mathématiques appliquées. Respectant la tradition bilingue de la conférence, elles se déroulaient autant en français qu'en anglais.

Environ 65 personnes ont participé à cet événement, qui regroupait des étudiantes et des étudiants de toutes les universités membres de l'ISM. Les organisatrices et organisateur avaient d'ailleurs encouragé la participation des étudiantes et étudiants de l'extérieur de Montréal, en offrant de couvrir leurs frais de transport et d'hébergement. L'événement était organisé par des étudiantes et étudiant provenant majoritairement de l'UQAM, mais aussi de l'Université McGill.

Le Colloque panquébécois en sera à sa 20e édition le printemps prochain et se tiendra à l'Université du Québec à Trois-Rivières.

Canadian Mathematical Society Awards Vincent Genest its 2016 Doctoral Prize

Vincent Genest

Vincent Genest, recipient of the 2014 Carl Herz Prize, has recently been awarded three national accolades for his Ph.D. thesis entitled *Algebraic Structures, Superintegrable Systems and Orthogonal Polynomials*, completed in 2015 at the Université de Montréal under the supervision of Luc Vinet.

After being awarded the Governor General's Academic Gold Medal in early June, Vincent was presented with the 2016 joint award of the Winnipeg Institute for Theoretical Physics and the Canadian Association of Physicists for the best thesis in theoretical physics. In addition, he was recently awarded the prize for the best thesis (Natural Sciences) from the Université de Montréal. Dr. Genest is currently Instructor in Pure Mathematics and NSERC postdoctoral fellow at the Massachusetts Institute of Technology (MIT, Boston, MA).

Vincent Genest follows in a long line of students from CRM partner universities to have been awarded the Doctoral Prize of the CMS: Xiangwen Zhang (student of Pengfei Guan, McGill, 2014), Marc Ryser (student of Nilima Nigam and Svetlana Komarova, McGill, 2013), Youness Lamzouri (student of Andrew Granville, Montréal, 2011), Matthew Greenberg (student of Henri Darmon, McGill, 2008), Vasilisa Shramchenko (student of Dimitry Korotkin, Concordia, 2005), Yuri Berest (student of Pavel Winternitz, Montréal, 1998).

Dr. Genest will receive his award and present a lecture at the CMS Winter Meeting to be held in Niagara Falls, Ontario, December 2–5, 2016. For further details, go to https://cms.math.ca/MediaReleases/2016/dp-award.

Les 24 heures de science 2016

Christiane Rousseau (Université de Montréal)

Le CRM maintient sa collaboration avec les centres du Réseau de calcul et de modélisation mathématique (rcm_2), soit le Centre interuniversitaire de recherche sur les réseaux d'entreprises, la logistique et le transport (CIRRELT), le Centre interuniversitaire de recherche en analyse des organisations (CIRANO), et le Groupe d'études et de recherche en analyse des décisions (GERAD).

Dans le cadre des 24 heures de science 2016 qui se tenaient sous le thème de l'écologie, ils ont organisé ensemble une demi-journée « Les mathématiques au service de l'environnement » le vendredi 6 mai 2016. Les activités ont compris quatre conférences.

Stephanie Peacock

La conférence, *Why conservation biology needs mathematics*, par Stephanie Peacock, University of Alberta, a mis en évidence le rôle essentiel des mathématiques dans le travail du biologiste s'occupant de questions de conservation. En effet, comme les données écologiques sont parcellaires et entachées d'erreurs, il est difficile de tirer des conclusions sur les facteurs qui influencent les populations sauvages et l'environnement. Il est alors judicieux de combiner les méthodes statistiques avec de la modélisation mathématique pour pouvoir tester des hypothèses alternatives, et évaluer les conséquences environnementales de différents scénarios de gestion des écosystèmes par les gouvernements et les industries.

La conférence de Jean-Philippe Waaub, UQAM et GERAD, *Comment les mathématiques peuvent-elles garantir la place de l'écologie dans les études d'impacts sur l'environnement*, a illustré le rôle des mathématiciens dans la compréhension des enjeux pouvant permettre de mener à des décisions éclairées. Ces enjeux peuvent inclure la conservation de la biodiversité, ou la protection des nappes phréatiques, etc. Comment les prendre en compte ? La conférence a discuté de la mesure des effets et de l'évaluation et de la comparaison des impacts des variantes de projets (y compris la possibilité de ne rien faire).

La conférence de Bernard Sinclair-Desgagné, HEC Montréal et CIRANO, *Comment la lumière éclaire l'économie*, a mis en évidence comment la nature et la société utilisent des principes d'optimisation semblables au principe de Fermat en optique.

La conférence de Lhoussaine Ameknassi, Université Laval, *Un pas vers le développement durable par une meilleure gestion des produits complexes en fin de vie* a commencé par exposer les concepts de base de développement durable pour montrer, via la programmation mathématique, son opérationnalisation dans le domaine de l'aéronautique et ce, à travers un cas d'étude portant sur le traitement d'avions en fin de vie.

Un théorème de Erik Demaine, Martin Demaine et Anna Lubiw affirme que pour tout ensemble de polygones dessinés sur une feuille de papier, il existe un pliage qui permet de couper tous les polygones et seulement eux d'un seul coup de ciseau. Pendant les pauses de cette journée, Julien Courtois, étudiant à la maîtrise à l'Université de Montréal a invité les visiteurs à explorer ce théorème avec des polygones de complexité croissante dessinés sur des feuilles de papier.

Entente de coopération CRM–IMPA

Une entente a été établie entre le CRM et l'Instituto Nacional de Matemática Pura e Aplicada (IMPA), basé à Rio de Janeiro. L'IMPA est un organisme privé sans but lucratif dédié à l'éducation, à la recherche, à l'innovation et aux activités d'information publique en mathématique. L'institut compte plus de 150 étudiants au doctorat et à la maîtrise, plus de 40 membres du corps enseignant et de nombreux chercheurs postdoctoraux.

L'entente CRM–IMPA est convenue pour une période initiale de trois ans et pourra être prolongée si les parties en conviennent. Le soutien logistique et administratif sera fourni pour les projets de recherche conjoints, les organisations d'événements et les demandes de subvention. L'entente prévoit également une aide logistique et financière dans le cadre d'échanges d'étudiants entre les deux instituts.

Les membres du CRM qui souhaitent plus d'informations sont invités à contacter le directeur-adjoint du programme scientifique au courriel dir-progsci@crm.umontreal.ca.

Marcelo Viana, directeur de l'IMPA (gauche) et Luc Vinet, directeur du CRM (droite)

44th Canadian Annual Symposium on Operator Algebras and Their Applications

June 13–17, 2016

Organizers: George A. Elliott (Toronto), Mikaël Pichot (McGill)

The field of operator algebras was begun by von Neumann early in the last century, shortly after the discovery of quantum mechanics, with two important papers around 1930, one of them the bicommutant theorem for weak operator closed *-algebras of bounded operators, the beginning of what is now von Neumann algebra theory, and the other the uniqueness (up to multiplicity) of a representation of the Heisenberg commutation relations, for finitely many degrees of freedom. The latter theorem, and its proof, presaged the abstract theory of C*-algebras developed by Gelfand and Naimark over ten years later. It also raised the challenge, met by Gaarding and Wightman over twenty years later, followed up by Mackey, Glimm, Effros, and others, of refuting this uniqueness in the case of infinitely many degrees of freedom.

At the same time, building on the monumental edifice created by Murray and von Neumann during the thirties, a world-wide community of operator algebraists gradually grew up, encompassing schools in a number of countries, including France, the U.K., the Soviet Union, Scandinavia, and Japan, as well as the U.S. and also Canada. More recently, Germany and several other European countries, India, Australia and New Zealand, China, and, notably, several countries in South America, have developed strong centres.

This community, bolstered by the early meetings in Baton Rouge, Kingston, and Romania, not to mention the very early annual meeting in Canada (COSy), followed by GPOTS, developed more and more rapidly, with essential contributions to all of mathematics ranging from Connes's noncommutative Chern character to the Jones knot polynomial and Voiculescu's free probability. It is now a rare person, or meeting, that can hope to cover the field as a whole.

The Canadian Annual Symposium on Operator Algebras and Their Applications, as it was originally named, by Israel Halperin, in 1972—COSy for short—has taken place every year (except one) since then. The 2016 event was an exceptionally large and well-attended meeting with more than 30 speakers. This was made possible by the help provided by the CRM, whether it be in terms of financial support, logistic support, or dedicated space and facilities made available for the participants to use. The organizers are very much indebted to the CRM for making the event possible.

One of the highlights of the conference has been the four lectures series given by Lewis Bowen (University of Texas at Austin), Matthew Kennedy (University of Waterloo), Zhuang Niu (University of Wyoming), and Narutaka Ozawa (RIMS, Kyoto University). These four series of lectures focused on the most recent advances in the fields of discrete groups, operator algebras, and dynamical systems. Having the students in mind, the speakers gave broad overviews of the most recent advances in their respective fields: sofic dynamical systems (Bowen), simplicity of group C*-algebras (Kennedy), the classification theory (Niu), and amenability and (weak) polynomial growth for discrete groups (Ozawa).

The four lecture series were complemented by conference talks. There were two sorts of talks, longer talks by plenary speakers, and shorter contributed talks. Ph.D. students and postdocs were able to give presentations of their recent work. It is one of the aims of COSy to expose young promising researchers to a wider audience. With about 70 participants, this goal was clearly achieved. We also want to point out that the meeting was rather well attended by women participants. In particular, eight talks were given by female researchers in the field.

StatLab–CANSSI–CRM Postdoctoral Fellow

Chien-Lin Su, Ph.D., National Chiao Tung University, 2015
Supervisors: Russell Steele (McGill), Lajmi Lakhal-Chaieb (Laval)

My main research interests focus on statistical inference for multivariate survival analysis under different data structures and copula-related research in biomedical applications. Specifically, I have worked on hierarchical clustered survival data in which copula models are applied to study the association patterns for subjects within and between clusters. In addition, I have also worked on recurrent events data subject to multiple competing risks. My current project aims to analyze recurrent event data under the framework of renewal processes.

2016–2017 CRM–ISM Postdoctoral Fellows

Stephen Lester, Ph.D., University of Rochester, 2013
Supervisors: Chantal David (Concordia), Dimitris Koukoulopoulos (Montréal), Maksym Radziwill (McGill)

My research lies within the field of Analytic Number Theory and my current work focuses on the intersection between Arithmetic and Quantum Chaos. In particular, given manifolds with special arithmetic structure, such as the torus or modular surface, I am interested in the behaviour of eigenfunctions of the Laplace–Beltrami operator in the limit as the eigenvalue tends to infinity. In a recent joint project with Maksym Radziwill we proved a special case of the Quantum Unique Ergodicity conjecture of Rudnick and Sarnak for half-integral weight automorphic forms, under the assumption of the Generalized Riemann Hypothesis. In another recent project with Zeév Rudnick, we looked at the distribution of toral eigenfunctions at small scales and proved that the L^2-mass of almost all such eigenfunctions equidistributes all the way down to nearly the Planck scale.

Rebecca Patrias, Ph.D., University of Minnesota, 2016
Supervisor: Hugh Thomas (UQAM)

My research is in algebraic combinatorics. In particular, my work has focused on the combinatorics that describes the K-theory of the Grassmannian. I study K-theoretic analogues of things like symmetric functions, tableaux, insertion algorithms, and differential posets.

Mattia Righetti, Ph.D., Università di Genova, 2016
Supervisors: Dimitris Koukoulopoulos (Montréal), Maksym Radziwill (McGill)

I work on problems in analytic number theory. My research has been mainly focused on the joint value distribution of L-functions in the half-plane of absolute convergence and its application to the existence of zeros of Dirichlet series without the Euler product property, in particular of linear combinations of L-functions and linear (additive) twists of L-functions. I am also interested in the distribution of the real parts of these zeros and in the least upper bound of these real parts.

Sanchayan Sen, Ph.D., New York University, 2014
Supervisors: Louigi Addario-Berry (McGill), Alexander Fribergh (Montréal)

I am interested in probability theory and applications of probabilistic techniques in problems arising from combinatorics, statistics, and statistical physics. I have worked in the areas of random trees, random graphs and complex networks, random metric measure spaces, percolation, random walks on random discrete structures, stochastic geometry, etc. A part of my research is focused on understanding properties of random discrete systems, in particular the phase transition in such systems, classification of such systems in terms of their scaling limits, and understanding the universality phenomenon exhibited by these systems.

Jan Volec, Ph.D., University of Warwick and Université Paris Diderot, 2014
Supervisors: Sergey Norin and Hamed Hatami (McGill)

My research concerns problems from extremal combinatorics and structural graph theory, which are two areas of discrete mathematics. In my work, I use analytic and probabilistic methods to understand large discrete structures, and my research often involves problems from the theory of graph limits. One of my results concerning graph limits is a counterexample to a conjecture of Lovász and Szegedy on the structure of finitely forcible graphs limits, which led to a general method of constructing such limits. Another result of mine is a proof of an old conjecture of Erdős and Sós on uniform Turán densities, which is based on a combination of analytic and computer-assisted arguments.

ABONNEMENT/DÉSABONNEMENT au *Bulletin*.
Veuillez compléter un bref formulaire à la page web : www.crm.math.ca/bulletin/abonnement.

SUBSCRIBE/UNSUBCRIBE to the *Bulletin*.
Please fill a short form at: www.crm.math.ca/bulletin/abonnement.

Septième atelier de résolution de problèmes de Montréal

16 au 20 mai 2016

Organisateurs : Thierry Duchesne (Laval), Odile Marcotte (CRM & UQAM), Stéphane Rouillon (CRM)

Cet atelier permit une fois de plus de réunir des représentants d'entreprises, des chercheurs universitaires, des étudiants et des stagiaires postdoctoraux afin qu'ils étudient et résolvent des problèmes se posant dans des entreprises et susceptibles d'être résolus par des méthodes mathématiques. L'atelier portait sur la finance et les assurances et c'était d'ailleurs la première fois au CRM qu'un atelier de résolution de problèmes portait sur un seul thème. Le premier problème (soumis par la Banque Nationale du Canada) était intitulé « Construction de portefeuille en présence d'un risque de co-dépendance » et le travail de l'équipe y travaillant était coordonné par Bruno Rémillard, professeur à HEC Montréal. Le deuxième problème (soumis par la compagnie The Cooperators) était intitulé « Utilisation des variables d'évènements dans le contexte d'analytique du client » et Thierry Duchesne, professeur à l'Université Laval, supervisait le travail de l'équipe qui s'est penchée sur ce problème. Le troisième problème (soumis par Desjardins Groupe d'assurances générales) était intitulé « Simulation d'évènements extrêmes avec dépendance spatiale » et Jean-François Quessy, professeur à l'Université du Québec à Trois-Rivières, était le coordonnateur de ce problème. Finalement, le quatrième problème (soumis par la Caisse de dépôt et placement du Québec) était intitulé « La VaR (valeur à risque) historique dans un contexte de taux bas » ; le travail de l'équipe étudiant ce problème était coordonné par Louis Doray, professeur à l'Université de Montréal.

Nous avons remarqué que chaque présentation du lundi ou du vendredi fut suivie de plusieurs questions et d'un échange animé, contrairement à ce qui se produit quelquefois pendant les autres ateliers. Ceci était dû au fait que tous les problèmes provenaient du même domaine. Plusieurs des participants, et en particulier tous les représentants des entreprises, firent part de leur enthousiasme à propos de l'atelier et exprimèrent le désir qu'un autre atelier de ce genre ait lieu l'année prochaine. L'atelier attira aussi des étudiants de Toronto, Colombie-Britannique et Terre-Neuve. Notons que le Septième atelier de résolution de problèmes industriels de Montréal fut le résultat d'une collaboration entre le CRM et l'INCASS, laquelle se poursuivra certainement dans les mois et les années qui vont suivre.

Stages dans le cadre de collaborations entre mathématiciens et organisations au Québec et en Ontario pour résoudre des défis de R-D

Le CRM et Mitacs, un organisme national à but non lucratif qui met en œuvre des programmes de recherche et de formation, ont conclu une entente de partenariat. L'objectif est de permettre à des étudiants des cycles supérieurs et des chercheurs postdoctoraux de résoudre des problèmes en collaboration avec l'industrie et les organismes à but non lucratif, grâce à l'application des sciences mathématiques.

Le partenariat fournira aux entreprises et aux organismes un accès aux meilleurs mathématiciens du Québec et de l'Ontario, particulièrement pour le développement de technologies et de services.

Voici des exemples de projets :

- prévision de la demande énergétique dans le réseau urbain au moyen de méthodes d'apprentissage automatique, en partenariat avec le contrôleur des services publics provinciaux ;
- optimisation de l'horaire du personnel pour répondre à la demande des clients à l'aide d'équations de prévision du volume d'appels, en partenariat avec une agence de service à la clientèle ;
- modélisation de la corrosion et de la détérioration de matériaux par l'utilisation d'équations mathématiques pour déterminer le risque de défaillance de la structure, en partenariat avec un entrepreneur en ingénierie des infrastructures.

Les étudiants des cycles supérieurs et les chercheurs postdoctoraux pourront appliquer leurs connaissances théoriques dans un contexte pratique, pour le bénéfice des entreprises locales qui amélioreront leur compétitivité grâce à un accès à de la recherche et de l'expertise de haut niveau.

L'accord entre le CRM et Mitacs sera concrétisé dans le cadre du programme de stages de recherche de Mitacs, qui promeut l'innovation au Canada à l'aide des partenariats universités/industrie. Les stagiaires et les chercheurs postdoctoraux auront la possibilité de développer des compétences professionnelles ainsi que des réseaux, tout en proposant des solutions pour des problèmes de recherche.

Pour plus d'information :
Heather Young, directrice, Communications, Mitacs,
604-818-0020, hyoung@mitacs.ca

2016 CAP–CRM Prize Recipient

Freddy Cachazo (Perimeter Institute)

Freddy Cachazo

The 2016 CAP–CRM Prize in Theoretical and Mathematical Physics is awarded to Freddy Cachazo, Perimeter Institute, for introducing elegant new mathematical ideas and methods that have led to unexpected insights in the way scattering amplitudes are calculated in Supersymmetric Yang–Mills theory. Inspired in part by twistor-string theory, the Cachazo–Svrcek–Witten and Britto–Cachazo–Feng–Witten recursion relations revolutionized the field, making it possible to perform previously impossible calculations analytically in a few lines using explicit integral formulae. These results turned out to be in remarkable correspondence with structures explored concurrently by mathematicians for completely different purposes, establishing a suggestive link with the modern theory of integrable systems.

Dr. Freddy Cachazo is a theoretical physicist who has made outstanding contributions to the field of mathematical physics, many of which are widely characterized as breakthroughs. With collaborators, Cachazo has creatively drawn upon a variety of elegant mathematical ideas to develop entirely new methods for studying scattering processes in gauge theories and gravity. Cachazo's contributions to quantum field theory range from applications of geometric engineering (in string theory) to understanding mysterious dualities relating theories in different dimensions to novel techniques to compute scattering amplitudes in Quantum Chromodynamics (and its generalizations). The latter has brought relatively new mathematics into physics, such as the positive Grassmannian and its combinatorial structure, the positroid.

Beyond providing deep new insights into the structure of quantum field theory, these new methods have had a major impact on high-energy physics, as evidenced by the fact that the Britto–Cachazo–Feng–Witten technique has already been incorporated into the newest edition of the celebrated textbook, *Quantum Field Theory in a Nutshell*, by Anthony Zee (2010) and in the new textbook, *Quantum Field Theory and the Standard Model*, by Matthew D. Schwartz (2015).

The physical and mathematical principles underlying Cachazo's research are profound. Cachazo's 60 papers since 2001 have attracted over 7,500 citations, attesting to the enormous influence of his new insights. Besides being of utility to huge accelerator experiments, Cachazo's works will have enduring and far-reaching impact in the search for a simpler, unified description of nature's physical laws and its connection to mathematics.

Jean-Philippe Lessard, winner of the 2016 CAIMS/PIMS Early Career Award

Jean-Philippe Lessard

Professor Jean-Philippe Lessard of Université Laval is the winner of the 2016 CAIMS/PIMS Early Career Award in Applied Mathematics. Professor Lessard obtained his Ph.D. in 2007 from the Georgia Institute of Technology. He held postdoctoral positions at the Free University of Amsterdam, Rutgers and Princeton, and is now associate professor at Université Laval. He is also a member of the Groupe Interdisciplinaire de Recherche en Éléments Finis (GIREF), which brings together researchers and research groups from a number of universities to promote research, development, specialist training and interaction with industry, in the field of modelling and numerical simulation.

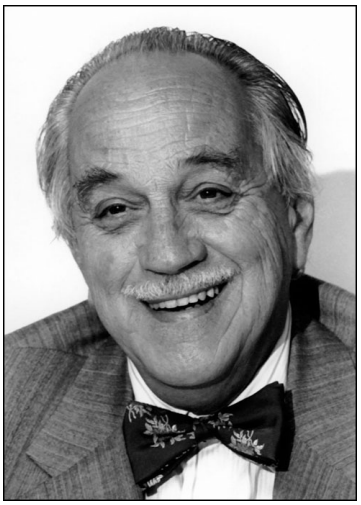
Professor Lessard's research interests are in dynamical systems. In particular, he uses and develops rigorous computational methods, topological methods and analytic estimates for the study of solutions of partial differential equations, delay differential equations and ordinary differential equations. Professor Lessard has made substantial contributions to the theory of rigorous computing, and was cited for being "one of the world leading experts in rigorous computing" and "at the forefront of applied mathematics in Canada, blending traditional analysis with traditional computation to build something entirely new."

Professor Lessard received his award and delivered a plenary lecture at the 2016 Annual CAIMS*SCMAI meeting at the University of Alberta in June, 2016.

For more informations about this award, see:
https://www.caims.ca/prizes/caimspims-early-career-award.

Jacques St-Pierre, un pionnier de la statistique au Québec nous quitte à 95 ans

Christian Léger (Université de Montréal)



Jacques St-Pierre

Jacques St-Pierre est décédé à Montréal le 29 mars 2016 à l'âge de 95 ans.

Un grand bâtisseur de l'Université de Montréal, Jacques St-Pierre a commencé sa carrière à titre de professeur de statistique au Département de mathématiques avant de fonder le Centre de calcul, le Département d'informatique, puis le Centre de recherches mathématiques et de servir à titre de premier vice-recteur à la planification pendant 10 ans.

Originaire de Trois-Rivières où il est né le 30 août 1920, Jacques St-Pierre a été le premier Québécois à compléter un doctorat en statistique en 1954. Suite à une formation combinant la théorie et les applications des schémas expérimentaux à l'Université de la Caroline du Nord à Chapel Hill, il est retourné au Département de mathématiques de l'Université de Montréal où il œuvrait depuis 1947. Dès son retour, plusieurs collègues d'autres départements, allant de la médecine (notamment le microbiologiste Armand Frappier) au droit, venaient le consulter pour analyser des données. Il ne se contentait pas de les analyser, mais allait voir comment ils travaillaient dans leurs laboratoires. Il s'enquérait du protocole expérimental, notamment de la manière qu'ils choisissaient leur rat au hasard ! Il est rapidement devenu indispensable pour eux en les aidant à améliorer leurs protocoles expérimentaux. C'est à ce moment que ses talents de développeur ont commencé à s'exprimer : il a mis sur pied un « centre de statistique », ancêtre de nos services de consultation. Les étudiants participaient avec enthousiasme à cette approche combinant la théorie aux vraies données. Parmi ceux-ci, notons Pierre Robillard qui a fait sa maîtrise sous sa direction avant de suivre ses traces à Chapel Hill pour le Ph.D. Il était un leader plein de potentiel comme son maître lorsqu'il est décédé tragiquement en 1974. Vous aurez sans doute reconnu l'homme en l'honneur duquel est remis le Prix de la meilleure thèse en statistique au Canada.

Très tôt, Jacques St-Pierre a senti le besoin d'aller au-delà des calculatrices de l'époque. En 1957, il a fait le nécessaire pour que le Département de mathématiques se dote d'un premier « cerveau électronique » au coût de 65 000 $.

À cette époque où tout était à faire, les gens de talent étaient rapidement identifiés. On lui a alors demandé de planifier une infrastructure informatique pour la recherche dont pourrait bénéficier toute l'Université. C'est ainsi qu'en 1964 Jacques St-Pierre a fondé et dirigé le Centre de calcul qui a fait l'acquisition d'un ordinateur CDC de plus de 2 millions de dollars. Mais ce n'était qu'une première étape. Alors que la discipline n'était qu'embryonnaire, il s'est attelé à développer l'enseignement et la recherche en informatique en quittant le Département de mathématiques en 1966 pour fonder et diriger le Département d'informatique, qui quelques années plus tard est devenu le Département d'informatique et de recherche opérationnelle (DIRO). Le DIRO, qui célèbre son 50e anniversaire cette année, est le deuxième plus vieux département d'informatique au pays. Il a attiré avec lui quelques statisticiens intéressés non seulement par la théorie mais également par les applications et la mise en œuvre informatique.

Toujours à l'affût de nouveaux moyens pour développer les sciences mathématiques, Jacques St-Pierre, avec l'aide de Maurice L'Abbé et Roger Gaudry, fonde le Centre de recherches mathématiques (CRM) en 1968 et en est le premier directeur de 1969 à 1971. Il est intéressant de se rappeler qu'un statisticien était là, à l'origine du CRM et du modèle qui a éventuellement mené à la création de l'Institut Fields, du PIMS et maintenant de l'Institut canadien de sciences statistiques. Toujours intéressé par la statistique, c'est également en 1969 qu'il a participé, avec d'autres, à la fondation du chapitre montréalais de l'American Statistical Association qui était très actif à l'époque.

En 1972, après avoir contribué à l'élaboration d'autant de nouvelles structures, le recteur Gaudry lui a demandé de servir à titre de premier vice-recteur à la planification, poste qu'il a conservé jusqu'à sa retraite en 1983.

Vous comprendrez qu'un homme plein d'énergie, d'idées et de vision comme lui ne pouvait pas tout simplement rester chez lui à ne rien faire durant sa retraite. Ainsi, en 1984 il a participé à la création de la Direction de l'enseignement de service en informatique (DESI) qu'il a dirigée jusqu'en 1999. En 1984, il a également participé à la mise sur pied de l'Association des professeurs retraités de l'Université de Montréal, association qu'il a présidée de 1985 jusqu'à sa retraite définitive à l'âge de 90 ans en 2011 !

Leader hors pair, homme de grand talent, il s'est également intéressé aux droits des professeurs. Ainsi, il a participé à la fondation du premier regroupement de professeurs de l'Université de Montréal, le présidant en 1959-60. Il s'est également investi dans l'exécutif de l'Association canadienne des

professeures et professeurs d'université, notamment à titre de président en 1965-66.

Il a reçu plusieurs honneurs tout au long de sa carrière. En 1986, la Société statistique du Canada lui a octroyé le titre de membre honoraire. Il a également été fait membre de l'Ordre du Canada en 1991 et chevalier de l'Ordre national du Québec en 1999.

Sur une note plus personnelle, j'ai fait la connaissance de monsieur St-Pierre dès mon arrivée au DIRO en 1988 alors qu'il dirigeait la DESI. Fraîchement sorti d'un département de statistique à l'Université Stanford, j'avais beaucoup de plaisir à discuter avec cet homme toujours souriant et très élégant avec son nœud papillon. Il m'a permis de mieux comprendre pourquoi il y avait des statisticiens dans deux départements. Alors que j'étais impatient de voir la situation de la statistique sur le campus s'améliorer, je me souviendrai toujours de sa très grande sagesse lorsqu'il m'avait expliqué qu'une université est comme un paquebot : ça ne change pas de direction rapidement, mais lorsque ça le fait, c'est pour une longue période. Pour ceux qui voudraient en découvrir davantage sur cette personne qui a tant fait pour la statistique au Québec et plus encore, je vous incite à lire l'entrevue avec Bernard Courteau [1].

[1] B. Courteau. "Entrevue avec monsieur Jacques St-Pierre". *Bulletin AMQ* 37 (1997), 10–16.

Ce texte est paru en mai 2016 *dans* Liaison*, le bulletin de la Société statistique du Canada, volume* 30*, numéro* 2.

In Memoriam

Carolyne Van Vliet (1929–2016)

Carolyne Van Vliet

Madame Carolyne Van Vliet a eu une carrière remarquable de plus de 25 ans au service du Centre de recherches mathématiques et du Département de physique de l'Université de Montréal. Elle fut extrêmement prolifique avec quelque 200 articles, et demeura très active après sa retraite en 1995. Tandis qu'elle poursuivait sa carrière de professeure à l'Université Internationale de Floride (Miami), elle conservait ses attaches au CRM.

La professeure Van Vliet a obtenu son doctorat de l'Université libre d'Amsterdam en 1956. De 1956 à 1970, elle fut tout d'abord stagiaire postdoctorale puis professeure en génie électrique à l'Université du Minnesota. Elle fut l'un des premiers chercheurs à être engagé par le Centre de recherches mathématiques en 1969. Ses intérêts, dès le début de carrière, ont touché plusieurs aspects de la physique mathématique, statistique et de l'état solide, plus spécifiquement, la mécanique statistique hors-équilibre (et particulièrement la théorie de la réponse linéaire et la description à N-corps des processus de corrélation et de relaxation), le transport quantique en matière condensée, les fluctuations et processus stochastiques, et les phénomènes quantiques mésoscopiques et en électrodynamique quantique.

En réponse à des critiques sévères formulées par van Kampen sur la théorie de la réponse linéaire de Kubo, Carolyne Van Vliet entreprit une révision profonde de la théorie remontant aux principes fondamentaux de la mécanique statistique telle la production d'entropie et l'irréversibilité dans les processus de transport. Utilisant la technique de projection opératorielle de Zwanzig et la limite de van Hove, elle dériva une équation maîtresse généralisée où les champs externes sont présents, des formules de réponse pour le cas à plusieurs corps et des équations de Bolztmann quantiques. Les quatre articles intitulés *Linear Response Theory Revisited* I–IV, parus dans le *Journal of Mathematical Physics* entre 1978 et 1984 constituent un exemple remarquable de sa contribution au domaine. Cette théorie mathématique fut appliquée au problème du magnéto-transport et à la conduction par sauts (« hopping conduction ») pour les matériaux désordonnés. Ses étudiants aux cycles supérieurs ont fourni d'autres applications importantes.

Un autre résultat important de madame Van Vliet est relié à la longue controverse sur le traitement du bruit $1/f$ en théorie quantique dû à Handel. C'est en 1988 que Van Vliet résolut cette controverse en donnant un traitement rigoureux dans le cadre de l'électrodynamique quantique. Une extension traitant de l'interaction électron-phonon a été proposée par un de ses étudiants.

D'après Anatole Joffe, un de ces anciens collègues au CRM : « Que ce soit sur le plan scientifique ou humain la professeure Van Vliet a été un personnage exemplaire. »

Ce texte est largement inspiré de l'article du Rapport Annuel du CRM (1995–1996) *paru à l'occasion de la retraite de la professeure Van Vliet.*

Hélène Desmarais et Luis Seco nommés au Conseil d'administration du CRM

Hélène Desmarais est présidente du Conseil d'administration et chef de la direction du Centre d'entreprises et d'innovation de Montréal (CEIM) et préside également le Conseil d'administration de HEC Montréal.

Luis Seco est le co-fondateur ainsi que le président et PDG de Sigma Analysis & Management. Il a débuté sa carrière en gestion du risque financier en 1996 comme professeur à l'Université de Toronto, établissant le RiskLab Toronto, un centre de recherche oeuvrant dans le secteur financier. Il est présentement le directeur du programme de finance mathématique de l'Université de Toronto.

Appel à propositions

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

Programmes thématiques

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

Programme général

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

Calendrier

Programmes thématiques

Nous sollicitons présentement des lettres d'intention en vue des programmes thématiques qui se tiendront en 2020. Les lettres d'intention devraient être transmises au plus tard le **15 mars 2017**.

Programme général

Le Comité scientifique international, qui se réunit deux fois l'an, examine les propositions qui requièrent plus de 5000 $ de financement du CRM. Les dates limites pour ces propositions sont le **15 mars** et le **15 septembre** de chaque année. Le Comité de direction du CRM examine les propositions qui requièrent au plus 5000 $ de financement du CRM. Les dates limites pour ces propositions sont le **1er février**, le **1er juin** et le **1er octobre** de chaque année.

Dans les deux cas, pour faire l'objet d'un financement, l'activité doit être réalisée au moins neuf mois après la date limite de soumission.

Conditions

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

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

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

Lignes directrices de présentation

Programme général

Les propositions d'activités dans le cadre du programme général doivent comprendre les documents suivants :
- un modèle de proposition complété (offert dans les formats .tex ou .doc) ;
- le C.V. de chacun des membres du comité organisateur.

Les propositions devraient présenter un argument convaincant (a) que l'événement est d'un haut niveau scientifique et (b) qu'il est fort probable que le projet réussisse.

Programmes thématiques

Les lettres d'intention pour le programme thématique devraient inclure l'information suivante :
- le titre du programme ;
- le C.V. de chacun des membres du comité organisateur ;
- une description scientifique de l'événement, incluant les principales activités de recherche et de formation ;
- une liste provisoire des principaux participants invités et leur rôle éventuel dans le cadre du programme ;
- une proposition de calendrier des activités.

Le modèle de proposition (.tex ou .doc) peut également être utilisé pour les lettres d'intention.

Les personnes qui souhaiteraient proposer un programme thématique sont encouragées à contacter le directeur du CRM (directeur@crm.umontreal.ca) ou le directeur adjoint aux programmes scientifiques (dir-progsci@crm.umontreal.ca) afin de discuter leur proposition avant de rédiger leur lettre d'intention.

Les activités scientifiques des programmes thématiques comprennent généralement des ateliers, des conférences et des écoles, et des visiteurs à court et long terme, y compris les titulaires de la chaire Aisenstadt. Les propositions sont examinées par le Comité de direction et le Comité scientifique international du CRM. Si le programme est accepté, les membres du comité organisateur seront responsables de l'organisation du programme thématique avec un plein soutien du personnel du CRM. Le CRM comprend également treize laboratoires scientifiques qui à l'occasion participent à l'organisation et au financement de semestres thématiques.

Call for Proposals

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

Thematic programs

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

General program

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

Timeframe

Thematic programs

We are currently inviting letters of intent (LOIs) for thematic programs to take place in 2020. LOIs should be received by **March 15, 2017**.

General program

Proposals requesting over $5000 in CRM funding are reviewed by the International Scientific Advisory Committee, which convenes twice annually. For such proposals, the deadlines are **March 15** and **September 15** of each year. Proposals requesting at most $5000 in CRM funding are reviewed by the CRM's management committee. For such proposals, the deadlines are **February 1**, **June 1** and **October 1** of each year.

In both cases, to be considered for funding, the activity must occur at least nine months after the submission deadline.

Requirements

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

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

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

Submission Guidelines

General program

Proposals for activities as part of the general scientific program should include the following documents:

- A completed proposal template (available in .tex and .doc formats).
- CVs for all members of the organizing committee.

Proposals should make a convincing case that (a) the event is of high scientific value, and (b) it is likely to succeed.

Thematic programs

Letters of intent for thematic program proposals should include the following information.

- The title of the program.
- CVs for all members of the organizing committee.
- A scientific description of the event, including the major research and training activities.
- A tentative list of the principal invited participants and their proposed role within the thematic program.
- A proposed timeline of activities.

The proposal template (.tex, .doc) may also be used for letters of intent.

Individuals interested in proposing a thematic program are encouraged to contact the CRM director (director@crm.umontreal.ca) or CRM deputy director for scientific programs (dir-progsci@crm.umontreal.ca) to discuss their proposal prior to preparing a letter of intent.

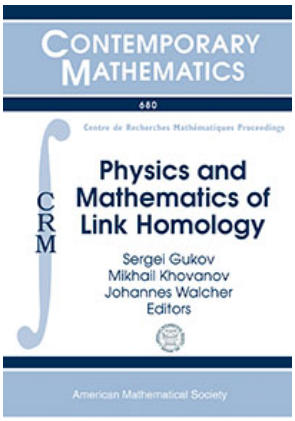
Thematic program activities typically include workshops, conferences and schools, and short/long-term visitors, including the holders of the Aisenstadt Chair. Proposals are reviewed by the CRM executive and by the International Scientific Advisory Committee. If the program is accepted, the members of the organizing committee will be in charge of the organization of the thematic program, with the full support of CRM personnel. The CRM also includes thirteen scientific laboratories, which sometimes participate in the organization and financing of thematic semesters.

Publications of the CRM

Physics and Mathematics of Link Homology

Contemporary Mathematics, AMS

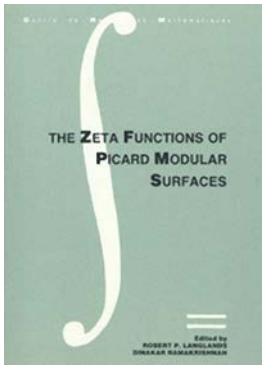
Sergei Gukov (Caltech), Mikhail Khovanov (Columbia), Johannes Walcher (Heidelberg), editors



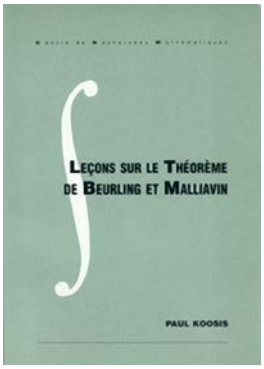
The 2013 Séminaire de mathématiques supérieures in Montréal presented an opportunity for the next generation of scientists to learn in one place about the various perspectives on knot homology, from the mathematical background to the most recent developments, and provided an access point to the relevant parts of theoretical physics as well.

This volume presents a cross-section of topics covered at that summer school and will be a valuable resource for graduate students and researchers wishing to learn about this rapidly growing field.

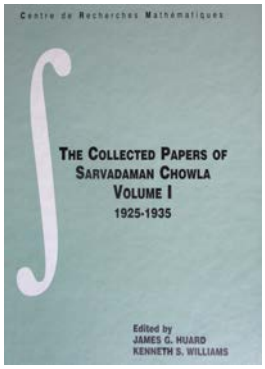
Expected publication date: January 13, 2017. To order go to http://bookstore.ams.org/conm-680/



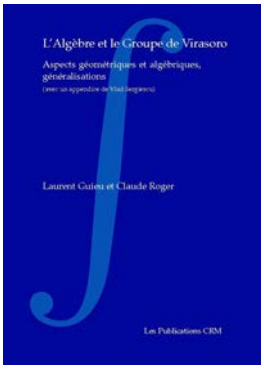
The Zeta Functions of Picard Modular Surfaces



Leçons sur le théorème de Beurling et Malliavin



The Collected Papers of Sarvadaman Chowla



L'Algèbre et le Groupe de Virasoro

To see the full list of our older CRM Publications please go to http://www.crm.umontreal.ca/pub/Collections/pub_CRMpublications/pub_CRMpublications_an.shtml. You can order by writing us at crmbooks@CRM.UMontreal.CA ou en français à crmlivres@CRM.UMontreal.CA

Yoshua Bengio et Andrea Lodi au cœur d'un investissement historique pour la recherche en intelligence artificielle

Le Centre de recherches mathématiques est fier de compter parmi ses membres Yoshua Bengio, le fondateur du MILA (Institut des algorithmes d'apprentissage de Montréal), un laboratoire du CRM, et Andrea Lodi, titulaire de la Chaire de recherche du Canada sur la science des données pour la prise de décision en temps réel, à Polytechnique Montréal.

M. Bengio, chef de file mondial dans le domaine des algorithmes d'apprentissage, et M. Lodi, chef de file international de la recherche en programmation linéaire et non linéaire en nombres entiers mixte, ont été au cœur du projet ayant abouti à une subvention historique de 93 M$ pour l'IVADO (Institut de valorisation des données, ivado.ca), un pôle scientifique et économique créé par l'Université de Montréal, Polytechnique Montréal et HEC Montréal.

Cette subvention, octroyée par le Fonds d'excellence en recherche Apogée Canada, servira à appuyer trois projets, dont le premier porte sur l'amélioration de l'intelligence artificielle dans le but de doter les ordinateurs de capacités équivalentes à celles des humains.

« Ce qui me motive depuis le début, c'est non seulement l'idée de renforcer Montréal comme pôle international de la recherche en intelligence artificielle, mais que ça soit aussi la graine pour créer ici une mini-Silicon Valley de l'intelligence artificielle et la science des données », mentionne M. Yoshua Bengio, professeur au Département d'informatique et de recherche opérationnelle de l'Université de Montréal et titulaire de la Chaire de recherche du Canada sur les algorithmes d'apprentissage statistique.

Les relations entre le CRM et l'IVADO sont promises à un grand avenir.

Le Bulletin du CRM
Volume 22, N° 2
Automne 2016

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

ISSN 1492-7659

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

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

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

Directeur : Luc Vinet

Directrice d'édition : Galia Dafni
Conception : André Montpetit

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

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

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

Entanglement and Quantumness

August 22–23, 2016

Gilles Brassard (Université de Montréal)

The two-day intimate CRM workshop on entanglement and quantumness was fascinating, as these topics play a central role in quantum information and computation. A score of participants gathered around six speakers to discuss fundamental issues in quantum information science. The organizers Gilles Brassard (Université de Montréal) and Tal Mor (Technion in Haifa, Israel) allowed substantial time for free discussions between the participants. The workshop featured six talks and two open sessions in a relaxed atmosphere in which each speaker was given up to 70 minutes for the talk, followed by 20 more minutes of question period, so that much more than a brief description of the new results could be presented, such as full mathematical proofs or detailed discussions.

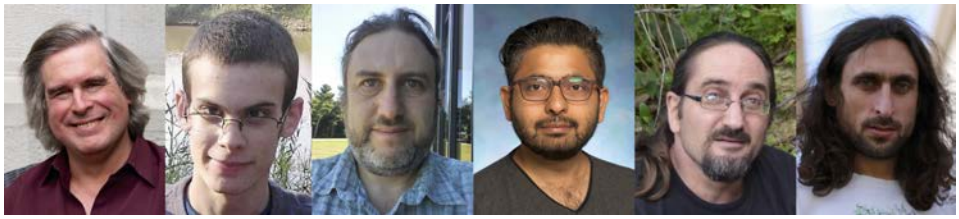
In the first day, Gilles Brassard talked about the exact simulation of entanglement by classical communication (joint work with Luc Devroye and Claude Gravel), Rotem Liss from the Technion spoke on the geometry of entanglement as seen from a Bloch sphere perspective (joint work with Michel Boyer and Tal Mor), and John Smolin from IBM Research in Yorktown Heights, USA, talked about bound entangled states with secret key and their classical counterpart, featuring what he called enclanglement (joint work with Graeme Smith and Maris Ozols).

The first-day open discussion was devoted to the view held by Gilles Brassard and his student Paul Raymond-Robichaud according to which the violations of Bell inequalities (including the recent so-called loophole-free experiments) are consistent with local realism.

In the second day, Kavan Modi from Monash University in Melbourne, Australia, spoke on full and efficient characterizations of non-Markovian quantum processes (joint work with Thomas Frauenheim, Mauro Paternostro, Felix A. Pollock and César Rodríguez-Rosario), Tal Mor talked about "void states," their entanglement, and their importance for quantum information and computation (joint work with Michel Boyer and Aharon Brodutch), and Aharon Brodutch from the University of Toronto gave a blackboard talk about entanglement and discord in mixed state quantum computation (joint work with Michel Boyer and Tal Mor).

The second-day open discussion summarized the workshop with a discussion about what gives quantum computing its power.

Throughout the two days, coffee breaks and delicious lunches for all participants (compliment of CRM) were the scene for ever more lively discussions, and dinner on the first night for speakers only (compliment of the Canadian Institute for Advanced Research—CIFAR) will not soon be forgotten. None of this would have been possible without the expert help of Sakina Benhima.



From left to right, in speaking order: Gilles Brassard, Rotem Liss, John Smolin, Kavan Modi, Tal Mor, and Aharon Brodutch

Mot du directeur

I am often visiting universities around the world and am always pleased to see the posters of our activities well in sight on the walls of these institutions. They remind me of the broad outreach that the CRM has and of how much our events are attended and appreciated.

Comme vous vous le rappellerez en lisant les différents articles du bulletin, l'été dernier et l'automne qui s'achève ont encore une fois été l'occasion de rencontres et conférences tout à fait remarquables. Je m'émerveille toujours qu'une si grande concentration d'événements d'une tenue exceptionnelle puisse être réalisée, mais voilà le talent et l'implication de notre communauté ne cessent d'opérer et de faire en sorte que le CRM brille de plus en plus. Que tout ceux qui ont mis la main à la pâte soient chaleureusement remerciés.

Un coup d'éclat sans précédent dans les annales des sciences mathématiques au Québec est l'obtention par IVADO d'une subvention APOGÉE de 93 M$. Il s'agit d'un succès retentissant qui aura un effet profond sur notre environnement. Nous félicitons chaleureusement tous les acteurs impliqués dans cette initiative et en particulier deux membres éminents du CRM : Yoshua Bengio, directeur du laboratoire MILA du CRM et Andrea Lodi, détenteur de la chaire d'excellence du Canada sur la science des données pour la prise de décision en temps réel. C'est avec beaucoup d'enthousiasme que le CRM développe son partenariat avec l'IVADO convaincu que celui-ci permettra d'affirmer sur des bases théoriques larges et grandissantes la prépondérance de Montréal en intelligence artificielle et en recherche opérationnelle mais aussi de faire en sorte que l'ensemble des chercheurs formidables du CRM œuvrant dans diverses disciplines fondamentales et appliquées bénéficient d'une visibilité et de moyens accrus alors que l'importance des méthodes quantitatives fait consensus.

There was a nice event at the beginning of the Summer involving many dignitaries to mark the establishment by the Québec Government of "mirror sites" for the three UMIs of the CNRS in Québec. The CRM is of course very grateful to be the host of one of those and to benefit from funding from the CNRS and the FRQNT. A TV program produced by Canal Savoir has been realized for the occasion and you are all invited to watch it.

The CRM is also very happy that two very distinguished individuals, Hélène Desmarais and Luis Seco, have joined its Board of Governors. I very much look forward to their advice.

Témoignage de l'excellence des membres du CRM, une avalanche de prix a déferlé sur ceux-ci depuis l'été : Vincent Genest, prix doctoral de la SMC et prix de la meilleure thèse de l'ACPP ; Henri Darmon, prix Cole de l'AMS ; Maksym Radziwill, prix SASTRA Ramanujan ; Jean-Philippe Lessard prix CAIMS/PIMS. Qu'ils trouvent ici l'expression de nos félicitations et de notre fierté.

With snow falling on Montréal as I am writing these words, I will take the opportunity to offer you my warmest Season's Greetings and to invite you to visit the CRM in 2017.

Mes meilleurs vœux pour le temps des fêtes et au plaisir de vous retrouver au CRM en 2017.

Luc Vinet

André Aisenstadt Prize—Call for Nominations

The CRM solicits nominations for the André Aisenstadt Mathematics Prize, awarded to recognize talented young Canadian mathematicians. This Prize celebrates outstanding research achievement by a young Canadian mathematician and consists of a monetary award and a medal.

The recipient is chosen by the CRM's International Scientific Advisory Committee. The prize is generally awarded yearly, although in a given year the decision may be made not to award it. Candidates must be no more than seven years from their Ph.D., and be either Canadian citizens or permanent residents of Canada, or hold a tenure-track academic position in Canada.

To be eligible for the André Aisenstadt Prize in the year N, a candidate must have received his/her Ph.D. (or equivalent degree) in the year $N-8$ or subsequently. The committee may exceptionally consider candidates who have received their degree prior but very near to the year $N-8$, if it can be demonstrated that special circumstances, such as parental leaves or other leaves of absence from work, delayed professional achievements.

The recipient is invited to deliver a lecture at the CRM and to write a brief article on his or her work for publication in the *Bulletin du CRM*.

The deadline for nominations is **March 1st, 2017**. The nominations should be submitted to the Director of the CRM, by at least two sponsors who are responsible for providing the following information:

- a cover letter explaining the basis of the nomination;
- a curriculum vitae;
- a list of publications;
- up to four reprints; and
- a maximum of four letters of support.

Unselected nominations remain active for two further years if not withdrawn and provided they still meet the Prize eligibility criteria. The nominations can be updated, if desired.