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Thematic Semester on Quantum Information

by Patrick Hayden (McGill University), Canada Research Chair in the Physics of Information

The 2011 fall thematic semester will focus on quantum information science, a field whose main goals are to understand the fundamental nature of information in a quantum mechanical world while simultaneously trying to exploit that understanding for technological gain. Quantum information has a long and illustrious history in Montréal, which is closely associated with two of the most important discoveries in the field, quantum key distribution and quantum state teleportation. The semester will address a range of topics spanning the interdisciplinary breadth of quantum information science, from algorithms for quantum computers, to connection between quantum information and condensed matter physics. The science will be informed and will strengthen existing links with branches of mathematics including random matrix theory, asymptotic geometric analysis, representation theory and free probability.

There is an ambitious range of activities planned, starting with a summer school and student conference in June, to be followed by four small workshops spread throughout the fall. The program will culminate with the premier annual conference in the field, *Quantum Information Processing* (QIP), which will bring together 300 of the leading researchers in theoretical aspects of quantum information. Two leading researchers, John Preskill of Caltech and Renato Renner of ETH Zürich, will hold the Aisenstadt Chairs. Preskill, director of Caltech's Institute for Quantum Information, began his career at the intersection of cosmology and particle physics. In the 1990s, however, he began to make important contributions to the development of fault-tolerant quantum computation and he hasn't stopped since. Renner is still relatively early in his career, but his Ph.D. thesis has already become one of the standard references in quantum information theory due to the power and widespread applicability of the tools he developed there.

The first event of the thematic semester's program will be the 11th annual Canadian Summer School on Quantum Information, which is being organized by Université de Sherbrooke researcher David Poulin with the assistance of his colleagues Alexandre Blais, Michel Pioro-Ladrière and Bertrand Reulet. The summer school is the 11th edition of a highly successful series with previous editions held in Calgary, Montréal, Toronto, Vancouver, and Waterloo. It follows the tradition of educating young researchers (prospective and current graduate students, as well as postdocs) on the rapidly evolving field of quantum information science and will bring together the world's experts from several different areas. The summer school will begin Monday, June 6th and run until Wednesday, June 15th, with a two-day break during the weekend.

The summer school will be followed immediately by the 8th Canadian Student Conference on Quantum Information. By tradition, the student conference is organized by students and for students, providing a venue for more junior members of the community to present their work and establish collaborations away from the critical and sometimes intimidating influence of faculty and supervisors. Guillaume Duclos-Cianci and Olivier Landon-Cardinal of the Université de Sherbrooke are coordinating the student conference.

Both the school and student conference will take place at the lovely Centre de villégiature Jouvence, located inside Québec's Parc national du Mont-Orford. This venue will isolate students from urban distractions that might interfere with their studies while providing an ideal location to engage in a range of intellectually stimulating outdoor activities including canoeing, hiking, and cycling. The summer school package includes housing and all meals that will be provided by the Centre de villégiature. In addition, participation at the summer school is an official academic activity for which students will receive 3 graduate-level credits from the Université de Sherbrooke. Participants in the student conference will receive 1 graduate level credit. These credits can be accounted for the student's graduate program, depending on regulations of their host institution.

The first of the semester's small workshops, being organized by Peter Hoyer of the University of Calgary and Alain Tapp of the Université de Montréal, will be **Quantum Computer Science**, to take place from October 4th to 7th. The computer science aspect of quantum information science has been quite active since the seminal work of Peter Shor, who invented a polynomial time quantum algorithm to factor large numbers, and Lov Grover, who proposed a technique to speed up the solution of NP-complete problems. The workshop will focus on the interplay between quantum algorithms and quantum complexity theory, that is between finding procedures for solving problems using quantum computers and classifying problems according to the physical resources required to solve them. The workshop will also cover recent results in communication complexity, the study of how much communication is required to cooperatively solve distributed computation tasks, an area with many surprising connections to quantum nonlocality.

The semester will then take a turn in the direction of physics, with David Poulin's workshop on **Quantum Information in Many-Body Physics**, scheduled for October 18th to 21st. Many recent developments in the theory of quantum information have led to important insights and applications in condensed matter physics. For instance, the theory of entanglement has shed new light on the density matrix renormalization and real space renormalization numerical methods, culminating in a deeper understanding of the strengths of the methods and applications to a wider class of problems including critical systems and systems in more than one spatial dimension. Similarly, the theory of quantum error correction has led to new classes of theoretical models of interacting particles that exhibit topological order, an exotic phase of matter where excitation can have non-Abelian statistics. The study of information propagation in a system of interacting particles was used to prove the existence of an entanglement entropy area law in the ground state of systems with local interactions. The problem of finding ground states of a system composed of interacting particles was proven to be complete for the complexity class QMA, the quantum analogue of NP. The purpose of this workshop will be to bring together some of the world's leading experts in quantum information and condensed matter physics with interests in the connections between the two fields. This will represent a opportunity to deepen our understandings of the connections between these fields and to tackle important open questions such as the quantum analogue of the probabilistically checkable proof (PCP) theorem and the existence of self-correcting phases of matter.

Another workshop will take place the following week with the title **Quantum Information: Codes, Geometry and Random Structures**, this timed organized by Aram Harrow of the University of Washington and Patrick Hayden of McGill University. One of the primary concerns of quantum information theory is the design of codes for achieving communication in noisy environments, often while simultaneously achieving cryptographic objectives. The probabilistic method is often used to prove the existence of good codes and may even play a role in more explicit and efficient constructions. At the same time, many basic quantum information theoretic tasks have natural geometric interpretations that link them to a range of other application areas like compressed sensing and approximation algorithms through shared underlying mathematics. This workshop will provide a forum for participants to present the latest developments in the theory of quantum communication while highlighting the range of mathematical techniques used in the area, including representation theory, asymptotic geometric analysis, random matrix theory and operator theory.

The final small workshop of the semester, from December 6th to 9th, is devoted to some of the conceptual questions motivating research in quantum information science. The workshop, **Quantum Foundations in the Light of Quantum Information**, to be organized by Gilles Brassard of the Université de Montréal and Christopher Fuchs of the Perimeter Institute, will be the third in the series to be held at the CRM over the years. Consider the two great physical theories of the twentieth century: relativity and quantum mechanics. Einstein derived relativity from very simple principles such as: "The speed of light in empty space is independent of the speed of its source" and "Physics should appear the same in all inertial reference frames." By contrast, the standard foundation of quantum mechanics is built on a set of rather strange, disjointed and ad hoc axioms. Why is this? Must quantum mechanics be inherently less elegant than relativity? Or is it rather that the current axioms of quantum mechanics reflect at best the history that led to its discovery by too many people over too long a period of time? Is it not time to take a pause, reflect on what has been achieved in the past one hundred years, and distill the truly fundamental within it?

The purpose of the workshop will be to search for a better foundation for quantum mechanics, preferably one that lies within the teachings of quantum information science. Indeed, the organizers postulate that the truly fundamental laws of Nature

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2010 CAP – CRM Prize Winner

Professor Clifford Burgess

by Robert Brandenberger (McGill University), Canada Research Chair

Professor Clifford Burgess (McMaster University/Perimeter Institute) is this year's winner of the CAP – CRM Prize in Theoretical and Mathematical Physics. To quote the citation, Professor Burgess was awarded the prize "for his prolific and influential work in theoretical physics, which covers many different topics ranging from condensed matter theory to particle physics and string theory. Professor Burgess made seminal contributions in all these fields, but his most widely recognized contributions are in the areas of string and brane cosmology, where he developed interesting and pathbreaking ideas about how strings or branes can generate inflation in the early universe."

Clifford Burgess was born and raised in Canada. He received his undergraduate education at the University of Waterloo and in 1985 obtained his Ph.D. at the University of Texas at Austin under the supervision of Nobel Laureate Steven Weinberg. After spending a brief period as a postdoctoral fellow at the Institute for Advanced Study in Princeton, he moved back to Canada in 1987 to take up a faculty position at McGill University. Professor Burgess remained at McGill until 2005 when he started his present joint position between the Physics and Astronomy Department of McMaster University and the Perimeter Institute for Theoretical Physics.

Professor Burgess is one of Canada's most well-known theoretical physicists. He has made important contributions over a wide range of fields, from condensed matter physics to astrophysics. His best known works are his seminal contributions to superstring cosmology. He is one of the pioneers in the field of string inflation model building. In particular, he was one of the first to realize that branes, higher-dimensional objects predicted by superstring theory, can lead to new candidates for the scalar field responsible for the accelerated expansion of space in inflationary cosmology. Specifically, it is the distance between a brane and a corresponding antibrane which yields the scalar field that gives inflation. At the time of writing, his original paper from 2001 on this topic has been cited more than 340 times in the particle physics literature. More recently, Professor Burgess has been collaborating with colleagues at places such as Stanford and Cambridge on constructing new models of inflation in string theory. He is recognized internationally as a leader in superstring cosmology and has been invited to lecture at many international schools and conferences on this topic. He is an excellent and entertaining lecturer, as all of us who attended his CRM seminar will realize.

As mentioned above, Professor Burgess has an unusually broad record at fundamental research in theoretical physics. He attacks both very fundamental questions and at the same time also much more technically well defined ones. As an example of the first, I would like to mention his ambitious work addressing the cosmological constant problem (which has been one of the key mysteries in fundamental physics for almost a century) in a new context, namely the context of codimension two branes in a six dimensional space-time theory. He is leading an international research program on this topic. There are many examples that I could mention for the second type of questions which he tackles. To mention just one, Professor Burgess is one of a handful of leaders in the study of the realm of applicability of "effective field theory." He has been invited to contribute review articles to leading journals on this subject.

Clifford Burgess

What is most unusual about Professor Burgess' research is the range of topics he works on. During his PhD studies, he was trained in the areas of string theory and effective field theories, in both of which he made important contributions in his early days of research. As a McGill faculty member Professor Burgess then vastly expanded the range of his research. He worked on particle phenomenology on topics such as neutrino physics, double beta decay and precision accelerator measurements, and has collaborated successfully with particle physics experimentalists on some of these topics. At the same time, he turned his interests to condensed matter physics and wrote important papers on the Quantum Hall Effect. Most recently, he has been applying techniques of superstring theory (specifically, the "AdS/CFT correspondence") to Quantum Hall systems, and this has led to the first analytical understanding of some intriguing experimental results.

Professor Burgess has received many awards for his research. In 2008 he became Fellow of the Royal Society of Canada. (*continued on page* 6)

Stages internationaux

Six étudiants gradués du CRM ont reçu des bourses de stage international FQRNT-CRM au cours de la dernière année, qui leur ont permis de visiter des centres d'expertise dans leur domaine de recherche situés aux États-Unis et en Europe.

Mr. Hirbod Assa, a Ph.D. student at Université de Montréal under the direction of B. Rémillard and M. Morales, visited the department of Operational Research and Financial Engineering (ORFE) at Princeton University where he worked under the supervision of Professor Birgit Rudloff. The department consists of a group of mathematicians, statisticians and physicists who work on problems related to finance as risk management, risk measures and studying the carbon emission markets. Professor Birgit Rudloff, has worked on the problem of hedging and pricing financial positions. The previous works of Professor Rudloff enables one to price a financial position through hedging against another financial position with a positive price bind. The structure of the hedging strategy is also given with a test function, which has a so-called 0-1 structure. This problem will likely have the same answer if we replace the positive price bind with a nonposition price bind, which is called hedging with attainable positions, but this was not worked out before. A new attack was devised applying the Lagrangian duality methods instead of Fenchel duality methods. This approach was successful, and the work done by Mr. Assa and Professor Rudloff during his visit at ORFE will constitute the core of a paper that they are currently writing.

Mr. Peyman Eslami is a Ph.D. student at Concordia University, under the direction of P. Góra. He worked with Dr. Misiurewicz at Indiana University Purdue University Indianapolis (IUPUI) for a period of four months. In this period, Mr. Eslami worked on a problem regarding the stability of dynamical systems. In the real world, dynamical systems are subject to errors in measurement and/or external noise. It is important to know whether certain systems or certain properties of a system are sensitive to such errors. If outputs are very sensitive to initial data, then the system is called unstable. During the internship, Mr. Eslami and Dr. Misiurewicz investigated the dependence on the parameters of absolutely continuous invariant measures for a family of piecewise linear piecewise expanding maps, and constructed an example to show that the transitivity of the maps does not imply the convergence of those measures to the absolutely continuous invariant measure for the limit map. This lead to a preprint which will soon be sent for publication.

M. Othmane Kortbi est étudiant de doctorat à l'Université de Sherbrooke sous la direction de É. Marchand. Il a séjourné au Département de statistique et de biostatistique de l'université Rutgers aux États-Unis de février à avril 2010, et prévoit y retourner pour un quatrième mois en 2011. Supervisé par le professeur William E. Strawderman, il a travaillé essentiellement sur deux problèmes en inférence statistique. Le premier se concentre sur la généralisation (à d'autres lois sphériques) de la méthode de Hartigan qui consiste à démontrer que l'estimateur de Bayes par rapport à la mesure a priori uniforme sur un concave C avec intérieur non vide domine l'estimateur sans biais X sous la perte quadratique (et ceci peu importe C et la dimension p). Le second travail est essentiellement centré sur l'estimation de la moyenne d'une distribution multivariée p-dimensionnelle à symétrie sphérique, sous coût quadratique et en présence d'un vecteur résiduel. Ce dernier travail a été soumis pour publication au *Journal of Statistical Planning and Inference*.

Ms. Isabelle Lajoie, who recently completed a master's degree (selected for the Dean's Honor List) at Université de Montréal under the supervision of P. Vincent et Y. Bengio, visited the Computational Neuroscience Group at the Universitat Pompeu Fabra in Barcelona from February to May 2010 to work with Professor Gustavo Deco.

Attention is a process allowing the increase of our capacity to detect surrounding relevant stimuli. Herrero et al. (2008) demonstrated that the visual attention, managed in the primary visual cortex (V1), is influenced by the presence of the neuromodulator acetylcholine (ACh), but still, the immediate effect of ACh on the cellular activity during attention remained unclear. To answer this question, Deco et al. (2009) have implemented a biased competition model network which is composed of one pool of non specific neurons, one inhibitory pool and two excitatory pools. Using this model, Deco et al. (2009) discovered that ACh has little impact on excitatory cortico-cortical interactions or thalamo-cortical inputs but reduces considerably the firing rate adaptation, through a reduction of after-hyperpolarisation currents, and increases the inhibitory synaptic drive. From this implemented model, one could want to bring some pertinent changes in a way that the model is even more biologically plausible, and Ms. Lajoie examined some of those changes during her internship at the Computational Neuroscience group. More precisely, the model of neurons used until then was the Integrate-and-fire (INF) model. An advantage to use the INF model is its simplicity, but a disadvantage would be its lack of detailed behavioural information during the neuron's spike. Indeed, the INF models the spike as followed: as soon as the neuron's potential reach a defined threshold, the neuron is said to have spiked and then its potential is resettled to its rest potential. Then to use a more realistic dynamic of the neuron's spike, Ms. Lajoie implemented the Hodgkin Huxley (HH) model of neurons and integrated it into the network used.

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Self-Avoiding Walks

Gordon Slade's CRM – Fields – PIMS Prize Lecture

by Lougi Addario-Berry (McGill University)

In the spring 2010 *issue of* Le Bulletin du CRM, *David Brydges described the research of* 2010 *CRM – Fields – PIMS Prize winner Gordon Slade, using as jumping-off point an old, interesting but only partially understood object: the self-avoiding walk. The self-avoiding walk (SAW) is a touchstone object in equilibrium statistical mechanics, a common model for large polymers, and a mathematical challenge.*

A self-avoiding walk of length n on a lattice — $\mathbb{Z}^d$, say — is simply a path of $n+1$ distinct lattice sites, starting from the origin, with each site adjacent to the preceding site. Place the uniform probability measure on the set of such walks, and call the resulting random variable — which we'll denote by $\omega(n)$ — "self-avoiding walk with n steps." What can be said about this object? In his prize lecture, Gordon Slade gave an overview of our mathematical understanding to date, and what tools are being brought to bear on the question.

Let $c_n = c_n(d)$ denote the number of self-avoiding walks with n steps. On any lattice, breaking a self-avoiding walk in two yields two self-avoiding walks, but concatenating two self-avoiding walks does not necessarily maintain the self-avoiding property. Thus $c_{m+n} \leq c_m c_n$, and Fekete's lemma shows that $\mu = \lim_n c_n^{1/n}$ exists. The quantity μ is called the *connective constant* of the lattice. For $\mathbb{Z}^d$, $\mu \leq 2d-1$ is easily seen since a SAW can never reverse direction, and $\mu \geq d$ can be seen by restricting to walks that always head toward a fixed orthant. In two dimensions, Nienhuis (1982) predicted a connective constant of $\sqrt{2+\sqrt{2}} = 2\cos(\pi/8)$ for the *hexagonal* lattice, a prediction finally proved in 2010 by Smirnov and Duminil-Copin. There is no other lattice for which the connective constant is explicitly known when $d \geq 2$ (however, the situation when $d > 4$ is more-or-less understood, thanks largely to work of Slade and his collaborator, Takeshi Hara — we will return to this case shortly).

A fundamental quantity parameterizing the behaviour of SAW is the *expected mean-square displacement* $\mathbb{E}(|\omega(n)|^2)$, where $|\omega(n)|$ is the Euclidean distance of the walk from the origin. For $d \leq 4$, it is not rigorously known either that $\mathbb{E}(|\omega(n)|^2) \geq cn^{2/d}$ (for some positive constant c) or that $\mathbb{E}(|\omega(n)|^2) \leq Cn^{2-\epsilon}$. Without the former bound, it is in principle possible that SAW with n steps essentially fills a ball of volume n around the origin; without the latter, it is possible that SAW essentially forms a straight line.

Despite this absence of rigorous results, there are widely-believed predictions for the asymptotic behaviour of SAW. In all dimensions, it is believed that

$$c_n \sim A\mu^n n^{\gamma-1}, \quad \text{and} \quad \mathbb{E}(|\omega(n)|^2) \sim Dn^{2\nu},$$

for some constants A, γ, D, ν (with a $(\log n)^{1/4}$ correction when $d = 4$, the *upper critical dimension* for SAW). The constants γ and ν are believed to be connected via an identity called *Fisher's relation*. To state Fisher's relation requires first introducing the *two-point function* for SAW, given by $G_z(x) = \sum_{n=0}^{\infty} c_n(x) z^n$,where $c_n(x)$ counts the number of self-avoiding walks with n steps ending at $x \in \mathbb{Z}^d$. When $z = z_c = \mu^{-1}$, it is believed that $G_{z_c}(x) \sim c|x|^{-(d-2+\eta)}$, for some constants c, η; Fisher's relation then states that $\gamma = (2-\eta)\nu$. Furthermore, these constants are predicted to be *universal*, which in this context means depending only on dimension and not on the underlying lattice.

As noted above, the situation in $d > 4$ is understood; in 1992 Hara and Slade showed that $\gamma = 1$ and $\nu = \frac{1}{2}$, and in 2008 Hara verified Fisher's relation by showing that $\eta = 0$. (This work, as with many of Slade's impressive results, relies on an approach called the lace expansion, a sophisticated inclusion-exclusion-based technique whose details we shall not attempt to describe here.) As mentioned in the 2010 Clay Mathematics Proceedings *Lectures on Self-Avoiding Walks* by Bauerschmidt, Duminil-Copin, Goodman and Slade,

> "the [upper critical] dimension 4 can be guessed by considering the fractal properties of the simple random walk: for $d \geq 2$, the path of a simple random walk is two-dimensional. If $d > 4$, two independent two-dimensional objects should generically not intersect, so that the effect of self-interaction between the past and the future of a simple random walk should be negligible."

In other words, when $d > 4$ self-avoiding walk should exhibit the same behaviour as simple random walk (its so-called "mean-field behaviour." Hara and Slade further verified this intuition by showing that for $d > 4$ the scaling limit of SAW is Brownian motion.

When $d = 4$, the expected number of intersections between two simple random walks grows logarithmically in the length, (this is related to the predicted $(\log n)^{1/4}$ correction to the expected mean-square displacement mentioned earlier). In this case, up to these corrections, the behaviour of the critical exponents should be the same as in $d > 4$, and it is a major challenge in the area to verify this. One promising and potentially extremely powerful approach is the rigorous renormalization group method currently being pioneered by Brydges and Slade, among others. As Brydges notes in his Park City lectures, the renormalization group

> "promises a complete analytic theory for the functional integrals of theoretical physics."

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Clifford Burgess

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A year earlier, he received one of the prestigious Killiam Research Fellowships. At McGill, he was awarded a James McGill Professorship. He has extensive international research contacts. He collaborates with other theorists across the world. He was invited to spend sabbatical years at Princeton's Institute for Advanced Study and CERN, Europe's International High Energy Research Laboratory. In particular in recent years, he has been invited to lecture at many leading international conferences and schools.

In addition to his research, Professor Burgess is also an excellent teacher. Based on a course he developed at McGill, he and his McGill colleague Professor Guy Moore recently completed a book (published by Cambridge University Press) which has become the standard text for a course on the Standard Model of particle physics.

Professor Burgess gave two prize lectures at the Université de Montréal this past November. On November 12th, he gave a colloquium in the Physics Department of Université de Montréal, and on November 16th he presented a CRM mathematical physics seminar. These two lectures reflected the range of his research interests. In the physics colloquium, he discussed the predictions of particle theory models for the Large Hadron Collider, the largest particle physics experiment in the world which is currently taking data at CERN. He gave an introduction to the Standard Model of particle physics, explained its successes and the challenges it faces which then led to the development of theories beyond the Standard Model. He discussed what these theories predict and why the results of the experiments are awaited with so much impatience. In the CRM Mathematical Physics Seminar the topic was completely different. There he spoke about string theory and its applications to other areas of physics including condensed matter physics. In particular, he gave an excellent review of the AdS/CFT correspondence, a well-supported conjecture which relates a gravitational theory living in anti de Sitter space to a nongravitational conformal field theory living on the boundary of this space. This correspondence is a key current tool in superstring theory. It offers a new concrete nonperturbative definition of a gravitational theory, and it is central to applications of string theory to quantum field theory, nuclear theory and condensed matter physics, the latter being one of his current research interests.

To quote again from the official prize citation, "Professor Burgess is one of Canada's most prolific and highly cited particle theorists. His research consistently demonstrates a very high quality and remarkable creativity and with this, Burgess has attained an outstanding international profile in the theoretical physics community." Clifford Burgess is a worthy recipient of this year's CAP – CRM Prize in Theoretical and Mathematical Physics.

Stages internationaux

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M. Louis-Xavier Proulx, étudiant à la maitrise à l'Université de Montréal sous la supervision de A. Bourlioux a effectué un stage de 3 mois au Lawrence Berkeley National Laboratory (LBNL) du 17 mai 2010 au 13 août 2010 sous la supervision du Dr. Phillip Colella, responsable en chef du Applied Numerical Algorithms Group (ANAG). Le stage de recherche s'inscrivait dans la démarche du développement d'un nouveau modèle mathématique pour la simulation de la propagation des feux de forêt en terrain complexe. Le modèle considère un champ vectoriel pour la vitesse du vent qui doit satisfaire la loi de la conservation de la masse. Ce champ vectoriel est généré à partir d'un champ initial construit préalablement à partir d'un vent donné en haute altitude et qui est ensuite corrigé à l'aide de la méthode de projection qui le force à devenir incompressible. La correction est trouvée en résolvant une équation elliptique sur un domaine irrégulier où la surface du terrain est encastrée dans la grille de résolution numérique du problème. Cela permet d'intégrer les effets de la topographie du terrain sur la direction du vent dans le calcul du champ vectoriel. Pour y arriver, l'approche cartésienne pour géométrie complexe appelée Embedded Boundary Method (EBM) a été utilisée. Cette méthode développée par Phillip Colella et son équipe du Lawrence Berkeley National Laboratory est basée sur la méthode des volumes finis. C'est la première fois que cette technique est adaptée pour un modèle empirique de simulation de la propagation de feux de forêt. Avant le début du stage, cette méthode a été implémentée et analysée par M. Proulx pour ce problème dans le cas en deux dimensions. Le stage au laboratoire de Berkeley avait pour objectif d'utiliser les algorithmes plus complexes développés par l'équipe du ANG pour résoudre le problème en trois dimensions.

M. Raphaël Rebelo étudiant au doctorat à l'Université de Montréal sous la direction de P. Winternitz a effectué un stage de 2 mois avec Decio Levi, professeur et chercheur à l'université Roma Tre. Durant le stage, M. Rebelo et Dr. Levi se sont penchés sur une nouvelle manière d'approximer les dérivées partielles de premier et second ordre par des expressions discrètes sur des maillages non uniformes et non orthogonaux. Contrairement aux définitions usuelles utilisées en analyse numérique, cette nouvelle définition des dérivées partielles discrètes permet, entre autres, d'appliquer la théorie des repères mobiles et donc de discrétiser des équations aux dérivées partielles en préservant leurs symétries. Les résultats de leur travaux ont été présentés par M. Rebelo à la conférence internationale « Symmetries and Integrability of Difference Equations (SIDE 9) » à Varna en Bulgarie du 14 au 18 juin 2010.

La Grande Conférence de Cédric Villani
« Quand la Terre était trop jeune pour Darwin »

de Christiane Rousseau (Université de Montréal)

La grande conférence de Cédric Villani du 5 novembre 2010 a attiré un public record, dont de nombreux jeunes des cégeps.

Le thème de la conférence portait sur l'historique des calculs de l'âge de la Terre. Cédric Villani a présenté les différents acteurs dans ce champ de recherche, en commençant par James Usscher, chef de l'Église anglicane, et en passant par de Buffon et Newton, pour se concentrer ensuite surtout sur la période commençant au milieu du 19e siècle. Le premier personnage à nous être présenté fut William Thomson, mieux connu comme Lord Kelvin, plus grand physicien de son époque et grand inventeur. On lui doit entre autres l'analyseur harmonique de Kelvin et le galvanomètre de Kelvin. Ses travaux sur l'âge de la Terre s'échelonnent de 1862 à 1897. Pour évaluer l'âge de la Terre, il utilise l'argument suivant : au moment de la formation de la Terre, celle-ci était une masse en fusion. À mesure que la Terre avance en âge, la Terre se refroidit et la croûte terrestre s'épaissit. Pour calculer le temps nécessaire au refroidissement observé, Lord Kelvin a utilisé l'équation de la chaleur de Joseph Fourier. Le conférencier a présenté cette équation et réussi le tour de force d'expliquer au public, de manière accessible, les concepts de dérivée partielle et de dérivée partielle d'ordre 2. Comment utiliser cette équation ? Joseph Fourier a montré qu'on peut calculer exactement sa solution sous les hypothèses suivantes : la courbure de la Terre est négligeable ; pas de source de chaleur ; la Terre est une boule solide uniforme ; une température initiale uniforme ; une température uniforme à la surface. Kelvin décide de faire l'application numérique. L'exploitation minière permet d'estimer le gradient de température au travers de la croûte terrestre. Kelvin utilise une conductivité et une température initiale estimée de 3 900˚. Son calcul l'amène à évaluer l'âge de la Terre entre 40 et 200 millions d'années, estimation corroborée par ses calculs de l'âge du soleil, basés sur un bilan énergétique.

La conférence est revenue sur le mode historique en décrivant avec moult détails les différentes controverses entre les physiciens, principalement Lord Kelvin, les géologues, et Darwin, le père de la théorie de l'évolution. Une crise scientifique majeure s'ensuivit. En effet, la théorie de l'évolution de Darwin requérait un âge minimal de 500 millions d'années pour la Terre. Les géologues évaluaient aussi que la Terre était beaucoup plus ancienne. Devant un public rivé à ses paroles, le conférencier a campé le portrait des différents protagonistes et narré le détail des controverses.

Il est ensuite revenu au cœur de la question, soit le véritable âge de la Terre, et a expliqué que la première erreur de Kelvin avait été de ne pas tenir compte des mouvements de convection à l'intérieur du manteau terrestre. Ces derniers, en remuant sans cesse le magma, amènent continuellement du magma à très haute température au contact de la croûte terrestre en refroidissement. Ceci ralentit la formation de la croûte terrestre et contribue à maintenir un gradient de température élevé au travers de celle-ci. C'est John Perry, ancien assistant de Kelvin, qui a révisé les calculs en faisant l'hypothèse d'une croûte solide surmontant un manteau fluide de température presque constante à cause des mouvements de convection. Sous ces hypothèses, les calculs permettaient alors un âge de 2 à 3 milliards d'années et une réconciliation avec les conclusions des géologues. Ses résultats ont été publiés dans la revue Nature en 1895, mais n'ont pas été entendus. L'idée du manteau fluide est révolutionnaire pour l'époque et jusqu'en 1960 on a cru à une Terre solide. C'est également dans les années 1960 que la dérive des continents est finalement admise. On sait depuis Rutherford en 1904 qu'une autre hypothèse de Kelvin était fausse, soit celle de l'absence de source de chaleur. En effet, les désintégrations radioactives dans le manteau terrestre contribuent à en élever la température. Les calculs de Rutherford, basés sur la radioactivité et ignorant la convection évaluent l'âge de la Terre à 4,6 milliards d'années.

Cédric Villani

La conférence a été magistrale, maintenant le public en haleine. À la clôture de la conférence, de nombreux jeunes se sont pressés autour du conférencier pour lui poser des questions et se sont fait photographier en sa compagnie. Cédric Villani a l'habitude des conférences pour le grand public. Son site internet personnel offre diverses conférences destinées à cette audience. Nous ne pouvons que le remercier d'avoir partagé avec le public montréalais sa passion pour les mathématiques et la science.

Aisenstadt Chairs — Fall 2010

by Olga Kharlampovich (McGill University), Alexei Miasnikov (Stevens Institute of Technology), and Mahmood Sohrabi (Carleton University)

*The Aisenstadt Chairs for the Thematic Semester on **Geometric, Combinatorial and Computational Group Theory** were Yuri Gurevich (Microsoft Research) who gave three Aisenstadt lectures in September* 2010, *Angus MacIntyre (Queen Mary, University of London) who gave four Aisenstadt lectures in October* 2010, *and Alexander Razborov (University of Chicago) who gave four Aisenstadt lectures in October* 2010.

Yuri Gurevich

Yuri Gurevich became famous for his pioneering works in logic, finite model theory, theory of computation and computer science. He is currently Principal Researcher at Microsoft Research, where he founded the Foundations of Software Engineering group, and he is professor emeritus at the University of Michigan. He is an ACM Fellow, a Guggenheim Fellow, a member of Academia Europaea, and Dr. *honoris causa* of Universiteit Hasselt in Belgium and of Ural State University in Russia.

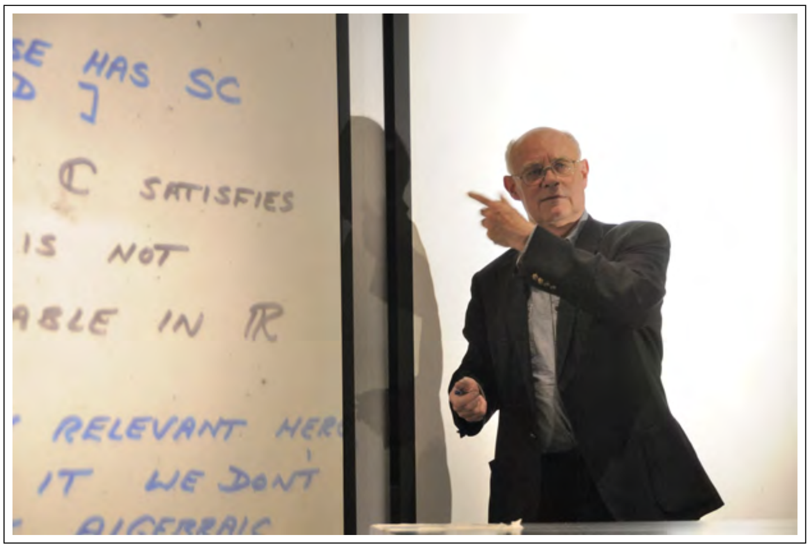
The first lecture, entitled "The Church – Turing Thesis: Story and Recent Progress," concerned the most fundamental problems of computation: what are computable functions and what are algorithms. The thesis says that every numerical function computable by means of a purely mechanical procedure is computable by a Turing machine. This thesis heralded the dawn of the computer revolution by enabling the construction of the universal Turing machine which led the way, at least conceptually, to the von Neumann computer architecture and to the first electronic computers. Gurevich explained his recent paper with Nachum Dershowitz of Tel Aviv University that makes an attempt to state axioms which embody the generally accepted properties of computability, and then to prove the thesis on that basis. Even though the Church – Turing thesis clarifies the problem of what is computable, it does not answer the question what is an algorithm. Indeed, it would be hard to argue that Turing machine simulation gives an adequate description of a modern operational system. In his talk, Yuri Gurevich described a solution to this problem based on abstract state machines.

In his second lecture, he discussed Security Policy as one of those fields where "engineers do logic." They created at Microsoft a policy language called Evidential DKAL (where DKAL stands for Distributed Knowledge Authorization Language). In the lecture, Yuri presented this piece of applied logic and discussed on the issues of real-world computability. In an interesting digression, he also touched on the subject of what kind of mathematics and logic should be taught to modern software developers, and his conclusions were surprising to many of us. In the third lecture, Yuri described some algorithmic problems that, unexpectedly, can be solved in linear time.

Angus MacIntyre is a famous model theorist, and a Fellow of the Royal Society since 1993. In 2003, he was awarded the Pólya Prize by the London Mathematical Society. Since 2009, he has served as the president of the London Mathematical Society.

Professor Macintyre's Aisenstadt lectures were on model theoretic study of exponential fields. A unital ring R is exponential if it is equipped with a function $E\colon R \to R$ such that $E(x+y) = E(x)E(y)$ and $E(0) = 1$. The most important examples of unital rings are the fields of real numbers and complex numbers with the analytically defined exponential. The first lecture of the series was addressed to a general audience, and described the motivations and history of the subject which goes back to the 1930's when Tarski posed the problem of extending the model theoretical work on the fields of real numbers and complex numbers to the setting of these fields equipped with the exponential functions. Ironically, Tarski himself proved that the complex exponential field is undecidable. This relatively superficial result inhibited for nearly 70 years any model-theoretic analysis of definitions in that structure. It took 60 years to make a breakthrough on the case of the real exponential, first through Wilkie's theorem in 1991 which states that every formula of the real exponential field is equivalent to a boolean combination of existential formulas. Though Wilkie's proof was not effective, the work of Macintyre and Wilkie in 1992 revealed that if Schanuel's Conjecture is true, then the process can be made effective.

The second lecture started with a description of Schanuel's conjecture or Schanuel's condition, which plays a role in every aspect of study of exponential fields. The biggest open problem in the field is to determine if the complex exponential field satisfies this condition, the so-called Schanuel's conjecture. Most of the lecture was spent on the theorems of Wilkie, and Wilkie and Macintyre mentioned above.



Angus MacIntyre

The third lecture was focused on Zilber's construction of "existentially closed" exponential fields, and his identification of very natural axioms for such fields. As it is typical in model theory, progress on specific classical structures is often made by the study of more general structures ("nonstandard models"). The work of Zilber reveals the amazing possibility that these axioms hold, as conjectured by Zilber, for the complex exponential field. Professor Macintyre sketched the state of the art knowledge in this area, including Zilber's theorem that his field has a unique model of the cardinality of continuum and described some of the natural questions about which the current knowledge is very limited, particularly about the connection between Zilber's field and models of the theory of the real exponential.

The fourth lecture concentrated on the speaker's very recent work on Shapiro's conjecture. He explained how it has recently become clear that there is a deep connection between Ritt's Factorization Theorem for classical exponential polynomials (from the 1920s), and definability questions arising in the model theory, and described more known connections between Zilber's fields and the complex exponential fields. This involves results typically proven by analytic methods for the complex field, and by algebraic methods for Zilber's field, a striking example involving exponential functions with no zeros (Schanuel Nullstellenatz). Professor MacIntyre concluded by discussing Shapiro's 50 year old conjecture on pairs of exponential polynomials with infinitely many common zeros.

Alexander Razborov won the Nevanlinna Prize in 1990 for introducing the ‘àpproximation method" in proving Boolean circuit lower bounds of some essential algorithmic problems, and the Gödel Prize in 2007 (with Steven Rudich) for their paper "Natural Proofs." He was elected Corresponding Member of the Russian Academy of Sciences in 2000. Since 2008, he is the Andrew MacLeish Distinguished Service Professor in the Department of Computer Science, University of Chicago.

His first lecture was concerned with some topics in extremal combinatorics, one of the branches of discrete mathematics which studies how large (or small) a collection of finite objects can be if it has to satisfy certain restrictions. The area has undergone a period of spectacular growth in the recent decades, and Alexander reviewed some classical results and techniques from this field. A substantial part of extremal combinatorics studies relations existing between densities with which certain given combinatorial structures (fixed size "templates") may appear in unknown (and presumably very large) structures of the same type. This was also the subject of the third lecture, on Flag algebras.

The second lecture was concerned with the complexity of propositional proofs, an area where the speaker is one of the world experts. The underlying question of propositional proof complexity is to know when interesting propositional tautologies possess efficient proofs in a given propositional proof system. The motivations for studying complexity of propositional proofs come from algebra, automated theorem proving and, of course, computational (especially circuit) complexity. Alexander described some of the methods and gave the audience a feeling of the current state of the art in the area. A special attention was paid to algebraic and geometric proof systems, such as Polynomial Calculus and various proof systems inspired by the Lovász – Schrijver relaxation procedures.

Alexander Razborov

The last colloquium lecture, entitled "Grand Challenges in Complexity Theory" was for a large audience, and there was about 200 people attending the very entertaining lecture. The talk focused on classical computational complexity and proof complexity, and Alexander revealed some of the beautiful and unexpected connections existing between the different branches of complexity theory. He discussed the "grand challenges" in the field, including "P vs. NP," and questions about the power classical proof systems.

Iosif Polterovich (Université de Montréal and CRM) awarded the 2011 Coxeter – James Prize by the CMS

Leading name in the field of spectral geometry, Iosif Polterovich receives the 2011 *Coxeter-James Prize for his contributions to mathematical research.*

Spectral geometry is one of the main areas of my research. I explore the properties of eigenvalues and eigenfunctions of the Laplacian and other differential operators defined on various geometric objects, such as Riemannian manifolds and Euclidean domains. My work on spectral asymptotics and heat invariants was discussed in one of the previous issues of this Bulletin [19]. The present article focuses on two other topics: shape optimization for eigenvalues and isospectrality for mixed boundary value problems.

Shape optimization for eigenvalues

Consider the following question: which drum has the lowest fundamental tone among all drums with a drumhead of a given area? In 1877, Lord Rayleigh in his famous book "The theory of sound" conjectured that it should be a circular drum. In 1920s, G. Faber and E. Krahn found a rigorous proof of the mathematical restatement of Rayleigh's conjecture. Namely, they showed that among all planar domains of a given area, the first eigenvalue of the Dirichlet boundary value problem attains its minimum on a disk. Later, Krahn proved a similar result for the second Dirichlet eigenvalue: in this case, the minimum is attained in the limit on a disjoint union of two identical disks.

For free membranes, or, mathematically, for the Neumann boundary value problem, an interesting question is to find shapes that maximize eigenvalues. Note that the Neumann spectrum always starts with zero and the corresponding eigenfunctions are constant. In 1954, G. Szegő ([21], see also [10]) proved that the disk maximizes the first nonzero Neumann eigenvalue among all simply connected domains of a given area. Shortly after that, H. Weinberger [22] obtained an analogue of this result for arbitrary Euclidean domains in any dimension.

In a joint work with A. Girouard and N. Nadirashvili [8], we considered the shape optimization problem for the second nonzero Neumann eigenvalue. We proved that among all simply connected planar domains of a given area, this eigenvalue is maximized in the limit by a disjoint union of two identical disks. The proof uses a combination of techniques from spectral theory, complex analysis, hyperbolic geometry and topology. As a corollary, our result implies an inequality for the second nonzero Neumann eigenvalue conjectured by G. Pólya back in 1954 (see [8, formula (1.1.2)]).

One may ask whether all Dirichlet and Neumann eigenvalues of planar domains attain their extremal values on unions of disks. As was shown by Wolf – Keller [23] and Poliquin – Roy-Fortin [18], this is not always the case. Numerical experiments indicate that rather intricate shapes optimize some of the higher eigenvalues. Understanding their geometry is a challenging open question.

Let me mention another classical, albeit less well-known, eigenvalue problem — the Steklov problem. It has various physical interpretations, one of them being the vibration of a free membrane with all its mass uniformly distributed on the boundary. Mathematically, the Steklov eigenvalue problem is given by

$$\Delta u = 0 \text{ in } \Omega, \qquad \frac{\partial u}{\partial n} = \sigma u \text{ on } \partial\Omega,$$

where the spectral parameter σ appears in the boundary condition. Here $\partial/\partial n$ denotes the outward normal derivative. As in the Neumann case, the Steklov spectrum starts with zero. In a joint work with A. Girouard [9], we proved that among all simply connected planar domains of a given perimeter (or, equivalently, of a given mass: note that the area in the Dirichlet and Neumann problems admits the same interpretation), the kth nonzero Steklov eigenvalue is maximized in the limit by a disjoint union of k identical disks. This is true for all $k \geq 1$: in contrast to the Dirichlet and Neumann eigenvalues, each Steklov eigenvalue attains its extremal value on a disjoint union of disks. The proof of our result is based on an inequality due to J. Hersch, L. Payne and M. Schiffer [12].

All the problems described above deal with eigenvalue problems on Euclidean domains. However, shape optimization for eigenvalues can be studied in the context of Riemannian manifolds as well — see [6, 8, 13, 15] and references therein.

Isospectrality for mixed boundary value problems

In 1966, M. Kac asked a celebrated question: "Can one hear the shape of a drum?" [16]. In other words, does the spectrum of the Dirichlet boundary value problem determine a planar domain up to isometry? Note that many geometric quantities are indeed "audible," such as the area of the domain and the length of its boundary.

For smooth domains, Kac's question is still an open problem. However, since the seminal paper of Gordon – Webb – Wolpert [11], it is known that there exist nonsmooth planar domains that are isospectral but not isometric. Such a pair of domains is presented on Figure 1. More examples in the same spirit could be found in [4, 5].

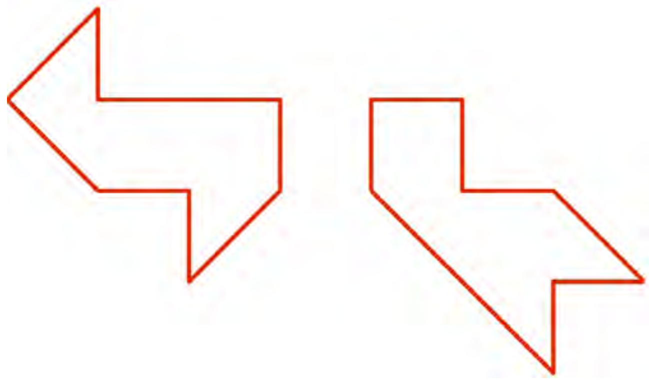


Figure 1. Isospectral domains from [11] known as "bilby" and "hawk."

These examples can be obtained using a method called "transplantation of eigenfunctions" (see [2, 4]). It is based on an ingenious algebraic construction due to T. Sunada [20], who has built a "machine" for producing isospectral but not isometric Riemannian manifolds.

With my collaborators D. Jakobson, M. Levitin, N. Nadirashvili and L. Parnovski, we have introduced a variation of Kac's problem ([14, 17], see also [7, Section VIII.A] for a brief survey of our results). We allow the boundary conditions to be mixed: Dirichlet on one part of the boundary and Neumann on the other. In other words, we allow drums to have drumheads that are partially fixed and partially free. Clearly, this gives us more freedom to construct isospectral domains — and, indeed, with an appropriate choice of boundary conditions (see Figure 2), a triangle and a square turn out to be isospectral! This example (which is somewhat reminiscent of [5, Figure 17]) is particularly simple and can be used to explain the "transplantation" technique to undergraduate students.

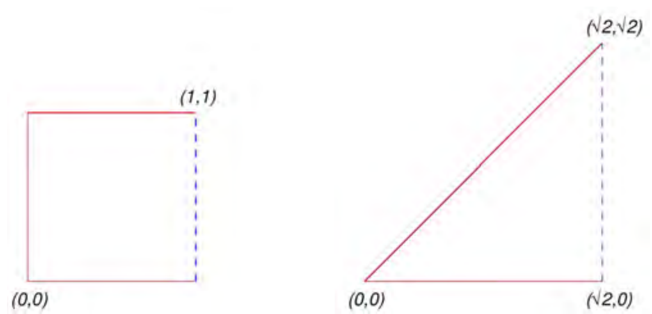


Figure 2. Isospectral square and triangle with mixed boundary conditions [17]. Here and below, the solid red line denotes Dirichlet boundary condition and the dashed blue line — the Neumann one.

Isospectrality for mixed boundary value problems was later studied in the context of spectral minimal partitions [3] and quantum graphs (see [1] and references therein).

Let me conclude with one more example of "mixed isospectrality" (see Figure 3). Note that the domains are identical, but the Dirichlet and Neumann boundary conditions are located differently — in fact, they are swapped! Surprisingly enough, this pair originally appeared in the study of a shape optimization problem for the first eigenvalue of the Laplace – Beltrami operator on a surface of genus two [13].

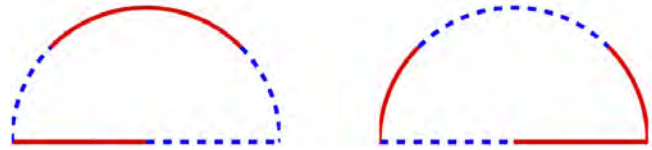


Figure 3. Isospectral semicircles with swapped Dirichlet and Neumann boundary conditions [13, 14].

Thus, the two topics discussed in this article turn out to be interrelated.

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Colloque sur les surfaces et les représentations

de Ibrahim Assem (Université de Sherbrooke)

Du 6 au 8 octobre 2010, l'Université de Sherbrooke a été l'hôte des Troisièmes Rencontres Universitaires Sherbrooke-Montpellier. Cet événement a été couplé avec la Rencontre de Théorie des Représentations tenue annuellement, et a porté le nom de Colloque Surfaces et Représentations. Les organisateurs étaient Christian Mercat (Université Montpellier 2), ainsi que Ibrahim Assem, Thomas BrUstle, Tomasz Kaczynski, Vasilisa Shramchenko, Virginie Charette et Jean-Philippe Morin (Université de Sherbrooke).

Il y avait plus de 65 participants, dont 30 étudiants et stagiaires postdoctoraux. Le thème du colloque était l'interaction entre géométrie des surfaces et théorie des représentations des algèbres, cette interaction étant un des outils principaux en théorie des algèbres amassées. Les conférenciers des deux minicours de trois heures, Ralf Schiffler (Université du Connecticut, États-Unis) et Todd Drumm (Université Howard, États-Unis), tous deux spécialistes de l'interaction géométrie/algèbre, ont été choisis dans cet optique.

Le choix des conférenciers pléniers a aussi reflété le souci de couvrir un éventail aussi large que possible de techniques, tout en restant fidèles à l'objectif de bien comprendre les différents aspects des algèbres amassées. Ces conférenciers pléniers étaient Syed Twareque Ali (Université Concordia, Montréal), Steven Boyer (Université du Québec à Montréal), Christian Mercat (Université de Montpellier 2, France), Konstantin Mischaikow (Université Rutgers, États-Unis), Maria Julia Redondo (Université Nationale du Sud, Bahia Blanca, Argentine) et Christophe Reutenauer (Université du Québec à Montréal).

En comptant les conférenciers pléniers et des conférenciers des mini-cours, plus de 35 conférenciers ont présenté des exposés lors des quatre jours du colloque. L'ambiance de travail a été relaxée et amicale tout au long de la rencontre. Le niveau d'échanges a été particulièrement élevé, avec de nombreuses questions fécondes permettant de préciser des points et parfois ouvrant de nouvelles pistes de réflexion.

Quantum Information

(*continued from page* 2)

concern information, not waves or particles. They propose to explain quantum-mechanical phenomena as inevitable consequences of information-theoretic considerations and to derive as much of quantum mechanics as possible from this perspective.

The final event of the semester will also be largest. The CRM will play host to *Quantum Information Processing* (QIP) 2012, albeit from the 12th to the 16th of December 2011. Louis Salvail of the Université de Montréal is chairing the local organizing committee, while the scientific program will be coordinated by an international committee of leading researchers. QIP, the leading conference on quantum algorithms, communication and complexity, will attract roughly 300 participants from all over the world. The most recent incarnations of QIP have taken place in Singapore, Zurich, New Mexico and New Delhi. Further excavation of its history, however, reveals that the year 2000 incarnation of QIP was also hosted by the CRM. This will be the first time QIP has ever returned for a second time to the same city, let alone the same institution. That the quantum information community is so enthusiastic to return to Montréal is in no small part due to the exceptional support the CRM has provided over the years !

Colloque « Méthodologie statistique contemporaine »

de Éric Marchand (Université de Sherbrooke)

Le colloque, tenu les 6 et 7 octobre au Département de mathématiques de l'Université de Sherbrooke, fut un franc succès et s'est distingué par les caractères nationaux (au Québec) et internationaux (Montpellier), ainsi que le niveau scientifique élevé des présentations. Le colloque a aussi permis de multiples échanges scientifiques et a permis à plusieurs jeunes chercheurs, parmi d'autres, de présenter leurs intérêts et derniers résultats de recherche. L'appui accordé par le laboratoire de statistique du CRM (déplacements et hébergements, frais inscription et repas pour les étudiants) et de l'ISM (pauses-café) furent critiques pour la réussite de l'évènement.

Même s'il n'y avait pas de thème retenu a priori, les présentations se sont articulées autour de tests d'ajustement, modélisation par copules, modélisation bayésienne, applications en économétrie et des caractérisations en probabilité. Les conférenciers étaient : Gilles Ducharme (Université Montpellier 2), Jean-Marie Dufour (Université McGill), Mhamed Mesfioui (Université du Québec à Trois-Rivières), Pierre Lafaye de Micheaux (Université de Montréal), Ali Gannoun (Université Montpellier 2), Taoufik Bouezmarni (Université de Sherbrooke), Jean-François Quessy (Université du Québec à Trois-Rivières), François Perron (Université de Montréal), Jean-Michel Marin (Université Montpellier 2) et M'Hamed Lajmi Lakhal Chaieb (Université Laval).

The 2010 CRM – SSC Prize in Statistics

by Russell Steele (McGill University)

The CRM – SSC Prize has been given conjointly by the Statistical Society of Canada (SSC) and the CRM every year since 1999. It was awarded in 2010 to Grace Yi, Professor in the Department of Statistics and Actuarial Science at the University of Waterloo for her contributions to the development of statistical methods for longitudinal studies and for the analysis of time-to-event data, particularly for problems involving missing observations and measurement error. Dr. Yi received the 2010 Prize at the meeting of the SSC held in Québec City in May 2010. Dr. Yi is the 12th recipient of the CRM – SSC prize.

Grace Yi

Grace Yi's published work showcases her outstanding breadth and depth in methodological statistics. Her publications appear in the most highly cited journals in statistics and her work has had a broad impact on the field. In particular, her work on marginal models for correlated data with incomplete response represented an important move forward for statistical methods research. Statistical inference for correlated data is difficult due to the dependence amongst observations that prevents the use of standard asymptotic results and modelling approaches. The problem is further complicated when data on particular observations is incomplete, for example when patients are unable to be followed to completion during a longitudinal study. Dr. Yi's body of work has addressed these kinds of important research questions both independently and in conjunction. She frequently blends rigorous asymptotic results with relevant applications in her research, particularly applications of statistics to medicine.

Dr. Yi gave the keynote address on October 22, 2010 at the CRM Workshop, **Missing Data Approaches in the Health and Social Sciences: A Modern Survey**, entitled "Analysis of Incomplete Data: Some Issues and Methods." Her talk gave an accessible, yet expansive overview of her work in semi-parametric approaches to missing data and measurement error. Semi-parametric approaches allow for more robust inference, as these approaches do not depend on assumptions about the underlying data-generating distribution. Dr. Yi presented several important results from her own work and discussed applications of these results to real data sets. Her presentation tied together several related ideas from other commonly used approaches to missing data and measurement error problems and generated substantial discussion with the audience of future directions for research both during and after her talk. Louis-Paul Rivest, director of the CRM Statistics Laboratory, introduced Dr. Yi on behalf of CRM Director Peter Russell.

Dr. Yi studied mathematics at Sichuan University in the People's Republic of China, where she obtained a B.Sc. in 1986 and an M.Sc. in 1989. She then completed an M.A. from York University in 1996 and conducted her Ph.D. research at the University of Toronto in 2000, under the supervision of Don Fraser. After postdoctoral studies with Richard J. Cook, she was appointed Assistant Professor at the University of Waterloo in 2001. She was promoted to Associate Professor in 2004 and was promoted to full Professor in summer 2010.

GASCom 2010

The 7th edition of this international conference initiated in 1994 in Bordeaux (France) took place from September 2 to 4, 2010 in the Sherbrooke building of the Université du Québec à Montréal. The scientific committee of the event was formed of Srečko Brlek (LaCIM, Montréal), Jean-Marc Fédou (Université Nice Sophia Antipolis), Renzo Pinzani (Università degli Studi di Firenze), Christophe Reutenauer (LaCIM, Montréal), Gilles Schaeffer (LIX, Palaiseau), and Vincent Vajnovszki (Université de Bourgogne, Dijon).

There were more than 25 participants coming from Canada, France, Germany, Italy, and the United States. The friendly environment allowed many exchanges between the participants. The conference focused on the random and exhaustive generation of combinatorial objects and bijective combinatorics with emphasis on the theoretical approaches. Relations with other parts of mathematics, as combinatorics, computer algebra, computer science, physics and biology, were also considered.

The first half day session focused on enumeration problems, and T. Walsh (UQÀM, Montréal) gave an exhaustive survey of counting maps on surfaces of genus 1. The others sessions were devoted to the generation of combinatorial structures. In particular, E. Barcucci (Firenze, Italy) talks about exhaustive generation by the ECO method, D. Gouyou-Beauchamps (Paris-Sud, France) talked about RNA secondary structures and unary–*k*-ary trees and F. Ruskey (Victoria, Canada) discussed Tatami tilings.

Self-Avoiding Walks

(*suite de la page* 5)

In Slade's CRM – Fields – PIMS prize lecture, he surveyed all the above material and much more. This material is presented this accessibly and engagingly in a brief survey by Slade, to appear in *Surveys in Stochastic Processes*, and available at `http://www.math.ubc.ca/~slade/spa_proceedings.pdf`. For the reader who wishes to begin understanding the mathematics behind the above results, this survey is a good place to start.

Mot du directeur

(*suite de la page* 16)

et prestigieux. L'impact du CRM sur la formation des boursiers postdoctoraux, de façon directe ou à travers les laboratoires du CRM, est considérable.

Le CRM appuie aussi deux colloques hebdomadaires de haut niveau, le colloque CRM-ISM-GERAD en statistiques et le colloque CRM-ISM en mathématiques, ainsi qu'une série de conférences pour grand public, les Grandes Conférences du CRM. Nous sommes également engagés, le plus souvent avec l'ISM, dans des activités de formation préuniversitaire et de premier cycle, à travers la commandite de magazines (Pi in the Sky, Accromαth) et de conférences organisés par et destinés aux étudiants de premier cycle.

Le CRM appuie la communauté mathématique canadienne conjointement avec les autres instituts grâce à un appui financier de réunions de sociétés savantes (SMC, SCMAI, SSC). Les trois instituts appuient également l'institut canadien des provinces de l'Atlantique, AARMS.

Le CRM est aussi engagé dans des initiatives industrielles. Il est membre du réseau MITACS avec qui, en collaboration avec l'institut Fields, il organise les ateliers de résolution de problèmes industriels. Le lieu de l'activité alterne entre Montréal et Toronto. Les partenaires industriels à ces ateliers y soumettent des problèmes concrets.

De plus, le CRM gère soit seul ou en collaboration avec les autres instituts ou une association professionnelle, quatre prix : le prix Aisenstadt, le prix CRM-Fields-PIMS, le prix ACP-CRM et le prix CRM-SSC. Ces honneurs sont attribués aux contributions exceptionnelles aux sciences mathématiques faites dans un contexte canadien.

À la lumière de ce qui vient d'être dit, les instituts canadiens coopèrent de près à un grand nombre de dossiers et d'initiatives. Les directeurs des trois instituts sont en contact régulier, soit directement soit par téléphone. Le CRM participe également à un réseau semi-formel regroupant les instituts nord-américains, développé à partir de leur participation commune aux événements porte-ouverte lors des réunions annuelles conjointes de l'AMS et de MAA.

Parmi les initiatives résultant de cette collaboration sont les programmes « Changement climatique et Développement durable » et « Mathématiques de la Planète Terre 2013 » qui sont précisés dans le dernier Bulletin du CRM. Nous sommes fiers de dire que le CRM joue un rôle de premier plan dans l'organisation de ces deux événements.

Au cours des dernières années, la SMC, la SCMAI, MITACS, le CRM et d'autres instituts ont joué un rôle primordial dans l'organisation de plusieurs évènements internationaux. À titre d'exemple, je souligne le Congrès Canada-France de 2008 à Montréal comptait plus de 800 délégués et le Congrès ICIAM 2011 en mathématiques industrielles et appliquées qui aura lieu à Vancouver cet été. Au chapitre de la coopération internationale, le CRM a conclu des accords bilatéraux avec la section mathématiques appliquées de l'Institut TIRF (Inde) et de l'École SISSA (Italie). De plus, une entente avec la section mathématiques pures du TIRF est à la veille d'être conclue et des pourparlers avec le CNRS (France) pour établir un Unité Mixte Internationale (UMI) sont terminés. L'UMI sera lancée officiellement en septembre 2011.

Je m'arrête ici. La présente édition est la dernière du Bulletin du CRM à paraître sous ma direction. Je quitte le CRM à la fin de mai pour profiter d'une retraite quelque peu reportée. J'anticipe de souhaiter la bienvenue au nouveau directeur. Je pense qu'il trouvera le CRM fondamentalement en bon état. Bien sûr, des tâches importantes l'attendent. Notre budget est équilibré et a été essentiellement stable au cours des dernières années tandis que les coûts et les demandes sont en croissance. La prochaine ronde de demandes au CRSNG et FQRNT sera cruciale.

Il est donc temps pour moi de dire au revoir à la communauté du CRM et de remercier tous ses membres pour leur confiance et leur coopération lors des deux dernières années, qui ont été très enrichissantes pour moi.

Peter Russell

Mark Lewis: 2011 CRM – Fields – PIMS Prize Recipient

We are delighted to announce that Professor Mark Lewis of the University of Alberta has been named the winner of the 2011 CRM – Fields – PIMS Prize. The CRM – Fields – PIMS Prize is a premier Canadian award for research achievements in the mathematical sciences. The prize winner is selected each fall by an independent international committee with six members, two being named by each of the three institutes. The prize winner is invited to give a lecture at each of the institutes in the following year. The prize includes a cash award of $10,000.

Mark Lewis holds a Canada Research Chair in Mathematical Biology, and is the Director of the Centre for Mathematical Biology at the University of Alberta. His research involves mathematical modelling of biological processes, and is an example of the best interplay of science and mathematics, where ideas from each discipline lead to advances in the other. Mark Lewis's work develops techniques in stochastic processes, dynamical systems and partial differential equations and has led to significant advances, for example, in modelling territorial pattern formation in wolf populations, predicting population spread in biological invasions like the West Nile virus, and assessing the effect of habitat fragmentation on species survival.

The Prize will be given to Mark Lewis at a ceremony on April 8, 2011 at the CRM.

Workshop on Mathematical Challenges for Sustainability

by Christiane Rousseau (Université de Montréal)

The project was a joint activity of six mathematical sciences research institutes, namely, the Institute for Pure and Applied Mathematics (IPAM), the National Institute for Mathematical and Biological Synthesis (NIMBios), the Statistical and Applied Mathematical Sciences Institute (SAMSI), the Center for Discrete Mathematics and Theoretical Computer Science (DIMACS) in the US, and the Centre de recherches mathématiques (CRM) and the Pacific Institute for the Mathematical Sciences (PIMS) in Canada. This workhsop sponsored by the NSF took place in DIMACS on November 15 – 17 2010. The organizers were Alejandro Adem (University of British Columbia), Christiane Rousseau (Université de Montréal), Fred S. Roberts (Rutgers University), Iain Johnstone (Stanford University), Louis J. Gross (University of Tennessee), Richard L. Smith (University of North Carolina at Chapel Hill), Russel E. Caflisch (University of California, Los Angeles) and Simon A. Levin (Princeton University).

The workshop was not be organized in the usual way, with lectures, panels, etc. Instead, leaders in the mathematical sciences community and scientists working in substantive areas that are amenable to mathematical analysis were asked to prepare white papers in advance that had been read in advance by all the participants. The 45 participants were chosen by invitation. Five themes were chosen:

1. *Human Well-Being and the Natural Environment* (white papers by Avner Friedman, Minnesota; Francesca Dominic, Harvard; Michelle Bell, Yale; Geoff Heal, Columbia)
2. *Human-Environment Systems as Complex Adaptive Systems* (white papers by Mary Lou Zeeman, Bowdoin; Doyne Farmer, Santa Fe Institute; Eugenia Kalnay, Maryland)
3. *Measuring and Monitoring Progress toward Sustainability* (white papers by Noel Cressie, Ohio State; David Schimel, Neon)
4. *Managing Human-Environment Systems for Sustainability* (white papers by David Shmoys, Cornell; Alan Hastings, UC Davis; Shripad Tuljapurkar, Stanford)
5. Energy (white paper by Warren Powell, Princeton)

At the workshop itself, the participants were split into the five focus groups. Each focus group was asked to develop agendas for future research, and had one or two rapporteurs with mandate to write up the discussions and present them to the entire workshop in a plenary session. The ultimate goal of the workshop is to produce a report written by a professional science writer who attended the workshop, and that will be published by the AMS and given widespread circulation both to the NSF, the NSERC, and to the mathematical sciences community. The CRM was represented at the workshop by Jacques Bélair and Christiane Rousseau. Jacques Bélair was rapporteur for group 2. Christiane Rousseau acted as an observer in order to coordinate with the coming initiative **Mathematics of Planet Earth 2013**, and so moved from group to group. The report should have been ready in January 2011 but, because of the illness of the science writer, it is expected later in the spring of 2011.

Le Bulletin du CRM

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

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

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

Le CRM tient à remercier ses divers partenaires pour leur appui financier à sa mission : le Conseil de recherches en sciences naturelles et en génie du Canada, le Fonds québécois de la recherche sur la nature et les technologies, la National Science Foundation, le Clay Mathematics Institute, 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 : Peter Russell

Directrice d'édition : *Chantal David*
Conception et infographie : *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 au
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Mot du directeur

La communauté mathématique canadienne, en collaboration avec le CRSNG, est présentement engagée dans un exercice de planification à long terme. La préoccupation des Instituts canadiens de mathématique (le CRM, le Fields et le PIMS) concernant la perspective de financement à long terme explique la mise en marche de cet exercice. Un comité de planification à long terme a été établi et a invité les instituts à soumettre un document conjoint décrivant leur rôle dans la communauté canadienne mathématique et statistique. Je voudrais alors profiter de cette occasion pour réfléchir un peu sur rôle spécifique du CRM, ce qu'il fait et comment il fonctionne. On peut supposer que ces réflexions seront toutes aussi pertinentes aux activités des autres instituts.

Une des activités fondamentales du CRM est l'organisation d'activités scientifiques. Elles vont de l'organisation de programmes thématiques d'une année complète ou de 6 mois, à des ateliers (une semaine pour la plupart, ou à l'occasion, de quelques jours). Il semble que les mathématiques prospèrent à partir de l'interaction personnelle entre les membres de la communauté. Ces interactions peuvent être cruciales quand il est question de favoriser la recherche interdisciplinaire. L'impact de nos activités sur les mathématiques au Canada est élevé. Ces activités scientifiques rassemblent des experts du monde entier au Canada afin qu'ils interagissent avec les membres des communautés mathématiques locales. Le CRM possède un Comité scientifique international de haut niveau très engagé dans la planification de programmes plus longs. Il donne son approbation officielle certes, mais il propose également des améliorations et de nouvelles directions dans lesquelles trouver des thématiques. Un comité scientifique local est également actif dans la sollicitation et la recherche de propositions de programmes à tous les niveaux.

Nos programmes thématiques (un concept original du CRM) consistent en des activités d'une année ou d'un semestre comprenant normalement une série d'ateliers, un programme de visiteurs et de boursiers postdoctoraux et une série de minicours ou de cours de cycles supérieurs spécialement conçus par les départements. À l'occasion, une école d'été est jumelée aux activités d'un programme thématique. Chaque programme thématique accueille les chaires Aisenstadt qui jouissent d'une grande visibilité, puisque des mathématiciens de très grande renommée sont invités pour un séjour d'au moins une semaine au cours duquel ils donnent une série de conférences. Les programmes thématiques sont largement financés par notre subvention CRSNG. Au cours des dernières années, les organisateurs ont aussi obtenu avec succès un bon cofinancement de sources américaines pour les participants américains, en particulier les étudiants de cycles supérieurs et les boursiers postdoctoraux.

Des programmes courts et des ateliers reproduisent certains aspects de programmes thématiques avec des activités concentrées, allant de quelques jours à un mois. Ils peuvent être organisés très rapidement tandis que les programmes thématiques sont habituellement initiés jusqu'à trois ans d'avance. Le Séminaire de Mathématiques Supérieures occupe une place très spéciale au sein de nos activités. Cette école d'été possède une longue et fière tradition. D'abord organisée par le Département de mathématiques et statistique de l'Université de Montréal, le CRM joue désormais un rôle de premier plan dans son organisation future qui s'étendra à travers le Canada.

Le CRM est activement engagé dans des initiatives de recherche multidisciplinaire. En plus d'un éventail complet de thèmes en mathématiques pures et appliquées et de statistiques, nous avons eu ou planifions des activités scientifiques reliées à la finance, la physique, la biologie, la médecine, la chimie, l'information quantique, etc.

Le CRM, en collaboration avec toutes les universités québécoises, officiellement ses partenaires, joue un rôle central dans l'organisation des activités de recherche mathématiques de la province. En fait, il est une organisation cadre pour dix laboratoires interuniversitaires spécialisés en sciences mathématiques. Le Comité des directeurs de laboratoires conseille le directeur du CRM quant à la gestion des laboratoires. Le CRM reçoit des subventions du Fonds FQRNT et des universités partenaires qui sont redistribuées aux laboratoires. Ces fonds, généralement avec effet de levier sur les laboratoires, sont la base critique du financement des étudiants de cycles supérieurs, des boursiers postdoctoraux, des séminaires et des ateliers. Tandis que l'organisation des programmes thématiques a tendance à demander un effort d'ordre international, plusieurs activités proposées proviennent des laboratoires. À un moment donné, le CRM a été le fer de lance d'une demande au programme CREATE (appui aux étudiants) du CRSNG avec la participation de chercheurs de plusieurs laboratoires. La demande a échoué mais la collaboration a été un exemple révélateur de la relation symbiotique entre le CRM et la communauté desservie.

Le CRM ne participe pas uniquement à l'aspect financier de l'éducation de cycles supérieurs. Un effort délibéré est déployé pour que les étudiants de cycles supérieurs participent aux activités scientifiques organisées par le CRM. Tel que souligné, des écoles et des cours préparatoires font partie de nos activités thématiques pour préparer les étudiants de cycles supérieurs aux ateliers avancés.

Le CRM parraine un programme postdoctoral régulier en collaboration avec l'Institut des Sciences Mathématiques (ISM). Dans ce cas aussi, la contribution financière du CRM sert de levier important. Malgré cela, nous ne pouvons financer qu'une infime proportion des nombreuses demandes de grande qualité que nous recevons chaque année pour devenir boursier postdoctoral CRM-ISM, un poste devenu très sélectif

(*suite à la page* 14)