CENTRE DE RECHERCHES MATHÉMATIQUES

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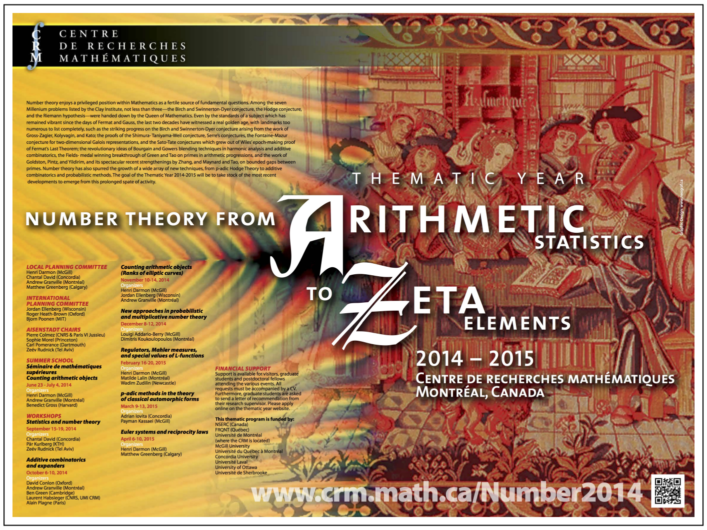
2014–2015 Thematic Year
Number Theory from Arithmetic Statistics to Zeta Elements

Organizers: Henri Darmon (McGill), Chantal David (Concordia), Andrew Granville (Montréal), Matthew Greenberg (Calgary)



Andrew Granville and Henri Darmon present the activities of the thematic year in an interview on February 13, 2014

Bulletin: What are the recent developments in number theory which prompted you to organize the thematic year?

Andrew Granville: *There is so much excitement in number theory it makes you want to cry. This year of course there have been the tremendous results on gaps between primes that have changed analytic number theory forever. And then in additive combinatorics there are all the ideas on group expansion, which we did have a workshop on a few years ago, but we are returning to. And certain topics that are popular in Montréal like arithmetic statistics have seen great leaps and bounds.*

Henri Darmon: *On the arithmetic side there have been dramatic developments on elliptic curves: notably, that the average rank of elliptic curves is bounded, from below…*

AG: *and above, the average rank is bounded from above, by analytic methods. We just heard about the latest development on that at the Québec–Vermont number theory seminar last week from Daniel Fiorilli* [Ph.D. 2011 Montréal]

HD: *Indeed, this is a lovely complement to the work of Bhargava, Skinner and Wei Zhang bounding it from below, unconditionally.*

Bulletin: So is there a particular importance to the timing of it this year, or is it just a good opportunity?

HD: *Yes, it's a good time to have a special year given all the spectacular progress that's taking place. We could have also had it the year before or the year after…*

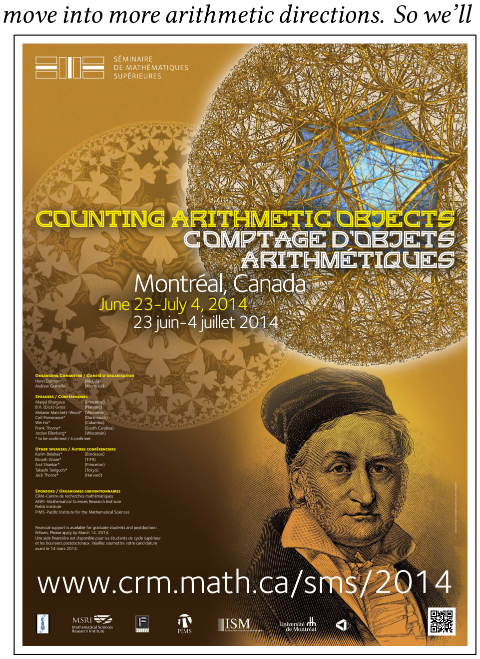
AG: *A lot of the credit goes to François Lalonde* [former director of the CRM].

Bulletin: Describe some of the anticipated activities.

AG: *Whoo! Well, one of the most exciting developments in number theory over the last five-ten years is the development of the methods of Manjul Bhargava, which have revolutionized the way we think of points on varieties in all sorts of situations. There hasn't really been a school to learn about Bhargava's ideas, and we will be having the first international school in the summer to kick off the special year, with all the major protagonists, including Bhargava, in residence.* [Séminaire de mathématiques supérieures, June 23–July 4, 2014]

AG: *And then later in the year, in November, we will have a workshop* [Counting arithmetic objects (Ranks of elliptic curves), November 10–14, 2014] *where the leading experts will come to discuss the latest theorems on Bhargava-type stuff. Bhargava's work spans a lot of great algebra, but he's also invented some brilliant new analytic methods and so there's great room for analytic discussion. It's a symbol of number theory in Montréal that we like to span between algebra and analysis, so Bhargava's work is perfect for that.*

HD: *The concept of the special year is to start off with analytic topics and then gradually move into more arithmetic directions. So we'll have the workshop in November which Andrew spoke about, devoted to ranks of elliptic curves, and then in the second semester there'll be activities around the theory of Euler systems which play an important role in establishing that many elliptic curves have rank zero and one—both algebraic rank and analytic rank; the synergy between these diverse techniques should be exciting.*



HD: *There will then be a workshop devoted to more p-adic topics* [p-adic methods in the theory of classical automorphic forms, March 9–14, 2015] *and then, last but not least, a workshop devoted to the Kudla programme* [April 6–10, 2015], *which also promises to be quite stimulating.*

Bulletin: Is that something that's a recent development?

HD: *Kudla's ideas have revealed profound connections between automorphic forms and algebraic cycles, and are very much in line with our overarching theme of building bridges between the analytic and algebro-geometric sides of the subject! The idea of a workshop devoted to Kudla's program came a bit late in our conception of the special year program. Part of the impetus came from the fact that we were able to recruit excellent postdocs working in this area.*

Bulletin: Since you mention postdocs, can you address the target audience of the different activities, highlighting the ones that are targeted towards students and postdocs?

AG: *Besides the* [Summer] *school, the workshop on additive combinatorics and expanders* [October 6–10, 2014] *took on a different dimension because the week before there's going to be a conference at IMA in Minnesota, so we planned with them that they will be having more of a school and having programs for young researchers, and then in Montréal the young researchers will be talking about their research.*

Bulletin: So that's a special activity for young researchers?

AG: *Well, we will have some top people here and they might be giving lectures series, but the idea is that the junior people will be giving invited talks. I should say that I didn't mention the workshop on probabilistic approaches in number theory* [New approaches in probabilistic and multiplicative number theory, December 8–12, 2014], *organized by two young colleagues, Louigi Addario-Berry and Dimitris Koukoulopoulos. There has been a lot of excitement recently where methods of truly deep probability are being used in analytic number theory, which hasn't really happened before, in my opinion. We've seen some stunning results, and as a reflection everybody in the field seems to be coming to that workshop: they're the first workshop to be completely full.*

Bulletin: When is it?

AG: *It's the one in December. There's quite some excitement about the concept of the workshop, it seems.*

Bulletin: Henri, do you have something targeted to Ph.D.'s and postdocs?

HD: *Well, all the workshops are going to be essentially aimed and young mathematicians: Ph.D. students and postdocs, largely. We're also hoping to organize some mini-courses and to coordinate the activities with the European ALGANT Masters and Ph.D. program to bring in a strong contingent of students from Europe.*

Bulletin: Do you have any semester-long courses?

HD: *We do. We haven't completely finalized the timetable but we do plan to have them.*

AG: *One special feature of the special year, which is special, is that we'll have an enormous number of postdocs: a dozen postdocs for the whole year, and maybe another dozen as single-semester postdocs. So with an enormous number of postdocs it gives the opportunity for the faculty to teach courses that will interest those postdocs, and it will be good for our students to be part of a mix with a lot of stunning junior researchers who got their Ph.D.'s but are still learning.*

Bulletin: So you are planning some more specialized courses?

AG: *Well, I am. I will probably teach "Pretentiousness"—it's time to teach the world to be pretentious.*

Bulletin: Can you say a few words about how the Aisenstadt chairs will contribute to the program?

AG: *We've asked two stunning lecturers in two of the main areas for two of our conferences to come: Zeév Rudnick, who has proved many fantastic theorems in the last few years and who has many speaking invitations. He comes quite regularly here and always we enjoy his lectures, so he has been asked to be the lead lecturer for the first meeting, on arithmetic statistics* [Statistics and number theory, September 15–19, 2014]. *He has probably the two most important papers in the field, but he's also just a brilliant lecturer. Zeév has been an organizer in Montréal in the past: the Summer school* 2005, *so he's familiar with our set-up.*

AG: *Then in December one of the world's most famous lecturers in number theory, Carl Pomerance, some of whose work has been important in the recent developments in probabilistic number theory, will be coming to give some lectures. He promises to come to all the conferences in the fall - he's pretty excited about everything in the program.*

HD: *In the winter and spring we'll have Sophie Morel, who is one of the young rising stars in the subject of the theory of Shimura varieties and the l-adic representations attached to their cohomology. Also around the workshop on p-adic methods we will have the pleasure of hosting Pierre Colmez, who is one of the leaders in applying p-adic techniques to number-theoretic questions. There was a very successful workshop in the previous number theory thematic year, organized by Adrian Iovita, in which he played a major role. During this workshop he announced a spectacular result in the theory of p-adic representations of local Galois groups. The new functor which he introduced to prove his results later became known as the "Montréal functor"!*

Bulletin: What year was that?

HD: *This was in* 2006. *So he has a long association with the CRM in Montréal and has been a frequent visitor who in addition to being a fantastic mathematician is also a wonderful expositor and great lecturer.*

Bulletin: What is the role of the other [CICMA] lab members in the organization?

HD: *I think one of the nice things about our lab is that the members are highly integrated and we all work very well together. Every workshop is being organised by different lab members, and I think*

(*continued on page* 8)

Une vieille énigme mathématique bientôt résolue ?

Benjamin Augereau

Noue reproduisons ici un article paru dans l'édition de 13 *janvier* 2014 *du journal Forum.*

C'est l'un des plus vieux problèmes mathématiques du monde. Il y a plusieurs siècles, la conjecture des nombres premiers jumeaux était formulée. Comme son nom l'indique, cette hypothèse, que plusieurs historiens des sciences attribuent au mathématicien grec Euclide, porte sur les nombres premiers, ces nombres divisibles seulement par eux-mêmes et par 1 $(2, 3, 5, 7, 11, \ldots)$. Selon cette supposition, il existerait une infinité de paires de nombres premiers dont la différence est égale à 2, appelés nombres premiers jumeaux (tels 3 et 5), mais personne n'a pu le valider jusqu'à présent.

En avril 2013, le mathématicien de l'Université du New Hampshire Yitang Zhang présentait une « version faible » de cette conjecture en prouvant qu'il existait une infinité de nombres premiers dont l'écart entre les deux nombres de la paire était inférieur à 70 millions.

Peu de temps après, James Maynard, postdoctorant au Centre de recherches mathématiques de l'Université de Montréal, allait encore plus loin, en réduisant l'écart à 600. Ce résultat représente un énorme progrès dans la quête visant à établir la conjecture des nombres premiers jumeaux et ravive une vieille question n'ayant pas progressé depuis des années.

Une approche plus simple

James Maynard
Photo d'Amélie Philibert

Comment ce jeune mathématicien de 26 ans, fraîchement diplômé de l'Université d'Oxford, en est-il arrivé là ? Grâce notamment aux travaux de sa thèse, il a trouvé un moyen d'améliorer et de simplifier la méthode de Yitang Zhang en remplaçant un outil qui estime la probabilité qu'un nombre soit premier. « *Yitang Zhang et moi sommes partis du même point, mais nous avons pris des chemins totalement différents. La méthode que j'utilise est beaucoup plus simple.* » À tel point que son directeur de recherche, Andrew Granville, affirme qu'elle « peut être enseignée dans un cours de troisième cycle ».

Depuis, des centaines de chercheurs travaillent à réduire l'écart à 2 et ainsi attester la véracité de la célèbre conjecture. Sur la plateforme collaborative Polymaths, ils sont nombreux à déposer les résultats de leurs recherches. Dans cette discipline où les chercheurs sont habitués à travailler seuls, c'est une méthode de travail assez exceptionnelle. Ce que confirme James Maynard. « *C'est assez inhabituel pour moi, qui ai l'habitude de travailler dans mon coin. Mais c'est vraiment intéressant de travailler en communauté.* » Aujourd'hui, l'écart continue à diminuer grâce à ce travail collaboratif.

Des nombres très utiles

Mais quel est l'intérêt d'en apprendre davantage sur les nombres premiers ? Le commun des mortels l'ignore, mais ces nombres occupent une place importante dans nos vies quotidiennes. La cryptographie y a recours entre autres pour assurer la sécurité et la protection des données. James Maynard prend l'exemple des achats sur Internet. « *Lorsqu'on achète quelque chose en ligne, on entre dans l'ordinateur ses numéros de cartes de crédit, mais il y a des risques de piratage. Ce sont les nombres premiers qui protègent nos données. Toute la sécurité bancaire des sites de vente est basée sur les nombres premiers.* »

De plus, élargir nos connaissances sur les nombres premiers pourrait nous permettre de résoudre des problèmes complexes dans d'autres disciplines telles que l'ingénierie ou la chimie.

Bientôt la fin de l'énigme ?

Arrivera-t-on un jour à démontrer la véracité de la conjecture des nombres premiers jumeaux en employant la « méthode Maynard » ? « *J'adorerais ça, mais je pense que non. Il y a de grosses difficultés à résoudre ce problème. Avec ma méthode, on devrait pouvoir atteindre un écart de* 6. *Mais il faudra une autre approche pour arriver à* 2. *Je suis persuadé que l'hypothèse est vraie, il y a de très bonnes raisons de le penser.* »

La démarche mathématique proposée par James Maynard fait en tout cas beaucoup parler. Elle devrait bientôt être publiée dans un journal scientifique et les réactions des chercheurs en mathématiques sont positives. Le jeune mathématicien a reçu de nombreux messages de félicitations et d'encouragement de la part de ses pairs. Sa méthode devrait en effet pouvoir être utile pour dénouer d'autres problèmes mathématiques.

Andrew Granville estime que le résultat de James Maynard est un « *grand progrès dans notre compréhension des nombres premiers, progrès que nous aurions pensé impossible il y a encore un an* ».

Et celui qui a la bosse des maths depuis qu'il est tout petit ne compte pas s'arrêter là ! Amateur de casse-têtes et de jeux de raisonnements, James Maynard sait que les nombres premiers présentent encore de nombreux mystères sur lesquels se pencher.

This article was originally published in the *Forum*, the weekly newsletter of the Université de Montréal (photo by Amélie Philibert). For further reading, please follow the links at `crm.math.ca/JamesMaynard_communique13_en/`.

James Maynard will be a plenary speaker at this June's CMS Summer Meeting in Winnipeg and at the Canadian Number Theory Association (CNTA XIII) meeting in Ottawa.

Thematic Semester: Biodiversity and Evolution

Aisenstadt Chair: Martin Nowak

November 4–8, 2013

Sabin Lessard and Christiane Rousseau (Université de Montréal)

As an Aisenstadt chair, Martin Nowak from Harvard University gave the opening talk of the CRM workshop on Biodiversity and Environment: Viability and Dynamic Games Perspectives, November 4–8, 2013, a more technical talk in the same workshop and a Grande Conférence Publique du CRM on November 6, 2013. His lectures were part of the MPE 2013 outreach activities at the CRM. They also belonged to the activities of the thematic semester "Biodiversity and Evolution," which took place in the second half of 2013.

Martin Nowak

Many problems that challenge us today can be traced back to a tension between what is good and desirable for society as a whole and what is good and desirable for an individual. This is illustrated in global problems such as climate change, pollution, hunger, and overpopulation. In his public lecture, "The evolution of cooperation: Why we need each other to succeed," Martin Nowak argued that cooperation—not competition—is the key to the evolution of complexity.

Martin Nowak first showed how widespread cooperation is in the living world. Bacteria cooperate for the survival of the species. Eusociality describes the very sophisticated behaviour of social insects like ants and bees, where each individual works for the good of the community. Human society is organized around cooperation, from the Good Samaritan to the Japanese worker who accepts to work on the cleaning of Fukushima's nuclear plant: "There are only some of us who can do this job. I'm single and young, and I feel it's my duty to help settle this problem." Cells in the organism cooperate and only replicate when it is timely, and cancer occurs when cells stop cooperating.

Martin Nowak then gave a mathematical definition of cooperation. A donor pays a cost, c, for a recipient to get a benefit, b, greater than c. This brings us to the Prisoner's Dilemma. Each prisoner has the choice of cooperating and paying the cost c or defecting. From each prisoner's point of view, whatever the other does, the better choice is to defect. This means that the rational player will choose to defect. But the other prisoner will make the same reasoning. Then they will both defect… and get nothing. They could each have got $b–c$ if they had behaved irrationally and had chosen to cooperate!

Natural selection chooses defection, and help is needed so as to favour cooperators over defectors. Martin Nowak identified five mechanisms for the evolution of cooperation in nature: direct reciprocity, indirect reciprocity, spatial selection, group selection and kin selection.

Direct reciprocity: *I help you, you help me.* Tit-for-tat has proved to be a very good strategy in repeated rounds of the Prisoner's Dilemma: I start with cooperation; if you cooperate, I will cooperate; if you defect, then I will defect. This strategy leads to communities of cooperators, but it is unforgiving when there is an error. This leads to a search for better strategies: the generous tit-for-tat strategy incorporates the following difference: If you defect, then I will cooperate with probability $q = 1–c/b$. This can lead to an evolution of forgiveness. Another good strategy is win-stay, lose-shift: If the play on the previous round resulted in a success, then the player uses the same strategy on the next round; alternatively, if the play resulted in a failure, then the player switches to another action. In general, direct reciprocity can lead to the evolution of cooperation if the probability, w, of another encounter between the same two individuals exceeds the cost-to-benefit ratio of the altruistic act, that is, $w > c/b$.

Indirect reciprocity: *I help you, somebody helps me.* The experimental confirmation is that, by helping others, one builds one's reputation: people help those who help others, and helpful people have a higher payoff at the end. Indirect reciprocity can promote cooperation if the probability, q, of knowing someone's reputation exceeds the cost-to-benefit ratio of the altruistic act, that is, $q > c/b$. Games of indirect reciprocity lead to the evolution of social intelligence. Since individuals need to be able to talk to each other, there should be some form of language and communication in the population.

Spatial selection: an individual interacts with his neighbours, which receive each a benefit b if the individual cooperates at a cost c. Then cooperation is favoured by selection if $b/c > k$, where k is the average number of neighbors per individual. This is studied through spatial games, games on graphs (the graph describing a social network), and evolutionary set theory.

Group selection: "*There can be no doubt that a tribe including many members who* […] *are always ready to give aid to each other and to sacrifice themselves for the common good, would be victorious over other tribes*; *and this would be natural selection.*" (Charles Darwin, The Descent of Man, 1871) In group selection, a population is subdivided into groups and individuals play strategies in their own group. Offspring are added to the group according to payoff. Groups divide when reaching a certain size. Groups may die. Group selection allows evolution of cooperation provided that $b/c > 1 + n/m$, where n is the group size and m the number of groups.

(*continued on page 8*)

Thematic Semester: Biodiversity and Evolution

Aisenstadt Chair: David J. Aldous

August 12–16, 2013

Lea Popovic (Concordia University)

David Aldous received his Ph.D. at Cambridge in 1977, *and joined the faculty at the University of California Berkeley in* 1979. *His many awards and honours include: the Rollo Davidson Prize in* 1980, *the Loève Prize in* 1993, *a Fellow of the Royal Society in* 1994, *a Fellow of the American Academy of Arts and Sciences in* 2004, *a Fellow of the American Mathematical Society in* 2012. *He was a plenary speaker at the International Congress of Mathematicians in Hyderabad in* 2010.

David J. Aldous

David Aldous is well known for his research on mathematical probability theory and its applications, in particular on topics such as exchangeability, weak convergence, Markov chain mixing times, the continuum random tree and stochastic coalescence. Among many other areas, his work helped develop important stochastic tools for the quantitative analysis of population genetics and evolutionary biology. He held an Aisenstadt Chair in August 2013 during the thematic semester on Biodiversity and Evolution (in the context of the year of Mathematics of Planet Earth 2013).

While his contributions have fundamentally broadened the scope of probability theory, his work was frequently inspired by its use and interpretation in a diverse range of applications. In addition, he continues to write reviews (around 100 so far) of non-technical books involving probability, contributes essays for the *Bernoulli News* and teaches exploratory project-based "lab courses" to undergraduates. Accordingly, in his first lecture (aimed at a broad public audience) he critically discussed instances involving probability in everyday life:

What does mathematical probability tell us about the real world?

Two different approaches were presented:

I. *Fiction*: one can consider what mathematical probability purports to be relevant. Most probability models in undergraduate textbooks are made up in the sense that they make a set of assumptions, which lead to exact formulas, and which have some aspect that a non-mathematician might care about. These models are easy to teach. However, in teaching them one does not commonly attempt to analyze the realism of the model.

Fact: one can also consider theoretical predictions involving randomness in the real world that are verifiable or falsifiable by an undergraduate student (not an experimental scientist) as a course project [7]. Here are some concrete examples:

(1) The Birthday paradox says that in a room of 23 people there is $\approx 50\%$ chance that some two people have the same birthday $\mapsto$ look up a sample of baseball teams of approximately this size.

(2) The regression effect says that if a variable is extreme on its first measurement then it will tend to be closer to its average on its second measurement $\mapsto$ look up performance of the top few best and the bottom few worst teams sports teams in the course of two seasons.

(3) The three arcsine laws for a random walk or Brownian motion say that the following quantities all have the distribution $P(X \leq x) = (2/\pi)\arcsin(\sqrt{x})$, $x \in (0, 1)$: (i) the proportion of time in a unit time interval that the process is positive, (ii) the last time within a unit time interval when the process changes sign, and (iii) the time at which the process achieves its maximum in a unit time interval $\mapsto$ consider non-overlapping time blocks of short periods of closing values of intra-day stock prices (relies on the usual random walk or Brownian motion models for stock market prices).

(4) The optional sampling theorem for martingales says that if the initial value of a martingale is x, then the probability of reaching or exceeding 100 before it hits 0 is equal to $x/100 \mapsto$ look at prediction betting markets for political elections, where the maximum betting price for each candidate is 100, choose a value x that is larger than all of the candidates' initial prices and count the number of candidates for whom the betting price ever reaches or exceeds x [2].

(5) The Kelly criterion for the borderline between aggressive and insane investing says that given a range of possible portfolios containing risky and safe investments, where a portfolio with allocation strategy α will produce a random return X_α, the optimal long term growth rate is insured by choosing α that maximizes $E \log(1 + X_\alpha)$.

One can imagine taking a number of other topics and trying to find concrete probabilistic statements that can be examined vis-a-vis real data, but evidently this is not as easy as it seems [1].

II. *Perception*: one can alternatively consider in what aspects of life one perceives that chance plays a role, and then examine whether mathematical probability has anything to say that is useful. The more standard directions of academic study deal with philosophy, logic and basic mathematics of probability ("how one should evaluate probabilities"), and with psychology of chance ("how humans, often irrationally, think about chance"). However, these do not quite illustrate how 'ordinary people' think about chance in everyday life. After examining various kinds of data for references to chance (queries to search engines, appearances in blogs and other written material) one can compile an annotated list of contexts in which people, who are not professionally (or in other serious ways) prompted to think about chance, perceive instances of chance. The entries on this list generally fall under events from the past and in the present that one deems unlikely, speculations about the future, and phenomena that we don't usually pay attention to but that can be explained by chance. What is interesting, and emphasized in the lecture, is the disconnect between examples from a typical textbook or other academic inquiry and the examples of chance gathered from everyday life contexts. Aldous' quotes here Nassim Taleb from his book The Black Swan: "*the sterilized randomness of games does not resemble randomness in real life*."

Many examples of collected real world data, a list of topics that can be used (and have previously been used) in a project-based course at UC Berkeley, the annotated list of a 100 contexts (with illustrative examples) in which we perceive chance, a draft of a book on the subject [4], and other relevant links are available on Aldous' website [5].

In recent years Aldous' theoretical research focused on finite Markov information exchange processes, discrete spatial networks and flows through random networks. His second lecture presented a new take on an area of applied probability that has an extremely broad-ranging use in other scientific fields [3,6].

Interacting particle systems as stochastic social dynamics

Models of individual interactions subject to randomness have been used in physics, computer science and electrical engineering, economics and finance, psychology and sociology, epidemiology and ecology. They are toy models of the ways in which individual 'agents' affect each other, and their goal is to assess the collective result of these interactions on the behaviour of the system as a whole. In mathematics these models are called 'interacting particle systems'; in computer simulations they are referred to as 'stochastic agent-based models.' All of these models are specified by: (i) a graph (or contact network) whose vertices represent agents (or particles, or individuals) and whose edges define the possible pairwise relations between them; (ii) rates (or frequencies) at which information is exchanged between each pair of (neighbouring) agents; (iii) the type of information exchange (or the rule for the state change) that is a result of each interaction. Stochasticity in the model emerges from occurrences of the pairwise interactions: times of all interactions are random and follow a set of Poisson processes with rates prescribed by (i) and (ii); the information exchange at each interaction is also potentially random as specified by (iii). The graph in (i) is often referred to as the underlying geometry of the system, while the rule in (iii) is referred to as the dynamics of the process. The rates in (ii) are often subsumed in the description of the dynamics.

A new technical framework for such models can be formalized as follows: consider a set of agents A and a nonnegative array $\mathcal{N} = (\nu_{ij}, i \neq j \in \mathrm{A} \times \mathrm{A})$ of unordered pairs ($\nu_{ij} = \nu_{ji}$) which is irreducible (the graph of edges on A corresponding to $\nu_{ij} > 0$ entries is connected); assume that each unordered pair $i \neq j$ of agents meets at times given by a rate ν_{ij} Poisson process, independent over different pairs. Let $\mathfrak{S}$ denote a set of possible states for each agent, and $X(t) = \big(X_i(t)\big)_{i \in \mathrm{A}}$ be a stochastic process taking values in $\mathfrak{S}^{\mathrm{A}}$, in which $X_i(t)$ records the state of agent i at time t. The value of $X_i(t)$ changes only at times t at which agent i interacts with some other agent j with $\nu_{ij} > 0$, and is specified by a (deterministic or random) function $F\colon \mathfrak{S} \times \mathfrak{S} \mapsto \mathfrak{S}$ in such a way that if $\big(X_i(t^-), X_j(t^-)\big) = (s_i, s_j)$ then $\big(X_i(t), X_j(t)\big) = \big(F(s_i, s_j), F(s_j, s_i)\big)$. The times at which pairs of agents interact are fully defined by the set of Poisson processes and are called the 'Meeting' process, while the whole process of state changes is referred to as the 'Finite Markov Information Exchange' (FMIE) process.

Many models that have been rigorously analyzed are contained in this description. One of the earliest ones is the classical epidemic model of susceptible, infected and recovered states (SIR) with exponentially distributed waiting times. Of the well known ones from statistical physics the voter model and the contact process (after the usual graph is enriched with one special agent) can be framed as a FMIE. For models in which the population is homogeneously mixing, the underlying graph is the complete graph on the number of agents n with $\nu_{ij} = 1/(n-1)$, $\forall i \neq j \in \mathrm{A}$. For models with Euclidean spatial structure, the finite graph is the discrete d-dimensional torus of strip size $m = \sqrt[d]{n}$ with $\nu_{ij} = 1/(2d)$, $\forall i \sim j$ adjacent in $(\mathbb{Z}/m\mathbb{Z})^d$. In the last two decades more general geometries have been used for the graph of agents, particularly instances of different types of random graphs (Erdős–Rényi, small world, preferential attachment, configuration model with prescribed degree distribution, etc). Graphs with an infinite number of agents can been considered as well (the infinite d-dimensional lattice, or the infinite d-regular tree, etc.), but the focus of this talk was on results that can be made about an FMIE on a finite graph as the number of agents n grows to infinity. The emphasis of the FMIE framework is to view these models as 'stochastic information flow through a network,' and to uncover quantitative aspects of the behaviour of an FMIE model in finite time (rather than in the limit as $t \to \infty$) and specifically their dependence on the geometry of the underlying network.

The following general principles can be useful in applying Markov chain theory to FMIE models: (1) if agents have only a finite number of states it is easy to see what happens in the limit as time goes to infinity; (2) notions of duality and time-reversal are a useful tool in studying the dynamics; (3) bottleneck statistics give crude general bounds; (4) it is often useful to consider some natural coupling of two FMIE processes; (5) certain special families of geometries have local weak limits which are infinite rooted random networks. Here are a couple of examples presented in the talk that illustrate the type of results that can be obtained for FMIE processes, and the power of these general principles.

The '*Pothead*' (or the '*Voter*') model: the state of each agent is one 'opinion' from the set $A = \{1, \ldots, n\}$. Initially each agent i has his own opinion i, when agent i meets agent j we choose uniformly one of the two directions $i \mapsto j$, $j \mapsto i$ and if the direction is $i \mapsto j$ then agent j adopts whatever opinion agent i holds at that time. Let $\mathcal{V}_i(t)$ be the set of agents $\subset$ A who hold the opinion i at time t, then $\mathcal{V}(t) = \big(\mathcal{V}_i(t)\big)_{i \in A}$ forms a random partition of A. Principle (1) tells us that in the long time limit $\mathcal{V}(t)$ will absorb in one of the n possible configurations, in which for some i $\mathcal{V}_i(t) = A, \mathcal{V}_j(t) = \varnothing \; \forall j \neq i$. On can then examine this time to absorption, called the 'consensus time.' Principle (2) can be used to consider the following '*Coalescing*' Markov chain model: initially each agent has one token labelled with his location $\{1, \ldots, n\}$; when agent i meets agent j in the direction $i \mapsto j$ then agent i gives all the tokens he holds to agent j. If we let $\mathcal{C}_i(t)$ be the set of labelled tokens agent i holds at time t, then $\mathcal{C}(t) = \big(\mathcal{C}_i(t)\big)_{i \in A}$ is also a random partition of A, and at any fixed time t the law of $\mathcal{V}(t)$ is equal to that of $\mathcal{C}(t)$. In particular the law of the consensus time is equal to that of coalescence time, which is the first time at which all the tokens in A are held by a single agent. One can easily show that on the complete graph for agents, the expected coalescence time is approximately $2n$. Principle (3) can then be used to estimate the expected consensus time on a graph with general geometry using bottleneck statistics on weighted graphs (such as the isoperimetric constant).

The '*Pandemic*' (and the '*First Passage Percolation*') model: the state of each agent is $\{0, 1\}$ recording whether the agent is infected or not; initially only one agent is infected, when an infected agent meets another the other becomes infected as well. The inverse of the rates of meetings define a notion of distance on the underlying graphs, and in the special case when all the strictly positive ν_{ij} are equal to 1 this is equivalent to the dynamical version of the '*First Passage Percolation*' process with Exponentially distributed passage weights. The pandemic model has been studied on many geometries, and exhibits the fastest possible spread of information on any FMIE model. On the complete graph for n agents one can obtain the following limit result for the proportion of infected agents $X_n(t)$: there exists a sequence of random variables G_n such that $\sup_t |X_n(t) - F(t - \log n - G_n)| \to 0$ in probability, where $F(t)$ is the logistic function, $\log n$ is the length of the initial phase of the infection, and G_n converges in law to a Gumbel distribution. Principle (4) allows one to apply these results to a number of other models that can be built upon the Pandemic model. Principle (5) can be used to get estimates for the expected spread of the epidemic, or the expected time until the infection spreads from agent i to a prespecified agent j, on a d-dimensional torus from known shape theorems for First Passage Percolation on the infinite d-dimensional lattice. Analogous estimates for general geometries remain unsolved.

In his third lecture Aldous described a specific Finite Markov Information Exchange process he recently proposed whose analysis gives rise to some interesting new mathematical objects.

The Compulsive Gambler process and the Metric Coalescent

Consider the following FMIE model called The 'Compulsive Gambler' process: the state of each agent is the amount of money he has, initially all agents have an equal amount of money, when two agents meet they play a fair winner-takes-all gamble (that is, the chance for each agent to win is proportional to the amount of money he brings to the gamble), and whichever agent wins takes all of the money from the agent that lost. Notice that once an agent loses a single gamble, he will have no chance of winning any other gamble in the future. Let $X_i(t)$ denote the amount of money agent i has at time t. In a model with finitely many agents, n, the total amount of money all the agents have is constant in time.

This process is interesting from a methodological point of view. The following techniques were useful in analyzing its behaviour: (1) martingales; (2) comparison with the Kingman coalescent chain; (3) ordered version of the model; (4) exchangeability.

(1) One can immediately observe that the number of agents which hold non-zero amounts at time t can only decrease in time, and the system will absorb as soon as one of the agents has all the wealth, when $X_i(t) = 1$ for some i. In case the geometry of the weighted graph of agents satisfies $\nu_\star = \min_{i,j} \nu_{ij} > 0$, then a simple martingale argument shows that in the long time limit the chance for each agent to accumulate all the money is proportional to his initial wealth. The collection of martingales $M_f(t) = (1/n) \sum_i f(i) X_i(t)$ for any function f on agents, whose second moment is bounded by $\nu^\star t$, can be used to show weak convergence of the empirical measure of the money allocation process.

(2) If the underlying network is a complete graph $\nu_{ij} = 1, \forall i \neq j$ then the number of agents with non-zero amounts is distributed as a Kingman coalescent chain. Using $\nu_\star = \min_{i,j} \nu_{ij}$ and $\nu^\star = \max_{i,j} \nu_{ij}$, one can estimate the time of wealth concentration T in a general graph by simple comparisons with the coalescence time of the Kingman chain, $2(1 - 1/n)/\nu^\star \leq ET \leq 2(1 - 1/n)/\nu_\star$.

(3) An ordered version of the model is as follows: suppose each unit of money is initially assigned an i.i.d. random label, and consider the ordered version of the gamble in which when two agents meet, the winner is determined as the owner of the unit with the lowest serial number. Notice that the owner of the unit that has the lowest serial number of all will eventually accrue all of the money. This process has the same distribution as the Compulsive Gambler process.

(4) The exchangeability property of this model refers to the conditional law of the money allocation process: given the amount of money each agent has, the ownership of serial numbers among agents is uniformly distributed on the set of all compatible partitions of A. As an immediate consequence, the agent who ultimately acquires all of the money is uniform random on A.

A new process, called the '*Metric Coalescent*,' was inspired by considering an abstract extension of this process: assume the total initial wealth is 1 and consider it as an arbitrary probability measure on A; instead of placing agents on the vertices of a graph consider them as points $a_1, \dots, a_n$ in a metric space $(\mathcal{A}, d)$; define meeting rates as functions of their distance $\nu_{ij} = \phi\big(d(a_i, a_j)\big)$; construct an empirical measure $\mu(t) = \sum_i X_i(t)\delta_{\xi_i}$ where ξ_i are i.i.d. locations of agents distributed as μ. The Compulsive Gambler process is equivalent to the evolution of this empirical measure in time. It is very likely that one can show that for each μ on $\mathcal{A}$ there exists a unique probability measure valued process $\mu(t)$ which evolves as the Compulsive Gambler from any time $t_0 > 0$ onwards and whose a.s. limit as $t \downarrow 0$ is equal to μ. The methodologies outlined above can be particularly useful in proving this result.

Aldous' lectures displayed an arsenal of classical tools in probability theory. The new FMIE framework he described proved the power of these tools to create new paradigms, when used creatively.

[1] D. J. Aldous, *The great filter, branching histories, and unlikely events*, Math. Sci. **37** (2012), no. 1, 55–64.

[2] ———, *Using prediction market data to illustrate undergraduate probability*, Amer. Math. Monthly **120** (2013), no. 7, 583–593.

[3] ———, *Interacting particle systems as stochastic social dynamics*, Bernoulli **19** (2013), no. 4, 1122–1149.

[4] ———, *On chance and unpredictability*: 13/20 *lectures on the links between mathematical probability and the real world*, available at http://www.stat.berkeley.edu/~aldous/Real-World/draft_book.pdf.

[5] ———, *Overview of probability in the real world project*, available at http://www.stat.berkeley.edu/~aldous/Real-World/cover.html.

[6] D. J. Aldous and D. Lanoue, *A lecture on the averaging process*, Probab. Surv. **9** (2012), 90–102.

[7] D. J. Aldous and T. Phan, *When can one test an explanation? Compare and contrast Benford's law and the fuzzy CLT*, Amer. Statist. **64** (2010), no. 3, 221–227.

Martin Nowak

(*continued from page 4*)

Kin selection occurs among genetically related individuals: "*I will jump into the river to save two brothers or eight cousins.*" (J.B.S. Haldane) The evolution of cooperation is then related to Hamilton's rule which states that it can occur if $r > c/b$, where r is a probability of sharing a gene which measures relatedness.

Direct and indirect reciprocity are essential for understanding the evolution of any pro-social behaviour in humans. Citing Martin Nowak: "But 'what made us human' is indirect reciprocity, because it selected for social intelligence and human language."

Martin Novak ended his fascinating Grande Conférence publique with an image of the Earth and the following sentence: "*We must learn global cooperation... and cooperation for future generations.*" This started a passionate period of questions, first in the lecture room, and then around a glass of wine during the vin d'honneur.

In his previous talk opening the workshop, "Evolution of sociality", Martin Nowak had compared two reproductive scenarios to make simple and testable predictions: a solitary life style with all offspring leaving to reproduce, and an eusocial life style with some offspring staying and helping raise further offspring. He had also shown the limitations of an inclusive fitness maximization approach that consists in making predictions in the presence of interactions between individuals by transferring fitness effects from recipients to actors weighted by coefficients of relatedness.

In his more technical talk delivered later on in the workshop, Martin Nowak presented an overview of stochastic models of "Evolutionary dynamics" in well-mixed populations as well as structured populations, including populations on graphs and on sets and extensions to n-strategy games.

Number Theory from Arithmetic Statistics to Zeta Elements

(*continued from page 2*)

there isn't a single lab member who isn't involved in organizing at least one workshop. The very first workshop is being organized by Chantal David...

AG: *together with an international committee* [Pär Kurlberg, Zeév Rudnick]*...*

HD: *and then the November workshop is organized by Andrew and me...*

AG: *I am organizing the second one in additive combinatorics* [with David Conlon, Ben Green, Laurent Habsieger, Alain Plagne], *the third one is the two of us* [with Jordan Ellenberg], *plus Dick Gross at Harvard* [co-organizer of the SMS Summer school], *and then the fourth one is this exciting thing for young people...*

HD: *organized by Addario-Berry, who is actually not a part of our number theory group...*

AG: *and Dimitris Koukoulopoulos* [from CICMA].

HD: *The second semester will be taken up by more arithmetic activities. The first workshop* [Regulators, Mahler measures, and special values of L-functions, February 16–20, 2015] *is being run by Matilde Lalín and me* [with Wadim Zudilin]. *Matilde is a mathematician whose expertise straddles both the analytic and the algebraic aspects of the subject. Her interests have been broadening towards the analytic direction recently, but a central focus is still the special values of L-functions and their interpretation in terms of the conjectures of Beilinson–Bloch, so we really think there is an occasion there to share ideas across boundaries.*

HD: *The next workshop is the one on p-adic methods which I'm organizing with Adrian Iovita, Matt Greenberg from Calgary, and Payman Kassaei, who is one of our newest members. Finally, the third workshop in the second semester is being organized by Eyal Goren and me, and will focus on the Kudla program.*

Bulletin: And there will be some courses too?

HD: *Exactly. The graduate courses have not completely been determined for the second semester, but we certainly expect that at least two of Eyal Goren, Adrian Iovita, Payman Kassaei and me will be teaching a graduate course aimed at the beginning and intermediate level graduate student.*

Grande Conférence publique du CRM

« La découverte des fractales lisses » de Vincent Borrelli

Christiane Rousseau (Université de Montréal)

Le 13 février dernier, les Grandes Conférences publiques du CRM ont accueilli Vincent Borrelli de l'Université de Lyon. Celui-ci a partagé avec le public la grande aventure à laquelle il a participé : « La découverte des fractales lisses ».

Nous connaissons tous le modèle plat du tore que le conférencier a illustré comme le monde de Pac-Man : si Pac-Man sort à gauche du carré il réapparaît à droite, et s'il sort en haut sa tête apparaît en bas. Pour passer au tore géométrique, soit le beigne ou la bouée, nous prenons une feuille de papier et nous en collons deux côtés opposés pour en faire un cylindre. Jusqu'ici, pas de problème. Mais si nous désirons recoller ensemble les deux extrémités du cylindre pour le transformer en tore, cela semble impossible sans froisser le papier. Si cela était possible nous aurions une transformation isométrique du tore plat dans le tore géométrique. Le conférencier a présenté le jeune mathématicien John Nash, extrêmement doué mais vantard, et le défi fantastique que lui a lancé Warren Ambrose en 1953 de résoudre le problème : « *Gnash, si tu es si bon, pourquoi ne résous-tu pas le problème du plongement isométrique des variétés riemanniennes* ? » Après s'être couvert de ridicule en se vantant d'avoir résolu le problème, Nash va finalement résoudre ce grand problème deux ans plus tard. On peut représenter le tore carré plat dans l'espace tridimensionnel sans déformer les longueurs, mais cette représentation produira une surface extraordinairement tordue. En effet, en termes mathématiques, la courbure de Gauss est une obstruction à la construction d'une isométrie de classe C^2 entre le tore plat et le tore géométrique. Le théorème de Nash-Kuiper (1954-1955) affirme qu'il existe une isométrie de classe C^1 entre ces deux surfaces. Le conférencier a fait sentir au public la différence entre une surface C^1 et une surface C^2, et le danger des surfaces ou courbes de classe C^1 dans la conception d'une piste de skateboard ou d'une courbe de chemin de fer. Mais le théorème de Nash ne permettait pas de visualiser la surface tordue qui compte un nombre infini de points de rupture de courbure. Le grand mathématicien Mikail Gromov s'est intéressé au sujet et il a développé un outil très puissant, l'intégration convexe, qui permet de donner une deuxième preuve du théorème de Nash-Kuiper. Là encore, la preuve ne permet pas de visualiser la surface mais elle donne des pistes. Son livre « Partial differential relations » sera la clé pour construire effectivement la surface.

L'équipe formée de Vincent Borrelli, Francis Lazarus, Boris Thibert et du doctorant Saïd Jebrane, s'attaque en 2007 au problème de construire une visualisation d'un plongement du tore plat dans $\mathbb{R}^3$. Le projet d'envergure, auquel se joindra en cours de route Damien Rohmer, se poursuivra jusqu'en 2012. La technique est la suivante : les images des lignes horizontales sur le tore plat donnent les parallèles du tore, et celles des lignes verticales les méridiens du tore. Les longueurs ne sont pas préservées lors du processus. On part initialement d'un tore plus petit sur lequel les méridiens et les parallèles sont plus courts que sur le tore plat. On ajoute alors, par itérations successives des épaississements, ou corrugations, permettant de corriger les défauts de longueur. Il faut pour cela corriger dans trois directions indépendantes (les mathématiciens de Montréal ont eu droit aux détails techniques de la construction lors du colloque le lendemain). Même si l'idée est simple, sa mise en pratique n'est pas évidente et le conférencier a montré plusieurs fausses pistes qui n'ont pas abouti. Le calcul de la surface a requis l'aide de super-calculateurs. Le conférencier a ensuite emmené le public en haleine visiter les recoins intérieurs et extérieurs de la surface à l'aide de nombreux zooms.

La surface obtenue n'est pas une fractale au sens usuel du terme : une courbe fractale, par exemple le flocon de von Koch, est seulement de classe C^0. Sa dimension est entre 1 et 2, sa longueur est infinie, et la courbe est auto-similaire, c'est-à-dire qu'on redécouvre la même structure lorsqu'on zoome sur un détail de la courbe. Par contre, la dimension du plongement isométrique du tore plat est 2 et l'aire de la surface est finie. Pourtant, on découvre de nouveaux détails lorsqu'on zoome à l'infini. Même si les détails à petite échelle ressemblent à ceux à grande échelle, les facteurs de compression ne sont pas les mêmes dans les différentes directions, ce qui permet à l'aire de rester finie et à la dimension de ne pas dépasser 2. On a vraiment obtenu une nouvelle classe d'objets géométriques : les fractales lisses.

La conférence de Vincent Borrelli a été magistrale et le public, enchanté de cette superbe conférence, a posé de nombreuses questions au conférencier, d'abord dans la salle, puis autour d'un verre de vin.

Christiane Rousseau et Vincent Borrelli

Daniel T. Wise, Recipient of the AMS Oswald Veblen Prize in Geometry

Eduardo Martínez-Pedroza (Memorial University)

Professor Daniel Wise from McGill University together with Ian Agol from the University of California at Berkeley were awarded the 2013 Oswald Veblen Prize in Geometry.

Dani and Eduardo

The Oswald Veblen Prize is granted every three years by the American Mathematical Society for outstanding publications in geometry or topology that have appeared in the preceding six years.

Professor Wise received the recognition "*for his deep work establishing subgroup separability (LERF) for a wide class of groups and for introducing and developing with Frédéric Haglund the theory of special cube complexes which are of fundamental importance for the topology of 3-dimensional manifolds.*"

Most recently, Professor Wise has been invited as a speaker at the 2014 International Congress of Mathematicians (ICM).

Daniel Wise obtained his Ph.D. at Princeton in 1996 under the supervision of Martin Bridson. His thesis title is "Non-positively curved squared complexes: Aperiodic tilings and non-residually finite groups." Among the results in his thesis, he found examples of nonpositively curved square complexes with non-residually finite fundamental groups [15, 16].

A group is residually finite if the intersection of its finite index subgroups is the trivial subgroup, and a classical result of Malt′sev states that finitely generated linear groups are residually finite.

One of the motivations for these examples is a famous open question of Gromov of whether hyperbolic groups are residually finite [5]. The notion of hyperbolic group, also known as negatively curved group, was introduced by Gromov in the early 1980s as a class of groups generalizing fundamental groups of closed hyperbolic manifolds.

While Wise's examples of non-residually finite non-positively curved groups were not negatively curved groups, they could be considered as evidence for a negative answer to Gromov's question.

In his thesis, he also introduced the notion of *clean square complex*, an early 2-dimensional version of special cube complexes. In his earlier work he propounded a theme: "word-hyperbolic groups have stronger residual properties than nonpositively curved groups."

He supported the theme with his celebrated article in *Inventiones* containing positive residual finiteness results for certain classes of hyperbolic groups, building evidence for a positive answer to Gromov's question. Wise's results relied on his notion of clean square complex [17].

The work of Sageev [13] influenced Wise to move from the 2-dimensional square complexes to the higher-dimensional cube complexes. Later, this yielded the introduction of special cube complexes in joint work with Haglund. Their development of the theory included remarkable extensions of some of Wise's results on residual finiteness [7, 8].

Wise extended the theory of special cube complexes in his long paper on quasiconvex hierarchies [20] reconfirming his early theme, proving Thurston's virtual fibering conjecture for hyperbolic 3-manifolds with boundary, answering a long standing conjecture by Baumslag on residual finiteness of one-relator groups with torsion, and stating a (former) conjecture, proved by Agol, yielding the solution to outstanding problems in 3-manifold topology.

The impact of Daniel Wise's work in 3-manifolds is nicely summarized by Mladen Bestvina in his article on the the fulfillment of Thurston's vision [4]:

"*In the late 1970s, Thurston revolutionized our understanding of 3-manifolds. He stated a far-reaching geometrization conjecture and proved it for a large class of manifolds, called Haken manifolds. He also posed 24 open problems, describing his vision of the structure of 3-manifolds. Pieces of Thurston's vision have been confirmed in the subsequent years. In the meantime, Dani Wise developed a sophisticated program to study cube complexes and, in particular, to promote immersions to embeddings in a finite cover. Ian Agol completed Wise's program and, as a result, essentially all problems on Thurston's list are now solved.*"

The set of Thurston's 24 open problems, referred to in the quote, appeared in his 1982 article in the *AMS Bulletin* [14].

In the rest of this short note we sketch the notion of *special cube complex* and *virtually special group*, and briefly describe some of the applications of the theory by Daniel Wise.

Let us mention that an excellent expository approach to the theory of special cube complexes can be found in the notes on cubical geometry by Wise [21], and for a rigorous approach we recommend the first article by Haglund and Wise on the subject [7].

An *n-cube* is a copy of $[-1, 1]^n$, its faces are restrictions of some coordinates to ± 1, and each face is regarded as a lower-dimensional cube.

A *cube complex* X is a topological cell complex in which each n-cell is an n-cube, and cubes are attached to each other along faces by isometries.

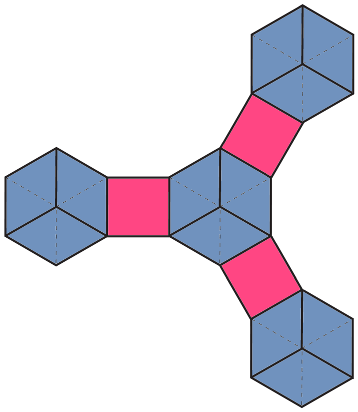


Figure 1: An example of a cube complex.

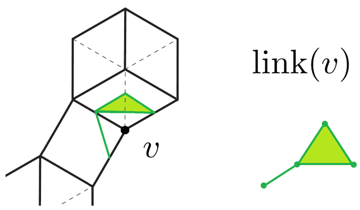


Figure 2: The link of the 0-cube v.

The *link* of a 0-cube v of X is the complex, made of simplexes, whose n-simplices correspond to $(n+1)$-cubes adjacent to v. Figure 2 illustrates this notion.

A cube complex is *nonpositively curved* if the link of every 0-cube is a simplicial complex with the following property: $n+1$ vertices span an n-simplex if and only if they are pairwise adjacent.

The success of the theory of (virtually) special cube complexes is in the fact that the class of its fundamental groups contains several classes of groups of interest in group theory and low-dimensional topology.

Now we define the notion of hyperplane of a non-positively curved cube complex X. First, a *midcube* is a subspace of a cube obtained by restricting one coordinate to 0.

In the case that X is simply-connected, a *hyperplane* is a maximal connected subspace of X such that the intersection with each cube is either a midcube or is empty—see Figure 3 for an illustration.

In the case that X is not simply-connected, a *hyperplane* of X is a map $H \to X$ induced by the universal covering map $\widetilde{X} \to X$, where H is the quotient space of a hyperplane $\widetilde{H}$ of $\widetilde{X}$ by the subgroup Stabilizer$(\widetilde{H})$ of $\pi_1 X$.

A *special cube complex* is a compact nonpositively curved cube-complex such that the following three properties, illustrated in Figure 4, hold:

(1) Each hyperplane embeds.

(2) No hyperplane directly self-osculates.

(3) No two hyperplanes both intersect and osculate.

We refer the reader to [7] for precise definitions.

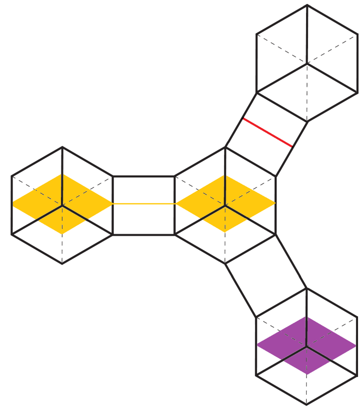


Figure 3: A cube complex and three distinct hyperplanes. This cube complex has twelve distinct hyperplanes.

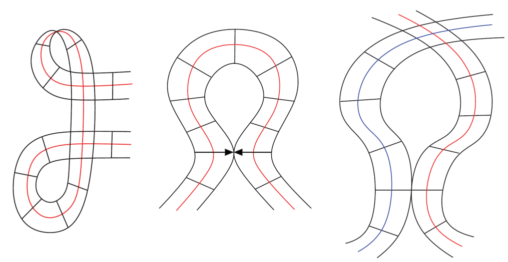


Figure 4: A hyperplane that self-intersects, a hyperplane that directly self-osculates, and two hyperplanes that both intersect and osculate.

For example, combinatorial graphs, or equivalently 1-dimensional cubical complexes, are special cube complexes. The product of special cube complexes is special, and convex subcomplexes of special complexes are special [7].

A group isomorphic to the fundamental group of a special cube complex is called *special*. A group is *virtually special* if it contains a finite index subgroup that is special.

The first remarkable result of Haglund and Wise is that virtually special groups admit faithful representations into $\mathrm{SL}_n(\mathbb{Z})$. This is obtained by showing that a special group has a finite index subgroup isomorphic to a subgroup of a right-angled Coxeter group [7].

Since virtually special groups are linear, in particular, they are residually finite. In fact this class of groups has richer separability properties. A subgroup Q of a group G is *separable* if Q equals the intersection of the finite index subgroups of G containing it.

In the case that a group G is virtually special and is also hyperbolic, Haglund and Wise proved that the quasiconvex subgroups of G are separable [7]. A quasiconvex subgroup of a hyperbolic group plays the role of a convex subspace in a metric space.

This separability result generalizes independent results of Haglund [6] and Wise [18] and is at the core of the solution of most of Thurston's 24 questions on hyperbolic 3-manifolds.

The last result that we want to mention is a deep theorem of Wise that describes a characterization of hyperbolic special groups in terms of *quasiconvex hierarchies*.

A quasiconvex hierarchy is a technical notion. Roughly speaking, a group G has a quasiconvex hierarchy if G can be built starting with trivial groups by using a finite sequence of HNN-extensions and/or amalgamated products over finitely generated subgroups that are geometric (meaning quasiconvex in the case that G is hyperbolic).

Wise proved that a hyperbolic group with a finite quasiconvex hierarchy is a virtually special group, and conversely every special group has a finite quasiconvex hierarchy [20].

This characterization in terms of quasiconvex hierarchies builts on results of Hsu and Wise [10], and a central result in the theory known as Wise's *Malnormal Quotient Theorem* [20].

A remarkable application of quasiconvex hierarchies is the positive solution of Gilbert Baumslag's conjecture from 1967 that one-relator groups with torsion are residually finite [2]. These are groups with a presentation containing a single relator which is a proper power, i.e., $\langle x_1, \ldots, x_m \mid r^n \rangle$ with $n > 1$.

It was known that one-relator groups with torsion are hyperbolic and have a finite hierarchy; work of Hruska and Wise [9] or Lauer and Wise [12] implies that the hierarchy is quasiconvex. Then Wise's characterization implies that one-relator groups with torsion are virtually special, in particular, linear and hence residually finite [20, 21].

Another application of quasiconvex hierarchies is the solution of Thurston's virtual fibering conjecture for hyperbolic 3-manifolds with boundary. The conjecture states that the manifolds have a finite cover which is a surface bundle over the circle [20, 21]. It was known that these manifolds admit quasiconvex hierarchies, hence Wise's result implies that their fundamental groups are virtually special, and then a criterion for virtual fibering by Agol applies.

We conclude by recalling a former conjecture of Wise in [8, 20], solved in 2012 by Agol. The conjecture was that compact nonpositively curved cube complexes with hyperbolic fundamental group have finite coverings that are special cube complexes.

Agol proved the conjecture using an ingenious and sophisticated argument together with a joint result with Groves and Manning known as the *Weak Separation Theorem* [1]. The separation theorem relies on work of Wise known as the *Virtually Special Quotient Theorem* [19, 20].

The solution to Wise's conjecture by Agol, together with theorems by Kahn and Marković [11], Bergeron and Wise [3], Haglund and Wise [8], and Wise [20] imply that fundamental groups of closed hyperbolic 3-manifolds are virtually special groups. As a consequence, all but one of Thurston's 24 open questions were positively solved, including the virtual fibering conjecture for closed hyperbolic 3-manifolds.

The work of Daniel Wise includes almost 70 research articles. We remark that this note mentions only some later developments, and we have left out several important results and milestones.

We conclude with a quote of Daniel Wise from his notes on cubical geometry that advocates the use of special cube complexes [21]:

"*Though G might arise as the fundamental group of a small 2-complex or 3-manifold, in many cases one should sacrifice this small initial presentation in favour of a much larger and higher-dimensional object that is a nonpositively curved special cube complex, and has the advantage of being far more organized, thus revealing important structural aspects of G.*"

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Lauréat 2014 du prix CRM-Fields-PIMS

Niky Kamran (Université McGill)

Les instituts en sciences mathématiques du Canada sont heureux d'annoncer que le Pr Niky Kamran est le récipiendaire du prix CRM–Fields–PIMS. L'essentiel de la carrière de Niky Kamran s'est déroulé au Canada et il travaille dans les domaines de l'analyse et de la géométrie différentielle. Ses champs d'intérêt ont une très grande portée. Les deux principaux axes de sa recherche sont d'une part les systèmes différentiels extérieurs et la théorie de Lie, sujet central de l'analyse géométrique des systèmes d'équations aux dérivées partielles, et d'autre part l'analyse mathématique de la relativité générale.

Niky Kamran

Les travaux de Niky Kamran sur les systèmes différentiels extérieurs ont leurs fondements dans ceux d'Élie Cartan où des objets géométriques locaux sont décrits en termes de formes différentielles qui sont invariantes sous les difféomorphismes et sous l'action d'autres (pseudo) groupes de Lie de dimension infinie. Les principales contributions de Niky Kamran portent sur l'existence de solutions et la classification des symétries de dimension infinie. Ses publications sur les sous-groupes d'isotropie de pseudo-groupes de Lie analytiques et transitifs font autorité et concernent des aspects globaux tels la cohomologie de complexes différentiels et des aspects locaux incluant par exemple les estimés de Malgrange qui découlent de sa preuve du théorème de Cartan et Kähler.

Les contributions de Niky Kamran à l'analyse mathématique des équations d'Einstein de la relativité générale ont également beaucoup d'influence dans un domaine en pleine effervescence. Dans une série d'articles importants écrits en collaboration avec F. Finster, J. Smoller et S.-T. Yau, Niky Kamran étudie la stabilité des espaces–temps lorentziens, un sujet qui est essentiel à l'élaboration de la cosmologie contemporaine. Le point crucial, dans ces examens de systèmes d'équations d'évolution non linéaires, est de bien caractériser au niveau le plus fondamental l'opérateur résolvant pour les équations linéarisées. Niky Kamran et ses collaborateurs ont réalisé une étude systématique des espaces–temps à trous noirs, c'est-à-dire des solutions de Schwarzschild et Kerr pour les équations d'Einstein. Ses travaux les plus récents portent sur les espaces de type anti–de Sitter, qui sont au cœur de l'approche de la gravitation quantique connue sous le nom de correspondance AdS–CFT.

Niky Kamran a publié plus de 125 articles scientifiques. Il est de surcroît un communicateur hors pair et a écrit des articles de survol et des monographies qui ont eu beaucoup d'impact. Ses travaux se distinguent par leur profondeur et leur originalité et couvrent un large spectre de sujets majeurs ; ils démontrent que leur auteur possède une vaste et profonde culture mathématique. Les apports de Niky Kamran laisseront leur marque sur les mathématiques canadiennes et mondiales. Le CRM est très fier que le prix CRM-Fields-PIMS ait été décerné à Niky Kamran, un membre du CRM et du CIRGET.

Colloque pan-québécois des étudiants de l'Institut des sciences mathématiques XVIIe édition 16 au 18 mai 2014, Université Laval

Ce colloque annuel est l'occasion de réunir les étudiants du Québec en mathématiques et en statistique le temps d'une fin de semaine. Tous sont invités à y présenter leur recherche courante ou un sujet qu'ils jugent digne d'intérêt, afin de découvrir différents sujets et échanger des idées avec d'autres étudiants. Les présentations étudiantes, d'une durée d'une vingtaine de minutes, seront ponctuées de conférences plénières de 50 minutes données par des professeurs renommés.

http://archimede.mat.ulaval.ca/ISM_2014/.

Exact Solvability and Symmetry Avatars August 25–29, 2014

This conference will be held at the CRM on the occasion of Luc Vinet's 60th birthday. His scientific work has had a profound impact on many of the fields where integrability occurs.

Integrable systems, both classical and quantum, share properties that make them easier to describe and study. It is therefore natural that many efforts are devoted to their study and that they found applications in diverse parts of mathematics and science: algebraic combinatorics, field and string theory, quantum information, orthogonal polynomials and special functions. The meeting will gather scientists from this broad horizon.

http://www.crm.umontreal.ca/Vinet60/.

Two Recent Scientific Activities in the Field of Financial and Actuarial Mathematics

Manuel Morales (Université de Montréal)

In the past nine years, the province of Québec and in particular Montréal, has seen a significant increase in the number of scientific activities in the field of actuarial and financial mathematics. The number of researchers working in this field has more than doubled and it is now composed of a good mix of young and well-established researchers making for a very dynamic research environment. Indeed, the research community has now attained a critical mass allowing for a sustained presence on the national as well as international stage. These two activities are a good example of this new dynamics.

4th Graduate Students Workshop on Actuarial and Financial Mathematics

Organizers: Mathieu Boudreault (UQAM), José Garrido (Concordia), Ghislain Léveillé (Laval), Manuel Morales (Montréal)

The 4th Graduate Students Workshop on Actuarial and Financial Mathematics took place at the CRM on December 6th, 2013. This is an initiative put forward by all four Québec universities offering graduate studies in actuarial and financial mathematics. It is now in its fourth consecutive year and, as every year, it aimed at showcasing the work of our graduate students in a casual fashion that encourages discussion. This year the program consisted in six one-hour presentations made by graduate students enrolled in both Master's and Ph.D. programs across Québec. Attendants had the opportunity to hear the latest results of two Concordia students, Nicolas Essis-Breton and Polynice Oyono; two UQAM students, Étienne Doucet and Erika Maldonado; one student from Université Laval, François Pelletier and one student from Université de Montréal, Hassan Omidi. The different topics presented in this edition bear witness to the variety of research directions being studied by our colleagues and their graduate students. Topics ranged from the numerical aspects of backward stochastic differential equations in finance, variable annuities valuation, risk theory, extreme value statistics in automobile insurance, and statistical modelling of financial returns. Attendance was good with over 40 participants from all across Québec making this edition yet another success. This workshop is now well established as a yearly meeting for the Québec research community working in the field. The next edition will be held at Université Laval at the end of 2014.

3rd Workshop on Insurance Mathematics

Organizers: Andrei Badescu (Toronto), Hélène Cossette (Laval), David Landriault (Waterloo), Ghislain Léveillé (Laval), Étienne Marceau (Laval), Manuel Morales (Montréal), Jean-François Renaud (UQAM)

The 3rd Workshop on Insurance Mathematics took place at Université Laval on January 31st, 2014. The aim of this workshop has always been to provide a venue for academics, including graduate students and postdoctoral fellows, to meet and discuss their latest research in the broad area of insurance mathematics and its related disciplines (e.g., mathematical finance, applied probability and statistics). Among others, this includes life and non-life insurance, risk management in insurance and finance, risk and ruin theory, financial modelling and applications of statistical methods in insurance. For years, Canada has established itself as a North American stronghold of actuarial scientific and professional research with many high-profile academics in its ranks. This workshop seeks to ensure continuity through the development of a strong cohort of young actuarial science academics. It also seeks to stimulate interaction and scientific collaboration, and foster relations of an academic and professional nature among the actuarial science groups, notably in the Québec–Ontario area.

This year, the program was composed of one keynote speaker and nine half-hour invited presentations. Among the invited speakers we find two Ph.D. students whose thesis work is near completion, Anne Mackay (University of Waterloo) and Hassan Omidi (Université de Montréal) and one young postdoctoral fellow Ionica Groparu-Cojocaru (Concordia University). These young researchers presented their latest work in a casual event that allowed them to hear feedback and engage in discussion with more experienced members of the community. The keynote speaker was Prof. Sheldon Lin from the University of Toronto, who gave a talk on the problem of fitting Erlang-based models to insurance data. As a means to facilitate their integration, new colleagues in the community, Prof. Julien Trufin (Université Laval) and Alexandru Badescu (UQAM) were invited to present their latest work. Their talks focused on two distinct but equally challenging questions in the field of financial and insurance risk modelling. The former described how new risk measures can be constructed from ruin theory whereas the latter discussed non-Gaussian econometric models for financial time series. Finally, Prof. Brian Hartman (University of Connecticut), Prof. Mhamed Mesfioui (UQTR), Prof. Ruodu Wang (University of Waterloo) and Prof. Jiandong Ren (University of Western Ontario) delivered talks on various problems ranging from risk management of storm damage in power lines, to multivariate risk modelling and extreme value risk measures. With over sixty registered participants, this event was another success that allowed for the perfect gathering of the Québec–Ontario research community working in the fields of insurance and financial mathematics.

Workshop on Nonparametric Curve Smoothing

Yogendra Chaubey (Concordia University)

This workshop was held at Concordia University, December 16–17, 2013, as part of the activities marking the International Year of Statistics. It was supported by the CRM Statistics Lab (under the direction of C. Genest) and Concordia University, and held in collaboration with active researchers in the area of nonparametric curve smoothing in Montréal and surrounding areas. It attracted 15 top speakers in the field, coming from Europe, the US and across Canada. The 59 participants included many graduate students and researchers from as far away as Vancouver and Newfoundland, in addition to those from universities in and around Montréal. Every talk was followed by ample discussion from the audience; these discussions continued often during the coffee/tea breaks. One of the speakers, impressed by the intellectual environment, proposed to organize a similar workshop next year at the Fields Institute.

The photo shows some the speakers with the organizer (Y. Chaubey):

From left to right: A. Krzyzak, O. Scaillet, G. Lugosi, A. Leblanc, D. Campbell, T. Bouezmarni, I. Gijbels, B. Vidakovic, Y.P. Chaubey, S. Provost, F. Camirand Lemyre, I. Mizera, N. Veraverbeke, Z. Zhou. Courtesy: J. Venettacci

TO APPEAR

Contemporay Mathematics

Perspectives on Big Data Analysis

S. Ejaz Ahmed (ed.)

This volume contains the proceedings of the International Workshop on Perspectives on High-Dimensional Data Analysis II, *held May* 30–*June* 1, 2012, *at the CRM.*

This book collates applications and methodological developments in high-dimensional statistics dealing with interesting and challenging problems concerning the analysis of complex, high-dimensional data with a focus on model selection and data reduction. The chapters contained in this book deal with submodel selection and parameter estimation for an array of interesting models. The book also presents some surprising results on high-dimensional data analysis, especially when signals cannot be effectively separated from the noise, it provides a critical assessment of penalty estimation when the model may not be sparse, and it suggests alternative estimation strategies. Readers can apply the suggested methodologies to a host of applications and also can extend these methodologies in a variety of directions. This volume conveys some of the surprises, puzzles and success stories in big data analysis and related fields.

CRM Nirenberg Lectures May 13–16, 2014 Alessio Figalli (University of Texas)

The first CRM Nirenberg Lectures will be given by Alessio Figalli, professor and R.L. Moore Chair at the University of Texas at Austin. He obtained his Ph.D. in 2007 *under the direction of Luigi Ambrosio and Cédric Villani. Professor Figalli has obtained outstanding results on the regularity of optimal transport maps, on the stability of functional and geometric inequalities, as well as on the weak KAM theory. He has received many awards and honours, including the prize of the European Mathematical Society in* 2012 *and an invitation to speak at the International Congress of Mathematicians in* 2014.

Alessio Figalli

The CRM Nirenberg Lectures are named in honour of Louis Nirenberg (Courant Institute).

"Stability results for geometric and functional inequalities"

Geometric and functional inequalities play a crucial role in several problems arising in the calculus of variations, partial differential equations, geometry, etc. More recently, there has been a growing interest in studying the stability for such inequalities. The basic question one wants to address is the following: Suppose we are given a functional inequality for which minimizers are known. Can we prove, in some quantitative way, that if a function "almost attains the equality" then it is close (in some suitable sense) to one of the minimizers? In recent years several results have been obtained in this direction, showing stability for isoperimetric inequalities, the Brunn–Minkowski inequality, Sobolev and Gagliardo–Nirenberg inequalities, etc. In these lectures I will introduce some of these stability problems, describe some possible ways to attack them, and show some applications.

Appel à projets

Le Centre de recherches mathématiques (CRM) vous invite à proposer des projets d'activités scientifiques. Les activités scientifiques se divisent en trois catégories : les semestres thématiques d'une durée de six mois ; les conférences, ateliers ou écoles d'une durée de quelques jours à 2 semaines ; et les périodes de recherche ciblée d'une durée d'une à deux semaines.

Un engagement à la diversité. Les demandeurs doivent s'assurer que le niveau de représentation des femmes et des groupes sous-représentés est adéquat dans l'activité proposée. Par exemple, ils devraient prévoir la participation de chercheurs se situant à différents stades de leur carrière, de boursiers postdoctoraux et d'étudiants issus d'une diversité d'institutions et provenant de divers endroits au Canada et à l'étranger.

Ateliers, écoles et conférences

Les propositions pour les ateliers, écoles ou conférences doivent être reçues par le CRM au moins un an avant la date proposée pour la tenue de l'événement. Exceptionnellement, l'échéance peut être réduite à six mois. Ces demandes seront évaluées par le Comité scientifique aviseur international du CRM.

Les demandes doivent inclure :

- le titre et les dates proposées pour la tenue de l'événement ;
- la composition du comité organisateur, avec les noms, les affiliations des membres du comité, et un bref curriculum vitæ ;
- une description scientifique détaillée de l'événement sur 3 à 5 pages qui doit d'abord rappeler le contexte scientifique, l'importance du sujet à l'heure actuelle, et les défis, questions et conjectures que l'événement se propose d'étudier, en mettant l'accent sur la pertinence de tenir cet événement maintenant ;
- une liste provisoire des principaux conférenciers avec leur affiliation et leur discipline (si autres que mathématiques ou statistique) ;
- un budget des revenus et les dépenses prévus.

Les propositions d'activités doivent être envoyées à : projet@crm.umontreal.ca.

Semestres thématiques

Les dates limites pour les propositions pour des semestres thématiques sont le 15 mars et le 1er octobre de chaque année. Les semestres thématiques ont lieu soit de janvier à juin (semestre hiver-printemps) ou de juillet à décembre (le semestre été-automne). Les propositions doivent être soumises au CRM au moins 18 mois avant la date du début du programme proposé. Les activités scientifiques des semestres thématiques incluent typiquement des ateliers, écoles et conférences ; des fonds sont aussi alloués pour les stagiaires postdoctoraux, les visiteurs à court et à long terme et une, deux ou trois chaires Aisenstadt. Toute proposition sera examinée par la direction du CRM et par le Comité scientifique international du CRM qui évalueront la qualité scientifique du projet : les fondements scientifiques, la pertinence du projet, les grandes conjectures et défis mathématiques. Si le programme est accepté, les membres du comité organisateur seront en charge de l'organisation du programme thématique, en collaboration avec le directeur et le personnel du CRM qui accompagneront les organisateurs pas à pas dans l'organisation du semestre, incluant les demandes de financement externe. Le CRM héberge aussi dix laboratoires qui participent souvent à l'organisation et au financement des semestres thématiques.

Comité organisateur. Le comité organisateur comprendra des membres de la communauté mathématique canadienne et internationale. Idéalement, au moins un membre de la communauté mathématique québécoise figurera parmi les organisateurs. Au moins 50 % des organisateurs du semestre seront hors Québec.

Activités scientifiques. Les activités scientifiques doivent comprendre grosso modo 4, 5 ou 6 semaines d'activités (ateliers, écoles, conférences) regroupées comme les organisateurs le désirent. Les organisateurs sont aussi fortement encouragés à organiser une école consacrée en priorité à la formation des étudiants gradués et des stagiaires postdoctoraux en début de programme. Entre ces périodes de concentration, les propositions doivent inclure une liste des activités auxquelles participeront les visiteurs à moyen et long terme : séminaires hebdomadaires, groupes de travail, mini-cours, cours gradués, etc. Les activités de formation prévues pour les étudiants et stagiaires postdoctoraux, tels les cours préparatoires, doivent aussi être décrites.

Chaire Aisenstadt. Cette chaire permet d'accueillir dans chaque programme thématique deux ou trois mathématiciens de très grande renommée pour un séjour allant d'une semaine à un semestre. Les titulaires de la chaire Aisenstadt donnent une série de conférences sur un sujet déterminé pour son intérêt et son impact dans le cadre de la programmation thématique dont la première, à la demande du donateur André Aisenstadt, doit être accessible à un large auditoire. Ils sont également invités à rédiger une monographie dans la série « CRM Monographs Series » diffusée par l'American Mathematical Society.

Visiteurs à long terme et stagiaires postdoctoraux. La demande doit aussi comprendre une liste préliminaire des visiteurs à moyen et long terme. Chaque semestre thématique accueillera aussi plusieurs chercheurs postdoctoraux. La durée des stages postdoctoraux associés aux semestres thématiques sera de six mois à un an.

Publications. Les organisateurs sont encouragés à présenter des projets pour publication dans une des séries publiées conjointement avec l'American Mathematical Society ou Springer.

Sources de financement. Les organisateurs sont fortement encouragés à appliquer à d'autres sources de financement pour leur programme, par exemple auprès de la National Science Foundation (NSF) ou du Clay Mathematical Institute. Les organisateurs seront pleinement épaulés par la direction et le personnel du CRM dans chacune des demandes de financement externe.

Ce que la demande doit inclure. Une proposition pour un semestre thématique au CRM doit inclure :

- Le titre et les dates proposées pour la tenue du programme ;
- La composition du comité organisateur, avec les noms et les affiliations des membres du comité et un bref curriculum vitæ ;
- La description générale du semestre mettant clairement en évidence les buts, la qualité scientifique et la pertinence du programme ;
- une liste préliminaire des visiteurs à court et à long terme ;
- des propositions pour les candidats aux chaires Aisenstadt.

Les propositions de semestres thématiques doivent être envoyées par courriel à : projet@crm.umontreal.ca.

Périodes de recherche ciblée

Les périodes de recherche ciblée sont conçues pour permettre à de petits groupes de chercheurs de saisir une occasion spéciale de recherche portant sur des sujets de pointe en sciences mathématiques. Les propositions peuvent être soumises en tout temps et seront évaluées en temps opportun. Les propositions doivent décrire les questions sur lesquelles le groupe travaillera ainsi que justifier la nécessité et la pertinence d'organiser cette période de travail. Le curriculum vitæ des chercheurs doit être soumis avec la proposition.

Call for Proposals

The CRM (Centre de recherches mathématiques) is soliciting applications for scientific activities to take place at the CRM. The proposals are divided in three categories: thematic semesters, of a duration of up to six months; workshops, conferences or schools, whose duration can vary from a couple of days up to two weeks; and targeted research periods for small groups of researchers lasting one to two weeks.

A commitment to diversity. Applicants must ensure proper levels of representation of women and underrepresented groups in the proposed activity. For instance, they should plan for participation of scientists at different stages of their career, including postdoctoral fellows and students, coming from a diversity of institutions and locations in Canada and abroad.

Workshop, Schools and Conferences

The proposal for workshop, schools or conferences must be received by the CRM at least one year before the date proposed for the event. In exceptional cases, this deadline can be reduced to less than a year. The proposals will be evaluated by the International Scientific Advisory Committee of the CRM.

The proposals must include:

- the title and dates of the proposed event;
- the composition of the organizing committee, with the names, affiliations and C.V. of its members;
- a detailed scientific description of the event (approximately 3–5 pages);
- a tentative list of the principal invited speakers, and their discipline if other than mathematics or statistics;
- a budget showing expected revenues and expenditures.

Proposals should be sent to the CRM by email at: proposal@crm.umontreal.ca.

Thematic Semesters

The deadlines for proposals for thematic semesters are March 15 and October 1st of each year. The thematic semesters take place from January to June (for the Winter-Spring Semester), and from July to December (for the Summer-Fall Semester). The applications must be submitted to the CRM at least 18 months before the beginning of the semester. The scientific activities of each semester typically include workshops, conferences and schools; some funds are also allocated to support postdoctoral fellows, short and long-term visitors and two Aisenstadt chairs. All propositions will be examined by the direction of the CRM and the International Scientific Advisory Committee which will evaluate the quality of each proposal: the scientific foundations, the pertinence and timeliness of the proposal, the main mathematical challenges and conjectures, etc. If the program is accepted, the members of the organizing committee will be in charge of the organization of the thematic program, in collaboration with the director and the CRM personnel which will be present at every step of the organization of the semester, including for the applications for external funding. The CRM also include ten scientific laboratories which sometimes participate actively in the organization and financing of the thematic semesters.

Organizing committee. The organizing committee will be formed by members of the Canadian and international mathematical community. Ideally, at least one member of the organizing committee will be chosen among the local mathematical community. At least 50% of organizers of the semester will be from outside Québec.

Scientific activities. The scientific activities of the thematic semester should include at least 4 to 6 weeks of activities (workshops, schools, conferences) grouped as per the wishes of the organizers. The organizers are also encouraged to organize a school aimed primarily at postdoctoral fellows and graduate students at the beginning of the theme semester. Between the concentration periods of the workshops and the schools, the thematic semester should include scientific activities involving the long-term visitors, like weekly seminars, research workshops, mini-courses, graduate courses etc. The training activities specially aimed at graduate students and postdoctoral fellows should be described in the application.

Aisenstadt chairs. The Chair allows to welcome in each of the thematic programs two or three world-famous mathematicians for a one-week to a one-semester stay. The recipients of the Chair give a series of conferences on set subjects, chosen because of their relevance and impact, within the thematic program, the first of which, in compliance to the donor André Aisenstadt's wish, must be accessible to a large public. They are also invited to write a monograph in the CRM Monographs Series published by the American Mathematical Society.

Long-term visitors and postdoctoral fellows. A tentative list of long-term visitors should be submitted with the application. Each semester will also host several postdoctoral fellows. The duration of the postdoctoral fellowships associated to the theme semester can vary from six months to a year.

Publications. The organizers are encouraged to present some projects to be published in one of the series published in collaboration with the American Mathematical Society or Springer.

Funding. The organizers are strongly encouraged to apply for other sources of funding for their thematic program, for example through the National Science Foundation (NSF) or the Clay Mathematical Institute. They will receive full support from the direction of the CRM in applying to these grant agencies.

What the proposal should include:

- the title and dates of the proposed event;
- the composition of the organizing committee, with the names, affiliations of its members and their short C.V.;
- a general description of the semester that must clearly highlight the goals, the scientific quality and the relevance of the program;
- a preliminary list of the long-term visitors;
- proposals of candidates for Aisenstadt Chairs.

Semester proposals should be sent to the CRM by email at: proposalr@crm.umontreal.ca.

Targeted Research Periods

Targeted research periods for small groups of researchers are designed to seize research opportunities focussing on ground-breaking topics in the mathematical sciences. Proposals can be submitted at any time and will be evaluated in a timely fashion. Proposals should describe the research to be worked on during the period as well as justify its need and timeliness. C.V.'s of the invited participants need to be submitted with the proposal.

L'Association québécoise des jeux mathématiques (AQJM)

Frédéric Gourdeau (Université Laval)

L'Association québécoise des jeux mathématiques est composée d'enseignants de tous niveaux et a pour objectif de stimuler et d'intéresser les jeunes aux mathématiques en leur proposant des défis de logique et de mathématiques abordables et motivants. En permettant de stimuler ainsi l'amour des mathématiques auprès de milliers de jeunes et de leurs enseignants, l'AQJM joue un rôle important en appui à l'éducation dans un domaine crucial pour notre avenir.

C'est principalement par l'organisation au Québec du Championnat international des jeux mathématiques et logiques que l'AQJM travaille dans ce sens depuis plus de 10 ans. Le championnat est ouvert aux jeunes de la 3e année du primaire jusqu'aux étudiants de niveau universitaire et est aussi accessible au grand public. L'AQJM encadre son déroulement au Québec ; en 2013-2014, plus de 19 000 jeunes et moins jeunes ont pris part au Championnat au Québec.

Les questions sont de niveaux très variables : en voici une, proposée aux jeunes dès la fin du primaire.

Qui perd double. *Trois joueurs ont joué trois parties de « qui perd double ». À chaque partie, il y a automatiquement un perdant et celui-ci doit doubler l'avoir de chacun des autres joueurs* (*le jeu s'arrête s'il est dans l'impossibilité de le faire*)*. Après ces trois parties, chaque joueur possède* 24 *dollars. Quels étaient les avoirs des trois joueurs, dans l'ordre croissant, avant le début du jeu, sachant que personne n'avait plus de* 40 *dollars ?* (*S'il y a plus d'une solution, on doit donner le nombre de solutions ainsi que deux bonnes solutions.*)

Le Championnat se déroule comme suit :

- Le quart de finale a lieu d'octobre à décembre dans des centaines de classes, partout au Québec ou directement sur le site web de l'AQJM.
- La demi-finale est organisée au mois de mars en salle, dans plus d'une quinzaine de villes du Québec.
- La finale québécoise se tient au mois de mai dans environ quatre villes.
- La finale internationale a lieu à Paris, à la fin août. Plus de 10 pays y participent. À chaque année, le Québec y est fièrement représenté ; des jeunes se sont régulièrement classés dans les cinq premières places, dont une première place en 2006.

Intrigué ? Intéressé ? Visitez le site www.aqjm.math.ca

Incontournables mathématiques !

9 mai 2014 au CRM

Vous êtes convié(e) à une demi-journée où vous découvrirez l'omniprésence des mathématiques autour de nous, leur côté créateur et leur aspect ludique. Vous pouvez assister à l'ensemble des activités ou vous joindre à nous pour une activité particulière. L'ensemble des activités aura lieu au Pavillon André-Aisenstadt de l'Université de Montréal.

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 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 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 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.

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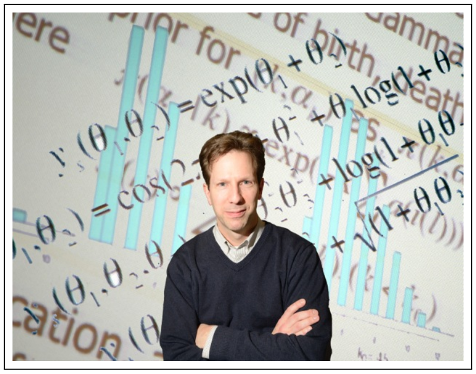
Le Bulletin est disponible à :
`crm.math.ca/docs/docBul_fr.shtml`.

Prix CRM-SSC

Derek Bingham en quête de l'émulateur parfait

Christian Genest (Université McGill)

Le 24 janvier, le CRM honorait Derek Bingham, professeur et titulaire d'une chaire de recherche du Canada en statistique industrielle à l'Université Simon-Fraser. Derek, qui est né et a grandi dans la région de Montréal, est le 15e lauréat du prix CRM-SSC. Cette récompense est décernée chaque année par le CRM et la Société statistique du Canada à un chercheur s'étant distingué par l'originalité et l'ampleur de ses travaux de recherche en statistique au cours des quinze premières années suivant l'obtention de son doctorat.



Derek Bingham

Dans son allocution, prononcée devant un public nombreux et attentif, Derek a relaté ses recherches sur les techniques statistiques d'émulation. Ces méthodes interviennent notamment dans l'étude de phénomènes physiques complexes dont le comportement dépend de nombreux paramètres. Les modèles employés à cette fin sont souvent déterministes. C'est dire qu'une fois les paramètres fixés, un tel modèle conduit toujours à la même solution. En général, celle-ci n'est toutefois obtenue qu'au prix de calculs longs et fastidieux, comme c'est fréquemment le cas en climatologie, entre autres. L'intérêt d'un émulateur statistique est de pouvoir prédire le résultat plus rapidement et à moindre coût. La technique s'apparente à la régression non paramétrique, à ceci près que la variable réponse n'a rien d'aléatoire. Comment faire alors pour exprimer l'incertitude qui entoure les prévisions ?

Pour résoudre ce problème, Sacks, Welch, Mitchell et Wynn avaient proposé dès 1989 qu'un émulateur statistique soit considéré comme la réalisation d'un processus gaussien. Il devenait alors possible de quantifier l'incertitude *a priori* au moyen de ce processus. Cette solution amène toutefois son lot de difficultés au plan numérique ; à titre d'exemple, l'évaluation de la vraisemblance en n points fait intervenir une matrice de covariance de taille $n \times n$. Cette lourdeur de calcul constitue un inconvénient majeur dans les situations où les paramètres du modèle déterministe doivent être calibrés de manière à refléter au mieux le comportement réel du phénomène sous étude.

Une nouvelle approche bayésienne d'émulation statistique a donc été conçue par Derek. Sa méthode consiste à décrire le phénomène par le truchement d'une base de fonctions surparamétrisée. Une expansion chaotique polynomiale généralisée, exprimée en fonction de la loi *a priori* des intrants, permet de représenter la surface de réponse du modèle déterministe. Les polynômes, soigneusement choisis, forment une famille orthogonale par rapport à la loi jointe des intrants, ce qui assure la convergence rapide de l'émulateur.

Pour quantifier l'incertitude, les chercheurs avaient recours jusqu'ici à une expansion limitée dont le degré était fixé arbitrairement. L'approche élaborée par Derek permet dorénavant de choisir les polynômes de manière adaptative — et par suite le degré de parcimonie du modèle — grâce à une technique d'échantillonnage de Monte-Carlo fondée sur une chaîne de Markov à sauts réversibles. Les conditions sous lesquelles cette méthode s'avère profitable ont aussi été précisées.

Les résultats dont Derek a fait état au CRM ont été obtenus de concert avec Bani Mallick et Avishek Chakraborty de l'Université Texas A&M. Leurs travaux ont été motivés par une expérience visant à calibrer un modèle de prévision du comportement d'ondes de choc hydrodynamiques à l'aide d'essais en laboratoire et de calculs par ordinateur. Dans ce contexte, l'approche prônée par Derek et ses collaborateurs s'est révélée nettement préférable à celle reposant sur le processus gaussien habituel, tant en termes de vitesse d'exécution qu'au plan de la prévision.

La quête de l'émulateur parfait, pour peu qu'il existe, sera sans doute longue et parsemée d'embûches. Rares sont ceux qui l'ont fait progresser autant que Derek Bingham. Aussi devons-nous nous réjouir de ses succès, qui rejaillissent sur tout le pays et sur son *alma mater*, l'Université Concordia.

A Word from the Director

Luc Vinet

It has been nine months already since I have been appointed Director; time has flown by and the CRM has been busy providing a vibrant research environment and reaping results.

The application process for the CTRMS grant from NSERC concluded with the meeting of the review committee in Ottawa in mid-March. I had indicated in the past *Bulletin* that this visit was to take place in early January. It was postponed due to the extremely cold temperatures over the continent at that time, which prevented the committee members from reaching Ottawa. Letters of evaluation were not sought either. I wish to thank Octav Cornea and Jacques Hurtubise, who kindly accompanied me to the meeting in Ottawa, as well as all of those who participated by phone; I trust we represented well how remarkable the CRM is. I am also very grateful to all of those who contributed to the preparation of the CTRMS application.

The application for the *Institute Innovation Platform* is nearing completion and has benefited from three meetings with NSERC officers, one in the presence of the committee members appointed to assess it.

We have also begun to focus on the renewal of the CRM's grant from Québec. There was a preliminary meeting of all the Directors of the *FRQNT Regroupements stratégiques* and there was a request for two one-pagers, which the CRM provided. The Letter of Intent is due by mid-May and the full proposal in October. I know that the CRM Laboratories and their Directors will actively collaborate to ensure that the CRM continues to be most successful again with this program. I also wish to acknowledge with gratitude the unwavering support of our partner universities, so essential to this success.

On the scientific front, we are delighted to witness the success of the current Theme Semester on New Directions in Lie Theory. Its winter schools proved tremendously beneficial. We applaud the spectacular results of CRM–ISM postdoctoral fellow James Maynard on gaps between primes, which received broad international attention. Other exciting developments in number theory will be showcased in the upcoming Theme Year, starting this summer with the *Séminaire de mathématiques supérieures*. We look forward to the inaugural CRM Nirenberg Lectures by Alessio Figalli coming up this May. We rejoice in the fact that the *Unité Mixte Internationale UMI-CRM* of the CNRS is highly regarded and has been awarded a remarkably high number of *délégations*. We congratulate with pride and admiration the current or past Montrealers, Daniel Wise, Niky Kamran and Derek Bingham, for the prestigious prizes they have received. You will learn about all this (and more) in the present *Bulletin*.

Happy reading, stay tuned!

Luc Vinet, Director

Winter 2014 Thematic Semester

New Directions in Lie Theory

As part of the ongoing thematic semester "New Directions in Lie Theory," two Winter schools were held: the first from January 6 to 17, and the second from February 24 to March 7, 2014. The first school featured two mini-courses, "Introduction to categorification" by Alistair Savage (Ottawa) and "Introduction to Kac–Moody and related algebras" by Erhard Neher (Ottawa). The second school presented a course on "Representations of semisimple and affine Kac–Moody algebras" by Vyjayanthi Chari (Riverside) and a course on "Vertex algebras for mathematicians" by Michael Lau (Laval). Both schools were a great success, with lectures supplemented by exercise sessions where students presented solutions to assigned problems. They attracted participants from across the globe, including Australia, Korea, France, Germany, Japan, the Netherlands, Spain, the USA and Canada. The accompanying photos show the participants of the first winter school with the instructors, Alistair Savage and Erhard Neher, and the participants of the second school with one of the instructors, Vyjayanthi Chari.