

SUBMISSION BY THE CENTRE DE RECHERCHES MATHÉMATIQUES TO THE LRP COMMITTEE

The *Centre de recherches mathématiques (CRM)* was founded at the Université de Montréal in 1969. It is now a national research institute chartered at the Université de Montréal with the major Québec universities, Université de Montréal, Université de Québec à Montréal, Université Laval, Université Sherbrooke, Concordia University and McGill University as academic partners. It is supported financially by the Federal Government, the Province of Québec and its Partner Universities. Together with the *Fields Institute* and the *Pacific Institute of Mathematical Sciences* it plays a pivotal role in the Mathematical Sciences in Canada. The CRM maintains a detailed website (crm.umontreal.ca) that is fully up to date on current events and lists past events back to 1999. The CRM works in close cooperation with the *Institut des Sciences Mathématiques (ISM)*, which it helped found. The ISM receives a grant from the Ministry of Education in Québec and is deeply involved in coordinating education at the graduate level for universities in the province.

1. The organization of scientific events is a primary activity of the CRM. These range in scope from thematic programs lasting from half a year a full year, to brief workshops (mostly week-long and occasionally weekend-long). They have a high impact both at the local and at the Canadian level since they bring in experts from all over the world to Canada to interact with our local community.

The CRM has an *International Scientific Advisory Committee (ISAC)* of prominent scientists. It has a crucial role in shaping the scientific direction of the CRM and approves all major scientific programs. Proposals for scientific activity received by the CRM undergo a preliminary evaluation by a *Local Scientific Committee* before being submitted to the ISAC.

1.1 Thematic Programs consist of term-long or year-long activities, and typically comprise a series of workshops, a postdoctoral and visitor program, and a series of linked graduate courses (in the departments) or mini-courses at the institutes. Occasionally a summer school forms part of the program. The subjects are chosen for their topicality and impact. They cover a broad spectrum of pure mathematics, applied mathematics and statistics, and also touch on an impressive number of related fields. Part of a theme activity are the CRM's prestigious *André Aisenstadt Chairs*. Outstanding mathematical scientists are nominated as chair holders and give a series of lectures over the course of one to two weeks, with one a public event aimed at a general audience.

The theme activities for 2010 were in

- *Number Theory as an Experimental and Applied Science* (spring)
- *Geometric, Combinatorial and Computational Group Theory* (fall).

Consult A.1 below in the appendix to gain a detailed representative picture of theme activities in a given year.

Future thematic programs have been planned through 2013:

- 2011 (Winter-Spring) *Statistics* (semester)
- 2011 (Summer-Fall) *Quantum Information* (semester)
- 2012 (Winter-Spring) *Geometric Analysis and Spectral Theory* (semester)
- 2012-2013 *Moduli Spaces, Extremality and Global Invariants* (year)
- 2013 *Mathematics of Planet Earth* (year)

1.2 The CRM supports a wide variety of shorter activities through its **General Program**. One example is the *Séminaire de Mathématiques Supérieures (SMS)*, a prestigious summer school that will celebrate its 50th anniversary this year with a school on *Metric Measure Spaces*. Long funded by NATO, it now receives support from ISM, Fields, PIMS and MSRI. A full list of activities in 2010 follows.

- First Montreal Spring School in Graph Theory, McGill, May 2-29, 2010.
- Colloque sur la génomique évolutive (ACFAS 2010), Univ. de Montréal, May 10, 2010.
- SMS-NATO Summer School/Advanced Study Institute in Quantum information processing and quantum cryptography, CRM, June 21 - July 2, 2010.
- 10th International Conference on Mathematics of Program Construction (MPC'10), Lac Beauport, June 21-23, 2010.
- 13th International Conference on Algebraic Methodology and Software Technology (AMAST 2010), Lac Beauport, June 23-26, 2010.
- International Conference on Image and Signal Processing ICISP 2010, UQTR, June 30- July 2, 2010.
- CNTA XI (Canadian Number Theory Association, XIth meeting), Acadia Univ., July 11-16, 2010.
- Workshop on Technology Integration in Teaching Undergraduate Mathematics Students, CRM, Oct. 1, 2010.
- 54e Congrès de l'AMQ "Mathématiques et environnement, c'est tout naturel", Rimouski, Oct. 22-24, 2010.
- Workshop on Mathematical Challenges for Sustainability, DIMACS, Nov. 15-17, 2010.

1.3 The **Multidisciplinary and Industrial Program** forms part of CRM's outreach to allied fields and industry. It should be noted that some theme activities also are very interdisciplinary in nature, as for instance the theme semester *Mathematical Problems in Imaging Science: From the Neuronal to the Quantum World* in 2009. The CRM is a driving force in the *Climate Change and Sustainable Development* program of the North American institutes and the upcoming worldwide *Mathematics of Planet Earth* initiative. A recurring activity in the industrial program is the *Industrial Problem Solving Workshop (IPSW)* taking place in the summer with industrial participation. Fields and PIMS have

similar programs and the IPSW now alternates between Montreal and Toronto. A list of all other activities follows.

- NICDS Workshop on Statistical Methods for Geographic and Spatial Data in the Management of Natural Resources, CRM, March 3-5, 2010.
- Conférence CRM-GIREF “Adaptation de maillages et estimation d’erreurs”, Quebec City, May 25-27, 2010.
- Micromacroscopic Systems: A Viability Approach (Course by J.-P. Aubin, Paris-Dauphine), CRM, Sept. 20-24, 2010.
- Joint CRM-GERAD-MITACS Workshop on Decision Analysis and Sustainable Development, CRM, Sept. 27-28, 2010.
- First North American Meeting on Industrial and Applied Mathematics, Vancouver, Dec. 8-10, 2010.

1.4 Roughly 1400 people participated in CRM workshops in 2010, almost half of them from abroad. The CRM makes an organized effort to obtain feedback from participants, particularly regarding the scientific impact of our activities. This is not an easy task, but some results can be found under A.2 in the appendix.

1.5 CRM, in association with ISM and GERAD, hosts two major weekly **Colloquium Series**, the *CRM-ISM Mathematics Colloquium* and the *CRM-ISM-GERAD Statistics Colloquium*.

2. In part jointly with professional societies and the other institutes, the CRM administers a number of **annual prizes** that recognize exceptional contributions in the mathematical sciences.

(1) *CRM - Fields - PIMS Prize*

(2) *André Aisenstadt Mathematics Prize*

(3) *CAP - CRM Prize in Theoretical and Mathematical Physics*

(4) *CRM- SSC Prize in Statistics*

3. **Outreach to the general public.** The *Grandes Conférences du CRM* are a regular lecture series that provides a window into the mathematical sciences to the general public. They are given by top flight scientists, but held to a level that keeps them very accessible to non-mathematicians. They have a faithful following with an attendance of two hundred or more at each event. The list for 2010 is

- Ivars Peterson (MAA), “Geometreks”, CRM, Feb. 4, 2010.
- Jean-Pierre Aubin (Paris-Dauphine), Graciela Chichilnisky (Columbia), Jean-Pierre Blanchet (UQÀM), “Table ronde sur le Développement durable et le rôle des scientifique”, CRM, Sept. 28, 2010.
- Cédric Villani (Lyon 1), “Quand la Terre était trop jeune pour Darwin”, CRM, Nov. 5, 2010.

Cédric Villani is a 2010 Fields Medalist.

4. The CRM Laboratories. Members of CRM are organized in ten research laboratories, each a research center in its own right. The CRM supplies financial support that is greatly leveraged through the use of individual grants of laboratory members. The laboratories significantly complement the CRM's scientific activities through regular seminar series, workshops, short conferences and by inviting research visitors. A *Committee of Laboratory Directors* is formally part of the CRM's administrative structure. The laboratories are an important source of ideas and initiatives for theme activities as well. In addition to their regular seminars the CRM laboratories organized the following workshops and conferences in 2010:

- Workshop on Virtual properties of 3-manifolds, UQAM, April 19-23, 2010.
- Workshop on Analysis of Multiphase Biomembranes, McGill, April 24-26, 2010.
- The Bellairs Workshop in Number Theory, Moduli Spaces and the Arithmetic of Dynamical Systems, May 2-9, 2010.
- Workshop on Bifurcation Analysis and its Applications, Concordia, July 7-10, 2010.
- LaCIM 2010: 20e anniversaire du laboratoire, UQÀM, August 29-31, 2010.
- GASCom 2010: Random and exhaustive generation of combinatorial objects, UQÀM, Sept. 2-4, 2010.
- CRM/Fields Montreal-Toronto Workshop in Number Theory, Sept. 4-5, 2010.
- Colloque "Méthodologie statistique contemporaine", Sherbrooke, Oct. 6-7, 2010.
- Colloquium on Surfaces and Representations, Sherbrooke, Oct. 6-9, 2010.
- CRM Workshop on Missing Data Approaches in the Health and Social Services, UQÀM, Oct. 22, 2010.

5. Postdoctoral Fellows. Since 1993, CRM jointly with ISM runs a prestigious postdoctoral fellowship program that currently brings each year to CRM or a Partner University four or five postdocs, selected through a competition, for two-year fellowships (there are thus normally between eight and ten CRM-ISM postdocs in residence each year). CRM and ISM together cover at least 50% of the fellowship costs. In addition, the CRM provides support to thematic program organizers for bringing two to four postdocs per year to Montreal. Here CRM provides 50% of the fellowship costs. As part of a cooperation agreement between CRM and the University of Ottawa, CRM and the university provide 25% of the fellowship costs of two postdocs (\$10K from CRM). Lastly, the CRM laboratories provide PDF support, varying from a small portion to 50% of the fellowship amount.

6. Training of HQP. An important feature of CRM's activities has been a widening of training opportunities available to graduate students and postdoctoral fellows. These range from mini-courses to spring and summer schools, and workshops (such as the Montreal Industrial Problem Solving workshop). A common feature of recent efforts in this area has been NSF funding, enabling American students and post doctoral fellows to participate. In addition, the Centre's ten laboratories run regular seminar series that are open to student participation where their research results can be presented to and

discussed with the local research community. A very special training opportunity for postdoctoral fellows is provided by a program, administered by the ISM, that brings the fellows as supervisors together with undergraduate students for summer research projects.

7. The CRM gives **support to the Canadian mathematical sciences community** by subsidizing the meetings of learned societies (CMS, CAIMS, SSC) and other periodic events like the Canadian Number Theory Association biannual meeting. It also supports AARMS in Atlantic Canada.

8. The CRM works in close **cooperation** with the other Canadian institutes (Fields, PIMS) and with other North American institutes in the mathematical sciences. This is set out in detail in the joint CRM-Fields-PIMS submission to the LRP.

9. International cooperation. The CRM has bilateral cooperation agreements with SISSA (Italy), with the applied wing of TIFR (India), with the (pure mathematics) School of Mathematics of TIFR (Mumbai, India). An agreement to establish a UMI (Unité Mixte Internationale) of CNRS at CRM has been signed and the first visitor will be coming this summer. The UMI is to be launched formally in September.

9. Funding. The CRM receives a federal grant of 1.2M from NSERC, a provincial grant of 605K from FQRNT, 646K from partner universities plus contributions in kind from Université de Montréal, 100K from ISM (contribution to the postdoctoral program), 50K from endowments. Other revenues include variable contributions to scientific events from other agencies and institutes (e.g., NSF, Clay, MITACS, MSRI) and income from publications and registrations.

APPENDIX

A.1 Thematic programs in 2010

The year began with a thematic semester in *Number Theory as Experimental and Applied Science* comprised of one conference, four workshops, three advanced courses and an Aisenstadt Chair lecture series.

- Course on Expander Graphs (E. Goren, McGill), Jan. 4 - Feb. 26, 2010.
- Course on Computational Aspects of Quaternion Algebras and Shimura Curves (J. Voight, Vermont), Jan. 4 - Apr. 30, 2010.
- Magma 2010 Conference on p-adic L-functions. Organizers: M. Greenberg (Calgary), X.-F. Roblot (Lyon I), M. Watkins (Sydney), C. Wüthrich (Nottingham), Feb. 22-26, 2010.
- Course on Point Counting and Cohomology (H. Darmon, McGill), March 1 - Apr. 30, 2010.
- Workshop on Graphs and Arithmetic. Org.: Winnie Li (Penn State), E. Goren (McGill), A. Granville (Montréal), March 8-12, 2010.
- Aisenstadt Chair: Akshay Venkatesh (Stanford), March 17-26, 2010.
- Workshop on Computer Methods for L-functions and Automorphic Forms. Org.: C. Citro (Seattle), B. Edixhoven (Leiden), M. Rubinstein (Waterloo), W. Stein (Seattle), March 22-26, 2010.
- Workshop on Computer Security and Cryptography. Org.: T. Lange (T.U. Eindhoven), K. Lauter (Microsoft Research), J. Silverman (Brown), April 12-16, 2010.
- Workshop on Counting Points: Theory, Algorithms and Practice. Org.: K. Kedlaya (MIT), J.-F. Mestre (Paris 7), April 19-23, 2010.

The 2010 Summer-Fall thematic semester focussed on *Geometric, Combinatorial and Computational Group Theory*. Five workshops, three Aisenstadt Chair lecture series and two series of "Lectures at the leading edge" made up the semester.

- Workshop on Geometric, Asymptotic, Combinatorial Group Theory with Applications (GAGTA). Org.: O. Kharlampovich (McGill), M. Sapir (Vanderbilt), N. Touikan (McGill) E. Ventura (U.P. Catalunya), Aug. 15-19, 2010.
- Lectures at the Leading Edge: Alex Lubotzky (Hebrew at Jerusalem), Aug. 15-19, 2010.
- Lectures at the Leading Edge: Efim Zelmanov (UC San Diego), Aug. 15-19, 2010.
- Workshop on Topics in Algorithmic and Geometric Group and Semigroup Theory. Org.: O. Kharlampovich (McGill), R. Gilman (Stevens Institute), A. Miasnikov (Stevens Institute), B. Steinberg (Carleton), N. Touikan, (McGill), Aug. 23-27, 2010.
- Workshop on Complexity and Group-based Cryptography. Org.: R. Gilman (Stevens Institute), A. Miasnikov (Stevens Institute), V. Shpilrain (CUNY), A. Ushakov (Stevens Institute), Aug. 30 - Sept. 3, 2010.
- Aisenstadt Chair: Yuri Gurevich (Microsoft Research), Sept. 13-17, 2010.

- Workshop on Group Actions and Dynamics. Org.: O. Kharlampovich (McGill), A. Miasnikov (Stevens Institute), D. Serbin (Genève), Oct. 4-8, 2010.
- Workshop on Equations and First-order Properties in Groups. Org.: O. Kharlampovich (McGill), A. Miasnikov (Stevens Institute), I. Kazachkov (McGill), V. Remeslennikov (Omsk), Oct. 11-15, 2010.
- Aisenstadt Chair: Alexander Razborov (Chicago), Oct. 11-15, 2010.
- Aisenstadt Chair: Angus MacIntyre (Queen Mary London), Oct. 18-22, 2010.

This semester also included ten mini-courses:

- Asymptotic cones, M. Sapir (Vanderbilt), August 2010.
- Quasi-isometric rigidity, D. Fisher (Indiana University), August 2010.
- Membership problems in group B. Steinberg (Carleton) and D. Serbin (Genève), August 2010.
- Algorithmic Group Theory, R. Gilman and A. Miasnikov (both Stevens Institute of Technology), September 2010.
- Group-based cryptography, V. Shpilrain (CUNY) and A. Ushakov (Stevens Institute), September 2010.
- Groups acting on R-trees, M. Bestvina (Utah), October 2010.
- Branch groups, V. Nekrashevich (Texas A&M), October 2010.
- Equations in solvable groups, N. Romanovskii (Novosibirsk), October 2010.
- Complexity of the diophantine problem in a free group, I. Lysenok (Steklov Institute, Moscow), October 2010.
- Generalizations of relative hyperbolicity, D. Osin (CUNY), October 2010.

A. 2 *Participants' feedback*

Two different questionnaires are used to collect information from participants after a CRM activity has been held.

The first is a "client-satisfaction" type questionnaire given to participants on the last day of a conference or workshop asking for feedback about the logistics and services offered during the activity as well as feedback about the scientific quality of the programming. The questionnaire is available online at: http://www.crm.math.ca/questionnaire/index_e.html. This questionnaire permitted us to improve substantially the computer services offered to participants a few years back. Since then the questionnaire responses have overwhelmingly given positive feedback.

The second deals with the scientific impact of CRM conferences and workshops. This questionnaire is used occasionally as it is best to wait for a year or two to see if developments occur (such as new collaborations). The data collected is qualitative since response rates for this type of questionnaire are regularly below 10%. The questionnaire sent during spring 2010 resulted in a 7% response rate (160 responses). Respondents gave information about new collaborations, new research projects launched as a result of participation, major results presented during the activity, and the impact of the activity on the given field or topic.

The responses to the three questions asked were quite wide in range. In their majority, they attest to a very positive impact on the respondents' scientific career. Quite a few, of course, are more neutral in this regard, but none are truly negative. We give a few excerpts from the responses received. Making a choice here is, of course, necessarily somewhat arbitrary.

Question 1: Did the event have a specific impact on your research work? Did the activity lead to the start of new research collaborations?

"It was my first conference on the subject, and it decided me to start my PhD in this field. The number of specialists, their disponibility convinced me to do so. I think the organization of the conference, for instance the long breaks, definitely encouraged interactions between students and top researchers."

"Yes, in the event I made contact with two researchers (Ibrahim Assem and Maria Jose Souto Salorio) and since then we are working in two papers."

"It had an impact not so much on my own research but on that of several of my graduate students who also took part in this event."

"The workshop provided a perfect up-to-date picture of recent development in the subject. It was one of the events that started an impressive series of analogous meetings under the common idea that contour dynamics can serve as a meeting point for complex analysts, probabilists and specialists in mathematical physics. Finally, it allowed the establishment of a new Birkhauser journal *Analysis and Mathematical Physics*."

"Yes. I had a lot of conversations in the field I rarely can discuss (Gromov--Witten invariants, moduli spaces) with a lot of specialists of very high level."

"My PhD student, who attended with me, and also spoke in a session, was greatly influenced by the meeting. He was motivated to take work that he and I had done and transplant it to an entirely different setting. This event was a catalyst for his development into an independent researcher. The wide remit of the conference, exposing him to broader issues than those he would see within a Department, enabled this to happen."

"The event did help me a lot in my research work in the sense that I learnt some combinatorial techniques that have proved very useful later on."

"It had a tremendous impact on my work. It led to a focused collaboration with a participant at the meeting, resulting in ongoing work on a computational toolbox for constrained continuation..."

“Oui. Un projet MITACS a été mis sur pied entre l'Université de Montréal et Tembec par l'intermédiaire de CanMET Énergie...”

“The workshop provided me with a good thesis research project for one of my students.”

“Yes, Yves Bourgault (U Ottawa) and I decided to start active collaboration regarding the electrical wave of the heart...”

“Yes, the event was my first contact with serious mathematical approaches to Biological systems and was critical in making a decision about my future line research.”

Question 2 : Were major discoveries announced at the event or directly result from the event?

“Discoveries in physics are rare. Future discoveries are less likely without meetings like these.”

“Dietmar Salamon gave an astonishing talk about the completely new Floer theory for hyperkaehler manifolds using hypercontact structures on the 3-sphere...”

“Yes. The construction of Yang-Mills instantons on curved backgrounds was announced at this meeting.”

“I think many mathematicians are reticent to describe their work as involving ‘major discoveries’. However I found the quality of invited speakers to be very high and the research presented by them was deep and broad; a very well-organized meeting.”

“Prof. Demailly’s work and his announcements concerning a possible approach to multiplier ideals due to Tsuji were very striking. It will take time to judge the significance.”

“Les exposés portaient effectivement sur la recherche de pointe. J'ai appris plusieurs éléments se rapportant à des découvertes récentes.”

“Major breakthroughs on the Lee-Huang-Yang formula (Lieb-Solovej), 2D lattice gases (Castin) and positivity of potentials (Seiringer-Lin) were announced.”

Question 3 : Is there any other impact that the event had on the field or question to which it pertains?

“This was the largest event ever organized worldwide in the subject of Symplectic Geometry and Topology, with 200 participants and a very nice Proceedings published in the CRM series.”

“For me the most valuable part of this event was active participation of many young researchers, in particular graduate students. I think this participation was very beneficial for them.”

“Given the diversity of the participants, there is no question in my mind that new directions in this field were initiated.”

“This meeting created a community and is likely to be one of a series of meetings on the Nahm transform.”

“Meetings like this are invaluable to my research not just for what I learn at them but also for the energy I bring back from the event.”

“The talks made me aware of a lot of work that I did not know before.”

“It brought together a large number of very active complex geometers, and, I think, played at least a partial role in the development of the field during the last few years. It was an important workshop.”

“The workshop was one of the few times this many researchers in this field were all together in one place at the same time.”

“This conference was arguably the best and most important conference in Quantum Chaos during the last five years or so. It brought together many of the world's top researchers...”