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A Retrospective of the Winter 2007 Thematic Semester: Recent Advances in Combinatorics

by F. Bergeron, S. Brlek, P. Leroux and C. Reutenauer (UQÀM)

The 2007 theme semester "Recent Advances in Combinatorics" took place at the CRM from January to June 2007. The focus was principally on three main areas: first, the interactions between algebraic combinatorics, algebraic geometry and representation theory, with an emphasis on the study of subjects such as the cohomology of Schubert varieties, Hilbert schemes, Gromov-Witten invariants, and their ties with symmetric functions such as Macdonald polynomials, as well as problems of enumerative geometry in the real, complex and tropical contexts; secondly, the algebraic aspects of combinatorics on words, focussing on their natural links to the study of free groups, free fields, free Lie algebras or to fine properties of continued fractions in relation to the study of Artin's billiards and real quadratic fields; finally, the relations between enumerative combinatorics and statistical physics, particularly the use of enumeration techniques for the study of gas models, Ising and Potts models, etc., with the specific purpose of computing phase transitions or thermodynamic limits. During the semester, five main workshops and four major schools took place, introducing junior mathematicians to the most recent developments in these areas.

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SMS 2007: Hamiltonian Dynamical Systems and Applications

by Walter Craig (McMaster University)

The 2007 NATO Advanced Study Institute took place during the two-week period from June 18 to June 29, 2007. It was held under the auspices of the Séminaire de Mathématiques Supérieures (SMS) at the Centre de Recherches Mathématiques (CRM), and supported by a grant from NATO and from the ISM, the combined graduate mathematics program of the Montréal area. The organisers were D. Bambusi (Milan), W. Craig (McMaster), S. Kuksin (Edinburgh), and A. Neishtadt (Moscow). There were more than 80 participants, coming from around the world, and in particular, groups of students from France, from Italy, from Spain, from the United States and from Canada were well represented. The program of lectures occupied two complete weeks, with five or six one-hour lectures each day, so that in total 57 hours of courses were presented.

The topic of the 2007 NATO-ASI was Hamiltonian dynamical systems and their applications, which concerns mathematical problems coming from physical and mechanical systems of evolution equations. Many aspects of the modern theory of the subject were covered, including low-dimensional problems

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Premier atelier de résolution de problèmes industriels de Montréal

par Odile Marcotte (directrice adjointe, CRM)

Au mois d'août 2007 s'est tenu pour la première fois à Montréal un atelier de résolution de problèmes industriels, dans la lignée des « study groups » conçus par le professeur John Ockendon de l'Université d'Oxford. L'atelier était organisé conjointement par le CRM, le GERAD, le rcm_2 (Réseau de calcul et de modélisation mathématique), le CIRANO, MITACS et le CIRRELT, et financé par MITACS et le rcm_2. Le comité organisateur était formé de Jean-Marc Rousseau (CIRANO et rcm_2, président du comité), Alan Bernardi (Laboratoires Universitaires Bell), Anne Bourlioux (Université de Montréal), Myriam Bouroche (Laboratoires universitaires Bell), Michel Gendreau (Université de Montréal), Alexandra Haedrich (MITACS), Pierre Hansen (HÉC Montréal), François Lalonde (Université de Montréal), Roland Malhamé (Polytechnique Montréal) et Odile Marcotte (GERAD et UQÀM). Seize chercheurs (dont un chercheur français, un chercheur de Toronto et un de Vancouver), 8 représentants de l'industrie et 42 étudiants ou stagiaires postdoctoraux ont participé à l'atelier.

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The Aisenstadt chair was held by Richard Stanley (MIT) who gave a series of conferences in March, on "Increasing and decreasing subsequences," "Alternating permutations" and "Some enumeration problems involving $\mathrm{GL}(n,q)$."

Richard Stanley

The semester started with the mini-workshop "Algebraic Combinatorics meets Inverse Systems," organized by F. Bergeron (UQÀM), K. Dalili (Dalhousie), S. Faridi (Dalhousie) and A. Lauve (UQÀM), which was held from January 19 to January 21. The focus of the workshop, which was a continuation of a sequence of successful such workshops held in Kingston (2004), Ottawa (2005), and Toronto (2006), was to unite two research communities whose interests are overlapping with increasing regularity. Each year has brought new connections and this year continued this trend. On the first day, both communities presented their research, while the second day saw quivers applied to questions in each community. As this sequence of workshops represents an attempt to get two communities with different languages and different interests to talk to one another, the tone and spirit has been (by necessity) friendly, patient, and cooperative, and this year was no exception. The impact of workshops such as this one, which create links between research communities and encourage the participants to acquire new languages, cannot be overstated.

This first workshop was followed by the school and workshop dedicated to "Statistical Mechanics and Combinatorics," organized by M. Bousquet-Mélou (Bordeaux), P. Leroux (UQÀM), T. Guttmann (Melbourne) and A. Sokal (New York), which took place from February 12 to February 23. The goal of the school was to introduce the basic methods of enumerative combinatorics and the concepts of statistical mechanics which are at the heart of the interactions between these two areas. The school was intended for graduate students, postdoctoral fellows and researchers wishing to be introduced to these questions. It was held in the Laurentians region, at the Far Hills Inn located in Val-Morin, Québec. The workshop has given rise to 24 expository and specialized talks on combinatorial problems raised by statistical mechanics, as well as 6 poster presentations. The topics covered included enumerative problems related to the classical models of statistical mechanics, self-avoiding walks, tilings, asymmetric exclusion processes, alternating sign matrices, plane partitions, multiple partitions, polymers and copolymers, Mayer's theory and graph weights, Potts model on graphs and Feynman diagrams.

The next events of the theme semester were the school and the workshop dedicated to "Combinatorics on Words," organized by S. Brlek (UQÀM), C. Reutenauer (UQÀM) and B. Sagan (Michigan State), which took place from March 5 to March 16. During the school, Jean Berstel (Université de Marne-la-Vallée) and Christophe Reutenauer (UQÀM) each gave a 10-hour lecture series. In his series of lectures entitled "Repetitions in words," Jean Berstel discussed the famous infinite word of Prouhet – Thue – Morse, discovered independently by those three mathematicians in 1851, 1912 et 1921, from very different points of view: Prouhet to solve a problem in arithmetic (that became known as the problem of Tarry and Escott), Thue for aesthetical reasons, and with the ultimate goal of solving different difficult problems (as he himself puts it), and Morse in relation with dynamical systems. There are applications of the Prouhet – Thue – Morse word to the towers of Hanoi problem, to magic squares, to algebraic series over fields of characteristic p, and to the Burnside problem. Berstel also presented his theorem on morphisms preserving square-free words, which allows the simplification of many constructions. The work of Crochemore, which gives an algorithmic characterization of the square-free morphisms and words, was also discussed. The lecture series concluded with a discussion of the notions of motive and of abelian square, and the work of Dekking and Currie – Visentin.

In his lectures, Christophe Reutenauer discussed the words of Christoffel. The main topics covered were: their definition by discretisation of finite intervals, following Borel – Laubie, Berstel and Osborne – Zieschang, and their equivalent definition by the Cayley graph of a cyclic group following Christoffel; the morphisms of Christoffel, which preserve the conjucacy classes of the Christoffel words and form a monoid; the theorem of Mignosi – Séébold and Wen – Wen, which shows that the generators are the positive automorphisms of the free group on two generators; the construction by palindromisation of the words of Christoffel; the Christoffel tree (Berstel – de Luca), which can be used to generate all those words, and its specialisation, the Stern – Brocot tree, related to Farey sequences; the conjugates of the words of Christoffel, which are the primitive elements of the free group on two generators; the relations between continued fractions and words of Christoffel, emphasizing their use in Markoff's theory of approximations of real numbers. In all the proofs presented, an effort was made towards (discrete) geometric approaches.

Most of the 48 participants to the school were also present at the workshop, and there were about 20 new participants. The main themes of the workshop were Sturmian words, which were discussed in the talks of J. Berstel (Marne-la-Vallée), V. Berthé (Université Montpellier II), A. Glen (UQÀM), P. Arnoux et S. Ferenczi (Institut de Mathématique de Luminy), A. Luca (Università degli Studi Napoli), and L. Vuillon (Université de Montréal); group theory, from the point of view of combinatorics on words, which was discussed in the talks of A. Miasnikov (McGill), D. Serbin (McGill) and A. Juhasz (Technion); sets of words which were discussed in the talks of G. Musiker (UCSD), B. Steinberg (Carleton) and D. Perrin (Marne-la-Vallée); infinite classical words, which were the subject

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The 2007 André-Aisenstadt Prize

by Gregory G. Smith (Queen's University)

What is a moduli space? Roughly speaking, a moduli space parametrizes a collection of objects; there is a bijection between the points in the space and the objects. However, not any bijection will do. The correspondence must be natural: as a point varies appropriately in a moduli space the corresponding objects should form a suitably nice family. For example, the Grassmannian $G(k, n)$ parametrizes k-dimensional subspaces of an n-dimensional vector space (over your favourite field). A point on $G(k, n)$ varies continuously if and only if the coefficients of the defining linear equations for the associated subspace vary continuously (in your favourite topology). Working over real numbers, this makes the Grassmannian into a compact real manifold of dimension $k(n-k)$. The key observation is that the geometry of a moduli spaces encodes families of objects. Category theory, especially representable functors, is needed to formalize these ideas. Although the precise definition is surprisingly short, it is conceptually difficult to internalize, so I will not include it here.

Moduli spaces play a central rôle in algebraic geometry. By design, a moduli space provides geometric structure to the objects it classifies. For the Grassmannian, this is relatively simple because the naive notion of nearby subspaces corresponds to neighbouring points on $G(k, n)$. Similar notions on the moduli space of curves $\mathcal{M}_g$, which parametrizes all isomorphism classes of smooth genus g projective curves, are substantially more involved (they require deformation theory). On the other hand, interpreting a given space as a moduli space elucidates its properties. For instance, the fact that each point on the Grassmannian corresponds to a vector space produces a tautological vector bundle on $G(k, n)$. Moduli spaces also arise naturally in an ever-widening number of fields, including combinatorics, string theory, complex analysis, representation theory and topology.

Below, I outline three projects that involve moduli spaces in different ways. The first constructs a parameter space, the second reinterprets certain varieties as moduli spaces and the third utilizes moduli spaces to define auxiliary gadgets. The projects also illustrate my affinity for algebraic spaces arising from combinatorial structures, such as toric varieties. These spaces provide an excellent computational environment. I enjoy implementing algorithms (typically in *Macaulay2*) to collect heuristic evidence and investigate conjectures. Indeed, all of the following projects benefited from computer calculations.

In a pair of papers, Diane Maclagan and I develop a multigraded variant of Castelnuovo – Mumford regularity. Intuitively, regularity measures the complexity of a module or sheaf. The regularity of a module approximates the largest degree of the minimal generators and the regularity of a sheaf estimates the smallest twist for which the sheaf is generated by its global sections. In the first paper [5], we work with modules over a polynomial ring graded by an abelian group. Our definition of regularity involves the vanishing of certain graded components of local cohomology. We establish the essential properties of regularity: its connection with the minimal generators of a module and its behaviour in short exact sequences. Using the dictionary between sheaves on a toric variety X and graded modules over the Cox ring (an appropriate multigraded polynomial ring), we prove that the regularity of an ideal sheaf on X bounds the multidegrees of the equations that cut out the associated subvariety. The connection to moduli spaces comes in the second paper [6]. Returning to Mumford's original motivation for regularity, we construct a space Hilb_X^P that parametrizes all subschemes of X with a given multigraded Hilbert polynomial $P \in \mathbb{Q}[t_1, \dots, t_r]$. This generalizes Grothendieck's Hilbert scheme which parametrizes subschemes of projective space. In a different direction, Milena Hering, Hal Schenck and I also use these techniques in [3] to provide new insights into the syzygies of projective toric varieties.

Gregory Smith receiving his prize from François Lalonde, director of the CRM

As the part of an ongoing project, Alastair Craw and I realize every projective toric variety X as a fine moduli space of quiver representations. More precisely, we introduce the multilinear series associated to a list $\mathcal{L} := (L_0, \dots, L_r)$ of line bundles on X and a choice of section in $H^0(X, L_j \otimes L_i^{-1})$ for $0 \leq i < j \leq r$. Combinatorially, the multilinear series is a bound quiver (Q, R); the vertices of Q correspond to the line bundles, the arrows in Q correspond to the sections and the ideal of relations R arises from binomial equations among the tensor products of sections. Generalizing classical linear series on X, the quiver Q defines a smooth projective toric variety $|\mathcal{L}|$

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of the talks of A. Blondin-Massé and S. Labbé (UQÀM), L. Balkova and P. Ambroz (Czech Technical University), A. Frid (Novosibirsk) and J. Cassaigne (Luminy). Finally, X. Provençal (UQÀM) talked about tilings of the plane by polyominos, and A. Fraenkel (Weizmann Institute of Science) applied combinatorics on words to a problem in game theory.

The next scientific events to take place during the theme semester were the school and workshop on "Combinatorial Hopf Algebras and Macdonald Polynomials," organized by M. Aguiar (Texas A&M), F. Bergeron (UQÀM), N. Bergeron (York), M. Haiman (Berkeley) and S. van Willigenburg (UBC), which took place from April 30 to May 11. During the school, the main speakers were M. Aguiar (Texas A&M), F. Bergeron (UQÀM) and M. Haiman (Berkeley). M. Aguiar discussed tensor categories, theory of species and graded Hopf algebras; F. Bergeron discussed symmetric functions, representation theory of finite groups and invariant theory (with an emphasis on the case of reflection groups), coinvariant spaces, harmonic polynomials and diagonal coinvariant spaces; M. Haiman discussed the Weyl character formula, algebraic representations of $\mathrm{GL}(n)$, Macdonald polynomials and Lascoux – Leclerc – Thibon polynomials, and combinatorial models for Macdonald polynomials. Written notes of all the lectures can be found at:

`karin.math.yorku.ca/~nantel/HopfAndMacdonald/`.

The workshop followed immediately the school. Many interesting new results were presented during the workshop, principally concerning the combinatorial models for Macdonald Polynomials and associated operators.

The school and workshop on "Interactions between algebraic combinatorics and algebraic geometry" took place from May 21 to June 1. The organisers were F. Bergeron (UQÀM), A. Geramita (Queen's), A. Knutson (Berkeley), R. Vakil (Stanford) and S. Faridi (Dalhousie). The goal of the school was the presentation of the basic methods of algebraic geometry for which there is a natural interaction with algebraic combinatorics, and of the tools of algebraic combinatorics that are of special interest for algebraic geometry. The three speakers were M. Vazirani (UC, Davis), E. Miller (Minnesota) and G. Smith (Queen's). M. Vazirani lectured on the representation theory of S_n, Hecke algebras, and affine Lie algebras, defining the basic objects, and explaining how an affine Lie algebra controls the rigid structure on the representation theory of S_n. E. Miller explained how modern combinatorial structures in algebraic geometry and commutative algebra hold the key to solving some old puzzles from classical complex variables. The lectures of G. Smith focused on toric varieties, discussing polytopes and their associated toric varieties, f-vectors and Hilbert functions, Minkowski sums and defining equations for toric varieties. The highlights of the workshop, which followed immediately the school, were the variations on the new combinatorial model for Macdonald polynomials of Haglund, Haiman and Loehr, and their relation with the Lascoux – Leclerc – Thibon polynomials.

The last activity of the theme semester was the workshop on "Real, Tropical, and Complex Enumerative Geometry," organized by V. Kharlamov (Strasbourg) and R. Pandharipande (Princeton), and described in detail on the article on page 11 of the present bulletin.

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as well as the theory of Hamiltonian systems in infinite-dimensional phase space and its applications to problems in continuum mechanics and partial differential equations. Applications to several important areas of research were also presented, including to celestial mechanics, control theory, partial differential equations of fluid dynamics, and adiabatic invariants.

Physical laws are for the most part expressed in terms of differential equations, and the most natural classes of these are in the form of conservation laws or of problems of the calculus of variations for an action functional. These problems can typically be posed as Hamiltonian systems, whether dynamical systems on finite-dimensional phase space as in classical mechanics, or partial differential equations (PDE) which are naturally of infinitely many degrees of freedom. For instance, the well-known n-body problem is still of great relevance to modern mathematics and more broadly to science; indeed in applications the mission design of interplanetary exploration regularly uses the gravitational boost of close encounters to manoeuvre their spacecraft (first used in the Mariner-10 mission, 1974). This is also true on the level of theoretical results, which can be traced to the work of Laplace, Lagrange and Poincaré, but whose modern successes date to the celebrated theory of Kolmogorov, Arnold and Moser (KAM) (1954/1961/1963). Recent mathematical progress includes the discoveries of new choreographies of many-body orbits (Chenciner and Montgomery, 2000), and the constructions of Poincaré's second species orbits (Bolotin and MacKay, 2001). Additionally, the last several years have seen major progress in the long outstanding problem of Arnold diffusion, with the advent of Mather's variational techniques (2003) related to a generalized Morse – Hedlund theory, Cheng's subsequent work, and the geometrical approach to the "gap problem" due to de la Llave, Delshams and Seara (2006).

Over the last decade the field of Hamiltonian systems has taken on completely new directions in the extension of the analytical methods of Hamiltonian mechanics to partial differential equations. The results of Kuksin, Wayne, Pöschel, Craig, Bambusi and Bourgain have introduced a new paradigm to the study of partial differential equations of evolution, where research focuses on the fundamental structures invariant under the dynamics of the PDE in an appropriate phase space of functions. Two basic examples of this direction of enquiry include

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Les Grandes Conférences du CRM de l'année 2006-2007

par Christiane Rousseau (Université de Montréal)

Les Grandes Conférences du CRM, cette nouveauté de l'hiver 2006, ont maintenant pris leur rythme de croisière avec trois conférences pendant l'année 2006-2007. Bart de Smit a entamé le cycle avec la conférence *The mathematics of Escher's Print Gallery* qui a eu lieu au Stewart Biology Building de McGill le 15 novembre 2006. Pendant l'hiver 2007, les Grandes Conférences se sont déplacées dans la belle salle du Pavillon Sherbrooke de l'UQÀM. Le 19 mars 2007, c'était au tour de Jean-Paul Delahaye de rejoindre le public montréalais avec *Les limites logiques et mathématiques*. La saison s'est clôturée le 3 mai avec la conférence de Francis Clarke, *Euler, la vie, l'univers, l'optimisation* célébrant le 300^{e} anniversaire de la naissance de ce grand mathématicien. Cette dernière conférence a été organisée en partenariat avec le Cœur des Sciences de l'UQÀM. Chacune des conférences a accueilli entre 150 et 200 personnes de tous les âges. Les vins d'honneur ont permis de poser des questions aux conférenciers en toute simplicité, de renouer avec d'anciens camarades d'universités et amis, et de faire la connaissance de personnes animées d'une bonne curiosité scientifique.

The mathematics of Escher's Print Gallery
par Bart de Smit, Universiteit Leiden

Qui d'entre nous n'est pas fasciné par l'œuvre d'Escher ? Cette fascination tient en grande partie à l'aspect mathématique de l'œuvre de cet artiste, qui n'avait pourtant aucune formation mathématique. L'une des gravures d'Escher, *Exposition d'estampes*, a particulièrement intrigué les mathématiciens parce qu'il n'a pas su la terminer. Enfants, nous avons tous été amusés par les couvercles de *La Vache qui rit* : sur la boucle d'oreille de la vache, on voit une vache, qui a une boucle d'oreille, sur laquelle on voit une vache, et ainsi de suite. Escher part d'une gravure du même type : un homme regarde un tableau dans une galerie, qui représente un homme regardant un tableau dans une galerie, etc. Comme pour le couvercle de *La Vache qui rit*, si on fait un zoom adéquat dans cette gravure, on retrouve la même image. En termes mathématiques, si on dénote les points (x, y) de l'image par les nombres complexes $z = x + iy$, on dira que l'image est invariante sous une transformation $z \mapsto Cz$ où C est une constante. Dans le cas de la gravure initiale d'Escher, la constante C est simplement un nombre réel positif plus petit que 1. Dans le cas de la Vache qui rit, la constante C a un argument non nul qui détermine la rotation nécessaire pour retrouver la même image après le zoom. Jusque là rien de bien spécial. Mais Escher applique une transformation à sa gravure initiale. Si bien que pour faire un zoom nous permettant de retomber sur le dessin initial, nous sommes emportés dans une spirale infinie. Escher a peint le début de sa spirale mais ne l'a pas achevée. C'est Hendrik Lenstra et Bart de Smit, deux théoriciens des nombres, qui ont montré comment compléter la gravure. Les transformations considérées sont des fonctions analytiques d'une variable complexe et elles ont donc la propriété remarquable de préserver les angles. Appliquons la transformation $z \mapsto Z = \ln z$ à l'image initiale. Puisque l'image initiale est invariante sous $z \mapsto Cz$, alors la transformée devient invariante sous la translation $Z \mapsto Z + \ln C$! Comme déjà la transformation $Z = \ln z$ est multi-forme avec une période de $2\pi i$ on obtient un pavage doublement périodique du plan avec la transformée de l'image initiale. On peut enrouler le plan pour en faire un cylindre dont le diamètre est donné par le segment $[0, 2\pi i]$ et alors l'image se répète une infinité de fois sur des petites tranches du cylindre. Mais on peut aussi enrouler le plan en biais et alors les images font des spirales infinies sur le cylindre. Ce collage revient simplement à faire $Z \mapsto \alpha Z$, α étant un nombre complexe choisi pour que l'image ait encore la période $2\pi i$. On applique la transformation inverse du logarithme complexe, soit la fonction exponentielle, et le tour est joué : on a bouché le trou de la gravure d'Escher. Vous venez de voir plusieurs formules ! C'est là que l'on voit l'art d'une conférence grand public qui se situe à plusieurs niveaux : Bart de Smit a expliqué les idées de la complétion de la gravure d'Escher sans aucune formule mathématique et pourtant les mathématiciens présents ont compris les ingrédients utilisés. La conférence était remarquable, tant par la qualité des explications que par les animations graphiques de très belle qualité.

Bart de Smit

Les limites logiques et mathématiques
par Jean-Paul Delahaye, Université des Sciences et Techniques de Lille

Plusieurs d'entre nous suivent chaque mois les chroniques de Jean-Paul Delahaye dans *Pour la Science*, et ont lu plusieurs de ses livres qui traitent aussi bien des nombres premiers que du fascinant nombre Pi ou encore d'informatique théorique. Jean-Paul Delahaye est un maître de la vulgarisation et il n'est pas étonnant que nous ayons été nombreux à nous pointer pour l'écouter parler des limites logiques et mathématiques. Même s'il est professeur d'informatique au Laboratoire d'informatique fondamentale de l'Université des Sciences et Techniques de Lille, Jean-Paul Delahaye se définit comme un mathématicien. Pendant son panorama d'une heure, Jean-Paul Delahaye a fait le tour des grandes questions de la logique qui ont ébranlé les mathématiciens et les informaticiens du 20e siècle. Après la découverte des paradoxes au début du 20e siècle, les mathématiciens ont senti un besoin de rigueur et la nécessité d'asseoir les mathématiques sur des bases solides. La logique mathématique est devenue une branche des mathématiques. Mais lorsqu'on est chercheur, ce qu'on trouve n'est pas nécessairement ce qu'on espérait trouver. Le mathématicien Kurt Gödel fut aussi surpris que les autres lorsqu'il démontra son fameux théorème de l'incomplétude de l'arithmétique de Peano : il existe des énoncés concernant les nombres entiers qui sont vrais mais indémontrables dans le cadre de l'arithmétique ! C'est également pendant le 20e siècle que nait l'informatique théorique. Il est important à ce chapitre de mentionner la contribution de Turing qui donne une définition révolutionnaire de fonction calculable : une fonction est calculable si et seulement si elle est calculable par un automate très simple appelé aujourd'hui machine de Turing. La difficulté d'un tel discours réside dans la définition même de fonction calculable, mais cette « définition » révolutionnaire tient toujours. Jean-Paul Delahaye a aussi fait le tour de plusieurs de ces grands problèmes de l'informatique dont les réponses sont surprenantes. Le problème de l'arrêt d'une machine de Turing en est un : lorsqu'on construit un programme, on aimerait bien savoir s'il va se terminer ou s'il va être coïncé dans une boucle infinie. Et on aimerait encore plus pouvoir programmer un ordinateur pour qu'il nous donne cette réponse. Malheureusement il a été démontré qu'il est impossible de programmer un ordinateur pour cette tâche.

Euler, la vie, l'univers, l'optimisation
par Francis Clarke, Institut Universitaire de Lyon

Francis Clarke, montréalais d'origine, a été directeur du CRM de 1984 à 1993. C'est lui qui a élevé le CRM au rang d'Institut national subventionné par le CRSNG et le FCAR. Il a également fondé l'Institut des Sciences Mathématiques qui coordonne les études supérieures en mathématiques à Montréal. Francis Clarke a relevé avec brio le défi que nous lui avions proposé, à savoir de souligner le 300e anniversaire de naissance d'Euler. Né le 15 avril 1707, Leonhard Euler est l'un des mathématiciens les plus prolifiques de tous les temps et la star mathématique incontestable du 18esiècle. Ses contributions couvrent un très large spectre des mathématiques allant de la théorie des nombres à celle des équations différentielles, en passant par la géométrie, l'optique et l'astronomie. Euler est notamment à l'origine d'une des idées les plus audacieuses de la science : le principe de moindre action, qui nous permet d'expliquer le monde en termes d'optimisation. La conférence a dressé un panorama de l'homme, de sa vie et situé ses contributions dans une perspective historique par rapport aux contributions de ses contemporains : Maupertuis, Lagrange, etc. Les concepts scientifiques et mathématiques ont été expliqués dans un langage simple et les exemples ont brillamment illustré la genèse des grandes idées qui ont révolutionné la science. Francis Clarke a présenté l'exemple célèbre de la colonne de Lagrange : quelle est la colonne de révolution de volume et de hauteur donnés qui est la plus résistante lorsqu'elle est écrasée par un poids ? On a faussement cru pendant longtemps que c'était la colonne cylindrique. La raison de cette erreur vient du fait que le profil de la meilleure colonne n'est pas lisse, mais a plutôt des angles. En fait, même si cela semblait surprenant au début, on reconnait maintenant que beaucoup de problèmes d'optimisation ou de contrôle ont des solutions non lisses ou encore discontinues. Dans un cadre moderne, Francis Clarke a illustré ceci par un exemple de modèle de gestion des pêcheries où c'est un contrôle discontinu qui donne les solutions optimales.

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and a map $X \to |\mathcal{L}|$. For each projective toric variety X, we prove in [2] that there exists $\mathcal{L}$ such that $X \to |\mathcal{L}|$ identifies X with the fine moduli space of stable representations for (Q, R).

Thirdly, Lev Borisov, Linda Chen and I describe the orbifold Chow ring for certain spaces. Inspired by physicists' orbifold string theories, the orbifold Chow ring is an algebraic cohomology theory for an orbifold or Deligne – Mumford stack. It is larger than the usual cohomology of the underlying space. The product structure on this ring arises from intersection theory on the moduli space of stable maps (i.e., Gromov – Witten invariants). The initial motivation for [1] was to compare the orbifold Chow ring of a simplicial toric variety with the Chow ring of a crepant resolution. To achieve this, we first develop the theory of toric Deligne – Mumford stacks. Modeled on toric varieties, a toric Deligne – Mumford stack corresponds to a combinatorial object called a stacky fan. Using this combinatorial data, we give an explicit presentation for the orbifold Chow ring of a toric Deligne – Mumford stack.

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Les premières années du CRM (1968-1971)

Une entrevue avec Jacques St-Pierre

L'histoire du CRM constitue une page importante de celle de l'Université de Montréal et quelqu'un devra l'écrire un jour. Dans cette perspective, nous avons demandé à Jacques St-Pierre, l'un des pionniers du CRM, de nous en raconter l'origine.

Au cours des années 66-67, la direction du Conseil national de recherche (CNR) à Ottawa, qui avait mis sur pied toute une série de laboratoires dans diverses disciplines, s'est posé la question : « N'y aurait-il pas lieu de faire quelque chose pour les mathématiques ? » Dans cette discussion générale, les idées allaient à droite et à gauche, comme de raison, et le recteur de l'Université de Montréal, monsieur Gaudry, qui faisait partie du conseil de direction du CNR, avait fait remarquer qu'un centre de recherches mathématiques, appliquées ou non, devrait avoir dans son voisinage des étudiants, parce que dans ce contexte-là les gens ne se servant pas d'autre chose que de papier, d'un crayon et de leur tête, il n'est pas nécessaire de monter un laboratoire, et le fait de placer pareil centre dans une université permettrait de développer chez les jeunes un intérêt pour les mathématiques. Cette idée a été retenue et on a convenu d'une formule qui, initialement, permettrait de mettre sur pied un groupe de mathématiciens, allant jusqu'à dix personnes, qui serait financé pendant cinq ans par le CNR avec l'idée que par la suite, l'université hôte accepterait de prendre la relève du financement.

Maintenant, on met ça où ? Comme à l'accoutumée dans ce genre de situation, Toronto disait : « On a tout ce qu'il faut pour accueillir ce projet », les gens de Colombie-Britannique déclaraient : « Il ne faut pas penser qu'à Toronto, il faudrait que ce soit nous un peu ». Pour poser la candidature de l'Université de Montréal, nous avons préparé un programme, en nous appuyant sur une équipe formée du chimiste Henri Favre, alors doyen de la Faculté des sciences, de Maurice L'Abbé, directeur du Département de mathématiques, de René J.A. Lévesque, directeur du Département de physique et de moi-même. En tant que directeur du Département d'informatique et de recherche opérationnelle, j'étais particulièrement sensible à la problématique des mathématiques appliquées et au fait que la recherche dans ce domaine soulève souvent des problèmes de mathématiques fondamentales. Finalement, en 1968, la décision a été prise au CNR de confier ce centre-là à l'Université de Montréal, étant entendu, bien sûr, comme c'était financé par le CNR, qu'il y aurait place pour des professeurs et des étudiants qui viendraient au CRM d'un peu partout au Canada. À ce moment-là, des moyens ont été pris pour diffuser l'information : le CNR a fait savoir partout au Canada qu'il y avait ce centre de recherches mathématiques qui était confié à l'Université de Montréal. Jusque-là, les centres de recherche étaient situés surtout à Ottawa, et l'idée de faire participer une université en particulier allait dans le sens d'un développement délocalisé des activités du Conseil.

Jacques St-Pierre

Une fois la décision prise, Maurice L'Abbé a eu la responsabilité de commencer à recruter des gens. Après avoir choisi comme directeur-adjoint Robert Brunet, un jeune professeur du Département de mathématiques, il a formé une première équipe de chercheurs : le mathématicien d'origine polonaise S.K. Zaremba, qui avait été attiré à Montréal par le Séminaire de mathématiques supérieures créé au Département de mathématiques au début des années 60, David Sankoff, qui terminait un doctorat en mathématiques à McGill sous la direction de Donald Dawson, et J. Patera, physicien mathématicien tchèque, qui avait déjà fait un stage au Département de physique quelques années plus tôt.

Quand Maurice L'Abbé est devenu vice-recteur à la recherche en 68, Gaudry m'a demandé de prendre la relève, d'aller recruter un mathématicien de grande qualité et de lui confier la responsabilité de meubler le Centre. L'Abbé et Gaudry ont tenté d'intéresser des gens de la Californie ainsi que des Français, mais à ce moment-là l'intérêt des Français, qui étaient venus ici au Séminaire de mathématiques supérieures, n'était pas de venir creuser les sillons et mettre le béton dans les formes pour construire l'édifice, mais plutôt d'attendre que tout soit en place. Il s'est avéré que ça ne marchait pas. Et Gaudry m'a dit : « Si on veut que ça marche, il faut que quelqu'un s'en occupe de façon active ». Alors, moi, à ce moment-là j'étais directeur du Département d'informatique et Gaudry m'a demandé de démissionner de ce poste, pour consacrer tout mon temps au développement du groupe de recherches mathématiques. Ce que j'ai accepté, un peu à mon corps défendant, en 69. Grâce à la correspondance que j'ai organisée d'une façon systématique avec les directeurs de départements de mathématiques, nous avons commencé à recruter un certain nombre de candidats intéressants. Comme, par exemple, Anton Kotzig et Karol Van Vliet. Kozig, un Slovaque, avait été le bras droit de Dubcek. Il avait réussi à quitter son pays et se trouvait en Amérique avec sa famille, parce qu'il avait des relations. Il s'est porté candidat et s'est avéré un mathématicien de grande qualité. Quant à Van Vliet, grand spécialiste de la mécanique statistique, il fut intégré au Département de physique, mais détaché en permanence au CRM.

Monsieur André Aisenstadt était un homme intéressant, de plusieurs façons. Après avoir fait un doctorat en physique mathématique à Zurich, il était venu au Canada, où il avait fait fortune dans l'industrie de la construction. C'était un mécène : il avait participé à la fondation du Festival de Marlboro en compagnie de ses amis Pablo Casals et Rudolf Serkin. Il a a vu dans les journaux qu'il y avait tout à coup des mathématiciens qui se retrouvaient à Montréal dans un centre de recherches, et ça l'a intéressé. Il a contacté Gaudry, qui lui a dit d'aller voir Maurice L'Abbé, qui lui a dit : « Il faudrait voir St-Pierre » ! Il nous a invités à tour de rôle dans l'un ou l'autre des grands restaurants qu'il fréquentait, et nous a déclaré qu'il serait prêt à financer une chaire. Il tenait, et il faut dire qu'il a réussi, à attirer au Centre des mathématiciens du plus haut niveau. La première Chaire André-Aisenstadt fut occupée en 1970.

J'avais accepté de diriger le CRM en 69 pour une période indéterminée, une année ou deux. Je l'ai quitté en 71, quand Gaudry m'a demandé de passer au secteur de la planification de l'Université, dont je suis devenu vice-recteur l'année suivante.

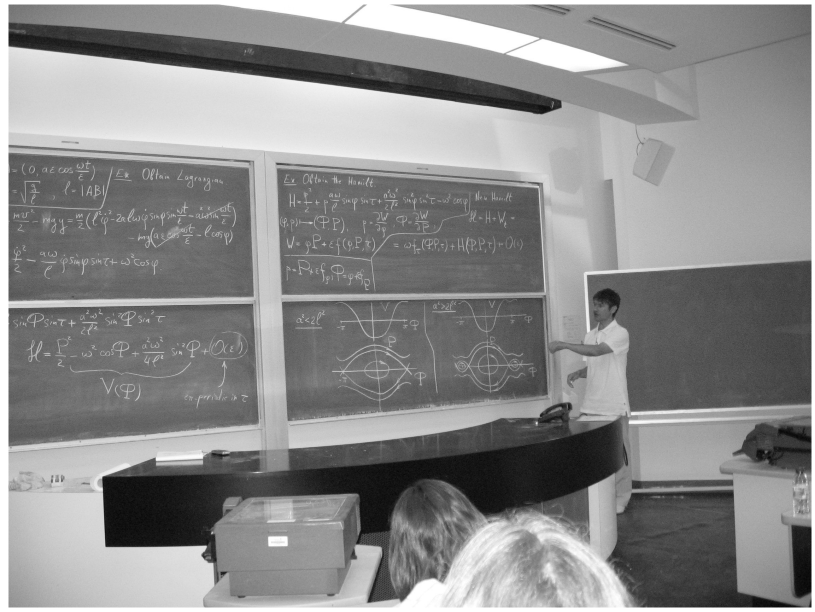
Propos recueillis par Jean LeTourneux

SMS 2007

(*continued from page* 4)

the development of KAM theory, and Nekhoroshev stability results, for systems with infinitely many degrees of freedom. These considerations show an exciting and extremely promising connection between Hamiltonian dynamical systems and harmonic analysis techniques in PDE. A case in point is the relationship between upper bounds on the growth of higher Sobolev norms of solutions of nonlinear evolution equations, and the bounds on orbits given by Nekhoroshev theory; similarly there is a possibly surprising connection between lower bounds on such growth and the existence of solution of PDE which exhibit phenomena related to Arnold diffusion. This research area of evolution equations and Hamiltonian systems is one of the most active and exciting fields of PDE in the last several years.

The subjects in question involve by necessity some of the most technical aspects of analysis coming from a number of diverse fields, and before our event there has not been one venue nor one course of study in which advanced students or otherwise interested researchers can obtain an overview and sufficient background to enter the field. What we have done with the Montréal Advanced Studies Institute 2007 is to offer a series of lectures encompassing the wide spectrum of topics in PDE and dynamical systems. Most of the major developers in this field were speakers at this ASI, including the top international leaders in the subject, which has made a unique opportunity for junior mathematical to hear a focused set of lectures given by major researchers and contributors to the field.



Dimitry Treschev (Moscow State University) lecturing on the nonlinear stability of the inverse pendulum under a periodic forcing.

In detail, the series of lectures of the 2007 ASI-NATO covered: Hamiltonian systems and optimal control (A. Agrachev, SISSA, Trieste); Birkhoff normal form and almost global existence for some Hamiltonian PDEs (D. Bambusi, Universita degli Studi di Milano); nonlinear oscillations in Hamiltonian PDEs (M. Berti, Universita degli Studi di Napoli); the n-body problem (A. Chenciner, Observatoire de Paris); variational methods for the problem of Arnold diffusion (C.-Q. Cheng, Nanjing University); the transformation theory of Hamiltonian PDE and the problem of water waves (W. Craig, McMaster University); geometric approaches to diffusion and instability (R. de la Llave, University of Texas at Austin); KAM for the nonlinear Schrödinger equation (H. Eliasson, Université de Paris 7); three theorems on perturbed KdV (S. Kuksin, Heriot-Watt University); averaging methods and adiabatic invariants (A.I. Neishtadt, Space Research Institute, Russian Academy of Science); periodic KdV equation in weighted Sobolev spaces (J. Pöschel, Universität Stuttgart); the forced pendulum as a model for dynamical behavior (P. Rabinowitz, University of Wisconsin); normal forms of holomorphic dynamical systems (L. Stolovitch, Université Paul Sabatier); Hamiltonian dynamical systems (D. Treschev, Moscow State University); infinite-dimensional dynamical systems and the Navier–Stokes equations (C.E. Wayne, Boston University); and KAM theory with applications to nonlinear wave equations. (X. Yuan, Fudan University).

Notes from each of the lectures, taken by the participants, are available on the CRM website of the SMS 2007. The lectures that took place at the 2007 NATO-ASI have been prepared for publication, and will appear in a volume published by Springer.

The "Yashafest" — Stanford, June 2007

by Samuel Lisi (Université de Montréal)

New Perspectives and Challenges in Symplectic Field Theory, a conference in honour of Yasha Eliashberg's 60th birthday, took place at Stanford University, 25 June to 29 June, 2007. The conference, colloquially known as "Yashafest," was organized by Miguel Abreu, Ralph Cohen, Sasha Givental, François Lalonde, Robert Lipshitz, Leonid Polterovich, and Rick Schoen, and was underwritten by the Mathematics Research Center (at Stanford University), the American Institute of Mathematics, the NSF, and the CRM. Yashafest was well attended, with over 130 participants, and drawing speakers from as far away as Sweden and Japan.

Reduced to its essence, Symplectic Field Theory (SFT) is the study of holomorphic curves in symplectic manifolds with cylindrical ends. It contains Gromov – Witten theory as the special case when the manifold has no ends, and symplectic Floer homology as the special case of holomorphic cylinders in the product of the closed symplectic manifold and a twice-punctured sphere. The general case, however, is far more subtle than either of these examples. In their seminal "Introduction to Symplectic Field Theory," Eliashberg, Givental and Hofer outlined the geometric phenomena which should occur in SFT. They also sketched a rich algebraic formalism, in terms of infinite-dimensional Poisson algebras, which captures these geometric phenomena. (The formalism is so rich, for example, as to lead to remarkable new examples of infinite hierarchies of integrable systems.) Since then, several other formalisms capturing parts of the SFT package have also emerged. These have led to striking relationships with other classes of invariants.

Despite the still limited understanding of its general technical underpinnings, SFT and related ideas have already had substantial practical impact. SFT and its immediate ancestors have provided the first modern tools for answering many questions of symplectic and contact topology. Applications include, for instance, distinguishing contact manifolds and their Legendrian submanifolds, answering classical existence questions for embedded Lagrangian submanifolds in symplectic manifolds, providing information about the contactomorphism group of contact manifolds and the symplectomorphism group of symplectic manifolds, revealing properties of closed Reeb orbits in contact manifolds (including many cases of the Weinstein conjecture), defining new topological invariants of three-manifolds and knots inside them, providing contact analogues of the symplectic non-squeezing theorems. Related fields include, among others, gauge theory and the many gauge-theoretic Floer homologies, Lagrangian intersection Floer homologies and cluster homology, enumerative invariants in algebraic geometry including Gromov – Witten theory and Donaldson – Thomas theory, quantum topology and string topology. Symplectic field theory, thus, touches on many other fields of modern geometry and topology. The conference touched on many of these, with talk topics ranging from foundational issues of symplectic field theory, to talks in related fields such as enumerative algebraic geometry, Floer homology, symplectic and contact topology, low-dimensional topology, and gauge theory. Many talks explored the often surprising and always rich connections between these fields.

Research talks were given by Dusa McDuff (Stony Brook), Helmut Hofer (Courant Institute), Gang Tian (Princeton), Dietmar Salamon (ETH Zürich), Ko Honda (Southern California), Emmanuel Giroux (ÉNS Lyon), Paul Biran (Tel Aviv), Claude Viterbo (École Polytechnique), Robert Gompf (Texas at Austin), Peter Osvath (Columbia), Eric Katz (Duke), Eleny Ionel (Stanford), Matthias Schwarz (Leipzig), David Gabai (Princeton), Rahul Pandharipande (Princeton), Kai Cieliebak (Ludwig-Maximilians), Tom Mrowka (MIT), Yong-Geun Oh (Wisconsin-Madison), Kaoru Ono (Hokkaido), Paul Seidel (Chicago), Cliff Taubes (Harvard), and Étienne Ghys (ÉNS Lyon). I would single out the talks by Cieliebak, by Taubes and by Ghys as representative of the breadth of topics covered.

Cieliebak presented a new construction he and Klaus Mohnke first announced last December whereby they define a version of the Gromov – Witten invariants without making appeal to the polyfold theory of Hofer, Wysocki and Zehnder. The idea is to introduce marked points to track intersections of pseudoholomorphic curves with a symplectic hypersurface of high degree (which exists by a result of Donaldson). This allows Cieliebak and Mohnke to overcome the classical difficulty of obtaining transversality in the presence of multiply covered spheres with negative Chern number.

Cliff Taubes presented his ground-breaking proof of the Weinstein Conjecture, establishing the existence of a periodic orbit for any Reeb vector field on any contact 3-manifold. His proof relates the existence of periodic orbits to that of solutions to a perturbed form of the Seiberg – Witten equations. This is closely connected to his ongoing project with Michael Hutchings to show that Seiberg – Witten Floer Homology and Embedded Contact Homology are equivalent. Despite the highly technical nature of the argument, he was able to provide an accessible overview of the key ideas, with some bonus tax advice on the side.

Étienne Ghys closed the conference with an engaging (and multimedia) talk about a new class of volume preserving flows, potentially the next class to consider beyond Reeb flows. Indeed, by a series of results (Weinstein, Rabinowitz, Hofer, . . ., Taubes) all Reeb flows in dimension three admit a periodic orbit. However, a construction due to G. Kuperberg gives the

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Atelier de résolution de problèmes industriels

(*suite de la page* 1)

De tels ateliers avaient déjà été organisés par l'Institut PIMS et le Fields Institute, mais jamais par le CRM. Le but principal de ces ateliers est de servir d'incubateurs pour des collaborations entre les entreprises et le milieu universitaire. Pour les chercheurs et les étudiants, il est fascinant de pouvoir s'attaquer à des problèmes concrets et de rencontrer des représentants de l'industrie. Pour les entreprises, ces ateliers ont de multiples avantages. Ils leur permettent de se faire connaître dans le milieu universitaire, de collaborer avec des experts canadiens ou étrangers en modélisation mathématique, d'acquérir de nouveaux points de vue sur des problèmes difficiles et de créer des liens durables entre les entreprises et les universités.

La planification et le déroulement d'un atelier de résolution de problèmes sont naturellement fort différents de ceux d'un atelier standard. Pour préparer l'atelier, il faut trouver des problèmes industriels concrets, proposés par des entreprises ayant besoin d'une expertise mathématique. Il faut ensuite recruter des chercheurs connaissant les domaines de ces problèmes et des étudiants désireux de participer à l'atelier. Les organisateurs doivent alors former des équipes comprenant des chercheurs, des étudiants et des représentants de l'industrie. Chaque équipe est affectée à un problème. Au début de l'atelier, tous les participants sont réunis dans la même salle, et les équipes présentent leurs problèmes respectifs. Les équipes travaillent ensuite chacune de leur côté. Au milieu de la semaine, tous les participants se réunissent pour faire un bilan provisoire de leur travail. Le travail en équipe se poursuit jusqu'à la fin de la semaine, où les équipes présentent les solutions trouvées.

Le premier atelier de résolution de problèmes industriels de Montréal a été conforme à ce modèle, mais il faut mentionner deux points qui le distinguent peut-être des autres ateliers de ce genre. Tout d'abord, à notre connaissance, c'est le seul atelier bilingue de ce type qui ait jamais été organisé. Trois des équipes ont travaillé en français et les autres en anglais. Cette caractéristique (ou qualité) complique évidemment l'organisation d'un atelier ! D'autre part, les problèmes examinés provenaient de domaines très divers, et faisaient appel à des techniques mathématiques très différentes les unes des autres. Les domaines en question sont la médecine, la vision par ordinateur, la planification d'entreprise, les transports, la fusion de données et la modélisation de procédés industriels. La majorité des étudiants participants étaient inscrits dans des universités montréalaises, mais l'atelier a aussi accueilli des étudiants de l'Université Laval, de l'Université d'Ottawa, de deux universités de l'Ouest canadien (University of Alberta et University of British Columbia) et de quatre autres universités ontariennes (Toronto, McMaster, Waterloo et University of Ontario Institute of Technology).

L'atmosphère conviviale de l'atelier et la qualité des interactions entre tous les participants ont assuré sa réussite. Pendant la semaine du 20 au 24 août, on pouvait voir les étudiants travailler avec zèle en face de leur ordinateur, soit dans les laboratoires, soit dans les aires communes du pavillon André-Aisenstadt. Le jeudi soir, après la pizza traditionnelle, presque tous les participants travaillèrent jusqu'à minuit pour préparer leurs présentations. La réussite de l'atelier est aussi due en grande partie à la collaboration des entreprises, et les organisateurs sont extrêmement reconnaissants aux entreprises suivantes de leur avoir fourni des problèmes stimulants : ART, Stellate, Matrox Electronic Systems, Kruger, Fédération des producteurs de lait du Québec, Lockheed Martin, Alcan et Hydro-Québec.

Les lecteurs désireux d'avoir plus de détails peuvent consulter le site `http://www.crm.umontreal.ca/probindustriels/`.

Les publications du CRM

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tard, *New Perspectives and Challenges in Symplectic Field Theory* (édité par M. Abreu, F. Lalonde et L. Polterovich), ainsi que *Combinatorics on Words* (rédaction par A. Lauve et F. Saliota des notes d'un cours donné par J. Berstel et C. Reutenauer), et, finalement, *Groups and Symmetries ; from the Neolithic Scots to John McKay* (édité par J. Harnad).

Le CRM ne s'est pas seulement associé à l'AMS pour publier ses livres. Un contrat avec Springer, au milieu des années 90, a permis la création d'une nouvelle collection, la *CRM Series in Mathematical Physics*, qui à ce jour compte huit volumes. Deux titres importants s'y ajouteront sous peu. En décembre sortiront les deux tomes de *Biology and Mechanics of Blood Flows*, l'ouvrage encyclopédique de Marc Thiriet sur la modélisation mathématique du système cardio-vasculaire. Et la prochaine année verra la parution de *Lectures on Random Matrices, Random Processes and Integrable Systems*, édité par J. Harnad. Notons enfin que le CRM a donné quelques titres à la collection *Lecture Notes in Statistics* de Springer.

Workshop on Real, Tropical, and Complex Enumerative Geometry — CRM, June 2007

by V. Kharlamov (Université Louis Pasteur) and R. Pandharipande (Princeton University)

The workshop on "Real, Tropical, and Complex enumerative Geometry," organized by V. Kharlamov (Strasbourg) and R. Pandharipande (Princeton), was held at the CRM from June 11 to June 22, 2007. The workshop was devoted to new developments in enumerative geometry, and in particular, to developments related to the recent appearance of tropical geometry and to a breakthrough in some enumerative problems over the reals, as well as to such recent ideas as string/gauge dualities which all pointed to new directions in enumerative geometry. All the fields mentioned above are developing very quickly, and one of the purposes was to bring together the people working in these different, but certainly closely related, directions, expecting that it will be helpful for further progress. To make familiar the important developments in these various directions, there were five series of introductory lectures by Jim Bryan, Carel Faber, Andreas Gathmann, Rahul Padharipande, and Jean-Yves Welschinger, in addition to advanced talks.

The main topics of the first week were the tropical and real enumerative geometries. A. Gathmann gave a series of four lectures on tropical geometry, and J.-Y. Welschinger gave a series of four lectures on real (symplectic) enumerative geometry. Both lecturers succeeded, not only to provide a thorough introduction into the corresponding subjects, but also to expose new results and new techniques. In the case of Gathmann, it was a new tropical intersection theory, and in the case of Welschinger it was a new method of computations and study of Welschinger invariants by means of symplectic field theory. Besides the specialized talks of the first week, it is worth to mention: Berkovich's talk making a bridge between tropical varieties and Berkovich non-Archimedian spaces; Itenberg's and Brugalle's talks devoted to Caporaso – Harris like formulas for Welschinger invariants in projective plane and, respectively, projective 3-space; Payne's talk on functoriality in tropical geometry; Markwig's talk on applications of tropical intersection theory for the proof of Kontsevich recursive formulas; and Parker's talk introducing a new enchanced, called by him exploded, tropical geometry. But the most sensational were the talks by J. Solomon who found completely new recursive formulas which combine Welschinger invariants with Gromov – Witten invariants. These formulas lead to a new kind of PDE close by their nature to WDVV equations; to discover their algebraic meaning is now an intriguing and challenging question.

The main topics of the second week were complex enumerative questions. The lecture series were delivered by C. Faber, J. Bryan, and R. Pandharipande. Faber gave an exposition of his work with Aluffi on a more or less complete description of the degree of the orbit of a plane curve (in the projective space of plane curves). The methods were classical. Bryan gave three lectures on modern questions. The first two concerned Donaldson – Thomas theory and the crepant resolution conjecture for quotient stacks. An outcome is closed formulas for box counting in new geometries (extending the classical MacMahon function). The last concerned again the crepant resolution conjecture and Hurwitz – Hodge integrals. Pandharipande's lectures started with the algebraic foundations of the virtual cycle and then moved to threefold theories: the GW/DT correspondence and then a new theory of stable pairs for threefolds (developed with R. Thomas). Among other complex geometry lectures: Zinger spoke about computing virtual contributions by deforming sections, and Maulik spoke about the connections between GW theory and Noether – Lefschetz loci for K3 surfaces. Shadrin explained Givethals theory of semisimple quantum cohomology with new applications to r-spin curves. There were also some computational talks by Sturmfels and Sottile during the second week of the workshop.

The "Yashafest"

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existence of a volume preserving flow on the 3-sphere with no periodic orbits. To define this new class, Ghys built on Arnold's asymptotic Hopf invariant. Using this, he then sketched a proof that, in a suitable sense, the periodic orbits in the Lorenz attractor form an "infinite fibred link," with a "fibration" compatible with the flow.

The conference also featured a mini-course in Symplectic Field Theory, aimed at graduate students (but well attended by all). Tobias Ekholm (Uppsala), Fréédéric Bourgeois (Université Libre de Bruxelles), Josh Sabloff (Haverford College) and Katrin Wehrheim (MIT) provided a lucid overview of various aspects of SFT, presenting new insights and new interpretations of the various elements of the theory. I have great hope the conference proceedings will contain survey articles on these topics, and thus become a much-needed user's guide to SFT. These will appear in the series "CRM Proceedings and Lecture Notes," published by the American Mathematical Society.

The banquet held in honour of Yasha Eliashberg's birthday was well attended, and featured the customary roast. It was clear, during the roast and throughout the conference, that Yasha is highly esteemed not only for his habitually innovative mathematics, but also for his warmth, generosity and great kindness. Happy birthday Yasha!

Short Program on Moduli Spaces of Riemann Surfaces and Related Topics — CRM, June 4 to June 15, 2007

by Marco Bertola and Dmitry Korotkin (Concordia University)

The theory of moduli spaces is centuries old: moduli spaces of Riemann surfaces, Hurwitz spaces (spaces of meromorphic functions on Riemann surfaces), spaces of holomorphic differentials, etc. With the advent of string theory in the past 40 years, the theory of moduli spaces became of interest to a larger community of researchers as a result of its application to physics. Moduli spaces play a central rôle in physics, prominently in Polyakov's formulation of perturbative string theory as well as other areas such as dynamical systems, statistical mechanics, random matrices, integrable systems etc, where Riemann surfaces naturally appear depending on parameters and hence requiring moduli–space techniques.

Topological field theory led to the development of the theory of Frobenius manifolds by Dubrovin, which turned out to be also closely related to moduli spaces inasmuch as the "prepotential" (suitably shifted in carefully chosen arguments) appears to coincide with generating functions of various "intersection numbers," namely certain fine topological information about the moduli space.

The theory of moduli spaces has many different aspects: analytical, differential geometric, algebro-geometric, group theoretical etc. The fast growth of the theory of moduli spaces in various directions has led to increasing specialization of researchers working on these different aspects of the theory. It was one of the main goals of the short program to bring together experts studying moduli spaces from different points of view, and to provide to non-specialists a well–rounded introduction to the topic. This twofold goal dictated the format of the sessions: the mornings were devoted to lecture series of a more pedagogical nature on the main subjects of the conference while the afternoons were reserved for communications of a more specialized nature.

The pedagogical series of lectures by I. Biswas, I. Morrison and R. Vakil were devoted to algebro-geometrical approach to moduli spaces. R. Vakil gave a general introduction to the algebro-geometric theory of moduli spaces and Hurwitz spaces. I. Morrison gave an introduction to the birational geometry of moduli spaces of pointed curves, while I. Biswas studied the moduli spaces of holomorphic connections over Riemann surfaces and their relationship with moduli spaces of Higgs bundles, moduli spaces of stable vector bundles and related applications.

A very accessible introduction to Teichmüller spaces and their differential geometric properties was given in the lecture series of S. Wolpert, devoted to the CAT(0) geometry and relationship between geometric properties of moduli spaces with spectral properties of Laplacian over Riemann surfaces and geodesic lengths. The lecture series of by R. Penner was devoted to ideal cell decompositions of decorated moduli spaces invariant with respect to the action of the mapping class group, and related topics. Relationship between moduli spaces, integrable hierarchies and Frobenius manifolds was discussed by B. Dubrovin, who discussed the surprising connection between the generating function of certain topological invariants of moduli spaces and the so-called prepotential of certain Frobenius manifolds. In a similar spirit, the lectures of T. Milanov were devoted to computation of Gromov – Witten invariants for orbifolds, and proving the Toda conjecture for the generating function of these invariants.

S. Lando presented a solution of the classical combinatorial problem of computation of Hurwitz numbers, i.e., the numbers of inequivalent coverings of Riemann sphere with given branch points. The answer to such question can be given in terms of various cohomology classes.

The series of lectures given jointly by L. Takhtajan and P. Zograf was devoted to the links between differential geometry of moduli spaces and spectral properties of the Laplacian operator on a Riemann surface. P. Zograf described the connection between the Weil-Petersson metric on moduli spaces of Riemann surfaces and the determinant of the Laplacian. He also presented a new analogue of this result, showing that the Kähler potential of a natural Kähler metric on Hurwitz spaces is also given by the determinant of a certain differential operator. L. Takhtajan presented also new results on moduli of parabolic vector bundles over Riemann surfaces.

With the morning session providing a comprehensive overview of the multifaceted aspects of moduli spaces, the audience had a solid background enabling to follow more closely the specialized talks given during the afternoon sessions. Five talks (T. Grava, C. Hertling, S. Shadrin, V. Shramchenko, I. Strachan) were devoted to Frobenius manifold structures associated to moduli spaces.

In several other talks (P. Zograf, L. Takhtajan, A. Kokotov, A. McIntyre), the speakers discussed relationship between spectral properties of moduli spaces (the determinant of the Laplacian) and moduli spaces. In the talk by C. Klein, the determinant of the Laplacian was used as a Morse function on the moduli space of genus two Riemann surfaces in order to find some topological information via Morse theory.

The problem of computation of Hurwitz numbers was addressed in the talks of M. Shapiro, I. Goulden and M. Kazarian. L. Chekhov discussed natural ways of quantizing the Poisson algebra of geodesic functions on the Teichmller space of Riemann surfaces with punctures and holes. I. Itenberg gave an overview to the rapidly growing area tropical geometry.

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Recent Workshops

The "Xth International Workshop on Differential Equations, Number Theory, Data Analysis Methods and Geometry," organized by S.T. Ali (Concordia) and R. Rodriguez Ramos (Havana) was held in Havana from February 19 to February 23, 2007. This was the 10th anniversary meeting of an annual series of activities that have been organized since 1998. The focus of these meetings have been in the areas of differential equations, signal processing, quantization and composite systems. This year the scope was widened to include number theory and integrable systems as well. The objective of these meetings is mainly to provide Cuban researchers and students with an opportunity to interact with mathematicians and physicists from outside Cuba, in order to help the development of collaborations and exchanges. Simultaneously, these meetings have provided opportunities for research groups from Canada, Europe and Latin America to network with Cuban mathematicians. The meeting this year was widely attended and brought together some of the leading experts in the domains represented.

The workshop "Groups and Symmetries: From the Neolithic Scots to John McKay," organized by J. Harnad (Concordia) and P. Winternitz (Montréal), took place at the CRM over a three day period (April 27 – 29, 2007). The talks covered a wide range of topics, with principal focus given to two of the areas in which John McKay has made pioneering contributions: "Monstrous Moonshine" and the "McKay Correspondence." The speakers were D. Allcock (Texas at Austin), P. Boalch (École Normale Supérieure), J. Conway (Princeton), H. Darmon (McGill), J.A. Devoto (Buenos Aires), I.V. Dolgachev (Michigan), C. Dong (UCSC), J. Duncan (Harvard), N. Elkies (Harvard), N. Ganter (UIUC), E. Goren (McGill), V. Gritsenko (Lille), G. Hart (Stony Brook), N. Katz (Princeton), Yu. Manin (Max-Planck), J. Morava (Johns Hopkins), M. Ram Murty (Queen's), I, Nakamura (Hokaido), V.V. Nikulin (Liverpool), S. Norton (University of Cambridge).

John McKay and Yousuke Ohyama (Osaka) working on a hands-on activity in which the participants jointly constructed a four-foot diameter sculpture made of sixty icosahedrally arranged components, and which can be considered as a physical presentation of the symmetry group. The sculpture is the work of George Hart (Stony Brook), and made up from laser-cut wooden parts.

The general areas included were: moonshine and monster, McKay correspondence, number theory, modular functions, group representations, Galois theory and algebraic geometry. A volume based upon the invited talks plus a number of additional refereed contributions will be published in the *CRM Lecture Notes and Proceedings* in 2008.

The minicourse: "Advanced Numerical Techniques in Applied Dynamical Systems" and the workshop: "Advanced Algorithms and Numerical Software for the Bifurcation Analysis of Dynamical Systems" organized by E. Doedel (Concordia) and H. Osinga (Bristol) took place at the CRM from June 30 to July 6, 2007. During the minicourse, the lectures of E. Doedel, Y. Kuznetsov, D. Roose and A. Vanderbauwhede presented the basic concepts and algorithms of numerical bifurcation analysis, including examples of actual use of the available software packages AUTO-07p, MatCont, and DDE-BifTool. This was followed by work sessions where the the participants could have hands-on experience with the software packages. The workshop followed immediately after the minicourse, and was organized in daily themes that consisted of an introductory survey talk followed by more technical presentations with new material. About one third of the speakers were asked specifically to give a "demonstration" rather than a "lecture." The demonstration focussed on working with a particular software package, or showing details of the implemented codes, while solving problems of interest. This format was found to be very successful, as it stimulated subsequent discussions. The workshop strengthened existing research connections and initiated new work. Samples of new directions or new projects starting during the extended workshop period include: new algorithms and their implementation for the continuation of generic and non-generic branch points in boundary value problems; implementation and use of methods for detecting homoclinic and heteroclinic connections between periodic orbits; the theoretical study of methods for the computation of invariant manifolds; two-parameter continuation methods, specifically in the context of computing Arnol'd tongues; study of new bifurcation phenomena in population models.

The workshop on the "Geometry of Holomorphic and Algebraic Curves in Complex Algebraic Varieties," organized by X. Chen (Alberta), J. Lewis (Alberta) S. Lu (UQÀM) and P. Russell (McGill), was held at from April 30 to May 4, 2007. The past decades have seen several major breakthroughs in our understanding of the structure of algebraic varieties both from the algebraic geometric side and from the complex analytic side. A major intersection of the two sides has to do with certain structural conjectures of Serge Lang that have catalyzed some of these advances. The conjectures are natural extensions of questions originating in hyperbolic geometry on the role of curvature in the distribution and behavior of curves and by analogy, rational points, in algebraic varieties. The aim of the workshop was to bring together experts in this area for an interaction on an international scale to expound the new ideas and to introduce the rapid developments to a new generation of mathematicians. This conference is intended as a small memorial to Serge Lang. The workshop was organized around a five day schedule for 28 speakers, alternating between algebraic geometry, complex geometry and some related arithmetic geometry. The principal speakers were E. Viehweg (Duisburg-Essen), F. Bogomolov (Courant Institute) and Y. Miyaoka (Tokyo) on the algebraic side; H. Esnault (Duisburg-Essen), Y. Tskinkel (Göttigen) and S. Saito (Tokyo) on the arithmetic side; J.-P. Demailly (Grenoble), B. Shiffman (John Hopkins), R. Kobayashi (Nagoya) and J. Winkelmann (Bayreuth) on the complex analytic side.

The "International Conference on Banach Algebras," organized by F. Gourdeau (Laval) and T. Ransford (Laval) was held at Université Laval from July 4 to July 12, 2007. There were 113 participants, including 40 graduate students and postdoctoral fellows. The plenary speakers were D. Blecher (Houston), I. Chalendar (Lyon), G. Dales (Leeds), J. Esterle (Bordeaux), P. Gorkin (Bucknell), M. Neufang (Carleton), N. Ozawa (Tokyo and UCLA), A. Pirkovskii (Moscow), C. Read (Leeds), S. Treil (Brown), G. Willis (Newcastle NSW).

This conference was the eighteenth in a series of international conferences in Banach algebras that started in 1974 at UCLA. These conferences have led to many fruitful interactions between the neighboring areas of Banach algebras, operator theory, operator spaces, harmonic analysis (both commutative and non-commutative), topological homology and amenability. Towards the end of the conference, there was an hour-long problems session, where participants had the opportunity to make short presentations of open questions. These problems have been posted on the conference website at `http://newton.mat.ulaval.ca/ba07/`.

The workshop "Statistical Methods for Modeling Dynamic Systems," organized by D. Campbell (McGill) and J. Ramsay (McGill), was held at the CRM from July 9 to July 13, 2007. The goals of the workshop were: to discuss statistical aspects of working with dynamic systems as models, including parameter estimation, confidence regions for parameters, and tools for selecting models; to exchange among researchers working in diverse areas of application about statistical problems encountered; to introduce researchers in statistics to the area of dynamic systems modeling; to provide information about latest developments in computation and statistical methodology in this area. The highlights of the workshop included presentation of recent computational advances by L. Biegler (Carnegie Mellon) and J. Schlöder (Heidelberg); exciting displays of new dynamic modeling problems in psychology by S. Chow (North Carolina) and J. Spencer-Smith (Illinois); the discovery that almost all dynamic systems over a wide range of areas were of the first-order bilinear form $DX = AX + X'BX + CU$; the use of dynamical phenomena such as bifurcations and limit cycles to explain apparent behavior in physiological and ecological systems and the need to for statistical methods targeted at confirming these in a quantitative manner; the presentation of recent work read to the Royal Statistical Society on collocation methods for system and parameter estimation by Campbell, Cao, Hooker and Ramsay.

Moduli Spaces

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J. Hurtubise gave a talk on relation between moduli spaces of monopoles and calorons and a special subclass of Hurwitz spaces. The relation between intersection theory on the spaces of r-spin curves and integrable hierarchies of KdV-type equations was discussed in the talk of D. Zvonkine. I. Artamkin discussed differential equations satisfied by generating functions of modular graphs. The talk of S. Abenda was devoted to the properties of geodesics on quadrics and their relationship to hyperelliptic curves. E. Previato discussed various relations (identities of the Fay type, differential equations) for a special class of hyperelliptic curves called Burchnall – Chaundry curves. R. Wentworth surveyed recent activity in the study of surface group representations into symmetric spaces.

Several of the talks were reserved to younger participants in the form of "short communications" of 40 minutes: B. Safnuk explained how localization technique from symplectic geometry can be applied to cohomology calculations on moduli spaces; R. Albuquerque described the properties of the symplectic twistor space associated to a Riemann surface; V. Przyjalkowski discussed the Gromov – Witten theory for the minimal Fano varieties; N. Do showed the audience a new path to Witten's conjecture going via hyperbolic geometry; the talk by E. Gorsky was devoted to an equivariant Euler characteristic of moduli space of genus two Riemann surfaces with punctures; T. Baird spoke about moduli spaces of flat connections over nonorientable surfaces; finally, D. Klein discussed the Goldman flows on these moduli spaces.

The short program then encompassed a very natural combination of the pedagogical and research components. The majority of the lecture series and research talks led to substantial discussion among the participants. The lecture series given by S. Wolpert and L. Takhtajan, as well as the results on new Kähler metrics on Hurwitz spaces reported by P. Zograf were specially impressive. To the junior participants, the conference represented a unique opportunity to be exposed to the international research in their field and to establish scientific contacts at the beginning of their academic career.

News from the Laboratories

Analysis Laboratory

François Germinet, Professor of Mathematics and Vice-Principal for Research at University of Cergy-Pontoise, gave a 10-hour mini-course on "A basic introduction to random Schrödinger operators" at McGill University from July 19 to July 23, 2007. The course was aimed at a relatively large group of advanced undergraduate students involved in summer research projects with the McGill Analysis group, and its goal was to expose students to state of the art research results in the theory of random Schrödinger operators. It has been predicted since the Nobel prize winning work of Anderson in 1958 that a Schrödinger operator with a random potential should exhibit dense pure point spectrum provided the disorder is large enough. The purpose Germinet's lectures was to present the basic elements of the theory of random Schrödinger operators together with a pedestrian proof of this fact. The topics covered in the course included: location of the spectrum and ergodic properties; generalized eigenfunctions; density of states and Wegner estimate; and multiscale analysis. The preparatory material for the course was taught by Eugene Kritchevski and Vojkan Jaksic (McGill). Germinet's course is now followed by year long research seminar at McGill dealing with various aspects of the spectral theory of random Schrödinger operators.

CICMA Laboratory

Andrew Granville (Université de Montréal) was the recipient of a Lester R. Ford Award (2007) of the Mathematical Association of America. He was also the first Canadian mathematician to be invited to give one of the named lectures of the American Mathematical Society, the Erdős Memorial lecture, which was held in Davidson, NC, in March 2007.
Henri Darmon (McGill) gave the Kuwait Foundation Lecture at Cambridge University in 2007.

Applied Mathematics Laboratory

Tucker Carrington has been appointed to a Tier I Canada Research Chair at Queen's University, Ontario. The chair is entitled "Computational Quantum Dynamics."
Nilima Nigam (McGill) was one of 50 recipients across Canada of an NSERC Discovery Accelerator Supplement, valued at $40,000 per annum for three years.

Statistics Laboratory

Christian Genest (Laval) is the president of the Statistical Society of Canada (SSC) since July 2007. One of the important task of the new president will be the organisation of the joint congress SSC – SFdS (Société française de statistique) in May 2008. The president of the scientific committee, Bruno Rémillard (HÉC Montréal) will assist him in this task. The Université Laval was chosen as the site of the 2010 Congress of the SSC, and the president of the local committee is Thierry Duchesne (Laval). Sorana Froda (UQÀM) was elected member of the International Institute of Statistics. The retirement of Jim Ramsay (McGill) has been underlined during the workshop "Statistical Methods for Modeling Dynamic Systems" in July 2007.
The Statistics Laboratory will organise the workshop "Using Statistics for the management of natural resources" at the CRM on October 19, 2007. The main speakers will be Anne-Catherine Favre (INRS-Eau) and Luc Perreault (IREQ).

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) de l'Université de Montréal a vu le jour en 1969. Présentement dirigé par le professeur François Lalonde, il a pour objectif de servir de centre national pour la recherche fondamentale en mathématiques et dans leurs applications. Le personnel scientifique du CRM regroupe plus d'une centaine de membres réguliers et de boursiers postdoctoraux. De plus, le CRM accueille d'année en année un grand nombre de chercheurs invités.

Le CRM coordonne des cours gradués 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 perfectionner 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 de notre mission : le Conseil de recherches en sciences naturelles et en génie du Canada, le Fonds québécois de la recherche sur la nature et les technologies, l'Université de Montréal, l'Université du Québec à Montréal, l'Université McGill, l'Université Concordia, l'Université Laval, l'Université d'Ottawa, ainsi que les fonds de dotation André-Aisenstadt et Serge-Bissonnette.

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Les publications du CRM

par Jean LeTourneux

En 1974 sortait des Presses de l'Université de Montréal (PUM) *Physical aspects of Lie group theory* de R. Hermann, le premier livre publié par le CRM depuis sa fondation en 1968. Cette monographie réunissait les conférences Aisenstadt données au Centre par l'auteur. Quelques années plus tôt, l'homme d'affaires montréalais André Aisenstadt, grand mécène des arts et des sciences, avait généreusement créé la Chaire qui porte son nom et qui, depuis 1970, a permis au CRM d'inviter des chercheurs prestigieux à prononcer des séries de conférences. Des fonds avaient été prévus pour inciter les invités à publier leurs textes. Huit titres parurent aux PUM dans la *Collection de la Chaire André-Aisenstadt* de 1974 à 1984. À elle seule, la liste des auteurs donne une idée du niveau de cette collection : R. Hermann, M. Kac, S. De Groot, J.-L. Lions, D.E. Knuth, Y. Ne'eman, R.T. Rockafellar, L. Schwartz.

Autour des années 90, des métamorphoses des Presses de l'Université de Montréal amenèrent cet organisme à se désengager de la publication des conférences Aisenstadt. Elles cessèrent également de publier les comptes rendus du Séminaire de mathématiques supérieures fondé par Maurice Labbé en 1962, et confièrent au CRM la vente des volumes déjà publiés dans l'une et l'autre collections. On en trouve le catalogue sur la page web du Centre, où l'on peut encore commander des exemplaires des titres non épuisés.

À vrai dire, si le CRM voulait donner un juste reflet de ses activités par ses publications, il devait publier non seulement les conférences Aisenstadt, mais les comptes rendus d'au moins quelques-uns des nombreux événements qu'il organisait, ainsi que les monographies proposées par ses collaborateurs. C'est la raison pour laquelle il commença à publier lui-même des livres à la fin des années 80. Il en résulta ce que l'on appelle familièrement « les publications maison » du CRM. On y trouve un peu de tout : le neuvième volume des Conférences Aisenstadt (*Quantum groups and non-commutative geometry* de Yu. I. Manin), des comptes rendus de conférences, des ouvrages pédagogiques (l'un d'eux jouit toujours d'une belle popularité, la réimpression de *Category Theory for Computing Science* de M. Barr et C. Wells), un ouvrage fort bien reçu par la critique (*Leçons sur le théorème de Beurling et Malliavin* de P. Koosis), et une rareté un peu exotique (la collection complète des articles du théoricien des nombres Sarvadaman Chowla, éditée par J.G. Huard et K.S. Williams). Le dernier titre paru devrait intéresser les physiciens autant que les mathématiciens : il s'agit de l'ouvrage monumental de Laurent Guieu et Claude Roger sur *L'Algèbre et le Groupe de Virasoro*.

Au moment où il lançait ses publications maison, le CRM mit aussi sur le marché les vidéos d'importantes conférences qui y avaient été présentées. Malheureusement, elles se vendirent mal et la collection ne contient que six titres. Dommage ! Maintenant que deux des conférenciers sont disparus, Serge Lang et Laurent Schwartz, on apprécie mieux la valeur de ces documents.

S'il est relativement facile de produire des livres, il est beaucoup plus difficile d'en faire la promotion et de les vendre ! Au début des années 90, la direction du CRM entreprit donc des négociations avec l'AMS, au terme desquelles cette société s'engagea à publier deux collections éditées par le Centre, la *CRM Monograph Series* et la *CRM Proceedings and Lecture Notes*. Les volumes de la première sont reliés, ceux de la deuxième brochés. Avec 26 et 43 titres, respectivement, elles représentent le plus gros des publications du CRM.

La collection des monographies regroupe plusieurs auteurs prestigieux comme, par exemple, Dynkin, Ruelle, Karatzas, Lusztig, Lafforgue, Majda et Guillemin. Elle présente, entre autres, la suite des Conférences Aisenstadt. C'est pourtant dans l'autre collection que se trouve *Stable marriage* de Donald Knuth, le best-seller des publications du CRM ! D'abord publiées en français par les PUM en 1976, ces conférences Aisenstadt de Knuth connurent un succès si durable que le CRM décida d'en publier la traduction anglaise en 1997. Un critique avait pourtant écrit de l'édition originale : « Anyone would enjoy reading this book. If one had to learn French first, it would be worth the effort ! »

Les manuscrits d'au moins trois nouvelles monographies devraient parvenir au CRM au cours des prochains mois : *Classification and Identification of Lie Algebras* de L. Snobl et P. Winternitz, *Hamiltonian Dynamics and Symplectic Topology* de V. Ginzburg, B. Gürel et E. Kerman, et, finalement, *Monoidal Categories, Species and Hopf Algebras* de M. Maguiar et S. Mahajan.

La plupart des volumes de la collection *CRM Proceedings and Lecture Notes* sont constitués d'actes de conférences. S'ils donnent une excellente idée de la qualité des activités du CRM, ils ne suggèrent manifestement rien de leur quantité. Il arrive pourtant qu'un semestre thématique soit particulièrement fécond, comme, par exemple, le premier de l'année 2006, consacré à l'analyse classique et à la théorie analytique des nombres, qui aura conduit à deux volumes : *Additive Combinatorics* (édité par A. Granville, M.B. Nathanson et J. Solymosi), tout juste sorti des presses, et *Anatomy of Integers* (édité par A. Granville, J.-M. De Koninck et F. Luca), présentement en préparation, qui paraîtra l'an prochain. Deux autres volumes sont également en préparation dans cette collection : *Singularities in PDE and the Calculus of Variations* (édité par S. Alama, L. Bronsard et P. Sternberg), ainsi que *Data Mining and Mathematical Programming* (édité par P. Pardalos et P. Hansen). Suivront, un peu plus

(*suite à la page* 10)