

2001

A N N U A L R E P O R T



THE FIELDS INSTITUTE

FOR RESEARCH IN MATHEMATICAL SCIENCES

Our Mission

The Fields Institute functions as a centre of mathematical activity in Canada – a place where mathematicians from educational and research institutions in Canada and abroad, from business, industry and financial institutions, can come together to carry out research on problems of mutual interest. Our mission is to provide a supportive and stimulating environment in which these diverse groups can interact, in order that Canada play a significant role in the rapidly expanding application of mathematics in the modern technological society.

On the cover

INTUITION

Sculptor: John Robinson

This symmetrical combination of interlocking hollow triangles, no two of which are linked, is an example of Borromean Rings studied in Knot Theory. The sculpture was presented to The Fields Institute on February 9, 1997 in recognition of the 90th birthday of Canadian geometer and mathematician H. S. M. (Donald) Coxeter by Robert A. Hefner III and Damon de Laszlo, with support from John Chadam, Frederick Helson, and James Stewart.

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Founded in 1992, The Fields Institute is named after the Canadian mathematician John Charles Fields (1863-1932). Fields was a pioneer and visionary who recognized the scientific, educational and economic value of research in the mathematical sciences.

He is best known for establishing the Fields medal, the premier international award that is considered to be the "Nobel Prize" for mathematics. The Fields Institute was initially located at the University of Waterloo, and since 1995 has occupied a building designed and constructed for Fields Institute activities on the University of Toronto campus.

Our mission is to enhance mathematical activity in Canada by bringing together mathematicians from across the country and abroad, and by promoting contact and collaboration between professional mathematicians and the increasing numbers of users of mathematics. The Institute supports research in pure and applied mathematics, statistics and computer science, as well as collaboration between mathematicians and those working in other areas such as engineering, the physical and biological sciences, medicine, economics and finance, telecommunications and information systems.

The Fields Institute environment is designed to support and enhance all of these activities. Office space is provided for as many as 78 visitors; a supportive staff enables program participants to devote their energies to research; and full access to the excellent mathematics collection at the University of Toronto is provided.

The primary activities at the Institute are its thematic programs, which are one or two semesters in length. These involve participants from Canada and around the world, and include graduate students, post-doctoral fellows, and more senior and well-established scientists. The topics of thematic programs embrace all of the mathematical sciences, as well as areas in which mathematics is, or can be, applied. Regular workshops, conferences and graduate courses are planned by the program organizers to support these goals, while all administrative and logistical details such as housing are carried out by the Institute staff.

In addition to its thematic programs, the Institute supports programs of shorter duration such as workshops and conferences, short courses, summer schools, and regularly scheduled seminars. Such activities are sometimes held off-site.

The Commercial and Industrial Mathematics Program (CIM) acts as a bridge between the mathematics community and businesses that benefit from research in the mathematical sciences. In this way the CIM program seeks to communicate results in mathematics to the business community, and conversely to create an awareness among mathematicians of the needs of that community.

The Institute is strongly committed to Mathematics Education. The focus of these efforts is the Mathematics Education Forum, which holds monthly meetings at the Institute to discuss issues of mathematics education at all levels. The Forum brings together participants from high schools, school boards, faculties of education, mathematics departments in universities and colleges, and the private sector. One of the major contributions of the Forum to education was the 1998 revision of the Ontario high school mathematics curriculum, carried out through a contract of the Fields Institute with the provincial Ministry of Education.

Major funding is provided by the Ontario Ministry of Training, Colleges and Universities and the federal Natural Sciences and Engineering Research Council (NSERC). The corporate sponsors of the Fields Institute are Algorithmics and Nortel Networks. Our five principal sponsoring universities are McMaster University, the University of Toronto, the University of Waterloo, the University of Western Ontario, and York University. In addition, there are six affiliate universities: the Ottawa-Carleton Institute for Mathematics and Statistics, Queen's University, the University of Guelph, the University of Manitoba, the University of Saskatchewan, and the Atlantic Association for Research in Mathematical Sciences (AARMS).



John Gardner, Chair

The Directorate's message outlines the constantly growing contribution made to Canada's research community by the Fields Institute. An additional initiative not to be overlooked is Fields' on-going involvement in mathematical education. A personal highlight for me, however, was last summer's Fields Medallists Symposium which brought together 9 medallists who shared their thoughts and ideas with several hundred attendees over a period of three days.

The Institute's full title is the "Fields Institute for Research in the Mathematical Sciences". That the title refers to sciences in the plural is recognized by the Institute's activity which encompasses a steadily broadening range of disciplines that includes pure and applied mathematics, statistics, and computer science. In

addition more and more of our attention is spent at the frontiers engaged with other disciplines such as biochemistry, epidemiology, manufacturing and finance. In addressing these needs, the Fields Institute is filling a void that existing academic structures have not addressed.

While making reference to the Institute's growing reach, I wish to welcome the University of Western Ontario, which has joined the universities of McMaster, Toronto, Waterloo and York as sponsoring members. The detailed report of the Institute's activity over the last year reflects the expanding nature and growing strength of our relationship with other academic bodies and with corporations for whom advanced mathematics and its benefits play an important role. Indeed, Fields is becoming an ever more visible fixture on the Canadian landscape.

Twelve months ago, Don Dawson had just retired as Director, and a search for his successor was under way. Not unexpectedly that search required considerable time and effort, as we were looking for a very special person. I would like to extend my thanks to the Search Committee both for the time and energy they devoted to their task and for the recommendation they made.

Ken Davidson, Director as of July 1st, is a highly respected Canadian academic who has been actively involved with the Institute from its very beginnings. He has been an E. W. R. Steacie Fellow (1988-90) and a Killam Research Fellow (1995-97), and was

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elected a Fellow of the Royal Society of Canada in 1992. Your Board of Directors and I look forward to working with Ken as he implements his vision for the Institute's future.

My final words are directed toward Bradd Hart, our Deputy Director, who also served as Acting Director, carrying a double load during the past twelve months. The Institute – indeed, all mathematics in Canada – owes a very special vote of thanks to Bradd whose energy and wisdom have enabled Fields to grow and strengthen its position during this challenging period.



John Gardner
Chair





Kenneth R. Davidson, Director; Bradd Hart, Deputy Director

The Fields Institute is beginning its 10th year of operation, and its activity level has never been higher. The past year has seen an increase in the scope of almost every aspect of our mandate. We are looking forward to continued expansion of our activities to enhance mathematics and mathematical science in academic research, education and commercial development.

The scientific program for 2000-01 consisted of two thematic programs and more than 35 onsite and offsite events. Over 2000 people participated in activities sponsored by the Institute. The fall program concentrated on Infinite Dimensional Lie Theory and Its Applications and consisted of three workshops and three graduate courses. The scientific leadership for this program demonstrated the strength in this area throughout Canada with organizers from Alberta, Saskatchewan, Toronto and Carleton. The program from January to June on Symplectic Topology, Geometry and Gauge Theory featured three workshops and four graduate courses. One of the workshops was organized jointly with the Centre de recherches mathématiques in Montreal. Each program had a Coxeter Lecturer to publicize the program: in the fall, Graeme Segal from Oxford spoke on The Idea of Space in String Theory and in

March, Alexander Givental from the University of California at Berkeley lectured on Gromov–Witten invariants in Higher Genus. Michael Sigal from the University of Toronto was awarded the CRM-Fields prize, and in his prize lecture, spoke on Some Mathematical Problems on Quantum Field Theory.

One new item on the calendar this year was a day devoted to the transition from this year's thematic program to the next, Numerical and Computational Challenges in Science and Engineering. Organized around the corporation's annual general meeting, Lisa Jeffrey from Toronto spoke on behalf of the outgoing program on Symplectic Topology, Geometry and Gauge Theory while Joseph Flaherty from Renssallaer Polytechnic Institute spoke for the upcoming year's program. The day concluded with dinner at the University of Toronto Faculty Club and a speech by former federal cabinet minister, Roy McLaren.

Among the various general scientific activities supported by Fields this year, two which exemplify much of what we are trying to accomplish were the Colloquium in Applied Mathematics and the Summer School on Quantum Information Processing. The Colloquium in Applied Mathematics was organized by Walter Craig from McMaster and Catherine Sulem from Toronto. The series saw talks from Peter Lax, Louis Nirenberg and Rafael de la Llave to name just a few. Held monthly with two talks in an afternoon, it was extremely well attended with participation from McMaster, Toronto, York and Waterloo. The Summer School on Quantum Information Processing was attended by over 100 "students" who ranged from graduate students to postdoctoral fellows to senior researchers. Organized as a series of short courses by experts in the field, the week concluded with a Distinguished Lecture by Peter Shor from ATT Bell Labs who spoke on Quantum Computing. Look for such summer schools to become a mainstay on the Fields calendar of events.

Mathematics education at all levels plays an important role at Fields, and our window on elementary and secondary education is our Mathematics Education Forum. Chaired by Eric Muller from

Brock, the work of the forum this year was superb with the creation of four task forces, devoted to mathematics teacher education, the transition from high school to university and college mathematics, the mathematics of data management, and online mathematics courses. The forum held monthly open meetings which were well attended by representatives from school boards, faculties of education, book publishers, mathematics departments and others with an interest in math education. One new initiative which you will hear more about in this upcoming year is the creation of The Canadian Partnership for Mathematics Education. The goal of the partnership is to link together existing expertise in mathematics education across the country and to bring that expertise to bear on problems which have national scope like in-service training and online learning.

One of the biggest success stories around Fields in the past few years has been our Commercial/Industrial Mathematics Program. The activities in the program range from seminars and workshops to professional short courses and our incubation program. One of the highlights from the past year was our Financial Mathematics Seminar Series which was held monthly and regularly drew over 100 participants from academia and industry. As one of the founding institute's in the Network Centre of Excellence, MITACS, Fields acted as the scientific and administrative hub for 8 projects doing collaborative work with industry. Three mathematical start-up companies were incubated by Fields during the past year, with one, Karthika Technologies, going from a two-person to a 17-person operation within 9 months.

The Scientific Advisory Panel did much work this year in preparing for upcoming thematic program years. Programs for the years 2002 through 2005 were approved: in the fall of 2002, there will be a program on Set Theory and Its Applications to Analysis; January through August, 2003 will be a program on Automorphic Forms; the program year 2003-04 will be devoted to Partial Differential Equations and 2004-05 will be on the Geometry of String Theory. There are still openings for shorter, mini-programs in the summers of upcoming years.

The success of the past year would not have been possible without the contributions of many in the broader Fields community. The Board and Members of the Corporation provide sound fiscal

management of the Institute while as noted above, the Scientific Advisory Panel provided expert scientific advice on both existing and future programs. The organizing committees of both thematic programs this year must be thanked for their splendid jobs in creating a solid research environment at the Institute. None of these activities would get very far if it were not for the efforts of the Fields staff who are regularly praised by visitors for their professionalism and effort. We would particularly like to thank Janet Stern, Alison Conway, Uma Gupta, Ben Schwartz and Philip Spencer for keeping things running during many of the hectic periods over the past year. A final note of thanks must go to John Gardner who took on an increased load this year and always seemed to have time for Fields during his busy schedule.

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Kenneth R. Davidson
Director



Bradd Hart
Deputy Director

Infinite Dimensional Lie Theory and its Applications

September 2000 to January 2001

Scientific Organizing Committee:

S. Berman, University of Saskatchewan; Y. Billig, University of New Brunswick; V. Ginzburg, University of Chicago; V. Kac, Massachusetts Institute of Technology; B. Khesin, University of Toronto; O. Mathieu, CNRS Lyon-1; A. Piazola, University of Alberta

This program was held at the Fields Institute during the fall term of the academic year 2000-2001. There were numerous activities associated with this program in which well over 200 mathematicians from around the world participated. Many of the activities were coordinated with our sister program Symplectic Topology, Geometry and Gauge Theory, held during the second term. This coordination was planned to take advantage of the close mathematical connections between the two broad areas represented; in fact many of the participants attended parts of both programs.

Infinite dimensional Lie theory has attracted great interest during the last 20 years owing to its rapid development and the astounding number of applications and interactions it has with other areas in mathematics as well as in physics. Various infinite dimensional Lie algebras and groups - including groups of diffeomorphisms and algebras of vector fields, the affine Kac-Moody Lie algebras and their generalizations to Borcherd's Lie algebras and to extended affine Lie algebras, algebras of pseudodifferential operators and their generalizations - were present in the lectures presented during the term. Also present were numerous applications to other areas of mathematics and physics. For example, quantum field theory, fluid mechanics, singularity theory, modular forms and number theory, vertex operator algebras, the monster simple group, algebraic geometry and torsors, and soliton theory, were all an intimate part of the program. Thus participants were able to understand better how all of these diverse parts of this enormous picture interact. Long-term visitors, and especially graduate students and post-docs, were able to benefit most from the great wealth and breadth of material presented.

The basic elements involved in shaping the program were the courses and mini-courses, the workshops, and the steady flow of visitors who presented lectures on their research during the semester. Of the four long courses covering the whole term, there were two that particularly helped participants to prepare for some of the material dealt with during the Symplectic program. These were the introductory course on symplectic geometry given by E. Meinrenken and Y. Billig's course on soliton theory. Meinrenken's



Y. Billig



O. Mathieu



S. Berman



B. Khesin



A. Piazola



V. Ginzburg



V. Kac

was given as a regular course of the mathematics department of the University of Toronto but was taken by many members of our program. The other two courses were both designed to provide some background knowledge to participants for the two workshops held during the first term. Thus, the course given by Y. Gao on extended affine Lie algebras fit in well with the first workshop "Infinite Dimensional Lie Algebras and Groups: Structure and Geometry", while the second course, given by C. Dong, provided a good background for the second workshop "Vertex Operator Algebras in Mathematics and Physics". The latter was only planned after we learned that Dong, one of the foremost experts in vertex operator algebras in the world, would participate in the program for the entire term. We were especially fortunate to have this course since this subject is very difficult to learn on one's own and is of increasing importance in the developing theory.

A third workshop, entitled "Quasiclassical and quantum structures", was held in early January and served as a bridging workshop between the two programs. Also the courses "Infinite Dimensional Lie Groups and Gauge Groups" by B. Khesin and "Symplectic Geometry and Hamiltonian Group Actions" by L. Jeffrey given during the second term, were cross listed with both programs and followed up on some of the topics from the first term. These workshops, as well as most of the courses, will be dealt with individually and in more detail below.

Besides the ongoing courses and the high intensity workshops, we also had a steady stream of visitors to round out the program. This allowed the coverage of material which would otherwise not have been possible. Many of these visitors gave what became termed as "Sophus Lie" lectures. Some of them stayed for an extended time of 2 or 3 weeks, often presenting not just one,

but a sequence of lectures on their current work. Two highlights were the lectures of P. Gille and D. Harari who lectured on some of the more geometric and cohomological aspects which have an influence on infinite dimensional Lie theory. In particular, the lectures of D. Harari helped stimulate some ongoing research in which toroidal algebras are viewed as forms over rings of finite dimensional simple algebras. The sequence of four lectures by B. Feigin on various models and coinvariants of some representations of the affine Kac-Moody algebras, were also a highlight; it was a great pleasure and benefit for all to see this well-known master of the subject present some of his recent work.

The Coxeter lecture series by Graeme Segal of All Souls College, Oxford was a fitting crescendo to our program. His title was "The idea of space in string theory". These lectures served to tie together many of the varied mathematical and physical works presented during our program into a cohesive whole from a very broad and grand perspective. Segal dealt with the geometry of space-time and its relation to geometric quantum field theory. The influence of, and interactions with, the representation theory of loop groups, especially the affine Kac-Moody groups, was discussed. It was interesting to hear his report of some recent joint work with M. Atiyah on a problem communicated to them by E. Witten. Segal outlined an emerging K-theoretic framework in which many of these ideas find their natural setting. All in attendance found the lectures stimulating and informative.

Even though it is too early to judge the long-term impact of the program, one aspect of it deserves special mention – the very positive effect on all of the postdoctoral fellows and graduate students. It is clear that they learned a great deal, made numerous new contacts in the area, and benefited from being able to interact with some of the best mathematicians in the world. They all matured a lot mathematically and this will certainly have a positive effect on their entire careers. Many of the long-term members became involved in joint projects out of which some research publications will soon appear, on topics which would not have been joined together if not for our program. A Fields Communication volume is planned to disseminate some of the research discussed in the workshop on vertex operator algebras. Also two Fields Monographs are planned. One of these will be based on Y. Gao's course on extended affine Lie algebras and the other on C. Dong's course on vertex operator algebras. This second monograph will be especially timely as there are virtually no texts which would enable a novice to get to the research level in this area – and Dong's course was designed to do just that. Both of these monographs will stimulate a lot of research in the future.

WORKSHOPS

Infinite Dimensional Lie Algebras and Groups: Structure and Geometry

September 25-29, 2000

Organizers: V. Kac, MIT; O. Mathieu, Lyon; A. Pianzola, Alberta

A wide variety of subjects within infinite dimensional Lie theory was represented and topics dealing with geometric aspects, structure theory, as well as representation theory were covered by the 18 speakers. Mathematical physics was also represented and many talks dealt with affine Kac-Moody Lie algebras or some of their generalizations such as toroidal algebras and extended affine Lie algebras. Kac-Moody groups and loop groups were central to several talks as were some vertex operator representations of the affine algebras. The breadth and depth of the material presented was remarkable and, judging by the remarks, questions, and lively discussions following the talks, the participants were highly stimulated by them. In addition, a lot of mingling and mathematical discussions took place at all hours of the day and night among participants, and all felt they got a lot out of the workshop.

Speakers

- B. Allison, Alberta
Isomorphism of Covering Algebras
- G. Benkart, Wisconsin
Lie Algebras BC
- V. Futorny, São Paulo
Categories of modules for Lie algebras with triangular decomposition
- V. Kac, MIT
An introduction to pseudoalgebras
- J-H. Kwon, Seoul
Tensor product of crystal bases over $U_Q(\mathfrak{g}(l,m,n))$
- S. Kumar, North Carolina
Frobenius splitting of Hilbert schemes of points on surfaces
- T. Larsson, Stockholm
Fock representations of non-centrally extended diffeomorphism algebras
- O. Mathieu, Lyon
Connections on stable bundles
- K-H. Neeb, Darmstadt
Central extensions of infinite-dimensional Lie groups
- E. Neher, Ottawa
Locally finite root systems
- G. Papadopoulos, Basel
Witt algebra, Steenrod algebras and noncommutative symmetric functions

S. Rao, Tata

Towards classification of integrable modules for Toroidal Lie-Algebras

A. Rudakov, Norwegian University of Science and Technology.

Remarkable complexes of representations of Lie superalgebras $E(3,6)$

O. Schiffmann, Yale

On the center of affine Hecke algebras of type A

L. Scott, Virginia

Representations in characteristic p of affine Lie algebras and algebraic groups

P. Slodowy, Hamburg

Loop groups, bundles over elliptic curves and elliptic singularities

C. Teleman, University of Texas

Twisted K-theory and the Verlinde algebra

E. Zelmanov, Yale

On Lie algebras over rings of differential operators

Vertex Operator Algebras in Mathematics and Physics

October 23-27, 2000

Organizers: S. Berman, University of Saskatchewan; Y. Billig, University of New Brunswick; Y-Z. Huang and J. Lepowsky, Rutgers

The main theme of this workshop was the relation between the theory of D-branes and the algebraic and geometric theory of vertex operator algebras. Recent developments in string theory, in particular the study of mirror symmetry via Gepner models and the world-sheet approach to D-branes, were well represented in the talks by some of the pure mathematicians as well as by some of the mathematical physicists. Also the algebraic and geometric sides of the theory were discussed by some of the speakers and one certainly got a feeling that we were hearing about the frontier of this rapidly developing area. The interactions with string theory and conformal field theory were present in many talks. Judging by the level of interest displayed by the lively discussions which took place throughout the week, as well as the many positive comments of the participants, one certainly could see there was a consensus that this workshop was very valuable to the participants.

Speakers

P. Bantay, Rolland Eotvos University

Permutation orbifolds

K. Barron, Santa Cruz

Change of variables formulas for $N=1$ Neveu-Schwarz vertex operator superalgebras and alternate notions of superconformality

C. Dong, Santa Cruz

Vertex operator algebras and dual pairs

M. Douglas, Rutgers

D-branes in Curved Space

B. Feigin, Landau Institute of Theoretical Physics

J. Fuchs, Karlstad

Solitonic representations and boundary categories

R. Griess, Michigan

Recent results on automorphism groups of VOAs

G. Hoehn, Freiburg

Genera of Vertex Operator Algebras and 3-dimensional Topological Quantum Field Theories

Y-Z. Huang, Rutgers

Riemann surfaces with boundaries and vertex operator algebra theory

J. Lepowsky, Rutgers

Aspects of the construction of conformal field theories

H. Li, Rutgers

Regular representations and Zhu's $A(V)$ -theory

F. Malikov, U.S.C.

Sheaves of vertex algebras over algebraic manifolds

G. Mason, Santa Cruz

Automorphic and combinatorial properties of free field theories at higher genus

A. Meurman, Lund

Integrable highest weight modules and vertex operator algebras

A. Milas, Rutgers

Vertex operator algebras and Q -functions

K. Nagatomo, Osaka

The minimal model on the projective line

M. Primc, Zagreb

Basic representations for classical affine Lie algebras

A. Recknagel, King's College

From Branes to Boundary Conformal Field Theory

V. Schomerus, Max Planck Institute

Brane Dynamics and Noncommutative Geometry

A. Tsuchiya, Nagoya

Seiberg-Witten differential as a period of rational elliptic surface

Quasiclassical and Quantum Structures

January 9-14, 2001

This was a joint workshop of the two thematic programs for the year. For a description please see page 12.

GRADUATE COURSES

Topics in Representation Theory

Instructor: Y. Billig, Carleton University

Besides presenting some basic representation theory of the affine Kac-Moody Lie algebras as well as basic soliton theory, this course presented results which relate the two areas. Thus a conceptual picture arises providing a notion of symmetry in the solutions of soliton equations. Towards the end of the course Billig presented some of his own recent generalizations to the case of toroidal Lie algebras. This course served to provide a background to some of the discussion of soliton equations which occurred in the Symplectic workshop during the second term and gave the participants an important and interesting application of some of the theoretical sides of the general theory.

Vertex Operator Algebras

Instructor: C. Dong, University of California, Santa Cruz

This course began with the basics on vertex operator algebras and quickly moved to topics in their structure theory. Next, representation theory was covered and the relationship of VOA's to other structures was discussed. The algebraic theory of VOA's was stressed. In particular, the relation to associative algebras (Zhu's algebra and its generalizations by Dong and his co-workers) as well as the Griess algebra (which is related to the Monster simple group) and some of its generalizations were covered. Towards the end of the course a panorama of many topics (dual pairs, orbifold theory, coset constructions, modular invariance and monstrous moonshine) were all touched on. The course certainly imparted on all who attended a feeling for the depth of the area.

Introduction To Extended Affine Lie Algebras

Instructor: Y. Gao, York University

The goal of this course was to present an example-oriented introduction to the rapidly developing structure theory of extended affine Lie algebras. The main examples used were the special linear Lie algebra, coordinatized in the various ways allowable by this theory, and the toroidal algebras. Enough of the general theory of EALA's was presented to show how these examples fit into the general framework. Other topics covered were central extensions and their computation in the cases covered, by using cyclic homology, the quantum torus associative algebra as well as the alternative and Jordan tori. Towards the end of the course, after dealing with structure theory, some topics in the representation theory of these algebras by vertex operators was discussed.

COXETER LECTURE SERIES

The Idea of Space in String Theory

December 5-7, 2000

Graeme Segal, Mathematical Institute,
University of Oxford

In the first week of December 2000 Prof. Graeme Segal, Oxford, gave three lectures as part of the Coxeter Lecture Series, entitled "The Idea of Space in String Theory". The general theme of the lectures was quantum field theory; roughly, a two-dimensional field theory associates a complex vector space H to a compact one-dimensional manifold (in other words, a circle) and associates a linear map from $H^{\otimes p}$ to $H^{\otimes q}$ to a compact oriented two manifold Σ whose boundary consists of a number of copies of the circle, p of which are positively oriented and q negatively. If Σ is equipped with a conformal structure and the output data are unchanged by diffeomorphisms of Σ preserving the conformal structure, then the theory is called a conformal field theory.



Examples may be constructed using the loop space of a Riemannian manifold X (the spacetime) and the space of smooth maps from Σ into X . In some illuminating examples the space H is a representation of the loop group associated to a compact Lie group. The lectures (which surveyed ideas based in part on joint work with M. Atiyah and G. Moore) outlined the idea of a B-field (or equivalently gerbe with connection) which features prominently in recent string theory and is the analogue of the parallel transport specified by a connection. A B-field gives rise to a closed 3-form, which is the analogue of the 2-form representing the curvature of a connection. A distinguished class of B-fields are those satisfying the natural set of field equations (analogues of the Einstein-Maxwell equations). Two examples of Riemannian manifolds X equipped with B-fields where the field equations are satisfied are flat Riemannian tori and compact Lie groups equipped with bi-invariant metrics. The lectures also described the concept of a D-brane, which is a submanifold of X equipped with additional structure (for example vector bundles with connections). Finally, the lectures outlined recent joint work with G. Moore in which D-branes are related to a form of K-theory (twisted K-theory).

Symplectic Topology, Geometry, and Gauge Theory

January 2001 to June 2001

Scientific Organizing Committee:

M. Audin, Strasbourg University; Y. Eliashberg, Stanford University; H. Hofer, Courant Institute, New York University; J. Hurtubise, McGill University; L. Jeffrey, University of Toronto; B. Khesin, University of Toronto; F. Lalonde, University of Québec, Montréal; E. Meinrenken, University of Toronto

The Symplectic Topology, Geometry and Gauge Theory Program held from January 2001 to June 2001 was the very first thematic program organised jointly by the Fields Institute and the CRM. It is certainly not premature to say that this semester has been a success from many points of view.

First of all, the subject itself is amongst the deepest and most exciting areas of research in pure mathematics and in theoretical physics. Symplectic geometry is a classical subject, whose roots go back to the development of analytical mechanics by the French school in the eighteenth century. But gauge theory and symplectic topology are much more recent: the former was introduced in physics in the middle of the 20th century, while symplectic topology really began in the seventies when the first case of the famous Arnold conjectures was solved. The mathematical development of the former received a definitive impulse when Donaldson applied gauge theoretic methods to the study of four-dimensional topology. The introduction of the pseudoholomorphic method by Gromov in 1985 had a similar effect on symplectic topology. Taubes' recent work on the Seiberg-Witten invariants has established a strong link between the two fields.

The joint FI-CRM program was the main international event on these subjects to take place in 2000-2001. It was preceded by the program on Infinite Dimensional Lie Theory and Its Applications. As a bridge between the two programs, Eckhard Meinrenken gave a graduate course on Symplectic Geometry during the first semester.

The first activity of Symplectic Topology, Geometry and Gauge Theory Program was the workshop on Quasiclassical and Quantum Structures held from January 9 to 14, 2001, organised

by Etingof and Khesin. The main topics included classical and quantum integrable systems, Macdonald theory, Poisson-Lie groups, quantum groups, and quantization of Infinite-Dimensional Lie algebras. It attracted some of the best mathematicians and mathematical physicists: Kac, Jimbo, A. Kirillov, Miwa, Reshetikhin, and many others. The interplay between algebra and geometry, between mathematics and physics gave rise to very stimulating discussions.

During the two months from mid-January to mid-March, three graduate courses were given by Jeffrey, Khesin and Meinrenken, and a week of lectures by Eliashberg. With about eight postdoctoral fellows and many long-term visitors, these activities were an essential part of the program. The courses covered the following topics: Symplectic Geometry and Hamiltonian Group Actions by Jeffrey; Infinite-Dimensional Lie Groups and Gauge Theory by Khesin; Moduli Spaces of Flat Connections by Meinrenken; and finally an introduction to Symplectic Field Theory by Eliashberg. This minicourse by Eliashberg ran from Monday to Friday, two hours a day, and covered the essential features of Symplectic Field theory. This theory was introduced very recently by Eliashberg, Givental and Hofer, and aims to give an extension of the usual notion of Gromov-Witten invariants when one replaces a closed symplectic manifold by a symplectic manifold whose boundary realises a cobordism between contact manifolds. The theory intertwines contact homologies (Eliashberg), homological geometry (Givental) and symplectic homologies (Floer-Hofer). It has some very interesting applications to invariants and obstructions in symplectic topology and contact geometry.

Givental gave the Coxeter lectures from March 12 to 14. For an account of them, see Coxeter Lecture Series, p. 16.

The long-awaited two-week workshop on Symplectic and Contact Topology, Quantum Cohomology, Symplectic Field Theory and Higher-Dimensional Gauge Theory was held from March 23 to April 7. The first week took place at the Fields Institute and the second week at the CRM. It was organised by Donaldson, Eliashberg, Givental, Khesin, and Lalonde. The organisers reserved two full VIA rail cars with meals to take the partici-

pants from Toronto to Montreal during the weekend between the two weeks. This workshop was definitely one of the highlights of the year in symplectic geometry and topology. It gave rise to lots of interactions, discussions, and joint works that were taking place everywhere, even in the train. Its main goal was to discuss the recent developments in the construction and computations of invariants of symplectic and contact manifolds and their automorphism groups, using methods of the theory of J-holomorphic curves, as well as those from gauge theory and dynamical Hamiltonian systems. The theory of these invariants is tightly related to enumerative algebraic geometry, quantum cohomology and mirror symmetry. Recent results, of both mathematicians and physicists, manifest the existence of surprising correspondences between various gauge theories on real and complex manifolds. The level of maturity and clarity that the whole field has now attained, the fecundity of its applications and the depth of its conceptual framework are the striking features of this year's event. The workshop was such a success that we had to limit the number of applicants – the rooms were full both in Toronto and in Montreal – so that sometimes the workshop looked more like a conference. Some of the main speakers included Auroux, Chekanov, Eliashberg, Fuchs, Fukaya, Getzler, Kotschick, McDuff, Parker, Polterovich, Salamon, Sikorav and many others. The organisers have decided to publish the proceedings of that workshop in the Fields Institute Communications Series.

The last workshop on Hamiltonian Group Actions and Quantization was held from June 4-13, 2001. It was organised by Audin, Hurtubise, Jeffrey, and Meinrenken. The main topics include geometric quantization and the Guillemin-Sternberg conjecture, generalized moment map theories, symplectic cobordisms, relation with geometric invariant theory, cohomology rings of symplectic quotients, and flat connections on Riemann surfaces. The list of speakers can be found on the Fields website. (<http://www.fields.utoronto.ca/programs/scientific/00-01/symplectic/hamiltonian/>)

The participants were especially pleased by the quality of the work done by the staff and the kindness of the welcome that they received both in Toronto and in Montreal. They expressed warm thanks to Alison Conway and Elena Kaufman at the Fields Institute, and Louis Pelletier and Josée Laferrière at the CRM.



E. Meinrenken



B. Khesin



F. Lalonde



H. Hofer



Y. Eliashberg



M. Audin



L. Jeffrey



J. Hurtubise

WORKSHOPS

Quasiclassical and Quantum Structures**January 9-14, 2001**

Organizers: P. Etingof, Massachusetts Institute of Technology and B. Khesin, University of Toronto

The goal of this workshop was to review the recent progress in the theory of quantization, quantum groups, integrable systems, and related areas in mathematics and mathematical physics. As a result, the scope of the conference was very broad and it attracted many well known mathematicians and mathematical physicists with diverse scientific interests, such as M. Semenov-Tian-Shansky, I. Cherednik, G. Felder, A. Varchenko, V. Kac, T. Miwa, N. Reshetikhin, A. Kirillov Sr., M. Kapranov, M. Jimbo, and others.

In addition to those delivering invited one-hour lectures, there were a number of participants, attracted by the high level of the conference, who expressed interest in giving talks. To accommodate their wishes, short evening talks were arranged, and the schedule of the conference became extremely busy – 35 talks in total, starting daily at 9 a.m., and ending at 10:30 p.m. Nonetheless, most talks were well attended, and many participants remarked that this was the best conference in the subject in several years.

Among the topics covered were classical and quantum integrable systems, Poisson Lie groups and quantum groups, affine and quantum affine algebras and their representations, Poisson geometry, quantization of Poisson manifolds, and Kontsevich formality theory.

There were also talks on related topics such as non-commutative algebra and geometry, Macdonald theory, elliptic hypergeometric functions, and quantum cohomology.

Speakers

D. Bar-Natan, Hebrew University, Jerusalem
Knot invariants, associators and a strange breed of planar algebras

I. Cherednik, University of North Carolina at Chapel Hill
Harish-Chandra transform and difference operators

B. Enriquez, ENS-CNRS, Paris
Quantization of Lie algebras and shuffle algebras

G. Felder, ETH Centrum, Zurich
From local to global quantization of Poisson manifolds

D. Gurevich, Valenciennes University
Quantum trace in braided categories and projective modules on quantum orbits

M. Jimbo, University of Tokyo
V. Kac, Massachusetts Institute of Technology
Exceptional De Rham complexes

M. Kapranov, University of Toronto
Analogs of Hall polynomials for affine Weyl groups and S-duality generating functions

A. Kirillov Sr., University of Pennsylvania
Family algebras; quantum eigen values and multiplicities

D. Lebedev, Institute of Theoretical and Experimental Physics
Quantum Toda Chains, Whittaker functions and representations of noncompact groups

E. Meinrenken, University of Toronto
Hamiltonian Poisson actions and the hyperbolic Dufflo map

T. Miwa, Kyoto University
Physical combinatorics

V. Ovsienko, CPT-CNRS, Marseille
Multi-parameter deformations of the module of symbols of differential operators

N. Reshetikhin, University of California, Berkeley
Quantization of degenerately integrable systems related to simple Lie algebras

C. Roger, University Lyon - I
Some recent results in Poisson cohomology and generalizations

A. Rosenberg, Kansas State University
Noncommutative spaces

M. Semenov-Tian-Shansky, University of Bourgogne, Dijon
Quantum Toda Chains, Whittaker functions and representations of noncompact groups

Y. Soibelman, Kansas State University
Quantum tori and abelian varieties

A. Vaintrob, University of Oregon
Spin quantum cohomology

A. Varchenko, University of North Carolina at Chapel Hill
The q-deformed KZB heat equation and $SL(3, \mathbb{Z})$

L. Vinet, McGill University
A. Voronov, Michigan State University
String Topology Revisited

P. Xu, Pennsylvania State University
Integrable spin Calogero-Moser systems

I. Zakharevich, Ohio State University
Lattices, Locality of Poisson structures, and Poisson-Lie groups

Symplectic and Contact Topology, Quantum Cohomology, Symplectic Field Theory and Higher-Dimensional Gauge Theory

March 26-April 7, 2001

Topologie symplectique et de contact, cohomologie quantique, théorie des champs symplectiques et théories de jauge

26 mars au 7 avril 2001

Organizers: S. Donaldson, London; B. Dubrovin, Trieste; Ya. Eliashberg, Stanford University; A. Givental, University of California, Berkeley; B. Khesin, University of Toronto; F. Lalonde, Université du Québec à Montréal

Topics of interest

The theory of Gromov-Witten invariants and quantum cohomology
Floer homology theories
Relations between holomorphic curves invariants and Seiberg-Witten theory in dimensions 3 and 4
The study of the group of symplectic diffeomorphisms and its relations to the theory of symplectic capacities

This two-week workshop brought together researchers from symplectic topology, algebraic geometry, and mathematical physicists working in gauge theory and quantum field theory. Its main goal was to discuss the recent developments in the construction and computations of invariants of symplectic and contact manifolds and their automorphism groups, using methods of the theory of J-holomorphic curves, as well as those from gauge theory and dynamical Hamiltonian systems. The theory of these invariants is tightly related to enumerative algebraic geometry, quantum cohomology and Mirror symmetry. Recent results, of both mathematicians and physicists, manifest the existence of surprising correspondences between various gauge theories on real and complex manifolds.

The first week, held at the Fields Institute in Toronto, emphasized relations of the theory of holomorphic curves with field theories, Mirror symmetries, as well as (higher dimensional) gauge theories. The second week, at the CRM in Montreal, concentrated more on the geometric, analytic and dynamical aspects of symplectic topology.

Speakers at the Fields Institute

S. Akbulut, Michigan State University
Lefschetz fibrations on compact Stein surfaces
K. Behrend, University of British Columbia
Differential graded schemes



Workshop participants S. Akbulut and B. Ozbagci

Y. Chekanov, Moscow Centre for Continuous Math Education
Proof of Arnold's four-cusp conjecture
M. Entov, Weizmann Institute of Science
Symplectic topology and geometry of conjugacy classes in Lie groups
D. Fuchs, University of California, Davis
Invariants of Legendrian mirror torus knots
E. Getzler, Northwestern University
The Toda conjecture for the Gromov-Witten invariants of CP^1
M. Hutchings, Stanford University
Periodic Floer homology
E. Ionel, University of Wisconsin, Madison
Applications of the symplectic sum formula for GW invariants
B. Kim, Pohang University of Science and Technology, S. Korea
Two definitions of virtual fundamental classes of genus 0 for convex zero loci
J. Li, Stanford University
Algebraic construction of relative GW invariants and related topics
S. Merkulov, University of Glasgow
Extended Kaehler cone
K. Ono, Hokkaido University
Lagrangian intersection Floer theory and deformation of Lagrangian submanifolds
T. Parker, Michigan State University
The symplectic sum formula for Gromov-Witten invariants
V. Pidstrigach, Georg-August-Universität Göttingen
Symplectomorphisms of the complex plane and instantons
D. Salamon, ETH Zurich
Gromov invariants, Hamiltonian group actions, and adiabatic limits
I. Smith, Mathematical Institute and New College, Oxford
Serre duality for symplectic surfaces
S. Tolman, University of Illinois at Urbana-Champaign
Gromov width of Grassmannians

Speakers at the Centre de recherches mathématiques (CRM)

- M. Abreu, The Fields Institute and Institute Superior Tecnico, Lisbon
Kahler metrics on toric orbifolds
- V. Apostolov, Université du Québec à Montréal
The curvature and the integrability of almost Kahler manifolds
- D. Auroux, École polytechnique, Palaiseau
Projective maps and invariants of symplectic manifolds
- P. Biran, Tel Aviv University
Floer Homology and Algebraic Degenerations
- F. Bourgeois, Stanford University
A Morse-Bott approach to contact homology
- O. Cornea, Université de Lille 1
Hopf invariants and periodic orbits of Hamiltonian flows on non-compact hypersurfaces
- Y. Eliashberg, Stanford University
Geometry of contact domains and transformations
- K. Fukaya, Kyoto University
Homotopical algebra, Floer homology and Mirror symmetry
- D. Kotschick, Harvard University
Bounded cohomology of mapping class groups
- W. Li, Oklahoma State University
Symplectic Floer cohomology and semi-infinite cohomology
- D. McDuff, SUNY at Stony Brook
Geometric variants of the Hofer norm
- Y-G. Oh, University of Wisconsin, Madison
Floer theory, a new invariant norm and length minimizing property of geodesics on the Hamiltonian diffeomorphism group
- L. Polterovich, Tel Aviv University
Growth of maps, dynamics and symplectic topology
- P. Pushkar, University of Toronto
Morse theory of generating families and invariants of Legendrian knots
- Y. Rudyak, University of Heidelberg
On Lusternik-Schnirelmann category and the Arnold conjecture
- J.-C. Sikorav, École normale supérieure de Lyon
Dual elliptic structures on CP^2
- M. Verbitsky, Moscow Centre for Continuous Mathematical Education
Deformation of non-compact holomorphic symplectic manifolds



Organizing Committee: E. Meinrenken, J. Hurtubise, L. Jeffrey (M. Audin absent)

Hamiltonian Group Actions and Quantization

June 4 - 13, 2001

Organizers: M. Audin, Université de Strasbourg; J. Hurtubise, CRM and McGill; L. Jeffrey, University of Toronto; E. Meinrenken, University of Toronto

The workshop on Hamiltonian group actions and quantization at the Fields Institute in June brought the thematic program on symplectic topology, geometry, and gauge theory to a close. It took place over nine days with almost 40 invited lectures. The workshop was also supported by a Connaught grant for international symposia and colloquia.

The subject of symplectic geometry was invented by Hamilton in the early nineteenth century as a mathematical framework for both classical mechanics and geometrical optics. Physical states in both settings are described by points in an appropriate phase space (the space of coordinates and momenta). In recent years, new and powerful techniques have transformed symplectic geometry into a deep and beautiful subject of pure mathematics.

The workshop focused on two special aspects of symplectic geometry. A "Hamiltonian group action" on a symplectic manifold is a group action by symmetry transformations, generated by a collection of Hamiltonians called the moment map. For instance, the action of the rotation group on the phase space of a particle in Euclidean space is a Hamiltonian group action, with moment map the angular momentum. "Quantization" of such a system means the construction of an action of the group on the quantum-mechanical phase space, the so-called Hilbert space.

One of the main goals of the workshop was to bring together specialists working on Hamiltonian group actions with mathematicians from other disciplines who use these techniques as tools in their subject. It was generally felt that the workshop led to a very successful interaction of the various fields, continuing a tradition set by the 1994 workshop at the Newton Institute in Cambridge.

Speakers

- M. Abreu, Fields Institute, Superior Tecnico
Kahler geometry on toric orbifolds and $U(n)$ -invariant extremal metrics
- A. Alekseev, Uppsala University
Poisson Lie groups and the Thompson conjecture
- M. Braverman, Northeastern University
Index theorem for transversally elliptic operators on open manifolds
- R. Brylinski, Pennsylvania State University
Equivariant quantization of coadjoint orbits
- R. Donagi, University of Pennsylvania
Gerbes, genus-1 fibrations, dualities, integrable systems, and mirror symmetry
- S. Evens, University of Notre Dame
Poisson structures on orbits and compactifications
- P. Foth, University of Arizona
Quaternionic flag manifolds
- L. Godinho, Instituto Superior Tecnico
Equivariant cohomology and Hamiltonian circle actions
- V. Guillemin, Massachusetts Institute of Technology
Equivariant Morse theory and graphs
- J. Harnad, Concordia University
Multi-Hamiltonian structures, classical r -matrix systems spectral transforms and separation of variables
- T. Holm, Massachusetts Institute of Technology
The mod 2 equivariant cohomology of the real locus of a Hamiltonian T -Space
- J. Hurtubise, McGill University
 R -matrices and surfaces
- A. Hwang, College of the Holy Cross
Extremal Kahler Metrics and the Momentum Construction
- Y. Karshon, Hebrew University
Quantization of toric varieties
- Y-H. Kiem, Stanford University
Cohomology pairings on singular quotients in geometric invariant theory
- A. Knutson, University of California, Berkeley
Non-differentiable action variables can come from algebraic families
- M. Kogan, Northeastern University
Symplectic leaves of the standard Poisson-Lie structure
- B. Kostant, Massachusetts Institute of Technology
Dirac cohomology for the cubic Dirac operator
- G. Landweber, MSRI/University of Oregon
Dirac operators for Kac-Moody algebras and homogeneous loop spaces
- E. Lerman, University of Illinois at Urbana-Champaign
Contact toric manifolds
- E. Markman, University of Massachusetts
The Classical Dynamical Yang-Baxter Equation; A geometric interpretation
- D. Metzler, University of Florida
Orbifold K -theory
- J. Millson, University of Maryland
Eigenvectors of sums, singular values and invariant factors of products and spaces of nonpositive curvature
- P. Paradan, Université de Grenoble I
Spin c quantization and the K -multiplicities of the discrete series
- S. Racanière, IRMA de Strasbourg
Equivariant cohomology of $SU(n)^{2g}$ and Kirwan's map
- S. Singer, Haverford College
The Kepler Problem
- R. Sjamaar, Cornell University
Some remarks on quaternionic symplectic geometry
- A. Szenes, Massachusetts Institute of Technology
Trace functional on the quantized moduli space of flat connections
- S. Tolman, University of Illinois at Urbana-Champaign
Surjectivity for Hamiltonian Loop Group Spaces. Part I
- J. Weitsman, University of California, Santa Cruz
Surjectivity for Hamiltonian Loop Group Spaces. Part II
- C. Woodward, Rutgers University
Lowest d in quantum Schubert calculus
- S. Wu, University of Adelaide and University of Colorado
Projective flatness in geometric quantization
- P. Xu, Pennsylvania State University
Dynamical r -matrices, symplectic fibration and quantization
- C. Zara, Yale University
Generators in equivariant cohomology and equivariant K -theory

GRADUATE COURSES

The Fields Institute hosted several graduate courses held in conjunction with the program on Symplectic Topology, Geometry and Gauge.

Symplectic Geometry

Instructor: E. Meinrenken, University of Toronto

This course was an introduction to basic concepts of symplectic geometry, covering the following topics: linear symplectic geometry; Darboux-Weinstein theorems; Poisson brackets, Hamiltonian systems; completely integrable systems; Hamiltonian group actions, moment maps; convexity theorems, Duistermaat-Heckman theory.

Infinite Dimensional Lie Groups and Gauge Theory

Instructor: B. Khesin, University of Toronto

This course covered the geometry and orbit structure of a variety of infinite dimensional Lie groups, such as affine Kac-Moody groups, the Virasoro group, groups of diffeomorphisms, of pseudo-differential operators and of gauge transformations, including the Etingof-Frenkel groups of double loops. It also touched on the relation of those groups to the Korteweg-de Vries equation and other integrable hierarchies, to the Hitchin systems and the Euler equations of hydrodynamics, to the moduli spaces of flat connections and holomorphic bundles, as well as to the Chern-Simons functional and its holomorphic analogue.

Symplectic Geometry and Hamiltonian Group Actions

Instructor: L. Jeffrey, University of Toronto

This course began with the basic notions of Hamiltonian dynamics and group actions and ended with the cohomology of symplectic quotients and localization formulas. The courses were very popular among the Fields Institute and the University of Toronto Mathematics Department undergraduate and graduate students and postdoctoral fellows, as well as among long-term participants of the Fields programs.

Moduli Spaces of Flat Connections

Instructor: E. Meinrenken, University of Toronto

E. Meinrenken's course on "Moduli Spaces of Flat connections" gave an overview of 2-dimensional gauge theory from the perspective of symplectic geometry. It developed the theory of Hamiltonian loop group actions and nonlinear moment maps, leading to simple constructions of the symplectic structure on the moduli spaces and to a short proof of the Witten volume formulas.

COXETER LECTURE SERIES

Gromov-Witten invariants in higher genus

March 12-14, 2001

A. Givental, University of California at Berkeley

In these lectures Givental outlined his recent spectacular proof of the so-called Virasoro conjecture for the Gromov-Witten potential for complex projective spaces. This conjecture claims, roughly speaking, that the Gromov-Witten potentials are annihilated by some special differential operators constituting half of the Virasoro algebra.



F. Lalonde and A. Givental

In the series of three lectures Givental introduced a formula expressing enumerative information about higher genus holomorphic curves in complex projective spaces (and, conjecturally, in many other complex algebraic manifolds) in terms of such information in genus zero. This subject intertwines the Witten-Kontsevich intersection theory on Deligne-Mumford moduli spaces of Riemann surfaces and axiomatic 2-dimensional topological fields theory with elementary representation theory of loop groups. Note that the results actually apply to the so-called virtual moduli space of holomorphic curves. The latter is a regularization of the ordinary moduli space done in such a way that the resulting space behaves as if it were Fredholm regular (i.e. as if its actual dimension coincided with the virtual dimension). Addressed mostly to specialists, these lectures also served as a natural extension of another highlight of the Symplectic Topology, Geometry, and Gauge Theory Program: the intensive course on an intriguing new subject, symplectic field theory, given two weeks earlier by Yasha Eliashberg (Stanford University).

Operator Algebras

Organizer: George A. Elliott,
The Fields Institute

Since the Fields Institute thematic year in Operator Algebras and Applications which ran from 1994 to 1996, George Elliott has run a program on Operator Algebras at the Institute as a Senior Distinguished Member, 1996-2002.



Elliott's work, in the last 30 years, has been mainly concerned with the classification of C^* -algebras, and he was principally responsible for introducing K -theory into the subject – a development which has had reverberations in other subjects as well, in particular in noncommutative geometry. He has also recently completed a major collaboration with Guihua Gong and Liangging Li, concerning the classification of simple (in the technical sense) amenable C^* -algebras.

The program has involved many doctoral and postdoctoral researchers – in the last two years: Andrew Dean, Igor Fulman, Cristian Ivanescu, Dan Kucerovsky, David Kerr, Peter Miegom, Hideki Nakamura, Ping Wong Ng, Igor Nikolaev, Shaloub Razak, and Andrew Toms. Dean, Kerr and Razak completed their Ph.D.s; Kerr received an NSERC Postdoctoral Fellowship, Dean and Kucerovsky were appointed to tenure-track positions at Lakehead University and the University of New Brunswick respectively, and Razak obtained a position at the Royal Bank of Canada. Fulman was appointed to a visiting assistant professorship at Arizona State University, and Nikolaev to a tenure-track position at the University of Calgary.

During the last academic year, Elliott gave a full-year course “Structure of C^* -algebras”, jointly with the University of Toronto and The Fields Institute.

Elliott has recently been appointed to a Canada Research Chair at the University of Toronto.

SEMINAR

Noncommutative Geometry December 2000-April 2001

Organizer: I. Nikolaev
Noncommutative geometry in the sense of A. Connes is a study of leaf spaces of foliations on compact manifolds. The algebraic data is usually encrypted in the so-called crossed product C^* -algebras, which have the structure of a noncommutative ring. A synthesis of ideas from K -theory, topology, geometry and C^* -algebras has led to new insights in this area.

Speakers

M. Kapranov, University of Toronto / Northwestern University
Noncommutative geometry based on commutator expansions
D. Kerr, University of Toronto
Topological pressure
N. Krupnik, Bar-Ilan University, Israel
Generalized Gelfand transform in noncommutative Banach algebras
P. Miegom, Fields Institute
Thom isomorphism and K -theory
J. Mighton, Fields Institute
A new reduction of graph theory and binary matroids
I. Nikolaev, Fields Institute
Bratteli diagrams, Elliott groups and geometry of algebraic curves
P. Wong Ng, University of Toronto
The Cutdown method for noncommutative tori. An exposition of a paper of Elliott and Lin



Distinguished Lecture Series: Peter Shor

AT&T Labs – Research

May 17-18, 2001

Quantum computing

Peter Shor is a mathematician at AT&T Labs. His research interests include quantum computing, algorithmic geometry, and combinatorics. He earned a B.S. in Mathematics at the California Institute of Technology (Caltech) in 1981, and a Ph.D. in Applied Mathematics at the Massachusetts Institute of Technology (MIT) in 1985. He was a postdoctoral fellow for a year at MSRI in Berkeley before starting at AT&T Bell Laboratories in 1986.

He is recognized worldwide for his work in various areas of mathematics and computation, most notably for his work in the theory of quantum computing.

Quantum computation is the study of information processing in a quantum mechanical framework. Since information is stored in a physical medium and manipulated by physical processes, it is impossible to separate any meaningful theory of computing from the laws of physics which govern computers or other information processors. For most practical purposes, the classical approximation to the laws of physics has sufficed, and will probably continue to suffice. However, early last century, scientists realized that classical physics is wrong and developed a new framework for expressing physical theory: quantum mechanics. It wasn't until nearly the end of the last century that scientists started to understand the non-trivial impact the more precise approximation to the laws of physics, quantum physics, has on the theory of computation.

A major breakthrough in understanding the power of quantum computers came in 1994, when Shor showed how, with a quantum computer, one can factor large numbers using a number of computational steps comparable to the number of steps needed to multiply two numbers. In other words, if we allow quantum computational steps, we can factor efficiently. Many public-key encryption systems in use today require that factoring large numbers is exponentially harder than multiplying. That is, we need that encoding the information is roughly as easy as multiplying, but cracking the code is exponentially harder and thus infeasible. Another widely used class of public-key encryption systems assumes that finding discrete logarithms in various mathematical groups is hard, but Shor also came up with an efficient algorithm for finding discrete



logarithms. This algorithm can easily be generalized in order to crack any of the discrete logarithm-based cryptographic systems. Shor won the 1999 Godel prize for this work. His factoring algorithm was the topic of his first distinguished lecture.

The discovery of these algorithms forced scientists to take more seriously the question of whether or not quantum computers could really be built or if there is some fundamental reason why large-scale quantum computations cannot be done efficiently. We can never hope to manipulate quantum systems perfectly, so we need to know if there is some reasonable way of coping with some degree of errors and inaccuracy. Shor again provided a major breakthrough on this front, pioneering the field of fault-tolerant quantum error correction.

Some of his more recent work includes an elegant new proof (with Preskill) of the security of quantum key distribution. He has also studied the capacity of various kinds of quantum channels for transmitting both classical and quantum information; this was the topic of his second lecture. His pioneering work in quantum computing also earned him the 1998 Nevalinna Award, the 1998 International Quantum Communication Award, and a 1999 MacArthur Fellowship. He was also named an AT&T fellow in 1998.

Lecture Series in Statistics: Peter G. Hall

Australian National University

September 28 and October 26, 2000

These events were sponsored jointly by NSERC, the Fields Institute, and the Department of Statistics at the University of Toronto. The talks took place in the Sidney Smith Building at the University of Toronto due to scheduling conflicts at the Fields Institute.

Organizer: Andrey Feuerverger, University of Toronto

1. Data Tuning

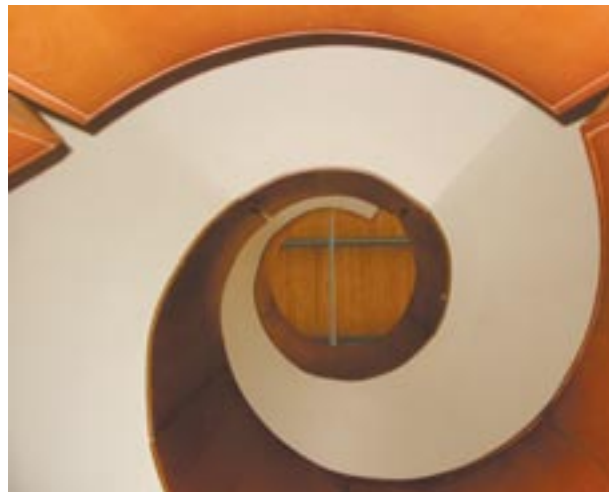
Until recently, altering one's data was sacrilegious. A major problem was that we didn't know how to do it objectively. Altering the data according to objective criteria turns out to be a surprisingly computer-intensive business, and in many instances wouldn't have been feasible a decade or two ago. Today, however, thanks to the ready availability of computing power, we can do all sorts of complex things to the data.

Data-tuning methods alter the data so as to enhance performance of a relatively elementary technique. The idea is to retain the advantageous features of the simpler method, and at the same time improve its performance in specific ways. Different approaches to data tuning include physically altering the data (data sharpening), reweighting or tilting the data (the biased bootstrap), adding extra "pseudo data" derived from the original data, or a combination of all three. Tilting methods date back to the 1950's, although only recently have they become popular. Evidence is growing, however, that sharpening is more effective than tilting, since it doesn't reduce effective sample size.



2. Estimating Fault Lines and Boundaries

A fault line in a regression model with bivariate design, $Z_i = f(X_i, Y_i) + \text{error}$, is a curve in the (x,y) -plane along which the function $z = f(x,y)$ has a fault-type jump discontinuity. Such problems arise, for example, in the measurement of benthic impacts or the estimation of lines along which sea-surface temperatures change. The fault is not necessarily the result of simple 'slippage', and in particular gradients do not necessarily match at the top and bottom of the fault. The methodology for both point and interval estimation of fault lines was described, as well as related problems such as estimation of fault lines in density or intensity surfaces, or estimation of support boundaries.



Israel Michael Sigal

2000

The Centre de recherches mathématiques and the Fields Institute jointly established the CRM-Fields prize in 1994 with the goal of recognizing exceptional work in the mathematical sciences. The recipient is chosen by the Advisory Committee of the CRM together with the Scientific Advisory Panel of the Fields Institute. The main selection criterion is outstanding contribution to the advancement of research.

ISRAEL MICHAEL SIGAL

2000 CRM-Fields Prize Recipient

Professor Sigal is a mathematical physicist, bringing the problems of physics and chemistry, especially the deep problems of the nature of matter, to mathematics. As such, he works in the part of mathematics concerned with modeling basic physical phenomena. While the models themselves can be deceptively simple, it turns out to be extraordinarily difficult to establish that they do in fact replicate experimentally known phenomena, an effort that has motivated the development of a large part of deep mathematical analysis.

Sigal's work goes to the very heart of quantum theory, that is, the long-term behaviour of particles under interactions. His work has primarily centered on the Schroedinger equation, which is at the heart of mathematical models of atoms and molecules. In the 1920's, Schroedinger formulated what has become the standard equation for quantum mechanics. It created a whole new field of mathematics dealing with the behaviour of the Schroedinger operators; that is with the general behaviour of the solutions. For fifty years, one major unsolvable problem remained. The theorem established through a series of papers by Sigal and his former postdoctoral student, Soffer, provided the first completely rigorous solution.

In recent years Professor Sigal has made ground-breaking contributions to the theory of interaction between light and matter, known as Quantum Electrodynamics. A basic set of equations to explain the interaction between electrons and photons was first proposed by Physics Nobel laureates Feynmann, Schwinger and Tomonaga around 1950. Their work created a need for a precise, consistent mathematical description of the theory and for over 40 years this task seemed to be beyond reach. Sigal's recent contribution is the first convincing attempt to provide a consistent mathematical description of Quantum Electrodynamics and represent a revolutionary approach to the subject.



Professor Sigal is currently a professor at the University of Toronto. He received his PhD from Tel Aviv University. His work has been rewarded by many honours; including several invited lectures to the International Congress on Mathematical Physics and the International Congress of Mathematicians, as well as the editorship of two of the most respected journals in the field, *Reviews in Mathematical Physics* and *Duke Mathematical Journal*. He is also a Fellow of the Royal Society of Canada and received the John L. Synge Award as the outstanding Canadian mathematician in 1993.

William T. Tutte

2001

WILLIAM T. TUTTE

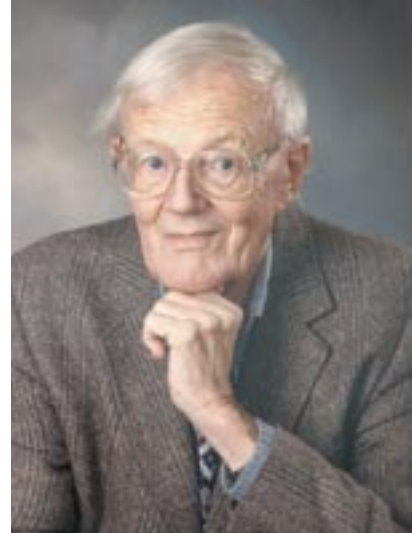
2001 CRM-Fields Prize Recipient

The annual Centre de recherches mathématiques/Fields Institute Prize was awarded this year to William T. Tutte, Professor Emeritus of the University of Waterloo, in recognition of his pre-eminence and leadership in the field of combinatorial mathematics, in the development of the University of Waterloo from a fledgling institution in 1957 to its present prominent role in mathematics, and in the maturation of Canadian mathematics in the last half of the 20th century.

Tutte, a native of the U.K., was educated at the University of Cambridge. Even as an undergraduate in chemistry, he made his mark in mathematics by developing, with three fellow students, the “sum of tree-products” method, which has become the standard and most efficient algorithm for calculating electrical network functions. This was published in a paper in 1940.

His reputation as a problem-solver led him to code breaking at Bletchley Park during World War II. His work there centered on “Tunny”, a code used primarily for messages between high ranking German personnel. From samples of the code alone, Tutte managed to determine the number of coding wheels and the number of sprockets on each wheel of the machine which generated Tunny. This accomplishment was characterized by Tony Sale in a 1997 article in *New Scientist* as ‘the greatest intellectual feat of the whole war’. Tutte and two collaborators subsequently developed algorithms to decode Tunny. For this purpose COLUSSUS – considered by many to be the world’s first electronic computer – was designed and built.

Transformed to a mathematician by these early successes, Tutte wrote a Ph.D. thesis at Cambridge after the war which established him as a pioneer in matroid theory. On completion of his degree there, he emigrated to Canada in 1948 to join the faculty at the University of Toronto. Then in 1962, he left for the University of Waterloo, becoming the seed from which both the Faculty of Mathematics and the Department of Combinatorics and Optimization grew and flourished.



Tutte has become the pre-eminent figure in graph and matroid theories, and the names of many theorems in these subjects bear witness to his influence: Tutte’s theorem on the characterization of graphs having a perfect matching, Tutte’s theorem on the characterization of regular matroids, Tutte’s theorem that every 4-connected planar graph has a Hamilton cycle, and the Tutte polynomial of a graph and a matroid – closely related to the Jones polynomial of a knot defined much later.

Professor Tutte has, not surprisingly, been the recipient of many other honors, including his election as a Fellow of the Royal Societies of both Canada and the U.K. and of the American Association for the Advancement of Science, the Tory Medal of the Royal Society of Canada, the Killam Prize, and most recently, his appointment as an officer of the Order of Canada.

WORKSHOPS

CITA (CANADIAN INSTITUTE FOR THEORETICAL ASTROPHYSICS) MEETING

August 26 - 30, 2000

Held at the Fields Institute

Also sponsored by: Canadian Institute for Advanced Research, CITA

“Directions in Theoretical Astrophysics at the turn of the Millennium”

Organizers: D. Bond, L. Kofman, N. Murray and U-L. Pen, University of Toronto; D. Henriksen and L. Widrow, Queen's University

The meeting brought together approximately 100 former CITA postdoctoral fellows, research associates and visitors as well as all members of CITA Inc. and others in the Canadian and astrophysics community as well as Fellows, Scholars and Associates of the Canadian Institute for Advanced Research's Cosmology and Gravity Program. The important directions for theoretical astrophysics at the Millennium, particularly those for which roots may be found in CITA-associated activity, were presented in the following areas of astrophysics: Star/Planet Formation and Dynamics, Interstellar Medium, High Energy Astrophysics, General Relativity and Relativistic Astrophysics, Galaxy Formation, Cosmology, Fundamental Astrophysical Processes.

TOPICS IN MODERN STOCHASTIC ANALYSIS

September 21-22, 2000

Held at the Fields Institute

Also sponsored by the Department of Statistics, University of Toronto

Organizers: J. T. Cox, Syracuse University; T. G. Kurtz, Madison University; D. M. Salopek, York University; and R. Srinivasan, University of Saskatchewan

The Fields Institute hosted the “Topics in Modern Stochastic Analysis” Workshop, September 21-22, 2000. This workshop was in celebration of Donald A. Dawson's contribution to Canadian mathematics and in particular to Probability Theory. The focus of the workshop was on the recent developments in measure-valued processes and stochastic partial differential equations and their applications.

Speakers

R.J. Adler, The Technion-Israel Institute of Technology

The Burgers Superprocesses

R. Durrett, Cornell University

Biodiversity

L.G. Gorostiza Ortega, Centro de Investigación y de Estudios Avanzados

Trajectorial fluctuations of particle systems, time localization and self-intersection local time

Andreas Greven, Friedrich Alexander-Universität,
Longtime behaviour of interacting stochastic systems

T. Kurtz, University of Wisconsin,

Brownian particle system with local time intersection and its corresponding SPDE

T. Lyons, Oxford University,

Stochastic differential equations driven by infinite dimensional Brownian motion

L. Mytnik, The Technion-Israel Institute of Technology,

SPDE driven by stable noise

G. Papanicolaou, Stanford University

Imaging and time-reversal in random media

E. Perkins, University of British Columbia

Super-chains with interactive branching and degenerate SDE's

G. Slade, University of British Columbia

Critical oriented percolation in high dimensions

S. R. S. Varadhan, Courant Institute of Mathematics, NYU

Regularity of the self diffusion coefficient

A. Wakolbinger, Johann Wolfgang Goethe-Universität

Random-constant limit intensities: two examples

WORKSHOP ON RIGIDITY OF FRAMEWORKS

September 22, 2000

Held at the Fields Institute

Also sponsored by: Department of Mathematics and Statistics, York University

Organizer: W. Whiteley, York University

The workshop took advantage of the presence of a number of experts on rigidity of spatial frameworks attending the AMS sectional meeting in Toronto. It consisted of six talks and an open problems session. The goal of the workshop was to summarize the results in rigidity of the past decade, including new applications, and to offer directions and problems for future

work in the field. Approximately 30 people attended, including a number of speakers in the AMS special session on Discrete Geometry, as well as undergraduate and graduate students from Toronto, Calgary, Montreal, and Cornell.

Speakers

J. Baracs, Université de Montréal

Digital course on Descriptive Geometry

R. Connelly, Cornell University

Stress and its applications

H. Crapo, Paris

On reading Grassmann

B. Servatius, Worcester Polytechnic

Unit distance graphs and rigidity

T.-S. Tay, National University of Singapore

Bends, motions, polarity and stress

W. Whiteley, York University

Geometric Constraints: Rigidity, angles, and applications

The workshop came to an end with an open session on unsolved problems and future directions.

WORKSHOP ON SIMPLE THEORIES

Oct. 18-22, 2000

Held at the Fields Institute

Organizers: B. Hart, The Fields Institute and McMaster; A. Pillay, University of Illinois, Urbana

Simple theories, a generalization of stable theories, were first defined by Shelah in his 1980's article "Simple, unstable theories". The subject remained essentially dormant until the foundational work of Kim and Pillay on the forking relation in simple theories, and the related work of Hrushovski on specific simple theories such as smoothly approximable structures and algebraically closed fields with an automorphism.

The past five years have seen an enormous amount of work by many researchers, in which more and more of the stability-theoretic machinery has been generalized to simple theories, and at the same time interesting new obstacles and phenomena have been observed.

The goal of this workshop was to examine this progress and report on the most current developments. Among the topics examined were outstanding foundational issues related to Lascar strong types, local forking and stable forking, as well as the role of groups in simple theories, and applications.

The workshop was attended by over 40 people from 8 different countries and included more than 20 postdoctoral fellows and graduate students.

PARTIAL DIFFERENTIAL EQUATIONS IN MATHEMATICAL PHYSICS AND APPLIED MATHEMATICS

April 16-21, 2001

Held at the Fields Institute

Also supported by the Canada Research Chairs Program

Organizers: W. Craig, McMaster University and C. Sullem, University of Toronto

The goal of the workshop was to highlight the relationship between PDE and the physical and engineering sciences, both from the point of view of the provision of tasteful and well motivated problems by the sciences to PDE, and conversely of the contribution of mathematics to ongoing research programs in applied areas. With this in mind, invitations to participate were sent to a wide spectrum of researchers, with an emphasis on the disciplines within PDE that are well represented in Canadian universities. Speaking in general terms, the topics with significant representation at the workshop were

- (i) mathematical theory of fluid dynamics and turbulence,
- (ii) modeling of pattern formation,
- (iii) the calculus of variations,
- (iv) nonlinear evolution equations,
- (v) dynamical systems and Hamiltonian PDEs,
- (vi) modeling of nonlinear optical fiber communications.

There were altogether 32 invited presentations.

In addition, the workshop hosted two mini-symposia, one on financial mathematics and the second on the mathematics of high-temperature super-conductivity organized by Lia Bronsard, McMaster.

WORKSHOP ON THOM'S GRADIENT CONJECTURE

April 27-30, 2001

Held at The Fields Institute

Primary participants in the workshop: M. Aschenbrenner, U. Illinois, Urbana; S. Kuhlmann, U. Saskatchewan; C. Miller, Ohio State; D. Novikov, U. Toronto; P. Speissegger, U. Wisconsin, Madison; and S. Starchenko, Notre Dame.

The main goal of the workshop was to work through the version of the proof of Kurdyka, Mostowski and Parusinski of the Thom gradient conjecture, with a view of generalizing the result to other o-minimal structures.

SUMMER SCHOOL IN QUANTUM INFORMATION PROCESSING

May 14-18, 2001

Held at the Fields Institute

Also supported by MITACS, the Perimeter Institute for Theoretical Physics and the University of Waterloo

Organizers: M. Mosca, Waterloo; R. Cleve, Calgary; R. Laflamme, Los Alamos; D. Lidar, Toronto; and A. Tapp, Waterloo

The goal of the school was to make the field of quantum computing accessible to a general audience of scientists, including computer scientists who have little familiarity with quantum mechanics, and physicists who have little familiarity with computational and complexity theory. Most (roughly 80%) of the lectures were at a tutorial level.

The Fields Institute lecture room was overflowing with 100 participants, with many more on a waiting list. Over 50% of the participants were graduate students. There were also a large number of postdoctoral researchers and faculty members, and a handful of senior undergraduate students. Close to 60% of the

participants were from Canada, 20% from the USA, with the remaining from Australia, Europe, Asia, and Central America. The vast majority of participants considered themselves to be theoretical physicists or computer scientists (with a small but noticeable bias towards physics). There were a handful of other mathematicians, engineers, and experimental physicists.

The lecturers were leaders in the field of quantum computation, from Australia, Europe, USA and Canada:

Charles Bennett, IBM	Michael Nielsen, Queensland
Gilles Brassard, Montreal	Peter Shor, AT&T
Richard Cleve, Calgary	Aephraim Steinberg, Toronto
Peter Høyer, Calgary	Alain Tapp, Waterloo
Emanuel Knill, Los Alamos	Barbara Terhal, IBM
Raymond Laflamme, Los Alamos	Umesh Vazirani, Berkeley
Daniel Lidar, Toronto	John Watrous, Calgary
Michele Mosca, Waterloo	Ronald de Wolf, CWI

Topics covered during the school included the "basics" of quantum information, quantum algorithms and complexity, fault-tolerant quantum error correction, quantum communication and cryptography, and implementations of quantum information processing.

The summer school lectures included two Distinguished Lecture Series talks by Peter Shor, open to the general public. The first, held on Thursday afternoon, was a classic introductory lecture on quantum computation and his famous factoring algorithm, while the second, on Friday afternoon, was an exciting talk on the capacities of quantum channels. The non-tutorial lectures on Friday, by Bennett, Laflamme, Vazirani and Shor were also open to the general public, and were very well attended.

Feedback from the participants and lecturers was very positive. The Fields Institute staff did a superb job. We are very grateful to the lecturers for agreeing to attend and for the sponsors for financing the school.



M. Mosca



R. Cleve



R. Laflamme



A. Tapp



D. Lidar

A WORKSHOP IN HONOUR OF ALLAN BORODIN'S 60TH BIRTHDAY

June 22-23, 2001

Held at The Fields Institute

Also sponsored by Department of Computer Science, University of Toronto

Organizer: S. Cook

The workshop was an opportunity to celebrate Allan Borodin's long and distinguished research career in computational complexity by featuring speakers among his former students, collaborators and colleagues. There was a strong response when the initial invitations were sent, resulting in a full high quality program of 22 speakers, each giving a 30 minute talk.

Several talks were motivated by the World Wide Web. Jon Kleinberg showed how to model the "small world phenomenon" of the web: almost any pair of major sites is connected by a path with just a few links. Madhu Sudan showed how to model web browsing with a "backoff process": a Markov chain with back buttons. Borodin's current student Panayiotis Tsaparas analyzed algorithms for finding "authorities" on the web, useful for web search engines. On another subject, Les Valiant showed how a certain class of quantum computations can be simulated classically in polynomial time, but warned that physicists are attacking the traditional foundations of complexity theory like termites slowly eating away basement beams. Avi Wigderson gave an excellent survey talk showing how algebra and combinatorics have been fruitfully combined to construct expander graphs.

Steven Rudich gave a talk on the futility of formal code obfuscation, and also demonstrated his phenomenal magical skills by mysteriously sticking a playing card signed by Borodin on the ceiling of room 220. This card permanently joins the one signed by Cook during the workshop in his honour in April, 2000.

The talks were consistently well-attended, despite the intense schedule. The workshop was followed by a banquet the evening of June 23. Pictures are available from the birthday link of Borodin's home page: www.cs.toronto.edu/~bor.

S. Ben-David, Technion
Computational Complexity vs. Statistical Generalization in Learning – A survey of current knowledge and major questions

J. Edmonds, York University
TCP has Competitive Flow Times

C. C. Gottlieb, University of Toronto
The New Real Estate, (Control of channels)

D. Kirkpatrick, University of British Columbia
Restructuring Ordered Binary Trees

J. Kleinberg, Cornell University
Small-World Phenomena and the Dynamics of Information

I. Munro, University of Waterloo
A Worst Case Constant Time Priority Queue

R. Ostrovsky, Telcordia Technologies
Non-Interactive and Non-Malleable Commitment and Zero-Knowledge

N. Pippenger, University of British Columbia
Random Boolean Functions

Y. Rabani, Technion
Geometric Search Structures in High Dimensional Spaces

A. Razborov, Steklov Mathematics Institute/IAS
Proof Complexity of Pigeonhole Principles

A. Rosen, Technion

Tight Bounds on the Performance of Longest-In-System on DAGs

S. Rudich, Carnegie Mellon University

Formal Code Obfuscation

B. Schieber, IBM - T. J. Watson Research Center

Online Server Allocation in a Server Farm via Benefit Task System

M. Sudan, M.I.T.

Random Walks with Back Buttons

H. Tamaki, Meiji University

Heuristic Algorithms For Euclidean TSP Based On Arora's Dynamic Programming Scheme

M. Tompa, University of Washington

Identifying Motifs in Orthologous DNA Sequences from Multiple Species

P. Tsaparas, University of Toronto

Link Analysis Ranking Algorithms on the World Wide Web

E. Upfal, Brown University

Can Entropy Characterize Performance of Online Algorithms?

L. Valiant, Harvard University

Quantum Computations That Can be Simulated Classically in Polynomial Time

J. von zur Gathen,

Randomness Brings Order

A. Wigderson, Institute for Advanced Study

Expanders – Where Combinatorics and Algebra Compete and Cooperate

R. E. Yaniv, Technion

On Clustering, Metric Selection and Information Theory

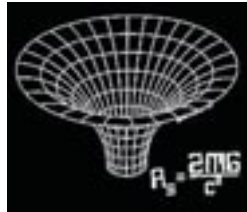


SEMINARS

STRING THEORY SEMINAR

October-November 2000

Held at the Fields Institute

Organizer: A. Peet,
University of Toronto

Superstring/M theory, commonly known as string theory, is by far the most promising candidate for a unified quantum theory of the gravitational, electroweak, and strong forces and matter. It illuminates the physics of ultra-high energies, and provides ways of building models of our low-energy world. There has been enormous progress in the field since late 1994. One result which caught the attention of many researchers was the 1996 computation of the Bekenstein-Hawking entropy of special black holes using stringy D-brane techniques. Since then, a more general understanding of black hole entropy in string theory has been obtained via the Black Hole Correspondence Principle. Further exciting new results, such as the Gravity/Gauge Correspondences, have been obtained via study of aspects of black holes.

Physicists, mathematicians, and CITazens attended, including faculty, postdoctoral fellows, graduate students, and even occasional undergraduates. The format was very informal, with questions encouraged at any time from any participant. A basic familiarity with quantum field theory and general relativity was recommended but not required.

These seminars were based on a set of introductory lectures given by Peet at the 1999 Theoretical Advanced Study Institute, the write-up of which can be found at <http://xxx.lanl.gov/abs/hep-th/0008241>. Topics discussed include: black hole thermodynamics and the information problem, supergravities and supersymmetric (BPS) states, duality, dimensional reduction, solution-generating, extremal and non-extremal branes, the Gregory-Laflamme instability, breakdown of supergravity and the Correspondence Principle, limits in parameter space, making black holes with intersecting branes, and explicit four and five-dimensional examples of entropy and Hawking radiation computations.

COMPLEXITY THEORY AND MODEL THEORY

October 2000 – April 2001

Held at the Fields Institute

Organizers: B. Hart, Fields Institute and McMaster; T. Pitassi,
University of Toronto

The goals of this seminar were to capitalize on the new additions to the logic scene in the greater Toronto area and to explore points of commonality between these two areas; talks were meant to be expository and informal. There was regular participation from faculty at McMaster, Toronto and Waterloo.

Speakers

Steve Cook, University of Toronto

A Model-Theoretic Proof of The Buss Witnessing Theorem

R. Cluckers, University of Leuven

Infinite Pigeonhole Principles and Grothendieck Rings of Definable Sets

B. Hart, McMaster University

The Independence Property and Vapnik-Chervonenkis Dimension

D. Haskell, McMaster University

Quantifier Elimination from a Model Theorist's Point of View

D. MacPherson, Leeds

The Asymptotics of Definable Sets in Finite Structures

A. Urquhart, University of Toronto

Riis's Complexity Gap for Tree Resolution, and the Independence of the Pigeon Hole Principle: A Nonstandard Model Theoretic Proof

A. Woods, Western Australia

Colouring Rules for Finite Trees, and Probabilities of Monadic Second Order Sentences

FIELDS REGIONAL COLLOQUIUM IN APPLIED MATHEMATICS: MONTHLY COLLOQUIUM

October 2000 – April 2001

Held at the Fields Institute

Organizers: W. Craig, McMaster University and C. Sulem, University of Toronto

The Fields Institute Regional Colloquium on Applied Mathematics is a monthly colloquium series intended to be a focal point for mathematicians in the area of applied mathematics and the analysis of partial differential equations. It is designed to bring together the applied mathematics community on a regular basis, to present current results in the field, and to strengthen the potential for communication and collaboration between researchers with common interests. The series consists of talks by internationally recognized experts in the field, some of whom reside in the region and others who are invited to visit especially for the colloquium.

Lectures

C. Bardos, Université Paris 7

Mathematical analysis of the time reversal method

L. Bronsard, McMaster University

Vortex lattices in layered superconductors

N. Ercolani, University of Arizona at Tucson

Landau theory for irrotational vector fields

R. de la Llave, University of Texas at Austin

Minimizers in periodic media

N. Kamran, McGill University

The long-time dynamics of Dirac fields in the Kerr-Newman black hole geometry

P. Lax, Courant Institute, NYU

Multiple eigenvalues

J. Lega, University of Arizona at Tucson

Hydrodynamics of bacterial colonies: a model

R. McCann, University of Toronto

Kinetic equilibration rates for granular media

L. Nirenberg, Courant Institute, NYU

Estimates for elliptic systems for composite materials

H. Segur, University of Colorado

A search for stable patterns of water waves

C. E. Wayne, Boston University

Reduced equations for hyperbolic problems on thin domains

SPONSORED ACTIVITY

ONTARIO TOPOLOGY SEMINAR, FALL 2000

October 14-15, 2000

Held at the Department of Mathematics at the University of Western Ontario

Also sponsored by NSERC

Organizers: R. Jardine and D. Christensen, University of Western Ontario

Topics included: Pro-spectra and duality; Universal homotopy theories, with applications; Topological resolutions of the $K(2)$ -local sphere; Algebro-geometric free loop space and vertex algebras; 4D topological gravity and wall-crossing formulas; Strange abelian categories; and Commutative ring spectra and co-Postnikov approximation".

2001 NERENBERG LECTURER AT THE UNIVERSITY OF WESTERN ONTARIO

March 20, 2001, 7:30 pm

Held at the University of Western Ontario

Given by S. F. Singer, George Mason University, University of Virginia, and SEPP

Where was global warming this winter when we needed it?

The Nerenberg Lecture recognizes the accomplishment of overcoming scientific, mathematical, or theoretical obstacles to communicate the significant ideas of our age to a broad audience.

NOVEL APPROACHES TO HARD DISCRETE OPTIMIZATION

April 26-28, 2001

Held at the University of Waterloo

Organizers: K. Anstreicher, The University of Iowa; P. Pardalos, University of Florida; F. Rendl, Universitaet Klagenfurt; T. Vannelli, University of Waterloo; H. Wolkowicz, University of Waterloo

The aim of the workshop was to bring together researchers from several communities – such as: algorithmic nonlinear optimization; combinatorial optimization, dealing with computational methods for NP-hard problems; computer scientists interested in scientific parallel computing – who share a common interest to do computations on (large-scale) hard combinatorial optimization problems.

MSRT 2001 – THE 23RD ANNUAL MONTREAL-ROCHESTER-SYRACUSE-TORONTO CONFERENCE ON HIGH ENERGY PHYSICS

May 15-18, 2000

Held at the University of Western Ontario
Also sponsored by Institute of Particle Physics, Ottawa, Ontario;
Perimeter Institute for Theoretical Physics, Waterloo, Ontario;
The University of Western Ontario, Faculty of Graduate Studies;
The University of Western Ontario, Faculty of Science

Organizers: V. Elias, G. McKeon, V. A. Miransky, University of Western Ontario

MRST 2001 was the 23rd of a series of meetings in theoretical high energy physics that usually rotate between McGill University, The University of Toronto, The University of Rochester, and Syracuse University. MRST is an excellent forum for speakers to disseminate their research findings to a knowledgeable, engaged and supportive audience.



Institute visitors

NATIONAL PROGRAM COMMITTEE

The Fields Institute supports a full range of activities in the mathematical sciences, most often in cooperation with other partners, as noted in the listings above. Many are supported through the National Program Committee.

The three Canadian Institutes in the Mathematical Sciences – the Centre de recherches mathématiques (CRM), the Fields Institute, and the Pacific Institute for the Mathematical Sciences (PIMS) – have initiated a program for the support of joint activities. The program is administered by the National Program Committee, which makes recommendations to the Directors of the three institutes.

APPROXIMATION, COMPLEX ANALYSIS AND POTENTIAL THEORY

July 3-7, 2000

Held at Université de Montréal, Montréal
Supported by the National Program Committee (CRM, Fields, PIMS), Université de Montréal, NSERC and NATO

Organizers: A. Daigneault, Université de Montréal; Norair Arakelian, Institute of Mathematics, National Academy of Science of Armenia

There were a total of 68 participants.
This NATO Advanced Study Institute, which was the 39th Session of the Séminaire de mathématiques supérieures at the Université de Montréal, focused on the interplay between complex analysis and potential theory.

The principal speakers were Alano Ancona, Orsay; Norair Arakelian, Armenian Academy of Sciences; David H. Armitage, Queen's University of Belfast; Thomas Bagby, Indiana; Mario Bonk, Michigan; Huaihui Chen, Nanjing Normal University; David Drasin, Purdue; Stephen Gardiner, University College Dublin; Paul M. Gauthier, Université de Montréal; Thomas Ransford, Laval; Arne Stray, Bergen.

The proceedings of the conference, Approximation, Complex Analysis, and Potential Theory, will be published by Kluwer Academic Publishers.

12TH CANADIAN CONFERENCE ON COMPUTATIONAL GEOMETRY

August 16-19, 2000

Held in Fredericton, New Brunswick

Supported by the National Program Committee (CRM, Fields, PIMS) and the University of New Brunswick, and sponsored by AARMS

Organizer: David Bremner, University of New Brunswick

Computational Geometry is concerned with algorithms, software, and mathematical foundations for the treatment of geometric data by computer. The Canadian Conference on Computational Geometry (CCCG) reflects this diversity of interest, with invited speakers and contributed papers on topics ranging from geometric applications in industry to the frontiers of pure mathematics. There were 75 participants at the conference from 10 countries. The plenary speakers were Gil Kalai, (Paul Erdos Memorial Lecture), Jerusalem; Naoki Katoh, Kyoto; and Colin Ware, New Hampshire.

A special issue of Computational Geometry: Theory and Applications devoted to papers from this conference will appear in October 2001.

FIRST PRAIRIE INDUSTRIAL PROBLEM SOLVING WORKSHOP

August 7-11, 2000

Held in Brandon, Manitoba

Supported by the National Program Committee (CRM, Fields, PIMS), Brandon University, the University of Manitoba, University of Regina, the Institute of Industrial Mathematical Sciences and Western Economic Diversification Canada

Organizers: Lynn Batten, Deakin University; John Brewster, University of Manitoba; Doug Pickering, Brandon University; and Michael Tsatsomeris, University of Regina

The First Prairie Mathematics and Industry Problem Solving Workshop attracted 45 faculty, students and industry representatives, predominantly from the provinces of Manitoba and Saskatchewan.

The participants developed solutions to three problems that were brought to the meeting by representatives of industry and government: Dr. Norman Corbett, Department of National Defence (in Winnipeg), Dr. Darryl Dormuth, Atomic Energy of Canada Limited (in Pinawa), and Dr. Graeme Strathdee, Potash Corporation of Saskatchewan (in Saskatoon). This was followed by three days of intensive work by the participants. The problem sessions were assisted by three experts: Bob Blakely of Texas A & M University facilitated the AECL problem, Chris Budd of the University of Bath facilitated the DND problem, and Tim Myers of Cranfield University facilitated the Potash Corporation problem. Each working group presented a summary and recommendations of their work to the full group. These summaries are currently being written into reports which will be published in a proceedings volume in the near future, in both English and French. The reports will also be available on the web at www.math.brandonu.ca/workshopmath.

APICS-AARMS: OCTOBER 2000

Atlantic Association for Research in the Mathematical Sciences (AARMS) and Atlantic Provinces Council on the Sciences (APICS) Annual Meeting

October 20-22, 2000

Held at Dalhousie University, Halifax

Supported by the National Program Committee (CRM, Fields, PIMS), CMS / CMS Students Committee, Dalhousie University, Nelson Canada, Pearson Education Canada, John Wiley & Sons, McGraw-Hill Ryerson, MathResources Inc., Waterloo Maple, Inc.

Organizers: A. Coley, S. Ruan and R. Wood, Dalhousie University)

There were 3 plenary lectures, by Joachim Lambek (Blundon Lecture), McGill; Morven Gentleman, Dalhousie; and Larry Bretthorst, Washington University, St. Louis.

The annual Undergraduate Mathematics Competition was held on Friday, with a team of two students from each university member of APICS. And special student sessions were held, in which students presented the results of their honour theses or summer projects.

A special APICS session on Applied Mathematics & Numerical Analysis was held on Saturday, with the goal of bringing together researchers from Atlantic Canada to communicate their research work and encourage possible collaboration.

Two AARMS special research sessions were held on Sunday, in category theory and Bayesian statistics.

CMS WINTER MEETING**December 10-12, 2000**

Held at Hotel Vancouver, Vancouver, B.C.
Supported by the National Program Committee (CRM, Fields, PIMS), the University of British Columbia, Simon Fraser University, The Vancouver Institute, the University of Calgary, The Centre for Experimental and Constructive Mathematics (CECM), MITACS, University of Saskatchewan, University of Alberta, The Royal Society of Canada

Meeting Director: Dale Rolfsen, UBC
Local Arrangements Co-Chairs: Afton Cayford and John Fournier, UBC

The meeting was attended by 286 participants.
The plenary speakers were Patrick Dehornoy, Caen; Richard Durrett, Cornell; Roger Howe, Yale; Izabella Laba, UBC; Stanley Pliska, UI Chicago; Paul Roberts, Utah; Peter Sarnak, Princeton. The Coxeter-James Lecture was given by Damien Roy, Ottawa; the CMS Doctoral Prize lecture by Stephen Astels, Georgia. Bernard Couteau, Sherbrooke was presented with the Adrienne Pouliot Award and Arthur Sherker, Toronto, received the CMS Distinguished Service Award.

There were special sessions in Algebraic Geometry, Classical and Computational Analysis, Financial Mathematics, History of Mathematics, Mathematical Education, Number Theory, Operator Algebras, Ordered Groups, Partial Differential Equations, and Probability and its Applications.

CANADIAN ANNUAL SYMPOSIUM ON OPERATOR ALGEBRAS**April 26-May 2, 2001**

Held at Mathematical Sciences Research Institute (MSRI), Berkeley
Supported by the National Program Committee (CRM, Fields, PIMS)

Co-Chairs: G. Elliott, University of Toronto and I. F. Putnam, University of Victoria

This meeting was joint for the first two days with the MSRI workshop on Quantization and Noncommutative Geometry, and during the three-day period April 29 - May 1 it functioned as a closing conference for the 2000-01 MSRI program on Operator Algebras.

BLACK HOLES III: THEORY AND MATHEMATICAL ASPECTS**May 19-23, 2001**

Held at the Kananaskis Inn and Conference Center, Kananaskis, Alberta

Supported by the National Program Committee (CRM, Fields, PIMS), The Canadian Institute for Advanced Research (CIAR), The Canadian Institute for Theoretical Astrophysics (CITA) and the University of Alberta

Organizer: V. Frolo, University of Alberta

Black Holes III was a research-related conference focusing on the latest advances in the theoretical and mathematical aspects of black hole physics. It paid special attention to such mathematically oriented problems as the string and M theory approach to black holes, numerical studies of black hole collisions and critical gravitational collapse, and exact solutions of Einstein's equations in higher and lower dimensions.

GROUPS, RINGS, LIE AND HOPF ALGEBRAS**May 28-June 1, 2001**

Held at Memorial University
Supported by the National Program Committee (CRM, Fields, PIMS), and the Memorial University of Newfoundland

Organizers: Y. Bahturin, E. Goodaire, M. Parmenter and Y. Zhou, Memorial University

Yuri Bahturin, with help from Edgar Goodaire, Michael Parmenter and Yiqiang Zhou of Memorial University, ran a highly successful International Workshop on Groups, Rings, Lie and Hopf Algebras, sponsored by AARMS (the Atlantic Association for Research in the Mathematical Sciences) and Memorial's Department of Mathematics and Statistics. The workshop attracted 40 researchers from 10 countries, from Russia to Japan and Belgium to Brazil. Professor Susan Montgomery of the University of Southern California was named the first AARMS "Distinguished Lecturer," and gave two talks on "Finite-dimensional Semisimple Hopf algebras".

In addition to a plenary talk, "Lie algebras over rings of differential operators", Fields medalist Efim Zelmanov delivered a well-attended public address entitled "Abstract Algebra in the 20th Century", on the first evening of the meeting.

More information and the schedule of the meeting may be found at <http://www.math.mun.ca/~yuri/GRLHA/default.htm>

CMS SUMMER MEETING

June 2-4, 2001

Held at the University of Saskatchewan
Supported by the National Program Committee (CRM, Fields, PIMS), and the University of Saskatchewan

Meeting Director: K. Taylor, University of Saskatchewan
Local organizers: C. Soteris, M. Bremner, Y. Cuttle and F.-V. Kuhlmann, University of Saskatchewan

The 2001 Summer Meeting of the Canadian Mathematical Society was both a scientific and organizational success. There are relatively few mathematicians who live within easy traveling distance of Saskatoon, so the total of 279 registered participants exceeded most expectations and seems to be a record for a regular summer meeting.

The CMS Jeffery-Williams Lecture was given by David Boyd, University of British Columbia, and the CMS Krieger-Nelson Lecture by Lisa Jeffrey, University of Toronto. The plenary lecturers were Georgia Benkart, Wisconsin-Madison; Zoe Chatzidakis, Paris; Geoffrey Grimmett, Cambridge; and Barry Simon, Cal Tech.

There were also ten well-attended special sessions in Abstract Harmonic Analysis, Geometric Topology, Graph Theory, Infinite Dimensional Lie Theory and Representation Theory, Mathematical Education: Cognition in Mathematics, Matrix Analysis, Model Theoretic Algebra, Number Theory – in Honour of David Boyd, Rigorous Studies in the Statistical Mechanics of Lattice Models, and Scattering Theory and Integrable Systems.

CAIMS

June 7-9, 2001

Held at the University of Victoria, B.C.
Supported by the University of Victoria, PIMS, The Fields Institute, CRM, MITACS and the Laboratory for Automation Communications and Information Systems Research (University of Victoria)

Scientific Committee Chair: Florin Diacu, University of Victoria
Local organizers: R. Edwards and D. Leeming, University of Victoria

About 120 participants enjoyed 6 thematic sessions plus a poster session. The sessions were:
Applied Dynamical Systems (plenary speaker, Jerrold Marsden),

Data Compression (plenary speaker, Bin Yu), Fluid Dynamics (plenary speaker, Grae Worster), Computational Biology (plenary speaker, Tandy Warnow), Mathematical Biology (plenary speaker, Hal Smith), and Neural Networks and Neural Dynamics (plenary speaker, Nancy Kopell).

A panel of five judges evaluated the contributed presentations (both posters and short talks) by graduate students and post-doctoral fellows. First prize was awarded to Ricardo Carretero-Gonzalez of Simon Fraser University, with honourable mentions going to Gustavo Carrero of the University of Alberta, and Chee Tiong Ong.

29TH ANNUAL MEETING OF THE STATISTICAL SOCIETY OF CANADA (SSC)

June 10-14, 2001

Held jointly with the Western North American Region of the International Biometric Society (WNAIR) and the Institute for Mathematical Statistics (IMS) on the campus of Simon Fraser University (SFU) in Burnaby, B.C.

Supported by the National Program Committee (CRM, Fields, PIMS) and Simon Fraser University

The meeting was a grand success with approximately 500 registered participants.

Four workshops were held:
Inferences from Genetic Data on Pedigrees by E. Thompson, U. Washington;
The Analysis of Sample Survey Data by J. Eltinge, U.S. Bureau of Labor Statistics and Texas A&M;
Data Mining by H. Chipman, U. Waterloo; and
Beyond MCMC: Monte Carlo Methods in Bayesian Computation, by J. Ibrahim, Harvard School of Public Health and M. Chen, Worcester Polytechnic Institute.

There were 55 sessions in total ranging from sessions on Genetics and Forestry to Discrete Probability and Combinatorics, with a range of internationally known speakers and sessions aimed at graduate students.

The complete program is available on the web at <http://www.math.sfu.ca/~tim/sscmtg.html>.

INTRODUCTION

The purpose of this program (CIM) is to provide links between the mathematics community and the business world – on the one hand transferring results in the mathematical sciences to the business community and on the other hand, informing the mathematics community of the mathematical needs of the business community. Our involvement in MITACS is an important aspect of CIM, and there are several other recent initiatives of note.

Activities of the 2000-2001 CIM program comprised

- Administering 8 MITACS projects;
- Organizing 2 seminar series;
- Organizing 3 workshops;
- Organizing 1 short course;
- Formation of a research center;
- Fostering and providing assistance to 2 startup firms.

FIELDS-MITACS PROJECTS

The MITACS federal Network of Centres of Excellence has brought to the Institute exciting university/industry collaborative research projects in several key sectors of the economy: biomedicine, commerce/industry, information technology, manufacturing, and trading/finance. MITACS provides mathematical models, software tools, and highly qualified personnel to assist Canadian firms.

This year the CIM program administered 8 Ontario-based MITACS projects in 4 key sectors of the economy:

BIOMEDICINE

Statistical Modeling and Analysis of Complex Traits in Human Populations

Project Leader: Shelley Bull, University of Toronto

Mathematical and Computer Modeling of Epidemics with Public Health Applications

Project Leader: John Hsieh, University of Toronto

INFORMATION TECHNOLOGY

Pattern Storage, Retrieval and Recognition Using Neural Networks

Project Leader: Sue Ann Campbell, University of Waterloo

Complex Adaptive Networks for Computing and Communication (CANCCOM)

Project Leader: Mihail Devetsikiotis, Carleton University

Applied Cryptography

Project Leaders: Scott Vanstone and Doug Stinson, University of Waterloo

Abelian Varieties in Cryptography – (Proposed Project)

Project Leader: V. Kumar Murty, University of Toronto

MANUFACTURING

Building and Modeling Semiconductor Nanostructures Using Cellular Automata

Project Leader: Harry Ruda, University of Toronto

FINANCE AND TRADING

The Mathematics of Financial Risk Management

Project Leader: Tom Hurd, McMaster University

SEMINAR SERIES

This year the CIM program offered two seminar series which were co-sponsored by the MITACS network. Each series focused on applications of mathematics in industry.

FINANCIAL MATHEMATICS SEMINAR SERIES

Held at The Fields Institute

Also supported by MITACS

Organizing Committee: P. Boyle, University of Waterloo; M. Crouhy, Canadian Imperial Bank of Commerce; D. Dawson, Carleton University; R. Dembo, Algorithmics Inc.; B. Hart, The Fields Institute; A. Levin, Bank of Montreal; T. McCurdy, University of Toronto; T. Salisbury, York University; S. Turnbull, Canadian Imperial Bank of Commerce

Seminars

September 27, 2000

Raymond Ross, Ontario Power Generation

Dynamics of Electricity Spot and Forward Prices and the Valuation of Contingent Claims

R. Almgren, University of Toronto

Optimal Execution with Liquidity Risk

October 25, 2000

M. Rindisbacher, Joseph L. Rotman School of Management,
University of Toronto

*Insider Information, Arbitrage and Optimal Portfolio and
Consumption Policies*

S. D. Promislow, Department of Mathematics & Statistics, York
University

Mortality Derivatives and the Option to Annuitize

November 22, 2000

P. Carr, Bank of America Securities

On the Nature of Options

G. Jiang, Schulich School of Business, York University

*Estimation of Continuous Time Processes via the Empirical
Characteristic Function*

January 31, 2000

J.-M. Dufour, Université de Montréal

*Simulation-based finite-sample inference in multivariate
regressions, with applications to asset-pricing models*

R. Kan, Joseph L. Rotman School of Management, University of
Toronto

Tests of Mean-Variance Spanning

February 28, 2001

M. Davison, University of Western Ontario

*Discrete and Continuous-Time Approaches to Modelling Spot
Electricity Prices*

S. Tompaidis, McCombs School of Business, University of Texas
at Austin

Market Imperfections, Investment Optionality and Default Spreads

March 28, 2001

T. Hurd, McMaster University

*Pricing in Markets Driven by General Processes with Independent
Increments*

R. Engle, Stern School of Business, New York University

Dynamic Conditional Correlations

April 25, 2001

Y. Tian, Schulich School of Business, York University

*Optimal Contracting, Incentive Effects and the Valuation of
Executive Stock Options*

T. McCurdy, University of Toronto

*News Arrival, Jump Dynamics and Volatility Components in
Individual Stock Returns*

GARP LECTURES

Held at The Fields Institute

Also sponsored by GARP

New to the Institute this year were a series of lectures coordinat-
ed by a newly formed Toronto chapter of the Global Association
of Risk Professionals (GARP), a not-for-profit, independent
organization of financial risk management practitioners and
researchers. The GARP lectures center on mathematical prob-
lems and solutions in the emerging profession of financial risk
analysis and management.

Seminars**October 18, 2000**

R. Dembo, President and CEO, Algorithmics Inc.

Where is risk management heading?

November 29, 2000

Dan Pastoric, Vice President, Ontario Hydro Energy Inc.

Trials and Tribulations of the New Energy Marketplace

January 10, 2001

Deborah Williams, Founder and Research Director, Meridien
Research

Technological Solutions for "Real-Time" Risk Management

CIM WORKSHOPS

CIM workshops provided for a dialogue between industrial and
university researchers on common mathematical topics of interest.

**CACR (CENTRE FOR APPLIED CRYPTOGRAPHIC
RESEARCH) WORKSHOP****November 10, 2000**

Held at The Fields Institute

Also sponsored by Certicom Corp.; Information & Privacy
Commission, Ontario; MasterCard International; MITACS;
Mondex International Limited; Pitney Bowes

Organizers: M. Gurski, Conference Chair, Information & Privacy
Commission, Ontario; A. Menezes, CACR and The University of
Waterloo; Sherry Shannon, CACR and SVI Consulting)

The Sixth CACR Information Security Workshop, also titled the 1st Annual Privacy and Security Workshop, was organized jointly with the Ontario Information & Privacy Commission, and focused on issues that arise when incorporating privacy into the security domain, and their solutions.

Privacy is a growing issue in technology (both wired and wireless applications), and needs to be understood as an issue separate from that of security. It needs to be addressed in the design and implementation of any system using PKI, wired and/or wireless technologies, including everything from devices to databases.

This workshop provided an opportunity for participants to develop a working vocabulary of privacy issues which technology needs to address for consumer acceptance. It also spoke to the need for public and private sector organizations to address privacy issues inherent in using these technologies. In addition, tools to assess the privacy impact of technologies were covered.

Moderators: M. Knowles (IBM Consulting Group IT Security & Privacy Services), K. Spector (Management Board Secretariat, Ontario Government)

Speakers

S. Brands, Zero-Knowledge Systems
 J. Catlett, Junkbusters.com
 A. Cavoukian, Information & Privacy Commission, Ontario
 P. Cullen, Royal Bank of Canada
 J. A. DeLaurentiis, Mondex Canada
 G. Herriges, Management Board Secretariat, Ontario Government
 P. Hope-Tindall, dataPrivacy Partners Ltd.
 B. Sookman, McCarthy Tetrault
 D. Wallace, Management Board Secretariat, Ontario Government
 B. Watkins, Treasury Board Secretariat, Government of Canada

WORKSHOP ON OPTIONS IN FINANCIAL PRODUCTS: APPROACHES TO VALUATION

December 8, 2000

Held at The Fields Institute

Also sponsored by the Royal Bank of Canada and NSERC (through a strategic project grant to the University of Waterloo)

Organizers: Phelim Boyle, Peter Forsyth, George Labahn, Ken Seng Tan, and Ken Vetzal, all from the University of Waterloo

The basic theme of this workshop was to explore the valuation of options in financial products (e.g. catastrophic reinsurance, variable annuities, segregated funds, etc.) in situations where the traditional no-arbitrage approach may need to be augmented by other techniques such as actuarial modeling or economic equilibrium arguments.

Over 100 participants, mainly from the financial and insurance industry, attended the workshop. There was much lively debate about the virtues of actuarial versus no-arbitrage approaches to valuing and hedging embedded options. The workshop was especially timely, in view of the recent regulatory changes concerning reserve requirements for segregated funds (which have been very popular in Canada).

Speakers

A. Brender, Office of the Superintendent of Financial Institutions
Liability and Capital Requirements for Segregated Funds
 D. Cummins, Wharton School of Finance
Pricing Excess-of-Loss Reinsurance Contracts Against Catastrophic Loss
 A. Kolkiewicz, Waterloo
Valuation and Hedging of Long-term Derivative Securities
 M. le Roux, SunLife
Risk-neutral valuation in practice: Implementing a hedging strategy for segregated fund guarantees
 D. Li, AXA Financial, New York
The Valuation of Basket Credit Derivatives: A Copula Function Approach
 M. Milevsky, York
The Real Option to Lapse a Variable Annuity: Can Surrender Charges Complete The Market?
 H. Windcliff, Waterloo
A No-Arbitrage Approach to Segregated Fund Guarantees

NEW DIRECTIONS IN FINANCIAL RISK MANAGEMENT

April 23-24, 2001

Held at McMaster University
Also sponsored by MITACS and McMaster University

Organizers: Tahir Choulli and Tom Hurd, McMaster University

Recent years have seen remarkable advances in quantitative approaches to such finance problems as asset pricing, interest rate modeling, optimal portfolio management, credit risk, equilibrium market modeling, and measurement of risk. These developments have occurred as a result of a strong convergence between the needs of industry practitioners and the research interests of academics. During this two-day conference we celebrated these connections and developments in quantitative finance and explored new directions, with particular emphasis on the ideas flowing in from mathematics and statistics. The meeting also had the purpose to highlight the new high-level career opportunities available to people with a quantitative background.

Speakers

Andrew Aziz, Vice President, Professional Services, Algorithmics Inc.
Phelim P. Boyle, Centre for Advanced Studies in Finance,
University of Waterloo
Lane P. Hughston, King's College, London
Dilip B. Madan, Robert H. Smith School of Business, University
of Maryland
Moshe A. Milevsky, Schulich School of Business, York University
Luis Seco, Mathematics, University of Toronto



L to R: Marshall Walker, David Ferguson, Lee Seitleman, Phil Tuchinsky (back to camera), David James, Bill Frey

SIAM – FIELDS INSTITUTE WORKSHOP: MATHEMATICAL CHALLENGES IN PRODUCT DEVELOPMENT AND MANUFACTURE

June 25-26, 2001

Held at The Fields Institute
Also sponsored by SIAM (Society for Industrial and Applied Mathematics)

Organizers: David Ferguson (Boeing), David Field (General Motors), Michael Lachance (University of Michigan-Dearborn), Ed Moylan (SIAM, Great Lakes Section), Mike Pratt (NIST), Marshall Walker (York University)

The purpose of this workshop was to identify research themes in computational and other areas of mathematics that offer the most promise over the next decade for addressing significant business and industrial problems, particularly in product development and manufacture, and to agree on next steps toward organizing an international conference around those themes.

Three overall themes were eventually chosen:

1. Reliable representation and manipulation of objects.
2. Dynamics of copious data.
3. Systems of systems / complex systems (applied mathematics of complexity).

The Fields Institute offered to sponsor research over the next two years along the lines identified.

The overwhelming consensus of the participants was to recommend holding the planned conference in Toronto.

PROFESSIONAL SHORT COURSE

The CIM program organizes professional courses, which are held at the Institute. These courses are targeted at professionals seeking a better understanding of the modern mathematical techniques applied in industry.

PROBABILITY AND MODERN FINANCE

October 18-19, 2000

Held at The Fields Institute

Instructors: Thomas S. Salisbury and Moshe Arye Milevsky, York University

This professional short course was designed for those in the financial industry – for example financial analysts, portfolio and risk managers, commodity and derivative traders - who are increasingly exposed to sophisticated mathematical techniques, many of very recent origin. It was also of considerable interest to actuaries, and was approved for PD credit by the Society of Actuaries.

Some of the topics discussed were the dependence of option prices on volatility rather than expected returns, stochastic integration, methods for distinguishing between real-world and risk-neutral probabilities, the relevance to modern financial theory of mathematical theories such as Brownian motion, Martingales, Ito's Lemma, Girsanov's Theorem, and the Black-Scholes/Merton formula.

FOSTERING STARTUP FIRMS

SIGMA FINANCIAL ANALYSIS AND MANAGEMENT

SIGMA is a new financial analysis and management firm housed within and assisted by the Institute. It was founded by David Rudd, and Professor Luis Seco of the University of Toronto. For the past 18 months SIGMA Analysis & Management has been analyzing and modeling the performance of hedge funds, trading advisors and other investment managers who try to provide superior investment returns. The object of the research was to construct portfolios of investments which can insulate investors from risk to the economy and provide solid, sustainable returns. "... investors will be looking for alternatives to exposure to the economy and will want positive returns with investment profiles not dependent on economic growth ... and SIGMA's detailed research leads us to believe we can deliver that product..." (David Rudd). SIGMA is now registered as an investment counselor and has received licensing from the Ontario Securities Commission to develop and market its product. SIGMA is meeting with interested parties who are looking to achieve superior returns while limiting their exposure to economic factors.

ONTARIO CENTRE FOR ENERGY FINANCE

Driven by the combined efforts of a team drawn from the MITACS project 'The Mathematics of Financial Risk', McMaster University, of Toronto, York University and the Fields Institute, the Ontario Centre for Energy Finance (OCEF) was created. OCEF is designed to study and develop risk management models for the electricity industry. Led by Professor Luis Seco, OCEF is mandated to develop "equitable" risk management models to help build liquid, efficient and transparent financial markets. The formation of the centre is an alliance between the Institute and a private sector partner, BetterMarkets Ltd., a developer of on-line trading engines providing businesses the opportunity to trade risk in a real time, high speed, secure environment.

KARTHIKA

Karthika Technologies (www.karthika.com), until recently housed and incubated by The Fields Institute, announced on April 4, 2001 the completion of a \$900,000 funding round, including a grant from the National Research Council of Canada through its Industrial Research Assistance program. Other sources of capital in this round of early-stage financing include the founding partners and strategic individual investors from around the globe. "With the completion of this round of financing, Karthika is in a strong position to aggressively pursue the development of cutting-edge encryption technologies, including Elliptic Curve Cryptography and Abelian Varieties Cryptography", says Hari Venkatacharya, recently appointed President of Karthika Technologies.

THE INDIVIDUAL FINANCE AND INSURANCE DECISIONS (IFID) CENTRE @ THE FIELDS INSTITUTE

The Individual Finance and Insurance Decisions Center (IFID) is a non-profit center, currently housed at The Fields Institute and associated with the Schulich School of Business at York University. Its broad objectives are to conduct and disseminate applied research in the field of financial risk management for individuals, including, in addition to finance and insurance, economics, actuarial science, taxation, operations research, law, psychology, sociology and marketing, insofar as they apply to individual consumers and their financial decisions.

The IFID center has two primary activities – linking and supporting a wide network of academic researchers interested in the topic of individual finance and insurance decisions, and focused consulting and contract work for industry and government.

The current executive director of the IFID center is Moshe Arye Milevsky (York University). It also has a governing board of directors and a variety of academic research members and affiliated research associates.

AGM

On June 18, 2001, the Institute began what we hope will become a tradition by having, in addition to the annual general meeting of the Members of the Corporation, several other events to mark the end of the old year and to ring in the new.

The first of these was a lecture by Professor Lisa Jeffrey of the University of Toronto, one of the organizers of the thematic program on Symplectic Topology, Geometry, and Gauge Theory, which was drawing to a close. Jeffrey began by explaining the origins of the subject in classical mechanics, and then described its relationship to Riemannian geometry, algebraic geometry, and Kähler geometry.

This was followed by a discussion of the three workshops associated with the program:

Quasiclassical and Quantum Structures (January 9-14), Symplectic and Contact Topology, Quantum Cohomology, Symplectic Field Theory and Higher Dimensional Gauge Theory (March 26-April 7), and Hamiltonian Group Actions and Quantization (June 4-13).

She described the topics in each of the workshops, explaining them and their importance, and spoke of some of the highlights of the workshops.

The transparencies used in her talk can be viewed at http://www.fields.utoronto.ca/programs/scientific/00-01/annual_general_meeting/JeffreyAGM.pdf.

The new thematic program in Numerical and Computational Challenges in Science and Engineering was initiated in a second lecture by Professor Joe Flaherty of Rensselaer Polytechnic Institute. He began by listing some of the "grand challenges" of computation – weather and climate, engineering design such as the Boeing 777, nuclear stockpiling, tissue engineering, and scientific discovery in such disciplines as biology and chemistry. He also mentioned in passing some of the "petty challenges" with more commercial but still important implications for the subject. The importance and growth of numerical analysis during the past few decades has been due in no small way to algorithmic breakthroughs, and one can expect such developments to continue unabated in the near future.



Left to right: Lisa Jeffrey, Bradd Hart, Joe Flaherty

The lecture concluded with a thorough discussion of the major topics of the thematic program: linear algebra, sparse systems, multilevel strategies, ODEs and DAEs (differential algebraic systems), dynamical systems, optimization, and PDEs.

In the evening a dinner was held at the University of Toronto Faculty Club, attended by many Board and Corporate members and the Institute staff, as well as by many mathematicians and others involved with the Institute. The highlight was an address by the Honourable Roy MacLaren, who has served as Canada's Minister of International Trade, and as our High Commissioner to the U.K. His speech stressed the current good fortune of Canada in spite of the pessimism of many Canadians, and the importance of trade, especially with the European Union, to our future.

FIELDS MATHEMATICS EDUCATION FORUM

The activities of the Fields Forum continue to grow. The Saturday meetings, held approximately once a month, have had an average attendance of about two dozen interested individuals from schools, colleges, universities and the publishing industry. In between these meetings a number of Task Forces busily work and move forward individual projects and issues that are reported back to the Forum.

There are presently four Task Forces. Their areas of concentration are Transition in Mathematics from Secondary to Post Secondary Institutions, Grade 12 Mathematics of Data Management, Mathematics Teacher Education, and Mathematics On-line Courses.

Ontario is currently moving from a thirteen to a twelve-year school requirement, and in 2003 the first students in the new program will be graduating with those from the thirteen year program. The Mathematics Education Forum has spent much time and energy addressing the issues that involve mathematics and the students caught up in this transition. Under the auspices of the Forum a group of individuals was contracted to develop the new secondary school mathematics curriculum. This year the revised Grades 9 and 10 mathematics courses are in place, and the new Grade 11 mathematics courses will start in September. Two Task Forces are addressing some of the issues arising directly from these changes.

The first, Transition in Mathematics from Secondary to Post Secondary Institutions, is working on the impact in mathematics on students making the transition from secondary to post secondary institutions to ensure that the lines of communications are open, that post secondary institutions are fully aware of the content and emphasis of the new secondary mathematics curriculum, and in particular that post secondary program mathematics requirements are consistent with the new secondary curriculum and that Mathematics Departments in post secondary institutions reconsider their first year course content to accommodate the changes occurring at the high school level.

A second Task Force is working on a specific Grade 12 course "Mathematics of Data Management". Members of the Forum believe that this is an area where few mathematics teachers have knowledge or experience, and that there is a need to adopt a philosophy for the development of both content and assessment materials and to establish goals for the course. This Task Force is working closely with members of Statistics Canada and together they hope to provide easy student access to Canadian data.

Many regions are beginning to experience a shortage of secondary school mathematics teachers. Ontario is no exception. It has always experienced a shortage of elementary teachers with a love of and confidence in mathematics. The Forum has had a Task Force on Mathematics Teacher Education for a number of years. This year the group addressed the shortage of mathematics teachers at the secondary level. It hosted a meeting with Chairs of Ontario University Mathematics Departments, with a view to developing strategies to encourage more students to go into teaching.

This Task Force has also studied admissions of qualified mathematics candidates into Faculties of Education, and it is developing an advertising campaign aimed at secondary and undergraduate students planning to become teachers to encourage them to take appropriate mathematics courses as part of their undergraduate teacher preparation. Ontario has a predominantly consecutive model for teacher preparation where future teachers complete an undergraduate program before applying to a Faculty of Education.

The most recent Task Force established is concentrating on On-line Mathematics Courses. Any new approaches or technologies bring opportunities and concerns. We have certainly seen this with the impact of computer technology in both school and undergraduate mathematics education. What are the opportunities and pitfalls arising from teaching and learning mathematics on-line? How should mathematics educators respond to them?

ESSO/CMS 2000 MATHEMATICS CAMP

July 9-14, 2000

Held at Brock University, St. Catharines, Ontario
Also sponsored by ESSO, CMS and Brock University

Director: E. Muller, Brock University

Students from Southwestern Ontario were invited to the camp on the basis of their scores in the National Cayley and Fermat mathematical contests. Twenty males and eight females attended. The scientific portion of the program was designed to amaze these very bright students with the breadth of mathematics at the start of this 21st century. Participating lecturers and workshop leaders included Howard Bell, Brian Calvert, Tom Jenkyns, Chuck Laywine and Bill Ralph, from Brock University. Other contributors to the scientific program were Vince Delisi from Texas Instruments and Gary Flewelling from the research project on Geometer's SketchPad at Queens University.

TEACHERS CONFERENCE: "REINVENTING THE MATH TEACHER"

August 21-22, 2000

Held at the Fields Institute
Also sponsored by Queen's University MSTE Group through the Imperial Oil Charitable Foundation

Organizer: P. Taylor, Queen's University

For two days, on August 21st and 22nd 2000, twenty-five mathematics teachers assembled at the Fields Institute for a consultation entitled Reinventing the Math Teacher. The agenda was a discussion and reflection on three aspects of the profession of mathematics teacher: teacher as scholar, teacher as student, and teacher as teacher. The participants represented a complete mix, from education students, to young teachers, to experienced teachers, coordinators and text book authors. The discussion was lively, inventive and on-target.

For the teacher as student, the participants reflected on their undergraduate years. There was a range of experiences from those who hated their university level mathematics classes to those who found them useful for a variety of reasons. The most interesting issue that arose was that of "relevance": what is it that makes things interesting to students. It was agreed that the focus should be not on "the real world" but on the level of engagement in the student. And here, the human dimension of mathematics needs to be emphasized.

For the teacher as scholar, participants began by trying to identify what it means to be a scholar, and then we discussed whether it is important for teachers to be scholars. It was agreed that to be a scholar was to be engaged in a struggle, to be motivated and curious enough to learn new things. There seemed to be no disagreement that a teacher should be a scholar in order to do his or her work effectively. It is crucial for example in helping us find a way to provide a real mathematical experience for our students in the context of a fragmented and highly technical curriculum and overly specified assessment rubrics. Quite simply, one must be a mathematician to teach mathematics.

For the teacher as teacher, participants generated a list of the constraints that exist in their teaching and tried to understand which of these might be overcome with more imagination or courage and which were more "serious" and how might they deal with those. High on the list were pressures of time, of packed and over-specified curricula, a narrow view of the subject, demands (and lack of trust) from government or other "authorities", lack of an active and supportive community in which to work.

All participants agreed that the discussion had been a wonderful experience, and that the conference represented the beginning of a community that was to live on and grow.

SIMMER

(SOCIETY INVESTIGATING MATHEMATICAL MIND-EXPANDING RECREATIONS)

October 2000-April 2001

Held at The Fields Institute

Also sponsored by the University of Toronto Mathematics Network

SIMMER brings together high-school mathematics teachers and students from all over the greater Toronto area (a unique opportunity to regularly meet other teachers with similar interests). SIMMER investigates recreational mathematics problems as well as the deeper mathematical ideas that arise from these problems. Each monthly SIMMER meeting features a keynote presentation by an invited speaker, along with a lively discussion of related recreational mathematics problems and ideas. All this takes place over the course of a light supper and refreshments.

Presentations

James Robert Brown, Philosophy, University of Toronto
Proving with Pictures

Dr. Greg Martin and Emmanuel Knafo, Mathematics, University of Toronto

A Tale of Two Series

Jeffrey Rosenthal, Mathematics/Statistics, University of Toronto
Gambling Games and Random Walks

Mark Spivakovsky, Mathematics, University of Toronto
Mathematical 'Hodgepodge' Part II

James Stewart, Mathematics, University of Toronto
Mathematics and Music

JUMP

JUMP (Junior Undiscovered Math Prodigies) is a tutoring program developed by mathematician and writer John Mighton. Through over ten years of experience in the public school system, it has been John's experience that many children, even those who are failing or are labeled as slow learners, can do well at mathematics. JUMP is committed to the advancement of education by providing free tutoring in mathematics to children identified as having difficulty succeeding in mathematics.

Over the past year, the program grew to more than 130 children from 5 inner-city schools in Toronto, using over 70 volunteers. Because of the donation of office space from the Fields Institute, JUMP was able to expand its currently volunteer-based organization to handle the rapid growth it is experiencing. Because of the desperate need of these children for help, JUMP plans to expand its program to reach 10,000 students in Toronto within 5 years.



2001-2002

Our Directorate and the Scientific Advisory Panel (SAP) provide the scientific leadership of the Institute. The SAP, which is chaired by the Director, includes the Deputy Director and a rotating membership of at least seven distinguished international mathematicians. This committee makes recommendations to the Board of Directors on the selection of thematic programs and workshops.

Walter Craig received his MS and PhD from the Courant Institute, New York University. His research focuses on nonlinear partial differential equations and Hamiltonian dynamical systems. He has taught at Caltech, Stanford University and Brown University, and is currently Professor of Mathematics and Canada Research Chair at McMaster University. He has lectured extensively at conferences and Institutes around the world, including the Tata Institute, ICMS Edinburgh, ETH, and IHES. He is a member of the Editorial Board of SIAM Journal of Mathematical Analysis, and is currently on the Council of the AMS.

Kenneth R. Davidson is the Director of the Fields Institute. He received his undergraduate degree at the University of Waterloo in 1972 and his Ph.D. from the University of California at Berkeley in 1976. He was a C.L.E. Moore instructor at M.I.T. for two years before moving to the University of Waterloo in 1978. His research interests are in operator theory and operator algebras, and he won the Israel Halperin prize in this area in 1985. He was an E.W.R. Steacie fellow 1988-90 and a Killam Research Fellow 1995-97. He was elected a fellow of the Royal Society of Canada in 1992. He has been on the editorial boards of various journals including the CMS journals and Integral Equations and Operator Theory. He has served on the CMS in various capacities including Vice President (Ontario) in 1995-97. He sat on the NSERC mathematics GSC in 1990-93, and served as chair; was a member of the NSERC Strategy Implementation Task Force in 1995, and on the Mathematics Steering Committee 1996-98. He served on the Fields Scientific Advisory Panel 1991-96, and was a co-organizer of the C^* -algebra year at the institute.

Donald Dawson received his Honours B.Sc. in Mathematics and Physics from McGill University in 1958 and his doctorate from MIT in 1963. He has taught at both McGill University and Carleton University and is currently Professor Emeritus and Distinguished Research Professor at Carleton and Adjunct

Professor at McGill. He has been a co-director of the Carleton-Ottawa Laboratory for Research in Statistics and Probability since 1982 and served as Director of the Fields Institute from 1996-2000. His research interests include large deviation theory, stochastic differential equations, stochastic partial differential equations, measure-valued processes and applications of probability to statistical physics, genetics, finance and communications. He is a Fellow of the Royal Society of Canada. He has given numerous invited lectures; including the 1991 Gold Medal Lecture of the Statistical Society of Canada, the 1994 Jeffery-Williams lecture of the Canadian Mathematical Society, an invited lecture at the 1994 International Congress of Mathematicians in Zurich, and a plenary lecture at the 1996 World Congress of the Bernoulli Society in Vienna. He has been a member of the editorial boards of a number of journals and Co-Editor-in-Chief of the Canadian Journal of Mathematics from 1988 to 1993. He has served on a number of NSERC committees, including the Mathematics and Statistical Sciences GSC's, Research Manpower, Postdoctoral Fellowship, International Relations and the 1995 Task Force on Strategy Implementation.

Andrew Granville completed his undergraduate education at Trinity College, Cambridge, and received his PhD from Queen's University, Kingston. He is the David C. Barrow Professor of Mathematics at the University of Georgia. He has also held visiting positions at Purkyne University, the Institute for Advanced Study, Isaac Newton Institute, Universidad Autonoma, Madrid, University of Michigan and University of Leiden. He was an invited speaker at the International Congress of Mathematicians in 1994. In that same year he was awarded a Presidential Faculty Fellowship by President Clinton, in 1995 the Hasse Prize by the MAA, and in 1999 the Ribenboim Prize in Number Theory. He is an editor of about a dozen journals including the Journal of Number Theory, Mathematics of Computation and the Electronic Journal of Combinatorics.

Bradd Hart is the Deputy Director of the Fields Institute. He received his undergraduate education at the University of Waterloo and received his PhD from McGill University in 1987. He is now Professor in the Mathematics and Statistics Department of McMaster University. He was awarded an NSERC University Research Fellowship in 1989. Before joining McMaster, he was a postdoctoral fellow at the University of California at

Berkeley. He has had visiting positions at the Mathematical Sciences Research Institute in Berkeley and the University of Illinois at Chicago. In 1996-97, he was an organizer of a thematic year in Algebraic Model Theory at the Fields Institute. He gave a plenary lecture at the European Logic Colloquium in 1998 and is a member of the Executive Council of the Association of Symbolic Logic.

Lisa Jeffrey obtained her A.B. degree in 1986 from Princeton University, her M.A. from Cambridge University in 1988 and her doctorate in mathematics from University of Oxford in 1992. She is currently Professor in the Department of Mathematics at University of Toronto. Prior to her present appointment she taught at McGill University and Princeton University. Her research involves symplectic geometry and mathematical aspects of quantum field theory. She has received a Sloan Fellowship, a Premier's Research Excellence Award, University of Toronto's McLean Award, and the Aisenstadt Prize of the Centre de recherches mathématiques, as well as the 2001 Krieger-Nelson Lectureship of the Canadian Mathematical Society. She is a past member of the Council of NSERC, and is on the editorial board of the Transactions of the American Mathematical Society.

Barbara Keyfitz received her undergraduate education at the University of Toronto and her MS and PhD from New York University's Courant Institute in 1970. She is now Professor of Mathematics and a John and Rebecca Moores University Scholar at the University of Houston. She is a Fellow of the American Association for the Advancement of Science and serves on the editorial boards of the SIAM Journal of Applied Mathematics, the Transactions of the AMS and Mathematical Methods in the Applied Sciences. Before joining the faculty at the University of Houston in 1983, she was a faculty member in Engineering at Columbia and Princeton, and in mathematics at Arizona State University. She has also held visiting positions at the University of Nice, at Duke University, at Berkeley, at the Institute for Mathematics and its Applications in Minneapolis and at the Fields Institute. She is Vice President for Programs for the Society for Industrial and Applied Mathematics.

Michael Overton received his BSc from UBC in 1974, along with the Governor General's Gold Medal of Arts and Sciences. He received the MS and PhD degrees in Computer Science from Stanford University. He is currently Professor of Computer Science and Mathematics at the Courant Institute of Mathematical Sciences, New York University. His research interests are in numerical algorithms, their analysis, and related issues, primarily in the areas of optimization and linear algebra. Michael Overton has held elected and appointed positions on the SIAM Board of Trustees and on the SIAM Council (Society for Industrial and Applied Mathematics). He is a member of the Council of FoCM (Foundations of Computational Mathematics). He has been a member of the editorial board of the SIAM Journal on Optimization, and served as Editor-in-Chief from 1995-1999. He has also been on the editorial board of the SIAM Journal on Matrix Analysis and Applications, from 1995 to the present.

Nicholas Pippenger received his PhD from MIT in 1974. He was a research scientist for IBM Research until 1989 and has been a professor at The University of British Columbia since 1988. He is a Fellow of the Royal Society of Canada, an ACM Fellow, an IEEE Fellow and was an invited speaker at the International Congress of Mathematicians in 1986. He was an IBM Fellow from 1987-89 and he was awarded a Killam fellowship in 1991. His main area of research is theoretical computer science and complexity theory.

William R. Pulleyblank is the Director of Mathematical Sciences in IBM's Research Division and the Director of the IBM Deep Computing Institute. He has also served as the Research Relationship Executive responsible for the Finance sector, the Utility and Energy Services industry and for the Business Intelligence group at IBM. He is currently a member of the Mathematical Sciences Board of the NRC, the External Advisory Board of DIMACS, the Advisory Council of the Pacific Institute for the Mathematical Sciences, the External Advisory Committee of the Center for Research on Parallel Computation, and RUTCOR, Rutgers University International Conferences on Discrete Applied Mathematics and Operations Research International Advisory Board. He is a member of the Industrial Advisory Committee of the Institute for Mathematics and its Applications and has served

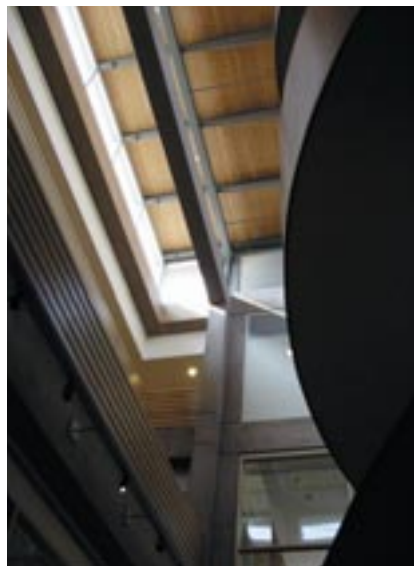
on the board of governors and was chair of the board for a year. Dr. Pulleyblank's personal research interests are in operations research, combinatorial optimization, and applications of optimization. In addition to writing a number of scientific papers and books, he has consulted for several companies; including, Mobil Oil on helicopter routing, Marks and Spencer on depot management, Statistics Canada on survey validation and CP Rail on train scheduling.

Nancy Reid is Professor and Chair of the Department of Statistics at the University of Toronto. She received her Bachelor of Mathematics in 1974 from the University of Waterloo, her PhD in 1979 from Stanford University, and held an academic appointment at the University of British Columbia from 1980 to 1986. She is a former President of the Institute of Mathematical Statistics, and a current Vice-President of the International Statistical Institute. She was elected a fellow of the Royal Society of Canada in 2001, and is a fellow of the American Statistical Association and the Institute of Mathematical Statistics, a recipient of the Presidents' Award of the Committee of Presidents of Statistical Societies, and the first recipient of the Canadian Mathematical Society's Krieger-Nelson Prize Lectureship. Her research interests include design of experiments, theory of inference, and asymptotic methods for likelihood based inference. Recent publications include several papers on the relationship between frequentist and Bayesian asymptotics, a topic of current interest in relation to the search for noninformative priors for Bayesian inference. She has also given several talks recently for non-specialist audiences, on various aspects of "Statistics in the News".

David Sankoff received his PhD from McGill University in 1969. He has worked in the field of computational biology, and in particular in the areas of sequence comparison, multiple alignment, RNA secondary structure and probabilistic methods. He developed the "empirical method" for discovering non-linear phylogenetic invariants. In the early 90's, he was responsible for stimulating the study of evolution through the mathematical analysis of genome arrangements. He is a member of the Centre de recherches mathématiques and a Fellow of the Royal Society of Canada and of the Canadian Institute for Advanced Research.

Peter Sarnak is a 1980 PhD graduate of Stanford University. He has been a tenured professor at the Courant Institute of Mathematical Sciences, Stanford University, and Princeton University, where he is a current faculty member and past department chair. He has held a Sloan Fellowship, NSF's Presidential Young Investigator award, a Sherman Fairchild Visiting Professorship at Caltech, and won the Polya Prize of the Society for Industrial and Applied Mathematics. He has served on the scientific advisory committees of the Mathematical Sciences Research Institute (Berkeley), the Institut des Hautes Études Scientifiques (Paris), and the National Science Foundation. He serves on the editorial board of *Annals of Mathematics* and other leading research journals in mathematics, and has supervised twenty-three doctoral students.

Gordon Slade received the B.A.Sc. and M.Sc. degrees from the University of Toronto and the PhD from the University of British Columbia. His research interests are probability theory and statistical mechanics. He has been Professor in the Department of Mathematics at UBC since 1999, following 13 years at McMaster University. He gave an Invited Lecture at the International Congress of Mathematicians in Zurich in 1994, was awarded the Coxeter-James Lectureship of the Canadian Mathematical Society in 1995, and was elected Fellow of the Royal Society of Canada in 2000. He serves as Associate Editor of *Annals of Applied Probability* and is a member of the Scientific Research Panel of the Pacific Institute for the Mathematical Sciences.



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Stephen Watt

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McMaster University

McMaster University is a research-intensive, mid-sized university located in Hamilton at the west end of Lake Ontario. Its Mathematics and Statistics Department has 31 faculty members who represent a wide range of mathematical research including algebra and number theory, analysis, geometry and topology, applied mathematics, probability and statistics and mathematical logic. The department has an extensive postdoctoral program with about 15 positions each year and a graduate program with over 40 students.

As one of the founding universities, McMaster's contribution to the Fields Institute has been substantial. Faculty members from McMaster were principal organizers of four of the first seven full-year programs at the Fields Institute, and there have been more than 15 joint McMaster-Fields postdoctoral fellowships. PhiMac is a group of faculty, graduate students, and postdoctoral fellows based in the department and dedicated to the theory and practice of financial mathematics. They have cooperated effectively with the Fields Institute and have received support from MITACS. Next year the department will establish the James Stewart Centre for Mathematics in Hamilton Hall, one of McMaster's two historic buildings, with the goal of creating an integrated teaching, research and outreach centre to enhance the visibility, linkages and impact of mathematics at McMaster University and the larger community.

University of Toronto

Research and teaching in mathematics is carried out at the University of Toronto in the Departments of Computer Science, Mathematics, and Statistics, with a combined total of over 140 faculty members.

The Department of Computer Science was the first computer science department established in Canada, and is characterized by its breadth of research and teaching interests, and the high quality of its faculty and graduate students. Faculty members have won many important prizes and awards, including the Turing Award (S.A. Cook), the Fulkerson Prize in Discrete Mathematics (A. Lehman), the IJCAI Award for Research Excellence (R. Reiter) and the Order of Canada (C.C. Gottlieb). The department has produced a large proportion of the computer science Ph.D.s in Canada, and has contributed faculty members to many

departments in Canada and abroad. The Department of Computer Science has strong ties with the Fields Institute. Members of the department have played a central role in several Fields programs, including the upcoming thematic program on Numerical and Computational Challenges in Science and Engineering, August 2001 to August 2002.

The Department of Mathematics at the University of Toronto is one of the leading mathematics research departments in Canada. Mathematics has been taught at the University of Toronto since 1827 and the first Ph.D. in mathematics was conferred in 1915 on Samuel Beatty – a student of John Charles Fields whose will established the Fields Medal and after whom the Fields Institute is named. Research in the department covers a broad spectrum, from mathematical foundations to interdisciplinary applications, from number theory and geometry to the analysis of shock waves and of financial risks. Research excellence is recognized through the highest research grant average in Canada, and members of the department have delivered addresses at every International Congress of Mathematics in the recent past. The department is home to the winners of the first three CRM/Fields Prizes and to the only mathematician ever awarded the Canada Gold Medal for Science and Engineering. The department is involved with the Fields Institute at all levels – through organization and participation in its workshops and thematic programs, events reaching out to high school teachers, and collaborative research projects within MITACS.

The Department of Statistics was established in 1977, and offers programs in actuarial science, statistics and probability. The department has a long history of innovation and advance in the theory and foundations of statistics, and is among the leading theoretical departments in the world. It has also been for many years at the forefront of developments in statistical computing, and maintains exceptionally strong ties with the biostatistics research group in the Department of Public Health Sciences. Research activity in probability, theoretical statistics, and methods of applied statistics is vigorous and growing, and the department has recently established a research cluster of Canada Research Chairs in data mining and machine learning, jointly with the Department of Computer Science.

Two members of the department have received the international COPSS award for outstanding achievement by a statistician under forty years of age, and two are fellows of the Royal Society of Canada. Graduate students have gone on to successful careers in academia, government and industry. The department is actively involved with the Fields Institute through a seminar series, recent thematic programs in probability and in graphical modelling in statistics, and MITACS projects in bio-medical research and information technology.

University of Waterloo

The University of Waterloo's Faculty of Mathematics is known for its innovation and leadership in education, research and technology transfer. With a population of 3,400 undergraduate, 250 graduate students, and 145 full-time professors, Waterloo ranks as the largest centre for mathematical, statistical and computer sciences in the world. The Faculty of Mathematics offers a broad range of studies through five departments: Applied Mathematics, Combinatorics and Optimization, Computer Science, Pure Mathematics, and Statistics and Actuarial Science. Widely known for its accomplishments in computer science, it also has exceptional strength and stature in discrete mathematics, applied statistics, and actuarial science. Recently, cryptography has seen rapid development with the appointment of two NSERC industrial chairs. The Faculty of Mathematics generated \$12.6 million in research funding last year. With the University's liberal position on intellectual property, research conducted in the Faculty has resulted in over 100 spin-off companies founded by professors, students and graduates.

Known for its mathematics and computer contests, its successful graduates, and its high standards, the Faculty of Mathematics consistently attracts the best students from around the world. Waterloo has placed among the top 10 schools in each of the past eight years in the Association for Computing Machinery (ACM) International Programming Competition, and has been the world champion twice (1994, 1999) during that time. As well, the University has placed in the top five in the Putnam

Competition eight times in the past decade, placing first in 1999 and tying for sixth place last year. UW routinely ranks among the top three or four schools in terms of the number of students who place in the top 200 in that competition.

For nine years in a row, a group of more than 3,500 senior administrators, company presidents, and academic counsellors surveyed by Maclean's Magazine judged the University of Waterloo to be the "Best Overall" university in Canada.

University of Western Ontario

Activity in Mathematics and its applications at the University of Western Ontario is focused within the four Mathematical Science departments. There is growing collaboration between the departments, and links with all other sectors of the University. There is substantial interaction with and support from the private sector.

The Department of Applied Mathematics is one of only two in the country. The department is research-intensive: areas of study include mathematical biology, medical science, financial mathematics, materials modelling and nanotechnology, atomic and high-energy physics, fluid dynamics, engineering science, environmetrics, cryptography and high performance computing using Beowulf clusters. The department participates in the



Ontario Research Center for Computer Algebra, and in the Imperial Oil Centre for Mathematics Education. Members of the department are at the forefront of a recently awarded multi-faculty, multi-university CFI grant for high performance computation.

The Department of Computer Science offers degrees at all levels in Computer Science, as well as degrees with specialization in Software Engineering. Research activities are grouped under the themes of Artificial Intelligence and Logic Programming, Graphics and Imaging, Software and Systems, Symbolic Mathematical Computation, and Theory of Computing, and include projects in cognitive science and machine vision, image compression, management of distributed systems, symbolic-numeric algorithms for polynomials, architectures for mathematical communication (MathML and OpenMath), programming languages, databases, molecular computing and bioinformatics, and automata theory and formal languages. The department hosts the Ontario Research Centre for Computer Algebra. Major research projects are funded by international, federal, provincial and private sector sources.

Research and teaching in the Department of Mathematics is traditionally concentrated in the area of “pure” Mathematics. The department offers programs at all undergraduate and graduate levels of instruction. Its research team is well known: faculty members have active research programs in homotopy theory, algebraic groups, algebraic K-theory, number theory, combinatorial algebra, noncommutative geometry, harmonic analysis, complex analysis and complex analytic geometry.

The Department of Statistical and Actuarial Sciences is active generally in data analysis and stochastic modelling. Data analytic methods include use of visualization in statistical analysis and the planning, design and analysis of data from a variety of types and sources, including the analysis of massive datasets as in fMRI and ultrasound imaging. Stochastic modelling includes queueing theory, risk theory, mathematical finance, actuarial models for nontraditional insurance products, utilization of health care resources, environmental impact assessment, reliability and quality control. The department runs a statistical laboratory (STATLAB) that carries out contract consulting research.

York University

The Department of Mathematics and Statistics at York University is home to a diverse group of scholars. Faculty members are active in research and publication in virtually all the major fields of mathematics and statistics. In particular, York has significant representation in several general areas including foundations of mathematics, probability and stochastic processes, analysis (differential equations and dynamics) and applied mathematics, algebra and geometry, and statistics. The quality of scholarly work produced by members of the department is attested to by its external grant support and recognition. The department has consistently been a major recipient of NSERC research grants in mathematics and statistics. In a 1995 study conducted by the US-based Institute for Scientific Information, which looked at the scientific impact of papers published in top journals, the Department of Mathematics at York University ranked second among Canadian mathematics departments in citations per paper.

The department is equally proud of its thriving graduate program. In addition to the regular MA and PhD degree programs, the department offers a long-standing MA Program for Teachers, which is designed to enhance the breadth of knowledge of high school mathematics teachers and their effectiveness in the classroom. The department also offers a Graduate Diploma in Financial Engineering, in collaboration with the Schulich School of Business. This diploma program provides the training in finance, mathematics, and computer science which is necessary to understand, design and value new financial instruments. York is also one of the three Canadian Universities participating in the project “Atlantis” funded by the Canada-European Community Program for Cooperation in Higher Education and Training. The program allows senior undergraduate and graduate students in mathematics and computer science to earn credit at York while studying in Belgium, Italy or Portugal. In addition, a number of York faculty and graduate students are involved in the National Centre of Excellence project entitled “The Mathematics of Information Technology and Complex Systems” (MITACS).

FIELDS INSTITUTE MONOGRAPHS

The Fields Institute Monographs Series (Series Code: FIM) features high-quality research monographs. Many of these are the result of activities at the Institute. All Monographs are available for purchase from the American Mathematical Society On-line Bookstore - <http://www.ams.org/cgi-bin/bookstore/bookpromo/fimseries> (ISSN 1069-5273) Hardcover.

1. Global Dynamics, Phase Space Transport, Orbits Homoclinic to Resonances, and Applications, by Stephen Wiggins, California Institute of Technology, AMS, 1993, 155pp.
2. Galois Module Structure, by Victor Snaith, McMaster University, AMS, 1994, 207pp.
3. Lectures on Operator Theory and Its Applications, ed. P. Lancaster, University of Calgary, AMS, 1996, 339pp.
4. Riemannian Geometry, eds. M. Lovric, M. Min-Oo and Y-K Wang, McMaster University, AMS, 1996, 115pp.
5. Multiplicative Galois Module Structure, by A. Weiss, University of Alberta, AMS, 1996, 95pp.
6. C^* -Algebras by Example, by K. R. Davidson, University of Waterloo, AMS, 1996, 309pp.
7. Bordism, Stable Homotopy and Adams Spectral Sequences, by S. O. Kochman, York University, AMS, 1996, 272pp.
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11. Shape, Smoothness and Invariant Stratification of an Attracting Set for Delayed Monotone Positive Feedback, by Tibor Krisztin, University of Szeged, Bolyai Institute, Hans-Otto Walthert, Universitat Giessen, and Jianhong Wu, York University, AMS, 1999, 256pp.

12. Ordered Exponential Fields, by S. Kuhlmann, University of Saskatchewan, AMS, 2000, 166pp.
13. Lectures on Operator Theory, eds. R. Bhat, Indian Statistical Institute, G. A. Elliott University of Toronto, and P. A. Fillmore Dalhousie University, AMS, 1999, 323pp.
14. Large Deviations, by F. den Hollander, Mathematical Institute, Nijmegen University, AMS, 2000, 143pp.

FIELDS INSTITUTE COMMUNICATIONS

The Fields Institute Communications Series (Series Code: FIC) features proceedings and lecture notes often growing out of the various activities at the Institute. All Communications volumes are available for purchase from the American Mathematical Society On-line Bookstore - <http://www.ams.org/cgi-bin/bookstore/bookpromo/ficseries> (ISSN 1069-5265) Hardcover.

1. Dynamics and Control of Mechanical Systems: The Falling Cat and Related Problems, ed. Michael J. Enos, The Fields Institute, AMS, 1993, 280pp.
2. Control of Flexible Structures, ed. Kirsten Morris, University of Waterloo, AMS, 1993, 243pp.
3. Hamiltonian and Gradient Flows, Algorithms, and Control, ed. Anthony Bloch, Ohio State University, AMS, 1994, 155pp.
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5. Pattern Formation: Symmetry Methods and Applications, eds. J. Chadam, McMaster University; M. Golubitsky, University of Houston; W. Langford, University of Guelph and B. Wetton, University of British Columbia, AMS, 1996, 358pp.
6. Pattern Formation and Lattice Gas Automata, eds. A. T. Lawniczak, University of Guelph/University of Toronto and R. Kapral, University of Toronto, AMS, 1996, 346pp.

7. Mechanics Day, eds. W. F. Shadwick, The Fields Institute; P.S. Krishnaprasad, University of Maryland and T. S. Ratiu, University of California at Santa Cruz, AMS, 1996, 260pp.
8. Conservative Systems and Quantum Chaos, eds. L. M. Bates and D. L. Rod, University of Calgary, AMS, 1996, 176pp.
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10. Integration Algorithms for Classical Mechanics, ed. J. Marsden, California Institute of Technology; G. Patrick, University of Alberta and W. F. Shadwick, The Fields Institute, AMS, 1996, 244pp.
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18. Topics in Semidefinite and Interior-Point Methods, eds. P. Pardalos, University of South Florida and H. Wolkowicz, University of Waterloo, AMS, 1998, 250pp.
19. Stable and Unstable Homotopy, eds. William G. Dwyer, University of Notre Dame, Steve Halperin, University of Toronto, Richard Kane, University of Western Ontario, Stanley O. Kochman, York University and Paul Selick, University of Toronto, AMS, 1998, 316pp.
20. Operator Algebras and their Applications, Volume II, eds. Peter Fillmore, Dalhousie University and J. Mingo, Queen's University, AMS, 1998, 170pp.
21. Differential Equations with Applications to Biology, eds. S. Ruan, Dalhousie University, G.S.K. Wolkowicz, McMaster University and J. Wu, York University, AMS, 1999, 509pp.
22. Topology and Markets, ed. G. Chichilnisky, Columbia University, AMS, 1999, 110pp.
23. Topics in Game Theory and Mathematical Economics. Essays in Honor of Robert J. Aumann., ed. M. Wooders, University of Toronto, AMS, 1999, 291pp.
24. The Arnoldfest. Proceedings of a Conference in Honour of V. I. Arnold for his Sixtieth Birthday., eds. E. Bierstone, University of Toronto, B. Khesin, University of Toronto, A. Khovanskii, University of Toronto, and J. E. Marsden, California Institute of Technology, AMS, 1999, 555pp.
25. Operator Theory and Its Applications, eds. A. G. Ramm, Kansas State University, P. N. Shivakumar, University of Manitoba, and A. V. Strauss, Ulyanovsk State Pedagogical University, AMS, 2000, 574pp.
26. Monte Carlo Methods, ed. N. Madras, York University, AMS, 2000, 228pp.
27. Hydrodynamic Limits and Related Topics, eds. S. Feng, McMaster University, A. T. Lawniczak, University of Guelph, S. R. S. Varadhan, Institute of Mathematical Sciences - New York University, AMS, 2000, 141pp.
28. Analysis of Communication Networks: Call Centres, Traffic and Performance, eds. D. R. McDonald, University of Ottawa, and S. R. E. Turner, University of Cambridge, AMS, 2000, 200pp.
29. Topics in Functional Differential and Difference Equations, eds. T. Faria, Universidade de Lisboa, and P. Freitas, Instituto Superior Técnico, AMS, 2001, 378 pp.

OVERVIEW

The 2000-2001 fiscal year was a success financially as well as academically. The Institute generated a surplus on operations of \$215,459. The increase in operating surplus relative to the prior year can be attributed almost entirely to increased revenues, as expenses for the year were virtually identical to those of the year before. The increase in revenues resulted from the addition of a new sponsoring university member, from greater registration fee and interest income, and from increased revenue from partnerships with companies in the Institute's commercial and industrial mathematics programs, classified under "miscellaneous". That total expenses were more or less unchanged from the prior year, in spite of an increased activity rate, can be attributed to the Institute's having to run without a Director during most of the year.

With an operating surplus for the past three years and no accumulated debt, the Institute is in a solid financial position, and can now move forward with confidence as it expands the range of research it stimulates and the breadth of applications it can sponsor.

Note: The following Auditor's Report is an electronic copy of the original document.

AUDITOR'S REPORT

To the Board of Directors of
The Fields Institute for Research in Mathematical Sciences

We have audited the balance sheet of **The Fields Institute for Research in Mathematical Sciences** as at March 31, 2001 and the statement of operations and surplus for the year then ended. These financial statements are the responsibility of the Institute's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with Canadian generally accepted auditing standards. Those standards require that we plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In our opinion, these financial statements present fairly, in all material respects, the financial position of the Institute as at March 31, 2001 and the results of its operations and its cash flows for the year then ended in accordance with Canadian generally accepted accounting principles.

Toronto, Canada,
April 25, 2001.

Ernst + Young LLP

Chartered Accountants

The Fields Institute for Research in Mathematical Sciences

BALANCE SHEET

As at March 31

	2001	2000
	\$	\$
ASSETS		
Due from University of Toronto <i>[note 3]</i>	560,250	325,182
Accounts receivable	95,994	43,847
Prepaid expenses	5,607	—
GST rebates receivable	29,394	40,429
	691,245	409,458
LIABILITIES AND SURPLUS		
Liabilities		
Accounts payable and accrued liabilities	151,501	86,836
Deferred revenue	281,701	280,038
Total liabilities	433,202	366,874
Surplus	258,043	42,584
	691,245	409,458

See accompanying notes



The Fields Institute for Research in Mathematical Sciences

STATEMENT OF OPERATIONS AND SURPLUS

Year ended March 31

	2001	2000
	\$	\$
INCOME		
Ontario Ministry of Training, Colleges and Universities	1,000,000	1,000,000
Natural Sciences and Engineering Research Council of Canada	962,911	969,802
Other NSERC program grant	67,614	—
NSERC computer grant	40,000	—
MITACS	158,437	126,365
SIGMA	40,949	—
University partners	162,000	132,500
Publications	21,152	24,586
Other external grants	—	175,480
Registration fee	77,556	39,870
Interest	35,512	15,922
Miscellaneous	40,156	2,560
	2,606,287	2,487,085
EXPENSES		
Scientific program	842,682	885,508
Salaries and benefits		
Scientific and support staff	479,921	429,818
Directorate	150,760	211,568
Administrative support staff	149,298	148,325
Employee research and administrative travel	13,107	13,938
Communications	39,074	47,463
Printed material and publishing	14,736	5,906
Equipment purchase, rental, maintenance and lease	89,632	77,220
General and office supplies	60,526	30,906
Rent and services <i>[note 3]</i>	529,442	524,519
Professional services	24,650	16,675
	2,390,828	2,391,846
Net surplus for the year	215,459	95,239
Surplus (deficit), beginning of year	42,584	(52,655)
Surplus, end of year	258,043	42,584

See accompanying notes



The Fields Institute for Research in Mathematical Sciences**NOTES TO FINANCIAL STATEMENTS**

March 31, 2001

1. PURPOSE OF THE ORGANIZATION

The Fields Institute for Research in Mathematical Sciences [the "Institute"] was founded in 1991 with federal and provincial funding. The Institute was incorporated as a corporation without share capital under the Corporations Act (Ontario) by Letters Patent dated September 28, 1994. The Institute is a centre for research in the mathematical sciences. The Institute's mandate includes programs devoted to leading-edge research in the mathematical sciences; advancement in mathematics education; enhanced graduate and post-doctoral training opportunities; and developing partnerships with industry to encourage technology transfer.

During 2000, the Institute received charitable tax status.

2. SIGNIFICANT ACCOUNTING POLICIES

These financial statements have been prepared by management in accordance with Canadian generally accepted accounting principles. The most significant accounting policies are as follows:

Revenue recognition

The Institute follows the deferral method of accounting for contributions. Unrestricted contributions are recognized as revenue when received or receivable if the amount to be received can be reasonably estimated and collection is reasonably assured. Contributions externally restricted are deferred and recognized as revenue in the period in which the related expenses are recognized.

Contributed materials and services

The value of contributed materials and services is not reflected in these financial statements.

3. RELATIONSHIP WITH UNIVERSITY OF TORONTO

The University of Toronto [the "University"] is the host site for the Institute and has agreed to provide certain services and access to certain facilities as described in the agreement between the Governing Council of the University and the Institute dated October 1, 1995. The agreement is for a term of 25 years.

The University processes all transactions for the Institute. Interest is earned or paid on the average monthly cash balance held by the University.

The University has licensed the Institute to use the premises located at 222 College Street, Toronto and charges the Institute an annual "Block Fee" of \$500,000 for the cost of this space and services.

4. STATEMENT OF CASH FLOWS

A separate statement of cash flows has not been presented, since in the opinion of management, the information it would contain is readily apparent from the other financial statements.



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Major funding is provided by the Ontario Ministry of Training, Colleges and Universities and the federal Natural Sciences and Engineering Research Council (NSERC). The corporate sponsors of the Fields Institute are Algorithmics and Nortel Networks. Our five principal sponsoring universities are McMaster University, the University of Toronto, the University of Waterloo, the University of Western Ontario, and York University. In addition, there are six affiliate universities: the Ottawa-Carleton Institute for Mathematics and Statistics, Queen's University, the University of Guelph, the University of Manitoba, the University of Saskatchewan, and the Atlantic Association for Research in Mathematical Sciences (AARMS).