The Fields Institute is 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. The Institute provides a supportive and stimulating environment in which these diverse groups can interact. Its goal is to ensure that Canada plays a significant role in mathematical discovery and mathematical application in our modern technological society.
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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 premier international prize in mathematics – the Fields medal – which is considered to be the Nobel Prize of mathematics. The Fields Institute occupies a building, situated on the University of Toronto campus, designed and constructed for Fields Institute activities.

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

The Institute building is designed to support and enhance these varied activities. Office space is provided for up to sixty-eight 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 and postdoctoral fellows, as well as more senior and well-established scientists. The topics of thematic programs embrace all 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 non-scientific details such as housing are arranged by the Institute staff.

In addition to its thematic programs, the Fields Institute supports a wide range of programs of shorter duration such as workshops and conferences, short courses, summer schools, recurring seminar series, and special lectures. Such activities are sometimes held off-site, many of them on the campuses of our sponsoring universities.

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. This year, the scope of this program has expanded to include the medical and health sector with the initiation of a Centre for Mathematics and Medicine.

The three Canadian mathematical institutes in cooperation with the Canadian statistical community, spawn the National Program on Complex Data Structures. The goal of this network is to foster nationally coordinated projects with substantial involvement of scientists working to analyze complex data sets, and as well to establish a framework for national networking of research activities in Statistics. NPCDS supports workshops designed to stimulate such projects and networks.

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 was the 1998 revision of the Ontario high school mathematics curriculum, carried out through a contract of the Fields Institute with the provincial Department 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). Our seven principal sponsoring universities are: Carleton University, McMaster University, the University of Ottawa, the University of Toronto, the University of Waterloo, the University of Western Ontario, and York University.

In addition there are five affiliate universities: Queen’s University, the University of Guelph, the University of Manitoba, the University of Maryland, and the University of Saskatchewan. The corporate sponsors of the Fields Institute are Algorithmics, General Motors of Canada, Generation 5, the Individual Finance and Insurance Decisions Centre (IFID), and Sigma Analysis Management.
THESE PAGES SURVEY THE WIDE AND GROWING VARIETY of scientific activity generated and supported by the Fields Institute. The Institute is reaching out and impacting mathematics across Canada in an ever increasing number of ways that in turn are responsible for the growing recognition of its stature.

At the annual general meeting a year ago the membership approved changes to the Institute’s by-laws that reshaped our Board of Directors, and elected a Board under those new by-laws. I am pleased to report that the new arrangement has worked exceedingly well. The Director and I have been impressed with the strengthened focus on the Institute brought to bear by the Board, and with the excellent working relationships developed among the members of the Board.

It was also one year ago that the Director’s responsibilities were transferred from Ken Davidson to Barbara Keyfitz. Barbara very quickly grasped the reins of the strong organization that Ken left in place, and through her role at the Institute is leaving an imprint on mathematics in Canada. Life continues to move on, however, and Tom Salisbury, who has contributed very strongly to the Institute as Deputy Director, will be leaving next summer to become President of the Canadian Mathematical Society. In anticipation of Tom’s departure, a search is now underway for his replacement.

The good news in the financial statements forming part of this annual report is that the Institute has benefited from a small increase in revenues. In addition the operating statement shows there has been an increase in the proportion of revenues going directly into the support of scientific activities. On the negative side, the Institute spent slightly more in total than the revenues received. While these expenditures were made in support of an enriched and heightened level of activity, they did diminish the Institute’s surplus. Obviously that imbalance cannot continue.

The bulk of the Institute’s funding comes either directly or indirectly courtesy of government. While we have every reason to believe that at both the provincial and federal level even greater benefits would flow from increased activity at Fields, we also recognize that the private sector benefits in a variety of ways from the Institute. Accordingly it is only reasonable to expect the private sector of our community to meet some of our resource needs.

At the end of 2004 the Institute launched its first annual giving campaign. The effort generated more revenue than was anticipated, and this initiative will be repeated in the future. The Institute is also studying the prospects of a
major fund-raising campaign that would seek capital gifts not to fund bricks and mortar, but increased levels of scientific activity. If the assessment, which is expected shortly, is positive, the Institute will enter into such a campaign.

It is always appropriate in these paragraphs to express on behalf of all members appreciation for the support that Fields enjoys from many directions. Our gratitude goes to our funding sources: the Province of Ontario, the Natural Sciences and Engineering Research Council of Canada and our university members in particular. The efforts of the members of our Board of Directors and of our Directorate are critical to the Institute’s success, as is the work of our external committees and panels, especially the Scientific Advisory Panel. Finally thanks are due to all the members of our staff, whose unending efforts make possible the myriad of activities that take place at and through the Fields Institute.

John R. Gardner, Chair
AT THE END OF MY FIRST YEAR AS DIRECTOR, I am pleased to present this Annual Report as a record of the varied activities carried on at the Fields Institute or under its sponsorship during the past year. Much of our activity is many years in the planning, and much of what you will read about in these pages has come to fruition as a result of the dedicated and imaginative leadership of Ken Davidson, Fields director from 2001 to 2004, who continues to be involved as an advisor, and who deserves the thanks of the whole community.

The key word for our activities this year has been “interdisciplinary”, as we have reached out in our thematic program on The Geometry of String Theory to embrace both mathematical and physical aspects of this topical area. The organizing committee consisted of three mathematicians, Lisa Jeffrey, Mikhail Kapranov and Boris Khesin, and three physicists, Kentaro Hori, Robert Myers and Amanda Peet. And let me hasten to add that even that disciplinary breakdown is misleading, for Kentaro is a faculty member in both mathematics and physics, while many of the participants held degrees in one discipline and appointments in the other.

Furthermore, we ran the program jointly with Perimeter Institute, a physics institute, in Waterloo. The program attracted a renowned international collection of visitors, including Clay Senior Scholar Eric Zaslow of Northwestern University, and an outstanding set of postdoctoral fellows who, as always, contributed greatly to the life of the institute. Fields medalist Edward Witten, claimed by both the mathematics and the physics communities, gave the Distinguished Lecture Series, while we had three stimulating Coxeter lecturers this year: Nigel Hitchin, Robbert Dijkgraaf and Renata Kallosh. (These speakers also represent both mathematics and physics.)

The one or two thematic programs at Fields each year are the single most important events we run, the reason for our existence and the greatest source of pride for the administration and for the staff. A year-long thematic program involves about six workshops, each one attracting thirty to fifty new participants in addition to the scholars in residence, and often, as this year, the program runs a summer school also. Visitors arrive here from twenty or thirty countries: principally the United States, Great Britain, France, Germany, Russia and Japan but also this year the Netherlands, Switzerland, Sweden, countries of Eastern Europe, Israel, Mexico, and countries of South America and of the Pacific Rim. Frequently, as is again the case this year, the Institute’s program is also a backdrop for a major national or international conference; this year it is “Strings 05”, which met in Toronto in July and is the premier international conference in string theory. As well as the dozen
postdoctoral fellows, the institute is home to about twenty long- and short-term visitors at any time. Postdoctoral fellows and visitors are here to work on research, to interact with each other and with the organizers, to communicate their results and to learn about new problems. At Fields, the atmosphere for research and collaboration is unequalled, with the credit going to our excellent staff who handle all the logistical details, as well as to our splendid building that seems to inspire creativity, and to the attractiveness of the city of Toronto.

We are now a few years into our new program of increasing “General Scientific Activity”, consisting of events that are not associated with the thematic program, and that may take place either at the Fields Institute or on the site of one of our seven Principal Sponsoring Universities (Carleton, Ottawa, McMaster, Toronto, Waterloo, Western and York) or at another Canadian university. This was the first full year with Carleton as a sponsoring university, and we are delighted at the activities this is stimulating. As an organization whose mission includes stimulating research and creating research opportunities, we have been encouraging proposals for interesting activities, including summer schools, workshops, lecture series and interdisciplinary activities. Fields adds value to such activities in several ways: We have the capability of organizing small and medium-sized events using our efficient staff and on-line registration and abstract system, thus freeing the organizers to concentrate on bringing the best science to their workshops; our reputation also attracts participants; and our effective communication system, both electronic and paper, gets the word out. Perhaps most important, our collective experience can help organizers learn the ropes of organizing first-rate events.

“Interdisciplinary” is a word that definitely applies to our thriving Commercial and Industrial Mathematics programs, beginning with our ongoing seminars in Quantitative Finance and in Risk Management. This year we started a new series in Industrial Optimization, organized by a committee led by Tamas Terlaky of McMaster, running along the lines of the Quantitative Finance seminar, with a pair of speakers (one from a university, one from outside) in the early evening once a month. In addition, the start-up companies we incubate, IFID and Sigma, have been joined by a non-commercial venture: a Centre for Mathematical Medicine, headed by Siv Sivaloganathan, an applied mathematician at Waterloo, and Amit Oza, an oncologist at Princess Margaret Hospital in Toronto. The Centre has already started a seminar series, and plans an opening this fall, ramping up to a full range of research activities involving medical researchers and mathematicians, including joint research projects, graduate courses, postdoctoral researchers, workshops and seminars aimed at diverse audiences. Their ambition is to be a nexus for the emerging area of mathematical research in biomedicine.

Fields reaches out to the community in many ways. Among them is our continuing presence in education, where, jointly with the Canadian Mathematical Society, we hosted a major event in May: a National Forum on Mathematics Education, which drew an attendance of over 200 teachers, instructors, researchers and provincial government representatives from across the country. In addition, we are active in the fascinating area of communicating mathematics to the public. For several years, we have helped the Royal Canadian Institute to offer a couple of mathematically oriented talks each year. This year, for the first time, we organized a public lecture in connection with the Clay Mathematics Institute’s Senior Scholars Program, when our visitor Eric Zaslow gave a lecture entitled Physmatics in June.

More and more we find ourselves part of the “community of institutes”. There are several dozen mathematics research institutes world-wide – including our fellow Canadian institutes the Centre de recherches mathématiques and the Pacific Institute for the Mathematical Sciences and eight US institutes. The Canadian institutes unite to support an Atlantic research network, AARMS, as well as to coordinate special efforts like the launch of MITACS in the mathematical research community, and the successful bid for the 2011 International Congress on Industrial and Applied Mathematics. Beginning with the 2006 prize, the CRM-Fields prize will change its name to the CRM-Fields-PIMS prize, which will be jointly awarded by all three institutes. These institutes have also joined with NRC in an initiative to bring scientists at the NRC labs into contact with the academic mathematical community. As a first step, we jointly ran a workshop in computational biology at CRM in March. In addition, Fields has undertaken to maintain a list of the research programs of eleven North American institutes and the Newton Institute in Cambridge, England. This helps in planning, to avoid duplication, and we have already
found that it leads to opportunities to cooperate with other institutes on related programs. We also coordinate a list of institutes worldwide, and we find this an attractive way to share information and to mentor new institutes.

Research institutes have changed the face of mathematics research, and have drawn attention to the role of communication and of interdisciplinary research in stimulating research mathematics. In Canada, the mathematics institutes have played an important part in focusing international attention on Canadian mathematics, as well as on giving Canadian mathematicians a window on international research directions. Fields is proud to be a part of this enterprise. As another busy year draws to a close, the nature of what it means to be a successful institute becomes clearer. In this report, you will discover how we have contributed to the effort.

Barbara Lee Keyfitz, Director
The Geometry of String Theory: September 2004–June 2005

Retrospective on the Thematic Program
Organizing Committee: Kentaro Hori and Lisa Jeffrey (Toronto), Mikhail Kapranov (Yale and Toronto), Boris Khesin (Toronto), Rob Myers (Perimeter), and Amanda Peet (Toronto)

Scientific Committee: Alexander Beilinson (Chicago), Jim Bryan (UBC), D. Freed (Austin), Kentaro Hori (Toronto), Jacques Hurtubise (McGill), Lisa Jeffrey (Toronto), Mikhail Kapranov (Yale and Toronto), Sheldon Katz (Urbana-Champaign), Boris Khesin (Toronto), Robert Myers (Perimeter Institute), Amanda Peet (Toronto), Edward Witten (I.A.S.) and Noriko Yui (Queen’s)

This year’s thematic program on the Geometry of String Theory was hosted jointly by the Fields Institute and Perimeter Institute for Theoretical Physics (in nearby Waterloo). The activities were essentially divided equally between Fields and Perimeter.

The central idea defining string theory is that, when viewed with sufficiently high resolution, all elementary particles will appear to be extended one-dimensional objects, i.e., strings. From this relatively simple starting point emerges an extraordinarily rich mathematical structure. For example, the internal consistency of the theories requires that the strings propagate in a ten-dimensional spacetime. So, six of the dimensions must be curled up on a compact geometry in order to reproduce the four-dimensional physics which we observe. In fact it is the intricacies of this internal geometry which are responsible for the complex physical interactions which emerge in the four-dimensional world. This is a simple example which illustrates the central role which geometry plays in string theory.

Further, string theory incorporates ‘supersymmetry’, a symmetry which changes the spins of elementary particles pairing each fermion with a boson – this is the origin of the ‘super’ in superstrings. On the physical side, supersymmetry plays an important role in taming high energy divergences which appear in theories of point particles. On the mathematical side, this symmetry is fundamental in constructing new topological invariants, e.g., in Seiberg-Witten theory. More recently, it has been realized that string theory is more than just a theory of strings. That is, there are other kinds of extended objects, known as Dirichlet-branes or D-branes, which play an important role. In fact in the past ten years, D-branes have been the source of a profusion of new ideas and remarkable progress in our understanding of string theory. In particular, D-branes played a crucial role in constructing new relations or ‘dualities’ between what were previously seen as five different consistent superstring theories. Instead it is now believed that they represent different phases of a single unified framework, commonly known as M-theory. Of course, mathematics played an important role in this progress as well. For example, the proper classification of D-branes comes from K-theory.

String theory originated from a ‘failed’ attempt in the 1960’s to describe the nuclear interactions. Soon after, it evolved towards a very much more ambitious goal of being ‘the theory of everything’ – that is a providing a unified framework to describe all of the elementary particles and fundamental forces in nature. Combining Einstein’s theory of gravity with the standard quantum theory used to describe physics at subatomic scales has lead to perplexing inconsistencies which have mystified physicists for over fifty years. Hence finding a quantum theory of gravity is often seen as the holy grail of theoretical physics. String theory is seen by many as the leading contender in this quest since as well as containing the appropriate structures...
to describe elementary particle physics; gravity is required by the internal consistency of the theory. However, even after more than three decades of intense investigation, our current understanding of string theory remains inadequate to understand whether or not it consistently describes physical phenomena at all energies, i.e., from the Planck scale, where the effects of quantum gravity and strings are manifest, through to energy scales accessible in present-day experiments.

Perhaps in an analogous way, string theory may also be fostering a unification of mathematics. For example, the ‘mirror symmetry’ of strings on Calabi-Yau manifolds displays a close connection between symplectic geometry and algebraic geometry. However, it must be said that the full mathematical implications of strings, supersymmetry, dualities and D-branes remain to be understood. There seem to be hints of new connections between such diverse areas of mathematics as derived categories, elliptic cohomology, geometric Langlands correspondence, quantum cohomology, differential geometry varieties with special holonomy and of special Lagrangian varieties. It is also clear that the full physics potential of this remarkable theory will only be realized once significant progress has been made in understanding its mathematical structure.

Of course, superstring theory has long stood at centre stage in the interplay between mathematics and physics and has already proven to be a phenomenal source of new ideas for both fields. Some of the most notable aspects of mathematics where the interplay with string theory is relevant include:

1. Algebraic topology (as with the first workshop at Fields on Elliptic Cohomology and Loop Spaces: loop spaces are a subject with obvious connections with string theory)
2. Algebraic geometry (particularly enumerative geometry, which has received a great deal of input from mirror symmetry)
3. Riemannian geometry (Riemannian metrics, connections and curvature belong in the toolkit of a string theorist, and most string theories are framed in terms of Calabi-Yau manifolds, those complex manifolds for which the canonical bundle is trivial. The differential geometry of manifolds with special holonomy and special Lagrangian manifolds has attracted a great deal of attention)
4. Homological algebra (as treated in the graduate course by Ragnar Buchweitz)
5. Category theory (topics such as derived categories have found many applications in string theory)
6. Representation theory (representations are ubiquitous in string theories, and some nonstandard versions such as the representation theory of affine Lie algebras and the geometric Langlands correspondence have strong connections to string theory)
7. Symplectic geometry and symplectic topology (as treated in the graduate course by Boris Khesin)
8. Algebraic combinatorics (which formed the focus of the Workshop on Schubert Varieties). This subject has to do with computing the Gromov-Witten invariants (quantum cohomology) of various target spaces (for example flag manifolds), and is an offshoot of the A model of topological string theory
9. Integrable systems (a subject with strong links to string theory, as in the KdV and KP hierarchies, the lectures of Boris Dubrovin on Frobenius manifolds, and in the mini-course on Toda theory)
10. Twisted K-theory, gerbes and other topics associated to equivariant cohomology (appearing for example in Nigel Hitchin’s Coxeter lecture series)

The aim of this year’s program was to foster new progress in understanding the foundations of string/M-theory. As well as the Fields Institute’s strong reputation in the mathematical community, the program capitalized on the recent creation of string theory groups in the Physics Department at the University of Toronto and at Perimeter Institute in Waterloo. In particular, running the program jointly with Perimeter Institute produced a particularly active year with over 800 participants, two parallel seminar series (one at each site), seven workshops, four graduate courses, three mini-courses and a graduate summer school. Further the program concluded in July by hosting Strings05, the premier international conference in string theory. The program attracted many of the world leaders in their respective fields. The most exciting topics at the forefront of research in string theory were reported on through all of the various activities, and innumerable collaborations and interactions were stimulated by all of this activity.

The activities in the fall term (between September and January) were planned to emphasize mathematical aspects, while those in the spring term (February to July) were planned to emphasize physical aspects. The highlights of the program were the seven workshops (see the list later in this section, and the individual workshop reports).
There were two additional associated events which were partially sponsored by the thematic program. The first was the Great Lakes Geometry Conference (held at Perimeter on April 30–May 1, 2005 – see the General Scientific Activity section for a description of this event). In particular, one plenary talk was given by the well-known string theorist, Sergei Gukov, from the Clay Mathematics Institute. Many other talks were related to areas of mathematics allied to string theory (for example, knot theory, geometric quantization, symplectic geometry and topology). The second associated event was a special session at the Canadian Mathematical Society summer meeting, which was held at the University of Waterloo (June 4–6, 2005) - see the Joint Institutes Initiative section for a description. L. Jeffrey, B. Khesin and R. Myers organized the special session on String Theory and Integrable Systems. Dan Freed (Texas at Austin) delivered a lecture on Correspondences, K-theory and loop groups as the plenary speaker invited in connection with this Special Session.

Over the year, there were three minicourses: The first, Frobenius Manifolds, Integrable Hierarchies, was given by Boris Dubrovin (SISSA, Trieste) at Fields on November 8-12, 2004. The second minicourse was held at Perimeter over two weeks on Generalized Geometries in String Theory. In the week of February 15–17, 2005, Marco Gualtieri (Fields) gave three lectures on Generalized Geometric Structures while Yi Li (Caltech) gave three lectures on Twisted Generalized Calabi-Yau Manifolds and Topological Sigma Models with Flux. The course concluded in the week of March 1–3, 2005 with three additional lectures by Mariana Grana (Ecole Polytechnique and Ecole Normale Supérieure) on Supergravity Backgrounds from Generalized Calabi-Yau Manifolds. The final minicourse consisted of lectures at Fields given by B.Khesin, A.Marshakov (on March 31, 2005) and M.Gekhtman (on May 27, 2005) on Toda lattices: Basics and Perspectives.

The thematic program also included five sets of special lectures by a superb collection of speakers. These activities began with the Coxeter lecture series by Nigel Hitchin (Oxford) on November 15-17, 2004. He lectured on the geometry of generalized complex manifolds, a topic which is tied to string theory by the study of B-fields and which was also seen in the winter minicourse at Perimeter. On January 17–20, 2005, the Coxeter lecture series was given by Robbert Dijkgraaf (Amsterdam). He began with a beautiful general lecture on Mathematics in String Theory and followed this by two lectures on Topological String Theory. Next on April 4–7, 2005, the Distinguished Lecture Series by Edward Witten (IAS, Princeton) dealt with the mathematical background behind well-known constructs in theoretical physics (scattering theory and its relation to analysis; solid state physics and the theory of superconductors, and its relation to four-manifold geometry via the Seiberg-Witten equations; and the quantum Hall effect with its relation to knot invariants). Renata Kallosh (Stanford) was the final Coxeter lecturer delivering a series of talks on May 9–11, 2005 describing recent progress on using string theory to describe early universe cosmology. All of the above lecture series included lectures delivered at both the Fields and Perimeter Institutes. The final special lecture was a Clay Math Institute Public Lecture by Eric Zaslow entitled Physmatics on June 2, 2005 at Fields – Eric is a Clay Institute Senior Scholar whose funding from the Clay Institute supported his participation in the program.

The seminar series was the driving force of the program and the interaction center of the program participants throughout the year. The talks and lecture series were given by program visitors, postdocs and guests of the University of Toronto Mathematics Department. Parallel series of seminars were held at both locations, Fields and Perimeter. The scheduling was arranged to maximize the interaction of program participants at both locations. In fall 2004, the regular seminars were held on Mondays at Fields and on Thursdays at Perimeter. For winter/spring 2005, the schedule was shifted to Tuesdays and Thursdays at Perimeter and Fields, respectively. In the mathematics domain, an impressive variety of topics was presented, ranging from representation and category theories to decorated Teichmüller spaces and mirror symmetry and Donaldson-Thomas invariants. A similarly diverse array of physics topics were discussed in the seminars, ranging from topological M-theory and holographic cascades for quiver theories to experimental constraints on supersymmetric theories coming from the cosmic microwave background. Overall the seminar series saw a good representation of the
Thematic Programs

most exciting topics at the cutting edge of research in string theory.

At Fields, the theme year participants included twelve postdoctoral fellows in both physics and mathematics: Marco Gualtieri, Manfred Herbst, Paul Horja, Nan-Kuo Ho, Shabnam Kadir, Kris Kennaway, Seongchun Kwon, Ruxandra Moraru, Martin Pinsonnault, Ashish Saxena, Alex Yong and Ke Zhu. These postdocs were partly supported by grants from Fields with additional support coming from the personal NSERC grants of various researchers, as well as university teaching support. One of these postdoctoral fellows, Paul Horja, held the Marsden Postdoctoral Fellowship. Another four (Gualtieri, Ho, Pinsonnault and Yong) came with NSERC Postdoctoral Fellowships, which may be taken to indicate both the high quality of the participants and the external attention drawn to the program. A substantial number of graduate students participated in the program, attending the graduate courses and the graduate Summer School (held at PI). The program sponsored approximately forty long term visitors, who spent anywhere from one month to the entire year at Fields and/or Perimeter as program participants. Activities at Fields were funded in part by generous sponsorship from Perimeter Institute. Further funding was also provided by the Connaught Fund of the University of Toronto, the University of Toronto at Scarborough and the National Science Foundation.

Of course, the goal of the string program was to stimulate new science, and also to foster discussions between mathematicians and physicists on new directions of research. The full impact of such a program is often difficult to measure and the new ideas which it stimulates usually do not come to fruition immediately. However, it is already clear that this program made a substantial contribution towards advancing the theory and fostering interaction between its different domains and researchers with different backgrounds. There were many positive comments about the string program from other mathematics and physics institutions around the world. As an example of the fruitful interactions, the course and workshop on Mirror Symmetry catalyzed collaboration of two world-class geometers, A. Bondal (Steklov Mathematical Institute) coming from algebraic geometry and W.-D. Ruan (University of Illinois, Chicago) specializing in symplectic geometry. The workshop on Topological Strings provided a stage for intensive discussions between mathematicians and physicists. It was recognized there, for the first time, that the topological string partition function should be regarded as the wave function of some quantum system, both in mathematics and physics. Ragnar Buchweitz’s course on Homological Algebra catalyzed many discussions around the question of what is the right mathematical language for string theory. Even after his course finished, he and many program participants (including M. Aldi, M. Gaultieri, M. Herbst, K. Hori, P. Horja, D. Page and several students) continued in a series of regular meetings to discuss Maximal Cohen-Macaulay modules and their relation to D-branes in Calabi-Yau and Landau-Ginzburg models. These meetings saw a vigorous exchange in which mathematicians and physicists taught each other what they knew and tried to learn something they wanted to know. These are just a few examples of the numerous collaborations and interactions which were generated by the string program.

Program activities continued beyond the period covered by this report. The three-week graduate summer school, Strings, Gravity and Cosmology, took place at Perimeter Institute. This school brought 23 first-class lecturers and roughly 90 students from all over the world for lectures which ran from introductory material to new (as yet unreported) research results. The final event was Strings 05, held on July 11-16, 2005 at the University of Toronto. The “Strings” conferences are the main international meetings in the field of string theory and they are held annually to bring together the world’s leading researchers to present and discuss the latest developments of string theory. Strings 05 marked the first time such meeting was held in Canada! Both these events will be reported on in detail in next year’s annual report.

GRADUATE COURSES

Course on Mirror Symmetry
September–December 2004
Instructor: Kentaro Hori (Toronto)

Course on String Theory
September–December 2004
Instructor: Amanda Peet (Toronto)

Mini-Course on Frobenius Manifolds and Integrable Hierarchies
November 8–12, 2004
Instructor: Boris Dubrovin (SISSA, Trieste)

Course: Introduction to Homological Algebra
January–June 2005
Instructor: Ragnar Buchweitz (Toronto)
Thematic Programs

Course on Symplectic Geometry and Topology
January–June 2005
Instructor: Boris Khesin (Toronto)

Mini-Course on Generalized Geometries in String Theory
(Held at Perimeter Institute)
February–March 2005
Instructors: Marco Gualtieri (Fields), Yi Li (Caltech) and Mariana Grana (Ecole Polytechnique & Ecole Normale Supérieure)

Mini-Course: Toda lattices: Basics and Perspectives
March 31 and May 27, 2005
Speakers: Boris Khesin (Toronto), Andrej Marshakov (Lbedev and ITEP, Moscow), and Michael Gekhtman (Notre Dame, IN)

WORKSHOPS

Workshop on Forms of Homotopy Theory: Elliptic Cohomology and Loop Spaces
September 27–October 2, 2004
Organizing Committee: Matthew Ando (UIUC), Michael Hopkins (MIT), Haynes Miller (MIT) and Jack Morava (Johns Hopkins)

Workshop on Mirror Symmetry
November 19–23, 2004
Held at Perimeter Institute
Organizing Committee: Denis Auroux (MIT), Mark Gross (Warwick), Kentaro Hori (Toronto) and Noriko Yui (Queen’s)

Workshop on Topological Strings
January 10–14, 2005
Organizing Committee: Ezra Getzler (Northwestern), Kentaro Hori (Toronto) and Sheldon Katz (UIUC)

Workshop on N=1 Compactifications
March 21–25, 2005
Organizers: Michael Douglas (Rutgers), Kentaro Hori (Toronto) and Savdeep S. Sethi (Chicago)

Workshop on String Phenomenology
March 28–April 1, 2005
Held at Perimeter Institute
Organizers: Jan Louis (Center for Mathematical Physics, Hamburg), Robert Myers (Perimeter) and Gary Shiu (Cornell)

Workshop on Gravitational Aspects of String Theory
May 2–6, 2005
Organizers: Per Kraus (UCLA), Don Marolf (UCSB) and Amanda Peet (Toronto)

Workshop on Schubert Calculus and Schubert Varieties
June 8–12, 2005
Organizers: Lisa Jeffrey, Megumi Harada, and Alistair Savage (Toronto); and Alexander Yong (UC Berkeley)

Summer School Program on Strings, Gravity and Cosmology
June 20–July 8, 2005
Held at Perimeter Institute
Organizers: Alex Buchel (Perimeter & UWO), Taejin Lee (Kangwon National U. & APCTP), Robert Myers (Perimeter), Moshe Rozali (UBC) and Gordon Semenoff (UBC)
To be reported in the 2006 Annual Report

Strings 05
July 11–16, 2005
Held at the University of Toronto
Organizers: Alex Buchel (Perimeter), Jaume Gomis (Perimeter), Kentaro Hori (Toronto), Robert Myers (Perimeter), and Amanda Peet (Toronto)
To be reported in the 2006 Annual Report

LECTURES

Coxeter Lecture Series
November 15–17, 2004
Nigel Hitchin (Mathematical Inst., Oxford)
Open orbits and geometrical structures
Instantons and bihermitian metrics
Geometry with B-fields

January 17–20, 2005
Robbert Dijkgraaf (Inst. for Theoretical Physics, Amsterdam)
The mathematics of string theory
Topological string theory I and II

May 9–11, 2005
Renata Kallosh (Stanford)
Towards string cosmology
Stabilization of moduli in string theory I and II

Distinguished Lecture Series
April 4, 5, 7, 2005
Edward Witten (IAS, Princeton)
Relativistic scattering theory
Gauge symmetry breaking
The Quantum Hall Effect
**Thematic Programs**

**SEMINARS**

*Fields Institute*

**September–December 2004**

- Kai Behrend (UBC)
  *On some aspects of the de Rham cohomology of stacks*
- Alexei Bondal (Steklov Mathematical Inst.)
  *Mirror symmetry via constructible sheaves*
- Jim Bryan (UBC)
  *The local Gromov-Witten theory of curves*
- Vladimir Fock (ITEP)
  *Cluster varieties in everyday life*
- Ionut Ciocan-Fontanine (Minnesota)
  *A generalization of the Hori-Vafa Conjecture*
- Marco Gualtieri (Fields)
  *An introduction to generalized geometry*
- Paul Horja (Fields)
  *Toric Deligne-Mumford stacks and mirror symmetry*
- Fyodor Malikov (Southern California & Fields)
  *Algebras of chiral differential operators and the Courant bracket (part 1 and part 2)*
- Wei-Dong Ruan (Illinois at Chicago)
  *Deformations of integral coisotropic submanifolds in symplectic manifolds*
- Jean-Yves Welschinger (Ecole Normale Supérieure de Lyon)
  *Invariants of real symplectic 4-manifolds out of reducible and cuspidal pseudo-holomorphic curves*
- Eric Zaslow (Northwestern)
  *Affine Manifolds, Torus Fibrations and the Y-Vertex*
- Ke Zhu (Fields)
  *Degeneration of the moduli space of J-holomorphic discs and Legendrian contact homology*

*Perimeter Institute*

**September–December 2004**

- Iosif Bena (UCLA)
  *Entropy and microstates of black rings*
- Cliff Burgess (McGill)
  *Supersymmetric large extra dimensions and dark energy*
- Leonid Chekhov (Steklov Inst., Moscow)
  *Quantum Teichmüller and Thurston theories*

- Jim Cline (McGill)
  *Inflation from string theory*
- Sumit Das (Kentucky)
  *Time dependent spacetimes from matrix models*
- Frederik Denef (Rutgers)
  *Distributions of string vacua*
- Henriette Elvang (UCSB)
  *Supersymmetric and non-supersymmetric black rings*
- Amir Ghezelbash (Waterloo)
  *Supergravity solutions of intersecting Branes based on embedding self-dual geometries in M-theory*
- James Gray (Durham)
  *Kahler potentials for bundle moduli in heterotic compactifications*
- Jan Gutowski (Oxford)
  *Supersymmetric black rings*
- Nick Halmagyi (USC)
  *Holographic RG flows and duality*
- Shamit Kachru (Stanford)
  *Learning to count*
- Stanislav Kuperstein (Tel Aviv)
  *Holographic aspects of non-critical supergravity*
- Larissa Lorenz (Waterloo)
  *Inflation with a UV cut-off*
- Oleg Lunin (IAS)
  *BPS deformations of Ad Sp x Sq*
- Arthur Lue (Texas, San Antonio)
  *Leakage into extra dimensions and cosmic acceleration*
- Gautam Mandal (Tata Inst., Mumbai)
  *Two dimensional strings, matrix models, and the rolling tachyon*
- Corinne Manogue & Tevian Dray (Oregon State)
  *Octonionic symmetry*
- David Mateos (Perimeter)
  *Supersymmetric black rings and supertubes*
- Liam McAllister (Stanford)
  *Open string corrections to D-brane dynamics*
- Vladimir Miransky (UWO)
  *Relativistic field theories in a magnetic background as non-commutative field theories*
Thematic Programs

Fields Institute
January–June 2005

Andrew Neitzke (Harvard)
Elements of topological M-Theory

Takuya Okuda (Caltech)
Statistical models of crystal melting, topological string theory and quantum foam

Jonathan Rocher (IAP, Paris)
Constraining SUSY GUTs with CMB data

Nemani Suryanarayana (Perimeter)
Half-BPS giants, free fermions and microstates of superstars

Anastasia Volovich (UCSB)
Yang-Mills amplitudes from twistor string theory

Ofer Aharony (Weitzmann Inst.)
Gravitational phase transitions from a field theory perspective

Anirban Basu (Chicago)
The M2-M5 Brane system and a Generalized Nahm’s Equation

Juan Cascales (Universidad Autonoma de Madrid-CSIC)
Holographic dual of the Standard Model on the throat

Matthias Gaberdiel (Zurich, ETH)
Topological permutation branes

Alexei Gorodentsev (ITEP, Moscow)
T-stabilities on triangulated categories

Amihay Hanany (MIT)
Quivers for metrics

Albion Lawrence (Brandeis)
Worldsheet RG and target space time evolution

Don Marolf (UCSB)
Clarifying holographic charges

Jaemo Park (Pohang)
Supertwistor orbifolds: gauge theory amplitudes and topological strings

Volker Schomerus (DESY)
Strings on supergroups

Albert Schwarz (UC Davis)
Khovanov knot homology and topological string theory

A. M. Semikhatov (Lebedev Inst., Moscow)
Nonsemisimple Verlinde algebras and quantum groups

Yan Soibelman (Kansas State)
Mirror symmetry and non-archimedean analytic geometry

Cobi Sonnenschein (Tel Aviv)
More on the non-critical gauge/gravity duality

Duco van Straten (Gutenberg)
An index theorem for matrix factorizations

Atsushi Takahashi (RIMS, Kyoto)
Matrix factorizations and representations of quivers

Piljin Yi (KIAS)
Closed strings and unstable D-brane systems

Perimeter Institute
January–June 2005

Niklas Beisert (Princeton)
Quantizing the spectral curve of AdS-CFT

Duiliu Diaconescu (Rutgers)
Topological amplitudes and localization

Jacques Distler (Texas)

Kris Kennaway (Toronto)
Quiver gauge theories and dimer models

Axel Krause (Maryland)
M-Theory inflation from multi M5-brane dynamics

Don Marolf (UCSB)
Clarifying holographic charges

Dario Martelli (CERN)
An update on AdS/CFT: Sasaki-Einstein metrics, toric quivers and Z-minimization

Ronen Plesser (Duke)

Soo-Jong Rey (Seoul Natl.)
Emergent 5d black hole out of weakly coupled hot 4d Yang-Mills Gas

Jorge Russo (Barcelona)
Strong magnetic limit of string theory

Joan Simon (Pennsylvania)
The library of Babel: the origin of gravitational thermodynamics

Sergey Solodukhin (IUB, Bremen)
Relaxation and unitarity in eternal black hole
Dam Son (Washington)  
*QCD and a holographic model of hadrons*

Tadashi Takayanagi (Harvard)  
Arkady Tseytlin (Ohio State)  
*Semiclassical approach to AdS/CFT*

### Thematic Programs

#### Course on Mirror Symmetry

**September–December 2004**  
**Instructor:** Kentaro Hori (Toronto)

The course gave an introduction to mirror symmetry in the context of string theory. It was designed to start up activity of the year-long Program on the Geometry of String Theory and was followed by graduate students as well as participants of the thematic program. Since the subject is currently under active investigation in theoretical physics and mathematics, one goal of the course was to point out the connections between the two approaches and to stimulate collaboration between researchers of both fields.

Beginning with an introduction to superconformal field theories, for example on Calabi-Yau manifolds, and the twisting to topological field theories, the course built up the foundations in order to state the conjecture of Mirror Symmetry as a duality between two superconformal field theories. It gave a physical explanation of the conjecture in terms of gauged linear sigma models and provided a number of examples of mirror pairs. The course closed with some aspects of mirror symmetry including non-perturbative extended objects such as D-branes in this context.

#### Course on String Theory

**September–December 2004**  
**Instructor:** Amanda Peet (Toronto)

String theory research began its life at the University of Toronto in the year 2000, and has been revving up since then. The international spotlight has shone particularly brightly on UofT and the Fields Institute in the academic year 2004-5, during the Theme Year on “The Geometry of String Theory” and for the final event “Strings 2005” in July. One of the primary groups of people benefiting from all of this activity was local graduate students - in both physics and mathematics. In order to ensure that junior students could benefit maximally, an introductory course on string theory was proposed, planned, and then taught in the Fall semester by Prof. Amanda Peet.

PHY2406F “Introduction to String Theory” was offered as a semester-long Physics course in the Fall of 2004-5. To enable students to commute to class from other Ontario universities, lectures were held in a two-hour block on Fridays with office hours later the same day. Six students took the course for credit: four at the University of Toronto and two at the University of Waterloo. There were a large number of auditors: approximately 40 at the beginning of the semester, later decreasing to a core about half a dozen who came to every single class along with registered students. Auditors included faculty, postdocs, graduate students, and even one undergraduate. The course textbook was the brand-new “A First Course in String Theory” by Barton Zwiebach of MIT (Cambridge, 2004). All lecture notes were offered in digital form on the course web hub.

Since PHY2406F was designed to serve junior graduate students, no graduate-level prerequisites were assumed. In particular, this course was taught alongside other standard graduate courses in high-energy theoretical physics such as quantum field theory and general relativity. Accordingly, the course began with a lightning overview of classical physics of non-relativistic and relativistic particles. This segued into the classical physics of non-relativistic and relativistic strings, with particular attention to gauge fixing in light-front gauge. Next came quantization in light-front gauge, starting with a discussion of free quantum fields of spin zero, one and two. The final dress rehearsal was quantization of the relativistic point particle.

Then came the part everyone was waiting for: quantization of the relativistic string. Worldsheet symmetries were a concentration. Closed strings and open strings were separately discussed, before worldsheet fermions and the superstring was introduced in the NSR formalism. The course then shifted gears to study of the more recent topic of D-branes. Gauge fields on many D-branes were a major focus, including quantization of strings stretched between different D-branes and hence possessing worldsheet different boundary conditions at their endpoints. Next came T-duality, circle compactification, and the Hagedorn phenomenon. Supergravity as the low-energy limit of string theory and black p-branes was introduced. This laid the groundwork for an explanation of one of the most famous results from string theory: computation from quantum statistical mechanics of strings and D-branes of the thermodynamic entropy of wide classes of black holes. Superstring duality, compactifications, and the gravity/gauge correspondences such as AdS/CFT rounded out the final section of the course.
Student and auditor feedback about the course was very positive - and useful to the faculty. Overall, the goals of the course were achieved with room to spare. It was quite a sight to behold for the first half of the course, with the Fields Institute Library room packed to the gunwales every Friday at 10am. Students (and auditors) were very much up to the challenge of the course, physicists and mathematicians included. This response augurs well for the continuation of String Theory as a course offering at the University of Toronto. For example: in 2005-6 Peet will again teach a course on string theory, this time in the Spring.

Minicourse on Frobenius Manifolds and Integrable Hierarchies
November 8-12, 2004
Instructor: Boris Dubrovin (SISSA, Trieste)

The minicourse consisted of 4 one hour lectures to participants in the Geometry of String Theory program. It introduced Frobenius manifolds, described the classification project for integrable hierarchies, and concluded with the universal integrable hierarchy of the topological type.

To mathematicians, the main source of Frobenius manifolds is the theory of Gromov-Witten invariants of a compact symplectic manifold. They are studied by mathematicians investigating symplectic topology and enumerative geometry. They also arise in singularity theory. Classical integrable systems entered quantum theory with the realization that the KdV equation was related to matrix models of 2D gravity. This led to Witten’s proposal to describe moduli spaces in terms of some unknown integrable hierarchy. In essence one classifies certain bi-hamiltonian systems of PDEs, in terms of moduli spaces given as Frobenius manifolds. Over the course of his lectures, Dubrovin described the development and consequences of these ideas.

Course: Introduction to Homological Algebra
January–May 2005
Instructor: Ragnar Buchweitz (Toronto)

This course was intended as a first year graduate course to expose the participants to the basic principles and guiding themes of the homological tool box. The audience of the course was comprised of graduate students from various southern Ontario universities, such as McMaster, Toronto, Waterloo, and York, as well as a healthy complement of participants at all levels from the program on String Theory. The course took a categorical approach and consequently began with the foundations of categorical algebra emphasizing the use of representable functors as a key tool. The concept of adjoint functors was illustrated with the Eilenberg-Watts theorem that classifies functors commuting with all colimits as left adjoints or as tensor products with generalised bimodules.

At the heart of the course was the study of Yoneda extensions in arbitrary abelian categories and the way this theory eventually gives rise to the construction of derived categories and the concept of triangulated ones. Examples treated ranged from quiver representations to classical module theory. The classical theory of injective and projective resolutions as a means to calculate extension groups was developed and the theorem on Morita equivalence for module categories proved. Some categories of small global dimension were studied.

To obtain course credit, students had the option to present special topics, and among those chosen were representations of blocks of the Bernstein-Gelfand-Gelfand category O, quantum groups and higher categories, perverse sheaves, and examples of tilting theory.

In May and June, the course morphed into a seminar on Landau-Ginzburg models and matrix factorisations, with the aim to understand and elaborate the dictionary between Physics and Mathematics in this area. The homological theory of matrix factorisations with its relations to stable module categories over Gorenstein rings or the…
homotopy category of Tate or complete resolutions, to Serre duality, the theory of algebraic cycles and to the variational Hodge conjecture were discussed. It was a very lively experience that offered the opportunity for a dialogue at a sophisticated level, involving participants at all stages of a research career.

**Course on Symplectic Topology and Integrable Systems**

January–April 2005  
Instructor: Boris Khesin (Toronto)

This course was an introduction to the principal notions and methods in several active research areas surrounding symplectic topology. It was also designed to be a bridge between the introductory course on symplectic geometry given at the University of Toronto Mathematics Department in the Fall semester and the thematic program on String Theory. As a result it attracted graduate students and postdocs from both sides, as well as students from institutions outside of Toronto, such as McMaster University and the University of Saskatchewan.

The course consisted of three major parts. The first one was devoted to the main tools and ramifications of symplectic topology and Morse theory. The topics developed ranged from symplectic properties of billiards to Floer homology and recent developments in Arnold’s conjectures. These conjectures, which to a large extent shaped this field of mathematics, predicted that the number of fixed points of Hamiltonian diffeomorphisms for symplectic manifolds is bounded below by the minimal number of critical points of a smooth function on this manifold. The latter is governed by Morse inequalities and the Lusternik–Schnirelmann category. Consequently, a large part of the course dealt with Morse theory and its various applications and ramifications, which are of independent interest: applications to geodesics, the Morse–Novikov theory for multivalued functionals, the Morse–Witten complex, etc.

The techniques discussed in the course also allowed one to describe the geometry and geodesics on symplectomorphism groups, to outline various symplectic non-squeezing results, the notion of symplectic capacities, Floer homology, the Hofer metric, etc.

Another closely related large topic was contact geometry and topology. The course described several key results on Legendrian knots and their invariants, as well as giving the definition of Chekanov–Eliashberg contact homology of Legendrian knots.

The last part of the course was devoted to the main tools in integrable systems. The key constructions, such as the Lax form, compatible brackets, and the shift argument method were illustrated by numerous examples. The principal one, the Korteweg–de Vries equation, was also used as the launching pad to describe infinite-dimensional methods in the theory, including the formalism of pseudo-differential operators and the Adler–Gelfand–Dickey brackets.

**Mini-course on Generalized Geometries in String Theory**

February 15–17, 2005  
March 1–3, 2005  
Organizer: Robert Myers (Perimeter)  
Instructors: Marco Gualtieri (Fields), Yi Li (Caltech) and Mariana Grana (Ecole Polytechnique & Ecole Normale Supérieure)

Held at Perimeter Institute

On more than one occasion during the theme year on The Geometry of String Theory, jointly hosted by the Fields and Perimeter Institutes, visiting lecturers mentioned with excitement the work being done by Nigel Hitchin at Oxford on generalized Calabi-Yau manifolds, and how surprisingly well it worked as a natural language for the mathematics of...
string theory. Nigel Hitchin himself came for the Coxeter Lecture Series in November and these new ideas were certainly central to his beautiful lectures. However, on this occasion, Hitchin expressed his excitement not at his own work, but that of his student, Marco Gualtieri, who was this year a postdoc at the Fields Institute. Thus it was a welcome addition to the activities of the Thematic Year when this mini-course was announced for February 15-17 and March 1-3. This gave everyone a chance to hear first hand as Marco explained his theory of generalized complex geometries in a set of three lectures. Additional lectures were delivered by Yi Li and Mariana Grana, who were already applying the theory to problems in string theory. The mini-course was held at Perimeter Institute in Waterloo, and for many of the mathematicians from Toronto, it was the first opportunity to enjoy these impressive facilities.

A generalized complex geometry essentially extends the notion of a complex structure (in its description as an endomorphism of the tangent bundle) by considering endomorphisms of the direct sum of the (complexification of the) tangent and cotangent bundles. An equivalent description can be given in terms of maximally isotropic sub-bundles of this direct sum; essentially, generalized complex structures are the complexified version of the Dirac structures of Courant. In addition to being useful in string theory, generalized complex structures include both symplectic and complex geometry as special cases, and can be defined on some manifolds for which no known symplectic or complex structure exists. Marco’s first lecture was on the linear algebra of the direct sum of an even-dimensional vector space and its dual. This space carries a natural inner product of signature (n,n), and so the study of the group O(n,n) and its associated spin group figured prominently. Maximally isotropic subspaces of this direct sum, known as linear Dirac structures, form the algebraic basis for the generalized complex geometries. These Dirac structures can be described in terms of ‘pure spinors’ for the Clifford algebra associated to O(n,n), which are those differential forms whose annihilators (under the standard representation of the Clifford algebra) are maximally isotropic. Any pure spinor can be acted upon by the exponential of a 2-form to obtain another pure spinor. In string theory terminology, these correspond to the ‘B-field’ transformations. Marco’s second lecture dealt with transporting the linear algebra of the first lecture to the sum of the tangent and cotangent bundles of a manifold, and considering the de Rham cohomology twisted by a closed form of odd degree. The integrability of a linear Dirac structure is determined by the requirement that it be closed under a bracket operation known as the Courant bracket. In addition to the diffeomorphism symmetry admitted by the usual Lie bracket on the tangent bundle, the Courant bracket also admits B-field transformations as symmetries. Integrable Dirac structures admit symplectic and Poisson geometry as special cases. Generalized complex structures are endomorphisms of the direct sum of the tangent and cotangent bundles that square to -1 and are orthogonal with respect to the inner product. The structure is integrable if its +i-eigenbundle (which is a complex Dirac structure) is closed under the Courant bracket. Generalized complex structures can be classified by an invariant called type, which ranges over the integers from 0 (the symplectic case) to n (the complex case), where n is half the dimension of the manifold (which is necessarily even-dimensional). His final lecture considered analogues for the generalized geometry of such usual geometric notions as Hodge theory, submanifolds, and Kahler manifolds (manifolds admitting two compatible generalized complex structures).

While Marco’s lectures gave new insights into these beautiful structures from a mathematical perspective, in their lectures Yi Li and Mariana Grana shared their more physical perspectives as string theorists. Yi Li is a graduate student at Caltech working with Anton Kapustin, and his lectures described their work together over the past year. They have incorporated generalized complex structures in the description of certain string theories from the perspective of the two-dimensional worldsheet of the strings. That is, they studied the topological sector of certain supersymmetric two-dimensional field theories, i.e., an extension of the A- and B-models for N=2 sigma-models. In particular, they extended the familiar models to the case where the background geometry in which the strings move is endowed with a nontrivial B-field and they found this naturally lends itself to a description in terms of twisted generalized Calabi-Yau manifolds. As Yi described then the space of topological observables is given by the cohomology of a Lie algebroid associated to one of the two twisted generalized complex structures. He also discussed mirror symmetry for their twisted generalized Calabi-Yau manifolds and the category associated with the Dirichlet branes in these models.

Mariana Grana delivered her lectures in the second week of the course. She is currently a postdoc based in Paris jointly at the Ecole Polytechnique and the Ecole Normale Supérieure. Mariana described her very recent work with various collaborators in both Europe and North America on the emergence of generalized Calabi-Yau manifolds in the
compactification of ten-dimensional superstring theories to physically interesting four-dimensional settings. Hence her perspective was one of working with the low-energy supergravity equations, i.e., the stringy equivalent of the Einstein equations, to describe these compactifications. Of course, Calabi-Yau manifolds have long been used by physicists to “curl up” the extra dimensions of string theory. Recently, however, interest has turned to giving these internal spaces “fluxes”, such as a nontrivial B-field. Mariana and her collaborators have found that Hitchin’s generalized Calabi-Yau manifolds emerge from the supersymmetry equations of supergravity. In particular, the supersymmetry transformations for type II theories on six-manifolds can be written as differential conditions on a pair of pure spinors, the exponentiated Kähler form and the holomorphic form. Interestingly, mirror symmetry appears as a symmetry of these equations under exchange of the two pure spinors and a choice of even or odd-rank RR-fields, which are additional flux fields which can appear in string theory. Further these RR-fluxes appear as an obstruction to the integrability of one of the pure spinors appearing in the generalized geometries. One might take this result and Mariana’s work that string theory actually uses further richer generalizations of generalized geometries which remain to be explored and understood.

It was perhaps appropriate that this mini-course on such a young area of research was delivered by such a youthful set of lecturers as Marco, Yi and Mariana. They all showed great enthusiasm for the mini-course and their research by working hard to prepare and deliver a very clear set of lectures. In particular, while Yi Li is still “only” a graduate student, everyone at the lectures would agree that he should be commended on his superb command of the material and the remarkable maturity which he showed in delivering his lectures. Of course, the lecturers’ enthusiasm was matched by that of the audience. As well as drawing a strong attendance for all of the lectures, the mini-course also generated many intense discussions of various aspects of generalized geometries over lunch or in Perimeter’s many discussion areas throughout the week of the course. As well as the Perimeter researchers, the audience included a strong contingent of both mathematicians and physicists coming from Toronto and other area universities. The lectures even attracted one student, Sven Rinke, all the way from the Physics Department at Duke University.

As seen in the mini-course, generalized geometries are currently at center stage in the interplay of mathematics and physics. It is a topic, which one continued to hear about in the seminars and workshops throughout the remainder of the String Theory program.

**Minicourse on Toda Lattices: Basics and Perspectives**

March–May 2005

Instructors: Boris Khesin (Toronto), Michael Gekhtman (Notre Dame) and Andrei Marshakov (Moscow)

Toda lattice theory, the subject of the minicourse given at the Fields Institute concurrently with the course on “Symplectic Topology and Integrable Systems”, is one of the main junctions in the theory of integrable equations. The minicourse consisted of three lectures given by three lecturers on different aspects of the Toda theory and covered motivations and basic properties of the system, the integrability of Toda flows on orbits of semi-simple Lie algebras and the rather unexpected appearance of Toda lattices in the Dijkgraaf-Vafa theory of matrix integrals. Although it was selfcontained, this minicourse naturally complemented the graduate course on integrable systems. It gave yet another very popular and well studied model, described along with its applications in field theory.

**Workshop on Forms of Homotopy Theory: Elliptic Cohomology and Loop Spaces**

September 27–October 2, 2004

Held at the Fields Institute

Organizers: Matthew Ando (UIUC), Michael Hopkins (MIT), Haynes Miller (MIT) and Jack Morava (Johns Hopkins)

This conference brought together mathematicians working on problems in algebraic topology which are related to string theory.
The conference featured reports of substantial progress in many areas. Here are a few highlights relating particularly to elliptic cohomology and string topology.

Elliptic cohomology mixes topology and number theory, by associating to a topological space various arithmetic quantities related to elliptic curves. It connects both of these subjects to string theory, as it is the natural receptacle of the one-loop amplitude of various string theories. How it manages to relate these things is somewhat of a mystery: Witten once compared the situation to seeing the peaks of a mountain range, while the valley below is shrouded in mist.

At the conference, Stephan Stolz reported on his work with Peter Teichner on elliptic cohomology and string theory, and there were reports on elliptic genera and orbifolds by Nora Ganter and Hirotaka Tamanoi. Perhaps the most spectacular event was Jacob Lurie’s announcement of his invention of “derived algebraic geometry”. This mixture of algebraic geometry and stable homotopy theory appears to simultaneously solve a number of the most important outstanding problems in elliptic cohomology.

The subject of string topology began with the discovery, by Moira Chas and Dennis Sullivan, of rich structure in the homology of the free loop space of a manifold. At the conference, Ralph Cohen reported on his Morse-theoretic approach to string topology, and Dennis Sullivan reported on his work on the action of various diffeomorphism groups (for example, reparametrizations of the loop) on string topology.

David Ben-Zvi and Paul Goerss gave talks on the Langlands program, to draw the attention of this community of researchers to the prominent role in the local Langlands program of the Lubin-Tate moduli spaces of formal groups and the covers of these spaces constructed by Drinfeld. These are fundamental objects of study in stable homotopy theory as well, and the situation strongly suggests a relationship which should be explored.

The conference featured very impressive talks by a number of graduate students and postdocs, including Mark Behrens, Alex James Bene, Michael Ching, Nora Ganter, Veronique Godin, Andre Henriques, Jacob Lurie, Eric Sharpe, and Andrew Stacey. Along the way, it also celebrated the influence of Jack Morava, on the occasion of his 60th birthday. The meeting was supported by the Fields and Perimeter Institutes, the National Science Foundation, and the Connaught Fund.

Speakers:
Mark Behrens (MIT)
Isogenies of elliptic curves and the K(2)-local sphere

Alex Bene (UCLA)
The locus at hyperelliptic fatgraphs

Michael Ching (MIT)
Operadic bar constructions and the Goodwillie derivatives of the identity

Ralph Cohen (Stanford)
String topology and Gromov-Witten theory of cotangent bundles

Christopher Douglas (MIT)
Twisted K-Theory of Lie groups

Nora Ganter (UIUC)
On orbifold genera, K(n)-local spectra, product formulas and power operations

Veronique Godin (Stanford)
Fat graphs and the mapping class group of a surface with boundary

Paul Goerss (Northwestern)
Morava modules and local Langlands

Vassily Gorbounov (Kentucky)
Mirror symmetry formula for elliptic genus of some Fano varieties
Andre Henriques (MIT)
Computation of torus-equivariant complex oriented cohomology theories of flag varieties

Michael Hopkins (MIT)
The work of Jack Morava

Po Hu (Wayne State)
On algebraic analogues of string topology

Mikhail Kapranov (Yale)
Floer homology for ind-schemes

Nitu Kitchloo (San Diego)
Buildings for Kac-Moody groups

Igor Kriz (Michigan)
Conformal field theory, Grothendieck-Teichmueller theory and other structures

Jacob Lurie (MIT)
Elliptic cohomology and derived algebraic geometry

James McClure (Purdue)
The intersection pairing for PL chains, with applications to string topology

Goro Nishida (Kyoto)
Steenrod algebra, Dickson invariants and the automorphism groups of the additive group law

Charles Rezk (UIUC)
On Dyer-Lash of algebras of operations on Morava E-Theory

Eric Sharpe (UIUC)
D-branes and derived categories

Andrew Stacey (NTNU, Trondheim)
A Construction of a Dirac operator on loop space

Stephan Stolz (Notre Dame)
Elliptic cohomology via conformal field theories?

Dennis Sullivan (SUNY Stony Brook)
Chain level Gromov-Witten theory

Hirotaka Tamanoi (UC Santa Cruz)
Decomposition of orbifold mapping spaces and geometric Hecke operators

Constantin Teleman (Cambridge)
Twistings in Gromov-Witten theory

Takeshi Torii (Fukuoka, Japan)
Degeneration of formal groups and generalized Chern characters

David Ben-Zvi (Texas)
The Geometric Langlands Program

Thematic Programs

Workshop on Mirror Symmetry
November 19–23, 2004
Held at Perimeter Institute
Organizing Committee: Denis Auroux (MIT), Mark Gross (Warwick), Kentaro Hori (Toronto) and Noriko Yui (Queen’s)

This workshop brought together leading mathematicians and theoretical physicists. The talks focused on various recent developments in the field of mirror symmetry, from both the mathematical and physical points of view, and provided a broad panorama of the current state of the art. Additional funding for the workshop was provided by the Connaught fund, and by the NSF through a grant in support of the program.

The mathematical aspects of mirror symmetry that the workshop focused on included the Strominger-Yau-Zaslow conjecture, the Kontsevich homological mirror symmetry conjecture, number-theoretic aspects (arithmetic and motives), and generalized Kähler geometry and T-duality. In addition, recent developments such as (0,2) mirror symmetry and (0,2) correlation functions, flux backgrounds, affine structures, etc., were discussed.

The talks on the theoretical physics side of mirror symmetry covered topics on topological sigma models, matrix factorizations, T-duality for holomorphic non-commutative tori, the Hori–Vafa conjecture, etc.

This workshop was the third or fourth concerning mirror symmetry held in Canada in the last four years. It was undoubtedly the biggest one in terms of number of participants, and also the broadest from the scientific point of view. It brought together leading mathematicians and theoretical physicists from all over the world for five days, to
study and discuss the recent developments in mirror symmetry. The notion of mirror symmetry originated in string theory, but it has exploded onto the mathematical scene. Most notably, many recent developments in Algebraic Geometry, Symplectic Geometry, Number Theory and Lie Algebras have been inspired by mirror symmetry and string theory. The workshop offered opportunities for mathematicians to exchange ideas and discuss problems surrounding mirror symmetry face to face with theoretical physicists.

Perimeter Institute’s new award-winning building provided a wonderful stage for the workshop. All talks were presented in the main auditorium equipped with state of the art high tech gadgets. Many mathematicians opted for blackboards for their presentations! There was plenty of time for participants to discuss mathematics and physics in informal settings; in particular, the “Bistro” on the fourth floor not only supplied lunches and refreshments, but also big blackboards! Congratulations go to Perimeter Institute for creating such an inspiring atmosphere.

**Speakers:**

- Allan Adams (Harvard)
  *Towards (0,2) mirror symmetry*

- Denis Auroux (MIT)
  *Homological mirror symmetry for Fano surfaces*

- Victor Batyrev (Universität Tübingen)
  *Cohomology groups in mirror symmetry*

- Andrei Caldararu (Pennsylvania)
  *Hochschild structures: an algebraic geometer’s point of view*

- Xenia de la Ossa (Oxford)
  *The arithmetic of Calabi-Yau manifolds*

- Kenji Fukaya (Kyoto)
  *Counting open Riemann surface with Lagrangian boundary condition and perturbative Chern-Simons gauge theory*

- Mark Gross (Warwick)
  *Affine structures, mirror symmetry, and K3 surfaces*

- Marco Gualtieri (Fields)
  *Generalized Kähler geometry and T-duality*

- Anton Kapustin (Caltech)
  *Topological sigma-models and generalized complex geometry*

- Sheldon Katz (Illinois at Urbana-Champaign)
  *(0,2) correlation functions*

- Albrecht Klemm (Wisconsin at Madison)
  *Higher genus amplitudes on compact Calabi-Yau and threshold corrections*

- Naichung Conan Leung (Minnesota)
  *G2 geometry and mirror triality*

- Grigory Mikhalkin (Toronto)
  *Complex, real and tropical curves*

- David R. Morrison (Duke)
  *Strominger-Yau-Zaslow revisited*

- Yong-Geun Oh (Wisconsin at Madison)
  *The [FOOO]-obstruction cycle and Landau-Ginzburg potential*

- Tony Pantev (Pennsylvania)
  *T-duality for holomorphic non-commutative tori*

- Rolf Schimmrigk (Kennesaw State)
  *Arithmetic varieties from string theory and D-branes*

- Bernd Siebert (Universitaet Freiburg)
  *Affine geometry of degeneration limits and mirror symmetry*

- Jan Stienstra (Utrecht)
  *Motives and strings*

- Helena Verrill (Louisiana State)
  *The Picard-Fuchs equation of the An family of Calabi-Yau varieties*

- Johannes Walcher (IAS Princeton)
  *Matrix factorizations: stability and mirror symmetry*

- Noriko Yui (Queen’s)
  *Certain non-rigid Calabi–Yau threefolds over Q and their modularity*

- Ilia Zharkov (Harvard)
  *Kähler affine structures and the affine Calabi conjecture*
Workshop on Topological Strings
January 10-14, 2005.
Held at the Fields Institute
Organizers: Ezra Getzler (Northwestern), Kentaro Hori (Toronto) and Sheldon Katz (Illinois/Urbana-Champaign)

Topological string theory is currently a very active field of research for both mathematicians and physicists. In mathematics, it leads to new relations between symplectic topology, algebraic geometry and combinatorics. In physics, it is a laboratory for the study of basic features of string theory, such as background independence, open/closed string duality, non-perturbative completion, as well as an effective framework for computing spectra and interactions in full-fledged string compactifications.

This workshop brought together a range of experts on different aspects of topological string theory from both the mathematics and physics communities. Twenty five lectures were given over five days, to over seventy participants. The workshop was held at the Fields Institute, as an activity in the Geometry of String Theory program, sponsored jointly by the Fields and Perimeter Institutes. Additional funding was supplied by the US NSF, through a grant in support of the participation of junior researchers in the thematic program.

Speakers:
Mina Aganagic (UC Berkeley)
Black holes, quantum Yang-Mills theory and non-perturbative topological strings

Jim Bryan (UBC)
The local Gromov-Witten theory of curves

Cheol-Hyun Cho (Northwestern)
A-infinity structure of open-closed map in A-model

Kevin J. Costello (Imperial College)
Topological conformal field theories and Calabi-Yau categories

Robbert Dijkgraaf (Inst. for Theoretical Physics, Amsterdam)
Topological M-theory, Part II

Duiliu Emanuel Diaconescu (Rutgers)
Geometric Transitions and Integrable Systems

Alexander Givental (UC Berkeley)
Quantum Riemann-Roch for orbifolds and Bernoulli polynomials

Hirzebruch-Riemann-Roch in quantum cobordism theory

Eleny-Nicoleta Ionel (Stanford)
Embedded curves and the Gromov-Witten invariants of 3-folds

Bumsig Kim (Inst. for Advanced Study Korea)
Generalization of Hori-Vafa conjecture

Yon Seo Kim (UCLA)
Computing Hodge integrals with one lambda class

Albrecht Klemm (Wisconsin at Madison)
Open/closed string duality for topological gravity with matter

Yuan-Pin Lee (Utah)
Invariance of tautological equations

Jun Li (Stanford)
Relative stable maps and topological vertex

Andrei Losev (ITEP, Moscow)
Homological algebra, BV formalism and (topological) string theory

Yong-Geun Oh (Wisconsin at Madison)
Compactification of the moduli space of holomorphic maps with prescribed singularities

Andrei Okounkov (Princeton)
Overview of Gromov-Witten/ Donaldson-Thomas correspondence

Quantum cohomology of the Hilbert scheme

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Many of the recent advances in this area are being made by younger researchers, and postdocs, and this was reflected in the choice of speakers. Specific topics they addressed include compactification with fluxes and the resulting landscape of vacua, generalized complex structures, non-perturbative effects in supersymmetric gauge theory and in the heterotic string, and the construction of models with the Standard Model spectrum of particles.

**Speakers:**

- B. S. Acharya (Abdus Salam ICTP)
  *Statistics of M theory vacua and the landscape*

- Anirban Basu (Chicago)
  *(0,2) duality*

- Chris E. Beasley (Princeton)
  *New instanton effects in N=1 supersymmetric string compactifications*

- Melanie Becker (Maryland)
  *Flux compactifications, cosmology and the standard model of elementary particles*

- Ralph Blumenhagen (Max Planck Inst.)
  *Recent progress with intersecting D-brane models*

- Volker Braun (Pennsylvania)
  *A heterotic standard model*

- Frederik Denef (Rutgers)
  *Landscape studies*

- Ron Donagi (Pennsylvania)
  *Geometric transitions, integrable systems, and large N duality*

- Bogdan Florea (Rutgers)
  *Moduli stabilization in F-Theory compactifications*
Mariana Grana (Ecole Normale Supérieure-Paris)
Hitchin functionals in supergravity

Sergei Gukov (Harvard)
Heterotic moduli stabilization with fractional Chern-Simons invariants

Ruben Minasian (École Polytechnique)
On mirror symmetry with fluxes and branes

Michael Schulz (Caltech)
Mapping flux to geometry

Gary Shiu (Wisconsin & Perimeter Inst.)
Building chiral flux vacua

Alessandro Tomasiello (Stanford)
Towards generalized complex mirror symmetry

Workshop on String Phenomenology
March 28–April 1, 2005
Held at Perimeter Institute

Organizers: Jan Louis (Hamburg), Robert Myers (Perimeter) and Gary Shiu (Wisconsin)

This workshop was mounted jointly by the Fields Institute and Perimeter Institute (in Waterloo). It ran at Perimeter, coming immediately after the closely related Fields workshop on N=1 Compactifications.

String phenomenology has emerged as a research area at the rich interdisciplinary boundaries of string theory, particle physics, and cosmology. Although research in string phenomenology is motivated by physical questions, progress often comes from connections to more formal and mathematical aspects of string theory. This meeting brought together an international array of over 80 researchers from the United States, France, Spain, Italy, Germany, England, Japan and, of course, Canada, representing interest in all aspects of this field.

Traditionally string phenomenology has focused on the issue of how the physics of elementary particles and forces, as observed in laboratory experiments, can arise from string theory. Hence the workshop included a number of technical talks assessing various proposals for how various features of the so-called Standard Model might arise in stringy constructions. In this domain, an extremely important question is how to recognize various signatures in the new collider experiments which will be run over the next few years. In particular, the largest such experiment, called the “Large Hadron Collider” (LHC), will turn on at the CERN laboratory in Geneva in 2007. Hence the workshop organizers called upon Gordy Kane (Michigan) to organize an “LHC Stretching Exercise”, in which he presented mock experimental data and challenged participants to determine the underlying stringy model. It is expected that such warm-up exercises will become a common feature for string phenomenology meetings as 2007 approaches.

A particularly exciting and active area of string phenomenology in recent years has been addressing questions at the interface between cosmology and string theory. Cosmology has entered an extraordinary era where experimental data has fixed the basic parameters describing the evolution of the universe and points towards the existence of an inflationary phase of accelerated expansion in its very earliest stages. At the same time, string theory has seen remarkable progress in the past few years in moving from a stage where people questioned the compatibility of string theory with cosmological observations to one where people regularly propose detailed models and compare their predictions with the experimental data. Hence a good proportion of the workshop was devoted to string cosmology with a variety of talks on topics such as cosmic superstrings, string signatures in the cosmic microwave background and even the wave-function of the universe.

One of the most interesting aspects of superstring cosmology has been the recent realization that rather than “providing a unique answer”, string theory may consistently describe a huge number of different kinds of universes. This broad array of different possible solutions is known as “the string theory landscape”. At the
workshop, Thursday was devoted to a range of talks on different aspects of the landscape. The day ended with a lively panel discussion on “The Landscape: What is it good for?”, in which Herman Verlinde (Princeton) moderated a discussion between Shamit Kachru (Stanford), Nima Arkani-Hamed (Harvard), Lee Smolin (Perimeter), Bobby Acharya (Trieste) and a fascinated audience. While the discussion drew no specific conclusions, it certainly proved that the landscape will remain a source of many new ideas and active debate in the future.

It is perhaps a reflection of the vigor and excitement about string phenomenology that one-third of the plenary talks were presented by postdoctoral researchers and graduate students. The organizers are grateful to the NSF for providing program funding that brought junior participants from American universities to the workshops. To further enhance the participation of junior researchers, Tuesday ended with a session in which participants were given the opportunity to describe their recent work in a short (5 minute) presentation – a challenge that all thirteen of the speakers handled masterfully. This session was unofficially known as the “Gong Show”. In fact the session came complete with a gong which Gary Shiu picked up in Toronto’s Chinatown while at the Fields workshop the previous week. The gong was also called into service throughout the week to announce the beginning of each new session.

While participants were mentally stimulated by a busy schedule of talks and ample informal discussions, the participants’ palates were also stimulated by meals in Perimeter’s Black Hole Bistro where Perimeter’s chef, Russell, served up various delights. Hence as the conference closed and people headed home on Friday, there were many compliments about both the science and cuisine. So the organizers were happy to declare the meeting a success.

They expressed thanks to the staff at both Perimeter and Fields for all their help in bringing the meeting together and ensuring that everything ran smoothly.

**Invited Speakers:**

- Ignatios Antoniadis (CERN)  
  *Moduli stabilization by magnetic fluxes and split supersymmetry*

- Sunny Arkani-Hamed (Toronto)  
  *Supersymmetry and predictive landscapes*

- Constantin Bachas (Ecole Normale Supérieure)  
  *Comments on spectrum-generating symmetries for D-branes*

- Per Berglund (New Hampshire)  
  *On moduli stabilization in Calabi-Yau flux compactifications*

- Robert Brandenberger (Brown)  
  *Moduli stabilization in string gas cosmology*

- Juan F. G. Cascales (Universidad Autonoma de Madrid-CSIC)  
  *The holographic dual of the standard model on the throat*

- Mirjam Cvetić (Pennsylvania)  
  *Chiral flux compactifications and ‘realistic’ particle physics*

- Oliver DeWolfe (Princeton)  
  *More landscape architecture*

- Keith R. Dienes (Arizona)  
  *A calculable toy model of the landscape*

- Michael Douglas (Rutgers)
Recent results in statistics of vacua
Emilian Dudas (Ecole Polytechnique)
Brane transmutation by internal magnetic fields and new supersymmetric orientifolds
Josh Freese (Princeton)
Chain inflation
Michael Haack (UC-Santa Barbara)
Loop corrections and inflation in string theory
Koji Hashimoto (Tokyo)
Reconnection of colliding cosmic strings
Simeon Hellerman (IAS)
On the landscape of non-geometric string compactifications
Shamit Kachru (Stanford)
Landscape architecture
Nemanja Kaloper (UC-Davis)
Shock therapy
Lev Kofman (CITA)
Landscape days in practical cosmology
Gordon Kane (Michigan)
What counts as string phenomenology?
Black box revealed
Elias Kiritsis (Ecole Polytechnique)
Hunting the standard model in the orientifold jungle
Axel Krause (Maryland)
Cascade inflation
Paul G. Langacker (Pennsylvania)
TeV-scale signatures of string constructions
Fernando Marchesano (Wisconsin)
Towards realistic flux vacua
Brent Nelson (Pennsylvania)
Neutrino mass in heterotic string
Burt Ovrut (Pennsylvania)
A heterotic standard model
Fernando Quevedo (Cambridge)
Large extra dimensions from flux compactifications
Saswat Sarangi (Cornell)
The wave function of the universe
Koenraad Schalm (Columbia)
Cosmological effective actions imply new physics in the CMB
Henry Tye (Cornell)
Searching for cosmic superstrings
Marco Zagermann (Stanford)
D3/D7-Brane inflation and semilocal cosmic strings

Workshop on Gravitational Aspects of String Theory
May 2–6, 2005
Held at the Fields Institute
Organizers: Per Kraus (UCLA), Don Marolf (UCSB) and Amanda Peet (Toronto)

Among the best known accomplishments of string theory are the insights that it has so far provided into intriguing aspects of gravitational physics. These include progress in understanding black hole entropy, and most notably Maldacena’s AdS/CFT correspondence which states that string theory (and thus a theory of quantum gravity) in a 9+1 dimensional spacetime is in fact equivalent to a non-gravitating quantum field theory on a fixed 3+1 dimensional spacetime background. The implications of this correspondence continue to provide fertile ground for research, though they have already been used to provide insight into the nature of strongly coupled quantum field theories by relating such physics to classical gravitational physics in curved backgrounds.

Yet there are many further problems in gravitational physics that remain to be explored. Chief among these is the question of how to deal with various singularities that arise, either inside black holes or at the initial moment of the big bang. It is here that a quantum theory of gravity is needed, as Einstein’s classical theory of general relativity breaks down. String theory appears to provide such a quantum theory and so ‘should’ provide the answers to such questions.
Other issues center around various apparent paradoxes related to black hole entropy, despite the significant progress mentioned above, and around the description of the process of inflation, through which our universe expanded rapidly from a tiny size to become large and smooth, while generating the tiny perturbations which eventually grew into the galaxies and clusters of galaxies that we see today.

The goal of the “Workshop on Gravitational Aspects of String Theory” was to further explore the implications of the connections described above, and to chip away at the fundamental questions which yet remain to be answered. Organized by Per Kraus, Don Marolf and Amanda Peet as a part of the thematic program on the Geometry of String Theory jointly sponsored by the Fields Institute and Perimeter Institute (in Waterloo), the workshop brought together approximately 75 theoretical physicists from across North America and Europe for a week of seminars and discussion.

Discussion and interaction were a central theme of the workshop: there were no more than four hours of talks each day, and the talks were presented by a variety of senior faculty, junior faculty, postdocs, and students. During the rest of the day the participants were strongly encouraged to make use of the Fields Institute facilities for numerous small to medium scale discussions on the above issues.

The result appears to have been a great success, leading one noted string theorist to state that the meeting was “probably the best meeting I have been to in a number of years.”

As one would expect from the theme, most of the talks addressed issues related to black holes and to cosmological singularities. Gary Horowitz of the University of California at Santa Barbara discussed an approach in which a cosmological singularity is mapped to a certain process in an ordinary quantum field theory via the AdS/CFT correspondence. As he explained, the hope is that the singularity might be more tractable in the new language. Bernard de Wit of Utrecht University and Alex Maloney of Stanford University described recent progress in using quantum gravity effects to cloak would-be naked singularities by event horizons. This leads to black holes whose entropy is small, but in precise agreement with certain microscopic computations in string theory, thus extending our microscopic understanding of black holes. Eva Silverstein of SLAC described a novel method for removing singularities by using tachyon condensation to effectively halt the spacetime evolution before the singularity can form. Another potential way of avoiding singularities in black holes is to look for new solutions which look like black holes far away, but in fact deviate close in such a way that there is no event horizon or singularity. This approach has been actively investigated in the past few years, and Simon Ross of the University of Durham described some recent progress.

Another type of pathology in gravity is the potential existence of closed timelike curves (“time machines”). Miguel Costa of Porto University discussed a mechanism for excising them from the spacetime using stringy effects.

An interesting development in the past year has been the discovery of new black ring solutions. These are black holes whose event horizons are not spherical, but instead have a ring topology. The workshop heard four talks by the pioneers in this subject: Henriette Elvang and Harvey Reall of the University of California at Santa Barbara, David Mateos of the Perimeter Institute, and Roberto Emparan of the University of Barcelona.
Shiraz Minwalla of the Tata Institute and Harvard University explained recent work on relating “plasma balls” (bubbles of deconfined phase within a confining gauge theory) to black holes. This was another example of the ability of the AdS/CFT correspondence to relate gravity and gauge theory in interesting ways. Antoine Van Proeyen of K.U. Leuven gave an overview of supergravity theories. Jerome Gauntlett of Imperial College described recent progress in obtaining new AdS solutions for use in the AdS/CFT correspondence. Renata Kallosh of Stanford University discussed new ideas for stabilizing moduli to obtain realistic solutions in string theory. Sumit Das of the University of Kentucky talked about a toy two-dimensional version of string theory, and its use in understanding cosmological and black hole physics.

But of course, the most interesting outcome of any workshop is the *new* research that it generates. Already, a number of papers have appeared on the arxiv acknowledging the importance of the workshop in their generation, but as usual one expects that the best is yet to come.

**Speakers:**
Miguel Costa (Porto U.)  
*Chronology protection in string theory*

Sumit Das (Kentucky)  
*Time dependent backgrounds in 2D string theory*

Bernard de Wit (Utrecht)  
*Variational principles for BPS black hole entropy*

Henriette Elvang (UCSB)  
*Non-supersymmetric black rings*

Roberto Emparan (Barcelona)  
*Nutty black rings and 4D black holes*

Jerome Gauntlett (Imperial College)  
*AdS solutions and some deformations*

Gary Horowitz (UCSB)  
*Holographic description of a cosmological singularity*

Renata Kallosh (Stanford)  
*A simple example of moduli fixing*

Alex Maloney (SLAC & Stanford)  
*Stringy resolution of null singularities*

David Mateos (Perimeter)  
*Microscopics of black rings*

Shiraz Minwalla (Tata Inst. & Harvard)  
*Plasma balls in confining large N gauge theories*

Harvey Reall (UCSB)  
*Supersymmetric black rings*

Simon Ross (U. Durham)  
*Non-supersymmetric smooth geometries and D1-D5-P bound states*

Eva Silverstein (Stanford)  
*The uses of tachyons*

Antoine Van Proeyen (K.U. Leuven)  
*The geometry and landscape of supergravity*

**Workshop on Schubert Calculus and Schubert Varieties**  
June 8–12, 2005  
Held at the Fields Institute  
Organizers: Lisa Jeffrey, Megumi Harada, and Alistair Savage (Toronto); and Alexander Yong (UC Berkeley)

The topics of this workshop are at the intersection of algebraic geometry, representation theory, symplectic geometry, and combinatorics. Although the basic questions of the field trace back to the earliest roots of algebraic geometry, exciting and fundamental developments are in full swing today.

Here is a simple prototypical problem of Schubert calculus: how many red lines $R_1$ and $R_2$ in 3-space (think real, then complex, then projective) intersect given “random” blue lines $B_1$, $B_2$, $B_3$, $B_4$? The answer is 2.

In the 19th century, the “proof” would be as follows: move $B_1$ and $B_2$ until they intersect, and do the same for $B_3$ and $B_4$. Then $R_1$ is defined by the two points of intersection and $R_2$ is defined by the intersection of the two constructed planes. The claim is that one can “degenerate” the general situation to this special situation without changing the answer. Justifying such claims for this problem and many others became the topic of Hilbert’s 15th problem (which is now mainly solved, thanks to decades worth of developments in intersection theory).
Thinking of this problem in terms of the space of lines in 3-space (or the grassmannian of planes in \( \mathbb{C}^4 \), we study the Schubert variety of all lines that meet a given line \( B \)). Then the above question translates to: how many “points” in our grassmannian are in the intersection of four of these Schubert varieties? This is then re-interpreted in terms of the cohomology ring of the grassmannian. The answer becomes computational, but such computations have beautiful combinatorial structure that we study today.

The main goals of the workshop were two-fold. First, it was to provide a forum whereby nonexperts could learn about the main themes of research through mainly expository lectures in an informal atmosphere. Second, it was meant to connect researchers at the University of Toronto and York University, who have worked in the field from two different directions (geometry and combinatorics).

Perhaps the best testimony of the attractiveness of the format was that although the workshop offered no travel support (being originally conceived as a local event), it had student and faculty attendance from a number of non-regional institutions, including the University of Michigan, Ohio State University, the University of Regina, the University of California, Berkeley and the Universidad de Cantabria (Spain)!

**Speakers:**
- Nantel Bergeron (York)
- Schubert polynomials
- Linda Chen (Ohio State)
- Equivariant cohomology
- Megumi Harada (Toronto)
- Schubert basics
- Equivariant cohomology and GKM theory for flag varieties
- Joel Kamnitzer (UC Berkeley)
- Mirkovic-Vilonen cycles
- Augustin-Liviu Mare (Regina)
- Quantum cohomology of full flag manifolds I. Generators and relations
- Quantum cohomology of full flag manifolds II. The quantum Chevalley formula
- Leonardo Mihalcea (Michigan)
- Equivariant quantum Schubert calculus
- Konstanze Rietsch (King’s College London)

**Coxeter Lecture Series**

November 15–17, 2004

**Nigel Hitchin** (Oxford)
- Open Orbits and Geometrical Structures
- Instantons and Bihermitian Metrics
- Geometry with B-fields

The Fall 2004 Coxeter Lectures were delivered by Nigel Hitchin.
Hitchin, Savilian Professor of Geometry at Oxford University. His research interests are remarkably broad, and have led him to highly original discoveries which have had significant impact on both mathematics and theoretical physics. His membership on a frightening number of editorial and planning boards also indicates his deep commitment to fostering the development of mathematics.

Hitchin is well-known for his deep contributions to the theory of harmonic spinors, hyperkähler geometry, gauge theory of instantons and monopoles, minimal surface theory, geometrical solutions of Painlevé equations, Einstein metrics, moduli spaces of Higgs bundles, and special Lagrangian geometry in mirror symmetry, among others. He is also a gerbe hunter par excellence. Any one of these topics would have been eminently relevant to the thematic program on the Geometry of String Theory being held at the Fields Institute. However, Hitchin laid these topics aside in favour of introducing a new field he has recently developed: that of generalized geometric structures.

In his first lecture, entitled Open Orbits and Geometrical Structures, Hitchin described a completely different method for studying special geometrical structures (such as Kähler, Calabi-Yau, or G_2 geometry). Traditionally they are viewed from the point of view of Riemannian holonomy groups or G-structures on the tangent bundle. Instead, he explained that these geometries can be viewed as the critical points of a diffeomorphism-invariant functional defined on open orbits of differential forms, or more generally as structures on the sum of the tangent and cotangent bundle. By viewing geometry in this way, Hitchin showed how one is led to define new (generalized) geometrical structures.

In his second lecture, entitled Instantons and Bihermitian Metrics, Hitchin presented in detail some examples of generalized geometries: generalized complex and Kähler geometry. He regaled the audience with a flurry of integrations by parts to prove the remarkable result that the moduli space of instantons on a bihermitian four-manifold carries a natural generalized Kähler structure.

For the final Coxeter lecture, Hitchin took the show on the road – to Waterloo, to be precise. The impressive new site of Perimeter Institute for Theoretical Physics was the ideal setting for his lecture on Geometry with B-fields, in which he detailed the correspondence between natural objects and operations in generalized geometry with certain geometrical phenomena in string theory. Following his lecture there was much excitement and discussion, among both mathematicians and physicists.

January 17, 18 and 20, 2005
Robbert Dijkgraaf (Amsterdam)
The Mathematics of String Theory
Topological String Theory I and II

The winter 2005 Coxeter Lectures were delivered by Robbert Dijkgraaf on January 17 and 20 at Fields Institute, and on January 18 at Perimeter Institute.

Dijkgraaf was awarded a Ph.D. cum laude under the supervision of the Nobel laureate Gerard ’t Hooft in 1989. He has been at the forefront in research in string theory, and his research greatly contributed to the remarkable interplay experienced by theoretical physics and mathematics in the last 15 years. His ideas have proved fundamental in a vast array of research directions including (topological) string theory, quantum gravity, Gromov–Witten theory, mirror symmetry and matrix models, to name just a few. A true Renaissance man, Dijkgraaf also studied painting at the Gerrit Rietveld Academie. He is an accomplished artist as well as a columnist for the newspaper NRC Handelsblad and the magazine Folia. In 2003, he was awarded the Spinoza Prize, the highest scientific award in the Netherlands.

The first lecture, entitled The Mathematics of String Theory, was a delightfully informal presentation of the main research directions that have brought together (reluctantly, one might say, at least in the beginning) physicists and mathematicians. Punctuated by historical quotes and pictures, as well as his own vivid drawings, Dijkgraaf took the audience on a tour that started with classical mechanics, touched upon the fundamental ideas in quantum mechanics and quantum field theory, and moved to string theory and quantum gravity. Paraphrasing the famous quote of Wigner, Dijkgraaf talked about the "Unreasonable Effec-
tiveness of Quantum Physics in Mathematics”. He then supported this assertion with a presentation of the main ideas that are involved in a plethora of subjects such as Gromov–Witten and knot invariants, mirror symmetry and Calabi–Yau varieties, matrix models and non-commutative geometry.

In the last two lectures, entitled *Topological String Theory*, Dijkgraaf explained how the B-model for topological strings on Calabi–Yau three-folds can be viewed as a way of “quantizing” the Calabi–Yau complex geometry. Constructing a Kodaira–Spencer type theory for the generalized variations of complex structures involves the consideration of $D$-branes (subvarieties, or sheaves) on the Calabi–Yau variety. In certain situations, these variations of complex structures can be understood by studying the periods of one-forms on a Riemann surface naturally associated to the considered three-fold geometry. Dijkgraaf characterized this result as a tree level computation. Remarkably, its quantum extension leads to matrix models and associated integrable systems, for example the KdV hierarchy.

May 9–11, 2005

**Renata Kallosh** (Stanford)

*Towards String Cosmology*

*Stabilization of Moduli in String Theory I and II*

Renata Kallosh, Professor of Physics at Stanford University delivered the Coxeter Lectures on May 9 and May 11 at Fields Institute and on May 10 at Perimeter Institute. Kallosh obtained her Ph.D. at the Lebedev Physical Institute in Moscow, and was later a professor there and a scientific associate at CERN before moving to Stanford in 1990. She has done fundamental research in a wide array of directions covering supersymmetry, supergravity, quantum theory of black holes, M-theory and string theory. Her recent work is concerned with the role of M/string-theory in the cosmology of the early universe and in the study of dark energy.

The first lecture, *Towards string cosmology*, had a pedagogical flavor, and dealt with some of the questions raised in string theory and higher dimensional supergravity by the recent cosmological and astrophysical observations supporting dark energy and inflation. The sign and the size of the cosmological constant have fundamental implications for the laws of physics. Kallosh detailed some of the models obtained during the last couple of years in the framework of string theory that incorporate inflation and a positive cosmological constant. Many hopes of the scientific community are related to the experimental data from the Large Hadron Collider (LHC) expected to go on-line in 2007 at CERN. Kallosh presented some of the crucial missing puzzle pieces that the future observations at the LHC might add to astrophysics and cosmology, as well as to supersymmetry and string theory.

The next two lectures were more technical and focused on the *Stabilization of moduli in string theory*. This is a theoretical method developed by Kallosh and her collaborators, as well as other groups, that eliminates some of the discrepancies suffered by previous string models, in light of recent observations. Near the black hole horizon, such models are based on special types of attractor K3 surfaces where a class of moduli are fixed by fluxes. The complex structures of such K3 surfaces can be determined explicitly with a Torelli type result. A careful analysis shows that stabilization of certain moduli is in fact a prerequisite for string cosmology. Other approaches were presented, some involving the so-called landscape of string theory. Another recent explicit result of Aspinwall and Kallosh provides the analysis of a geometrical model of M-theory compactified on a product of K3 surfaces and its dual type IIB orientifold theory, where the instanton effects and the fluxes generically fix all the moduli.
Organizer: George A. Elliott (Fields Institute and University of Toronto)

The Operator Algebras Thematic Program began in 1996 (after a two-year major program in the same subject) and has continued since then. During the 2004-05 year, five postdoctoral fellows participated in the program: Xiaodong Hu, Cristian Ivanescu, Hanfeng Li, Frédéric Latrémolière, and Anamaria Savu. There were also thirteen students involved with the program: seven Ph.D. students - Alin Ciuperca, Kris Coward, Toan Minh Ho, Zhuang Niu, Brian Pigott, Leonel Robert, and Luis Santiago; two M.Sc. students - Michael Bailey and Greg Maloney; and four undergraduate research assistants - Branimir Cacic, Nadish DeSilva, Lloyd Elliott, and Brandon Lee.

Several mathematicians visited for shorter periods. In particular, Ola Bratteli (Oslo) and Andrew Toms (UNB) visited for a month after the Fields Institute Summer School in Operator Algebras and the Canadian Operator Symposium held at the University of Ottawa from June 7 to 24.

A regular working seminar was held, usually meeting on Tuesday and Thursday afternoons for three or four hours, and concerned mainly with operator algebras and noncommutative geometry. One subject considered in some detail was the structure and classification of amenable C*-algebras.

As an offshoot of the program, a group of about ten high school students was supervised during weekly meetings under the auspices of the University of Toronto Arts and Science Mentorship Program. This was carried out by the following graduate students: Kris Coward, Zhuang Niu, Brian Pigott, and Leonel Robert (co-ordinator).

**Ontario Non-Commutative Geometry and Operator Algebras Seminar**
July 2004–June 2005

**Speakers:**
Alin Ciuperca (Toronto)
Kris Coward (Toronto)
Thierry Giordano (Ottawa)

_Dynamical systems and C*-algebras_

Toan Ho (Toronto)
Cristian Ivanescu (Fields)
David Kerr (Tokyo & Texas A&M)
_Directories and Gromov-Hausdorff convergence_
Frederic Latremoliere (Toronto)
Hanfeng Li (Toronto)
_Banach space dynamical entropy_
Zhuang Niu (Toronto)
Brian Pigott (Toronto)
Sarah Reznikoff (Victoria)
_Hilbert space representations_
Leonel Robert (Toronto)
Anamaria Savu (Toronto)
Andrew Toms (New Brunswick)
The Spring 2005 Distinguished Lecture Series was delivered by Edward Witten, the Charles Simonyi Professor of Mathematical Physics at the Institute for Advanced Study in Princeton. Widely regarded as the most influential thinker in mathematical and high energy physics over the last quarter-century, Witten is certainly exceptional in the massive extent to which his ideas have influenced and energized fields of pure mathematics, including parts of algebraic topology, algebraic geometry, knot theory, geometry of 3- and 4-manifolds, and symplectic geometry, among others. Witten has received numerous awards and honours, including a MacArthur fellowship, the Dirac Medal, and a 1990 Fields Medal.

Witten is one of the world’s foremost experts on superstring theory, currently the most promising candidate for a unified theory of fundamental physical interactions. As a result of this and his many public appearances explaining string theory to a general audience, he is well-known to anyone with an interest in current trends in theoretical physics. His lectures, held in several large auditoriums at the University of Toronto, were well-attended. Academics and aspiring researchers from many disciplines were on hand to hear Witten’s three lectures. Instead of speaking about his groundbreaking work in string theory, Witten chose to describe several much more well-established physical ideas which do not receive as much mathematical attention as they deserve.

The first lecture focused on the relativistic scattering of fundamental particles. Witten explained that the scattering was described by an $S$-matrix, described as a geometric quantization of a symplectomorphism on the infinite dimensional manifold of free fields. The $S$-matrix depends on the incoming and outgoing particles in the scattering, described by points on a real quadric in Minkowski space, which has two components. Amazingly, the $S$-matrix
extends to a holomorphic function on the complexified quadric, which has only one component. Physicists call this property of the S-matrix crossing symmetry and Witten explained how it can be used to deduce the existence of antimatter.

In the second lecture, the audience was treated to an eminently understandable account of gauge symmetry breaking in the context of superconductors. Witten described the Landau-Ginzburg model of superconductivity, where the material is endowed with a section of the square of the electromagnetic line bundle. Witten then explained that although a superconducting ring maintains a current for an extremely long time, the current does decay due to the nucleation of flux lines, which correspond to zeros of the section. The flux lines may attract or repel depending on the properties of the superconductor, and in the limiting case the equations describing the superconductor’s 4-dimensional worldvolume approach Taubes’ perturbation of the Seiberg-Witten equations for 4-manifolds. In this way, Witten showed that smooth invariants of 4-manifold theory pertain to the properties of superconductors! He then turned to the description of the weak force in directly analogous terms, but for a $U(2)$ connection instead of the $U(1)$ of electromagnetism. The breaking of $U(2)$ to $U(1)$ is described by a section of the $U(2)$ bundle, and the same mechanism which keeps magnetic fields out of superconductors is responsible for the fact that the W and Z particles of the weak force are visible only at high energies and short distances.

In the third lecture, Witten introduced the quantum Hall effect, whereby a thin conducting surface, when exposed to perpendicular electric and magnetic fields, generates a measurable current whose strength is quantized. Witten then described a topological mechanism which explains the quantization of this current. The remarkable thing is that the model describing the quantum Hall effect involves no degrees of freedom associated to the surface whatsoever. In other words it is a pure gauge theory. Witten then produced the Lagrangian describing this model, which is a $U(1)$ Chern-Simons theory on the 3-volume of the conducting surface. Generalizing this situation to an arbitrary gauge group, Witten described other invariants of 3-manifolds as well as the Jones polynomial invariant of knots in a 3-manifold. In the spirit of the previous lectures, we learned that esoteric 3-manifold invariants are directly linked to measurable physical phenomena.
the pair on an equal footing. In the former case an analysis using regression would usually be of interest, and in the second some study of correlation may be more natural. Graphical models provide a concise way to summarize these differing aspects of the measured variables. Variables are represented by nodes in a graph, variables on equal footing are placed in blocks, and links between variables are represented by edges in a graph. A directed edge links an explanatory variable to a response variable, and an undirected edge links variables in blocks. Absence of an edge represents some form of statistical independence. The blocks are assumed to form an acyclic recursive system, starting with a block of purely explanatory variables, to a block of purely response variables. The other variables are conveniently called intermediate. By this means complex sets of data can be studied in a structure that reflects potential causal relationships, and isolates relationships of particular interest for the substantive problem for which the data was collected.

Cox went on to discuss five canonical structures: the fully directed graph, the concentration graph, the covariance graph, seemingly unrelated regression, and block concentration regression. Edges in a covariance graph correspond to non-zero elements of an associated covariance matrix, and edges in a concentration graph correspond to non-zero elements of the inverse covariance matrix. The graphs naturally encapsulate various types of statistical models for multivariate data. There has been much theoretical work on the properties of these graphical models, often emphasizing the concentration graph. Linear least squares can often shed light on the underlying structure.

The second lecture developed the use of matrix analysis and linear least squares in more detail, and elucidated the special role of concentration matrices. The connection to partial and total regression coefficients suggests a generalization to probabilistic models, which was illustrated on quantile regression. This formulation has implications for understanding the role of confounding variables in causality. Two examples were discussed where the response was multivariate; in the first case a relatively simple explanation of the data was provided via a linear transformation of the components; the second example included some more complex dependencies in time in the responses. Work joint with Andrew Rodham was illustrated the use of graphical models on a rather complex data set derived from a partially observational and partially designed study, the Barry-Caerphilly milk study. This study had several background variables, and responses taken at three succeeding time periods. The approach via graphical models and linear transformations gave a concise and elegant interpretation of the main dependencies, as well as a simple means of presentation of the conclusions.

2004 CRM–FIELDS PRIZE LECTURES

Donald Dawson

Stochastic Dynamics of Evolving Populations
November 4, 2004

Donald Dawson, the CRM/Fields prize winner for 2004, delivered his prize address at the Fields Institute on November 4, 2004. This prize, for outstanding mathematical research carried out in Canada, is awarded jointly by the Centre de recherches mathématiques and Fields Institute. Previous winners include Donald Coxeter, George Elliott, James Arthur, Robert Moody, Stephen Cook, Michael Sigal, William Tutte, John Friedlander, John McKay, and Edwin Perkins.

Dawson, now of Carleton and McGill Universities, is justifiably well known as one of Canada's leading mathematicians, having made profound and influential contributions to probability theory and related fields. He is almost as well known for his dedicated service to the Canadian mathematical community, through the CMS, NSERC and other organizations, not least of which was his four-year term as director of the Fields Institute. He is currently President of the Bernoulli Society for Mathematical Statistics and Probability.
Dawson’s title “Stochastic dynamics of evolving populations” reflects his interest in stochastic processes with both a spatial and a branching or genealogical component. He reviewed classical probabilistic models from population genetics, and their generalization to superprocesses, with particular attention to the Fleming-Viot infinitely many alleles model (IMA). Using a representation due to Donnelly and Kurtz, he showed how the duals of these processes give rise to coalescents – now a major object of study in and of themselves.

This led naturally to the principal focus of his talk, namely the large-time evolution and analysis of spatial structure in these models. This can be understood from the point of view of a tagged particle, using coalescent ideas, or in terms of block averages that describe the behaviour of the process at multiple scales. The former approach allows one to decompose the IMA process into immortal super-Brownian clans, for which one can prove self-similarity (e.g. using results of Dawson and Greven). On the other hand, the analysis in terms of block averages in principle allows one to represent a host of different models as fixed points of a certain non-linear mapping, including both the Fleming-Viot and mutually catalytic branching models. He expressed the hope that similar ideas will succeed for models of the evolution of interacting species, shedding light on such topics as coevolution, symbiosis, and speciation.

2005 CRM–FIELDS PRIZE

David W. Boyd

The Centre de recherches mathématiques (CRM) of l’Université de Montréal, and the Fields Institute jointly established the CRM–Fields Prize in 1994 with the goal of recognizing exceptional work in the mathematical sciences. Recipients are 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.

David Boyd of the University of British Columbia is this year’s recipient of the CRM–Fields Prize, for his seminal contributions to analysis, number theory, geometry and mathematical computation. David has also played a prominent role in Canadian mathematical life through his involvement in the CMS, PIMS, and NSERC – serving in 1977-78 and 2001-02 as chair of the Grant Selection Committee and on the Steacie Prize Selection Committee during 1990-92 – and on the boards of both the Centre de recherches mathématiques and the Fields Institute. He will deliver a lecture on his work in Fall 2005

Established in 1994, the CRM–Fields Prize has become the premier prize in Mathematics in Canada. It is awarded in recognition of exceptional achievement in the Mathematical Sciences, for research conducted primarily in Canada or in affiliation with a Canadian university. Boyd is the last recipient of the CRM-Fields prize; starting in 2006 it will be renamed the CRM-Fields-PIMS prize.

One of the principal themes of Boyd’s research has been Mahler measure. The logarithmic Mahler measure of a polynomial $P(z)$ with complex coefficients is defined to be the average of $\log |P|$ over the circle,

$$m(P) = \int_0^1 \log |P(e(t))| dt$$

where $e(t) = \exp(2\pi it)$. If $P(z) = a_0(z - \alpha_1)\ldots(z - \alpha_d)$ (with $a_0 > 0$), it follows from Jensen’s formula that the Mahler measure

$$M(P) := \exp m(P) = a_0 \prod_{1} \max(1, |\alpha_i|).$$

The so-called Pisot and Salem numbers are of considerable interest in the subject because the Mahler measure of their monic irreducible polynomials is often very small. Boyd, in a series of papers in the 1970s, single-handedly revitalized this field. For example in a remarkable paper in the Duke Mathematics Journal in 1977, he showed that the construction used by Salem to prove that every Pisot number is a limit point of Salem numbers, can be used to produce every Salem number. He then exploited this construction to determine the smallest Salem numbers known, lending credence to Lehmer’s conjecture – the most prominent
outstanding question in this field – that $m(P)$ is bounded below by $c > 0$ for noncyclotomic polynomials $P$ with integral coefficients.

A little later, he showed that the logarithmic Mahler measure of a polynomial in $n$ variables (its average over the $n$-torus) is the limit of the Mahler measures of suitable polynomials in one variable, at least for certain $P$ – for example $m(1 + x + y)$ is the limit of $m(1 + x + x^3)$ as $n \rightarrow \infty$. This was proved later for general $P$, and made it apparent that it is natural to look at the larger set of (logarithmic) Mahler measures $m(P)$ for polynomials of one or more variables. This led C. Smyth to show that the logarithmic Mahler measures of certain polynomials of 2 or 3 variables were given by the values of $L$-functions – for example that $m(1 + x + y^2) = L'(\chi, -1)$ where $\chi$ is the quadratic character of conductor 3. This in turn led C. Deninger (in 1997) to show that, if $P(z_1, \ldots, z_n)$ does not vanish on the $n$-torus, then $m(P)$ is a Deligne period of the motive associated to the variety defined by $P = 0$. At the same time, he conjectured further connections between Mahler measures and the values of $L$-functions, this time of elliptic curves. Boyd followed this by finding families of (conjectural) formulas of this general type relating $m(P)$ to $L(E, 2)$ for certain $P(z_1, z_2)$, where $E$ is a factor of the Jacobian variety of the curve $P = 0$.

More recently David has established, in a sequence of papers (two of which are joint with F. Rodriguez-Villegas), a fascinating and deep connection between the Mahler measure of certain polynomials of degree 2 and the values of the Bloch-Wigner dilogarithm $D(z)$ and of the zeta functions of number fields, in particular for “A-polynomials” which arise from one-cusped hyperbolic 3-manifolds. In this case, as in so many others, David’s pursuit of the problem through extensive numerical calculations has led to startling new insights. A fuller description of Boyd’s work on which this note was based in part may be found at www.pims.math.ca/Scientific_Programme/CRM-Fields--PIMS_Prize/David_Boyd:_Recipient_of_the_2005_CRM-Fields_Prize/

PUBLIC LECTURES

RCI/Fields Institute Public Lectures
Rob Almgren and Agnes Tourin
November 7, 2004
Held at the University of Toronto

The Mathematics of Glider Racing

For over 150 years, the Royal Canadian Institute for the Advancement of Science has been sponsoring weekend public lectures in Science. In recent years, the Fields Institute has, with the help of Chandler Davis, co-sponsored one or two talks each year on mathematical themes. On November 7, 2004, Rob Almgren (Toronto) and Agnes Tourin (McMaster) together delivered a public lecture on the Mathematics of Glider Racing.

Almgren, who is also a glider pilot, introduced the elements of the sport of glider racing over distances of hundreds of kilometers. A graph of the glider’s vertical elevation would actually be an irregular, saw-tooth shaped function. The reason is that the glider descends gradually till it reaches an updraft (a column of rising air, typically with a cloud sitting at the top), whereupon it can again gain altitude. Since the strength and exact location of such updrafts are not entirely predictable, optimizing the speed of travel turns out to be a problem in stochastic control theory – a singular problem in fact. What one controls is the angle of descent (steeper is faster). For example, it may be preferable to bypass a weak updraft for a stronger but more distant one,
in which one will ascend more rapidly. If so, one’s angle of
descent should be as steep as possible, subject to the con-
straint that one must reach the updraft before hitting the
ground! Fortunately, modern gliders come equipped with
computers, and programs to help one make quick decisions.
Almgren described how to set up the glider control problem
mathematically, and indicated the type of solutions one
gets.

At this point Tourin took over, and tried to give the audi-
ence a sense of the mathematics that goes into producing
a solution. The saw-toothed nature of the trajectories
means they are not smooth functions at all. She described
how the modern machinery of viscosity-solutions allows
one to circumvent this difficulty, and still pose a well-
defined mathematical problem having a unique solution.
She illustrated the utility of this approach by giving other
applications of exactly the same mathematical ideas, from
the propagation of flame fronts to solving for optimal asset
allocation in the presence of transaction costs.

An enthusiastic audience of over 200 attended the talk,
and kept the speakers busy answering questions for long
afterwards.

Clay/Fields Institute Public Lecture
Eric Zaslow
June 2, 2005
Held at Fields Institute

Physmatics

Mathematics and physics, once a wonderful marriage,
underwent a divorce, but now the relationship has recon-
ciled as “Physmatics” in large part due to String theory.
Eric Zaslow (Northwestern) provided a lecture based
on this story, enjoyed by layperson and expert alike. His
slide presentation, interspersed with informative pictures,
quotations and analogies, traveled from the beginnings of
the interaction of physics and mathematics, to present day
investigations in String theory: an attempt to provide a
unified framework for the physics of the big and small. This
theory provides rich and unexpected predictions of duality
between mathematical objects of previous independent
importance.

The work of mathematicians to both put these predictions
inside the appropriate mathematical setting, and to fur-
thermore verify them, has in turn advanced the physics. It
is this interdependence of the two subjects that has been a
driving force in the aforementioned reconciliation.

Zaslow was a Clay Senior Scholar, in residence at the Fields/
Perimeter Institute thematic program on the Geometry
of String Theory. His participation in the program, and
his associated public lecture, were generously supported
by the Clay Mathematics Institute, based in Cambridge,
Massachusetts. In his lecture he surveyed the relationship
between mathematics, statistics, and physics, illustrated with examples from quantum theory, relativity, and differential topology. He went on to explain the central ideas of gauge symmetry, categories, and duality, giving examples ranging from electromagnetism to architecture (e.g. the Suite Vollard building) and television sit-coms. This was then tied together, with a discussion of the role of mirror symmetry in string theory. A transcript of this fascinating talk can be found on the Clay Mathematics Institute website, www.claymath.org

CMS/Fields Institute Public Lecture
Stephen Lewis
May 6, 2005
Held at the University of Toronto
Deciphering Our World

More than 200 mathematics educators - including teachers, education researchers, mathematicians - plus provincial government representatives from across the country gathered May 6-8, 2005 for the 2005 Canadian Mathematics Education Forum, organized by the Canadian Mathematical Society and the Fields Institute (see the “Mathematics Education” section of this annual report for details).

As part of the forum, Stephen Lewis delivered a public lecture titled *Deciphering our World*. The large audience in the University of Toronto’s Medical Sciences auditorium was treated to a lively and engaging exploration of the importance of mathematics education in creating a questioning and informed public. Mr. Lewis is the UN Secretary-General’s Special Envoy for HIV/AIDS in Africa. He is also a Commissioner for the World Health Organization’s Commission on the Social Determinants of Health, and a Senior Advisor to the Mailman School of Public Health, at Columbia University in New York. He is a director of the Stephen Lewis Foundation, which is dedicated to easing the pain of HIV/AIDS in Africa. Stephen Lewis is a Companion of the Order of Canada, a former leader of the Ontario New Democratic Party, and was Maclean’s magazine’s inaugural “Canadian of the Year” in 2003. He has served as Canadian Ambassador to the United Nations, and as the Deputy Executive Director of UNICEF in New York.

His talk contained a passionate and moving description of the plight of HIV/AIDS sufferers in Africa, and the social and personal devastation brought on by this disease. The effort to raise awareness of this scourge among the public and among policy makers provides an example of the general problem of communicating complex social issues in today’s society. In that context, a numerate and well educated public is essential, since the language of public debate is increasingly that of statistics. A familiarity with data, graphs, and mathematical reasoning is necessary in order to assess (and debunk if necessary) the arguments for or against particular programs or courses of action. To that end, Mr. Lewis applauded the work of the forum, in seeking to improve mathematics education in Canada, and to bring mathematical ideas to life for Canadian students. Not only is fear of mathematics an impediment to full participation in the public debate of important social and economic issues, but failure in the mathematics classroom erects barriers to employment in today’s knowledge-based and technological economy. Efforts to broaden the success of Canadian students in mathematics, and remove these barriers is thus one element in the pursuit of equity and social justice.
Special Events

Fields 2005 Annual General Meeting
June 9, 2005
Held at the Fields Institute

This year’s AGM started with a well-attended lunch for representatives of the Principal Sponsoring Universities (PSUs). The discussion included information on how Fields budgets and distributes general scientific activity to other sites. Events are approved based on how well they support Fields’ mission of stimulating research activity, and on their potential impact. The contribution of the PSUs to the support of Fields is warmly recognized. Reciprocally, PSUs get both tangible and intangible benefits for their contribution. There was discussion of the importance of documenting results, and different departments compared notes on how to get the most benefit from their PDF programs.

Next year, Fields would like to experiment with some new programs: methods to increase contact between PDFs and visibility of the program, and encouragement of PSUs to invite Fields visitors to their institutions. Input by PSUs to Fields programs is solicited, and the meeting stressed also the importance of making good appointments to the corporation, expanding Fields involvement to all departments that use mathematical sciences in the university, including business and engineering; and setting up Sponsoring Universities Activities Committees. Overall, the exchange marked another step in a continuing dialogue.

The intellectual highlight of the afternoon was a lecture by Mikhail Lyubich, co-organizer of next year’s thematic programs, “Renormalization and Universality in Mathematics and Mathematical Physics” in Fall 2005 and “Holomorphic Dynamics, Laminations and Hyperbolic Geometry” in Winter/Spring 2006. Misha began his lecture with a diagram, and proceeded to explain the central role of holomorphic dynamics, with historical developments and a list of outstanding conjectures. He described the rich world of rational maps, the early work of Julia and Fatou, Smale’s horseshoes, and the notion of universality which has profound connections to physics. One focus of the program will be the famous MLC conjecture that asserts that the Mandelbrot set is locally connected, a particular case of the Rigidity Problem.

More of this story will unfold during the coming year in six workshops, beginning with “Percolation, SLE and related topics”, September 20-24. The Distinguished Lecture Series will be given by Gregory Margulis in January 9-11, 2006, and there will be three Coxeter Lecture Series, by Oded Schramm, Lai-Sang Young and Yair Minsky. Among the
distinguished long-term visitors, Clay Senior Scholar Leo Kadanoff will give a public lecture. We anticipate an exciting and interdisciplinary year.

Following tea, the AGM itself was chaired by John Gardner, who began on the positive note that the revision of the by-laws has been a success. As of this year, Board members serve as individuals, rather than as representatives of some constituency. Now the Board is more focused on the Institute and its needs.

The Director’s report at the AGM summarized the year’s activities, particularly the interdisciplinary String Theory program, which has lived up to its promise of an exciting year. Beyond the coming year’s program in holomorphic dynamics and related topics, described above, programs in Cryptography (Fall 2006), Homotopy Theory and Applications (Winter/Spring 2007) and Operator Algebras have been approved. Keyfitz’s report also touched on the Institute’s other programs: General Scientific Activity, Summer Schools, NPCDS, CIM, Math Education and prizes and lectures. Beginning in 2006, the CRM-Fields prize will be renamed the CRM-Fields-PIMS prize, with PIMS joining as an equal partner.

The financial report shows that the budget is largely in balance, though the surplus is gradually being eroded. The fraction of the Institute’s budget that goes directly to programs has increased modestly over last year.

Philip Siller, deputy chair of the board, gave a report on fundraising. Recognizing that the chance of increased funding from public sources is slim, Fields is exploring the feasibility of fundraising from private sources. Last winter, a first “Annual Giving” campaign netted enough revenue to run an extra workshop. A draft “Case for Support” brochure has been generated, and a planning study is underway. A decision will be made in the fall; meanwhile, ideas are welcome.

This year, five new Fields Institute Fellows were announced: David Boyd (UBC), Walter Craig (McMaster), Lisa Jeffrey (University of Toronto), John Mighton (JUMP), and Tamas Terlaky (McMaster). This recognition is awarded to individuals who have made outstanding contributions to the Fields Institute, its programs, and to the Canadian mathematical community. Fields congratulates the new Fellows and thanks them for their service to Fields and to mathematics.

As its final official action of the meeting, a quorum of members of the corporation elected the Board of Directors for 2005-2006.
The AGM was followed by a brief meeting of the Board of Directors and a reception at Fields. In the evening, the Institute hosted a banquet at Hart House for members of the corporation, Fields staff and guests. Ron Dembo, Board member and founding CEO of $footprint$, delivered an inspiring talk on “The Golden Age of Mathematics”. The gist of his message was that the industrialized countries must move towards sustainability, and an important tool to move an environmental agenda forward will be mathematical modelling.

**Graduate School Information Day**

November 20, 2004
Held at the Fields Institute

For several years, the Fields Institute has organized a graduate student information day, in which graduate students and senior undergraduates have an opportunity to obtain information about Mathematics, Statistics, and Computer Science programs at local universities, and to discuss these programs with faculty representatives. The event includes a pair of lectures accessible to undergraduates, as well as information sessions. Twelve universities participated at the 2004 event. Student transportation was provided when possible.

The Fields Institute Newsletter (FieldsNotes) provided the following student perspective on the event.

**A Student Point of View**, by Sandra Gregov (York)

Despite the cold and rainy weather in Toronto on November 20th, the atmosphere at the Graduate School Information Day at the Fields Institute was warm and welcoming as university representatives and prospective graduate students mingled in conversation. The universities present were mainly from the Ontario region, including Carleton, Guelph, McMaster, Ottawa, Queen’s, U of T, Waterloo, Western, Windsor and York.

I was particularly gratified though, to find representatives from Syracuse University and the University of Rochester present, giving me the chance to find out the importance of the GREs in applying to graduate programs in the US. As well, it gave me a chance to discuss the similarities and differences between Canadian and American universities and how a Canadian undergraduate education compares with an American education in mathematics.

There was an abundance of information available from each university. The variety of professors and graduate students, ranging from pure math to applied math and from computer sciences to statistics, provided knowledgeable advice on application procedures, scholarships, course prerequisites and grades. As well, they outlined the influence which research experience, poster competitions and conference talks have on one’s application.

The first talk entitled “An infinite pigeonhole principle” by Deirdre Haskell of McMaster University introduced the pigeonhole principle and its use in defining an infinite set. Dr. Haskell gave examples of rings of equivalence classes of sets, some of which have the infinite pigeonhole principle. As one member of the audience pointed out, this talk showed that logicians do more than manipulate symbols, and showed how various mathematical areas can be interwoven to develop a stronger understanding of mathematical concepts.
Achim Kempf of the University of Waterloo gave the second talk, “Discreteness vs. Continuity: From Music Recordings to Cosmology” which discussed the significance of being able to interchange between discrete structures and continuous structures. The talk took an exciting tour through the history of the discrete versus the continuous – how a link between the two structures aided in the progression of music recordings, the development of sampling theory, and the partial solutions to unsolved questions remaining in the field of mathematical physics focusing on cosmology. The students present learned of the many options available to them through the large variety of graduate programs at Canadian universities, which provide a solid foundation to future mathematicians.

New Fellows of the Royal Society of Canada
October 24, 2004
Held at the Fields Institute

In the Fall the Fields Institute celebrated the election of new members to the Academy of Sciences of the Royal Society of Canada with an afternoon of lectures by a selection of the initiates.

Elizabeth Cannon
Positioning and navigation with the global positioning system: pushing the limits

Elizabeth Cannon is Professor of Geomatics Engineering at the University of Calgary. This is the scientific discipline that brings us the GPS (Global Positioning System). Her talk had three parts: the history of the development of GPS technology (driven originally by military needs, but now primarily by societal and commercial applications); a description of how GPS systems work (simple mathematics enters, like the geometry of triangulation, and also more advanced mathematics, needed to analyze the reflection of signals); and finally, a preview of developments yet to come: integration of GPS with “dead reckoning”; applications to ship clearance, to 911 services, to automation of operations like variable rate fertilizing, and animal tracking and search and rescue.

Stephen Fienberg
Mathematical glimpses of statistical models for frequency data at work

Stephen Fienberg, who is the Maurice Falk University Professor of Statistics and Social Science at Carnegie-Mellon University, is from Toronto and spent part of his career at York University. He has been president of the Institute of Mathematical Statistics. In his talk, mathematical glimpses of statistical models for frequency data at work, he spoke about contingency tables for high dimensional data and their relation to algebraic geometry. By redefining the parameters of a log-linear model in terms of various odds ratios, one can then restrict these odds ratios in interesting ways, leading to more robust and parsimonious models. It is perhaps worth mentioning that, in addition to the elegant mathematics presented in his talk, Fienberg is well known for is work in very applied areas, and has contributed to the dialogue on the use of US census data.

Jacques Hurtubise
Integrable systems

Jacques Hurtubise is the former Director of the Centre de recherche mathématiques and the newly appointed Acting Vice-Principal (Research) of McGill. Jacques, who was a student of Nigel Hitchin, has worked in several areas,
including the topology of moduli spaces and moduli spaces on Riemann surfaces. His talk focussed on related work in integrable systems, from the viewpoint of symplectic geometry. The relation between the geometric concept of Hamiltonian structure and the analytic one leads to beautiful correspondences (loop agebras and Fourier series, for example) which can be summed up as a meta-theorem: “Things are much simpler (and more elegant) than one has any right to expect.”

Barbara Sherwood Lollar

*Compound specific stable isotope analysis: a novel tool for investigation of biodegradation*

Barbara Lollar is Professor of Geology and Director of the Stable Isotope Laboratory at the University of Toronto. Her lecture focused on a piece of geochemical detective work: using properties of stable isotopes of carbon and of hydrogen to study biodegradation. The context is underground transport of petroleum hydrocarbons and chlorinated solvents. These contaminants, which pose hazards to human health, are attacked by naturally occurring microbes in the soil, and broken down into harmless compounds. However, when a pollutant that was present disappears, how do we know whether it has really been converted as intended, or has just flowed downstream? Because degradation, unlike other processes like dissolution, is not isotopically conservative, one can use measurements of the fraction of different isotopes at different times and places in the contaminated field to discover whether biodegradation is taking place. A possible future project is to combine this chemical research with mathematical and computational modelling of the flow process itself, to better direct remediation efforts.

It was a fitting conclusion to a program that gave so many connections between mathematical structures and other sciences, and between one area of mathematical sciences and another.
THE NATIONAL PROGRAM ON COMPLEX DATA STRUCTURES (NCPDS)

Director: Jamie Stafford (Toronto)

Program Committee: David Bellhouse (UWO), Richard Cook (Waterloo), Paul Gustafson (UBC) Mike Hidiroglou (Statistics Canada), Nancy Reid (Toronto), Randy Sitter (Simon Fraser), Ed Susko (Dalhousie), and Louis-Paul Rivest (Laval)

NPCDS is a joint initiative between Canada’s Statistical Sciences Community and the nation’s three Mathematical Sciences Institutes, with funding provided by NSERC. Its goal is to foster nationally coordinated interdisciplinary research projects involving interactions between statisticians and scientists working with complex data sets. A two-stage mechanism is used in which an inaugural workshop gets the research network going, to be following by a proposal for a two-year research project.

During the 2004–05 year projects and pilot projects within the National Program met April 9–4 at the Banff International Research Station. Leaders in Computer Experiments, Data Mining, Genomics and Survey Methods each organized a day of activity in their respective fields. An additional day was devoted to three pilot projects that had inaugural workshops planned in the areas of Biomedicine, Forestry and Marine Ecology. Research presentations were incredibly varied and included topics that concerned pharmacophore identification, complex HIV proteomic data structures, communications security, studies of complex traits, social behaviour, forest fires, high throughput genomics, tracking of leatherback turtles, turbulence, and so on. Underlying such a diverse set of topics was a genuine common interest in complex data, regardless of its origin. This, in effect, bonded participants in their vision of what NPCDS can bring to the statistical sciences community in Canada. As such the event was instrumental in generating considerable enthusiasm for the Program’s model. Concretely, the establishment of interdisciplinary projects with quantitative leadership was viewed as a vehicle that gives the statistical community a greater voice in the research agendas of other disciplines. These projects have the potential to create a culture in statistics where training takes place in intensely interdisciplinary environments ensuring young researchers become effective collaborators in the long run. This was evident by the number of excellent presentations given by graduate students, including Norberto Pantoja Galicia, Jason Loepky, Pritam Ranjan and others

The event was timely as the Program is currently entering the second half of its four year funding cycle and it offered an opportunity for participants to assess what has been accomplished thus far. The general view was “a lot!”. With potentially seven national projects established in a two year span the Program has engaged the broader community in a robust way. Credit must be attributed to the many individual researchers who are investing time and energy in this endeavour. During the week at Banff general meetings were held where progress, and the future of the program, was discussed openly. For example, issues concerning budget surpluses led to consideration of an RFP for training initiatives, which is now being drafted for the approval of NPCDS governance. In addition, plans for the renewal of the program have been set in motion, although these have been complicated by the uncertainty surrounding NSERC’s reallocation process. One positive development has been the consideration of expanding the Program as a joint CIHR/NSERC initiative. This appears to be an extremely exciting, if challenging, prospect. General enthusiasm for this comes not only from our own community, but also from key players within CIHR. This gives some cause for cautious optimism.

Enthusiasm for the National Program from other disciplines was clearly evident during the inaugural workshop on Forests, Fires and Stochastic Modelling held at the Fields Institute May 24–28, 2005 (see the detailed report later in this section). Forest fires are a natural component of many of Canada’s forested ecosystems but they also pose threats to public safety, property and forest resources. Every year, forest fires cause millions of dollars worth of damage and force the evacuation of some communities. Such problems will be exacerbated as people establish more homes and cottages in and near forested areas and climate change alters forest vegetation and weather. The purpose of the workshop was to bring together forestry researchers and statisticians to identify areas of potential collaboration. The event began with a day of introduction to the language of forest fires with contributions by researchers from the Ontario Ministry of Natural Resources, the Canadian Forest Service, Fire Science Lab and the US Forest Service. The remainder of the workshop focused more on statistical techniques, although even here applications abounded including modeling wildfires, lightning strikes, seismology, fire indices, visualization, weevil infestations, Boreal ecosystems and so on. Many keynote speakers such as David Vere-Jones, David Brillinger, Gail Ivanoff, Andre Dabrowski, Dean Slonowsky, focused on issues of considerable depth including spatial
– temporal point processes, set – indexed martingales, spatial generalizations of renewal processes and so on.

There is a lot of enthusiasm about this initiative among forestry researchers including those in ecology and hydrology as well as in fire. They are open to all sorts of statistical and probabilistic ideas. This is evident from a subsequent electronic discussion group that has been established that includes over 40 subscribers. This has been instrumental in the preparation of a proposal for a full NPCDS project. In addition, a follow-up meeting will take place at the Banff International Research Station next spring and a promising proposal has been submitted to GEOIDE for matching funds. All of this activity in such a short space of time speaks to the vibrant environment being created by this group and to the promise of significant advances at the interface of Forestry, Probability and Statistics.

The Centre de recherches mathématiques hosted the joint NPCDS/SAMSI workshop on Latent Variable Models and Survey Data for Social and Health Sciences Research. The workshop was attended by about 65 participants, from Canada, the United States, and the United Kingdom. Although the majority of participants were statisticians from universities or government agencies, there was also a good representation from the social sciences and health sciences. The opening tutorial, by Anders Skrondal and Sophia Rabe-Hesketh was based on their recent book and covered a great deal of ground, including a thorough introduction to the authors’ framework for latent variable models, and a variety of interesting applications. It was very valuable for both experts and newcomers to latent variable modelling. The meeting was tied to the NPCDS Complex survey data project.

The workshop provided an opportunity to showcase some of the accomplishments of the SAMSI theme year on latent variable models. A review and summary was provided by the organizer of the theme year, Ken Bollen of the University of North Carolina. Some of the sessions included reports and discussions of the activity of the complex surveys working group, formed at the opening workshop at SAMSI in September 2004. The difficulties in adapting latent variable methods to complex survey data are perhaps best appreciated in the context of multi-level models. Chris Skinner of Southampton University provided an excellent overview of progress to date in this area. Under his leadership, the complex surveys working group had focused on weighting and estimation for multilevel models. Several papers at the workshop provided further insights into currently available estimation techniques and software. A very gratifying feature of the workshop was the high quality of the presentations, and of the analyses put forward in applications. Attempts will be made to organize more occasions for statisticians and social scientists to interact on methodological challenges.

A project on DataMining is being vetted by NPCDS, following an inaugural workshop held at Fields October 28–30, 2004 (see the detailed report later in this section). The idea for this meeting emerged from discussions Fields organized between Generation 5 and NPCDS. A follow-up meeting is planned for fall 2005.

In other news, an NPCDS project on the Design and Analysis of Computer Experiments for Complex Systems received final approval and is moving forward following a successful inaugural workshop held at BIRS, July 13–17, 2004. NPCDS funding also supported various interactions with SAMSI, and allowed junior researchers to attend the August 5–6, 2004 Fields workshop on Missing Data Problems (see the General Scientific Activity section for a description of this event). Inaugural workshops on Spatial-temporal models for Marine Ecological Systems and Longitudinal and Clustered Data Analysis take place August and October of 2005 respectively. Please watch for announcements as student travel stipends are available.

NPCDS Projects underway

Statistical Methods for Complex Survey Data (inaugural workshop April 30–May 2, 2003 at CRM)

Statistical Genomics (inaugural workshop September 3–5, 2003 at Fields)

Design and Analysis of Computer Experiments for Complex Systems (inaugural workshop July 13–17, 2004 at BIRS)

Workshops

Workshop on Missing Data Problems
August 5–6, 2004
Held at the Fields Institute
- see General Scientific Activity section for a description of the event

Data Mining Methodology and Applications Workshop
Held at the Fields Institute
Organizers: Hugh Chipman (Acadia), Antonio Ciampi (McGill) and Michael Vainder (Generation 5)

Data mining is the science of learning from large and complex data sets. Although it lies at the intersection of many
disciplines, some common elements emerge: intensive computation, mathematical models, and large, complex data sets arising from real-world problems.

Data mining has been a well-defined area of research for about a decade, but new developments are happening both in methodology and in applications. These recent developments were the focus of a three-day workshop held at the Fields Institute on October 28-30, 2004. The workshop was sponsored by Generation 5 Mathematical Technologies, the National Program on Complex Data Structures (NPCDS), and the Statistical and Applied Mathematical Sciences Institute (SAMSI). The idea for the workshop emerged from discussion the Fields Institute organized between Generation 5 and NPCDS.

The program included a mix of plenary addresses, invited talks, and open discussion sessions, all directed at showcasing the best innovations and focusing on challenges that lie ahead.

Of the frontiers identified, both research and applications seem to be driven by new, complex data structures, such as categorical data, unstructured text responses to surveys, relational data (for example, two persons in a database who belong to the same household), semi-supervised learning, high-dimensional data, and problems with rare, interesting events (such as a purchase in direct marketing or the identification of a drug effective against a biological target).

A panel discussion featuring leaders from research and industry brought out several interesting and provoking perspectives on the future of data mining. Jerome Friedman (Stanford), one of the world’s leading researchers in statistical methods for data mining, identified six of the most pressing problems in data mining: Efficiently modeling categorical variables with many levels, analysis of relational data, semi-supervised learning, interpretation of black box models, analysis of unstructured data, such as raw text data from forms, and also the urgent need to train more statistical data miners. Milorad Krneta, president of Generation 5 Mathematical Technologies, put forward the thought-provoking idea that in applications, mathematical methods for data mining cannot be left exclusively in the hands of research mathematicians, but instead must be automated as much as possible. This ambitious goal is being accomplished at Generation 5 by studying and quantifying the actions of a skilled analyst during data mining, and then abstracting these steps and incorporating them into data mining software. Thus, Generation 5 is pursuing innovation on two fronts: new data mining algorithms (for example for variable selection, prediction, or clustering) and automation of analyst tasks. At the same time, he stressed the importance of having models that make believable, understandable predictions.

Another plenary speaker, computer scientist Yoshua Bengio (Montreal) encouraged both researchers and practitioners to “get out of local minima” and consider what the other group has to offer. Practitioners should consider going beyond established tools like logistic regression and decision trees, and take advantage of new methods such as ensemble models and support vector machines. Researchers should reconsider new, ambitious problems that are stimulated by real-world applications.

The workshop was near-capacity for the Fields, with 113 participants, including 30 graduate students, 33 participants from industry/government, and 50 academics. Among the research areas represented were statistics, computer science, machine learning, marketing, engineering, and physics. In the scientific program were presentations on a number of hot topics, including ensemble methods, support vector machines, unsupervised learning, parallel computation for improved data mining performance, mining industrial process data, and rare event problems. In many of these areas (notably unsupervised learning, parallel computation) perspectives from both academic researchers and industry practitioners were presented.

A significant outcome of the workshop is the establishment of new research collaborations involving academics, students and industry. In addition to serving as a catalyst for these collaborations, the workshop has showcased hot new research and exciting real-world problems. The science of data mining is very much alive in Canada, both in methodology and application.
**Speakers:**

Roberto Aldave and Simon Gluzman (Generation 5)  
*Prediction of real variables with non-polynomial approximants*

David Banks (Duke)  
*Scalability of models in data mining*

Yoshua Bengio (Montréal)  
*Statistical learning from high dimensional and complex data: not a lost cause*

Merlise Clyde (Duke)  
*Bayesian perspectives on combining models*

Adele Cutler (Utah State)  
*Random forests: proximity, variable importance, and visualization*

Alex Depoutovitch (Generation 5)  
*The use of grid computing to speed up prediction*

Jerome H. Friedman (Stanford)  
*Importance sampling: an alternative view of ensemble learning*

Wenxue Huang (Generation 5)  
*Dependence degree and feature selection for categorical data*

Grigoris Karakoulas (Toronto)  
*ROC-based learning for imbalanced class problems*

Theodora Kourti (McMaster)  
*Data mining in industry for process and product improvement*

Helmut Kroeger (Laval)  
*Learning in neural networks with small-world architecture*

Xianping Liu (Generation 5)  
*Generation 5 hybrid clustering system and its application*

Joaquín Ordieres Meré (U. la Rioja)  
*Data-Mining for industrial processes*

Saharon Rosset and Ji Zhu (Michigan)  
*II regularization: efficient and effective*

Russell Steele (McGill)  
*Algebraic geometry and model selection for naive Bayes networks*

Godfried T. Toussaint (McGill)  
*Proximity graph methods for data mining*

Steven Wang (York)  
*Clustering categorical data based on distance vectors*

S. Stanley Young (NISS)  
*Linking and pattern matching in multiple large data two-way tables*

Ruben Zamar (UBC)  
*Robust methods and data mining*

Ji Zhu (Michigan)  
*Piecewise linear SVM paths*

Mu Zhu (Waterloo)  
*An adaptive radial basis function network model for statistical detection*

Djamal A. Zighed (U. Lyon 2)  
*Constructing induction graphs*

Alex Zolotovitski (Generation 5)  
*Automated trade area analysis: case study of G5 MWM software application*

**Workshop on Forest Fires and Point Processes**  
May 24–28, 2005  
Held at the Fields Institute  
Organizers: W. John Braun (UWO), David Martell (Toronto) and Rick Schoenberg (UCLA)

Forest fires are a natural component of many of Canada’s forested ecosystems but they also pose threats to public safety, property and forest resources. Every year, forest fires cause millions of dollars worth of damage and force the evacuation of some communities. Such problems will be exacerbated as people establish more homes and cottages in and near forested areas and climate change alters forest vegetation and weather.

The purpose of the workshop was to bring together forestry researchers and statisticians to identify areas of potential collaboration. The meeting was supported by Fields,
MITACS, NPCDS, the Sustainable Forest Management NCE, and the Ontario Ministry of Natural Resources.

The event began with a day of introduction to the language of forest fires. Rob McAlpine (Ontario Ministry of Natural Resources) gave the opening talk which gave an excellent overview of the problems in forest fire management in Ontario. Short term prediction of fires (1-10 days) remains a high priority problem. Assessing fire prevention and suppression performance is a problem that will require statistical input. Dave Martell (Toronto) continued on the management theme, highlighting a number of open problems, including a spatial queueing problem where fires are viewed as customers, and fire crews and aircraft are viewed as the servers; one of the difficulties with the queueing problems arising in this area is that the service time distribution depends on the waiting time in the queue. Mike Wotton’s (Canadian Forest Service) first talk was a useful tutorial focused on the Canadian Forest Fire Danger Rating System. He also gave brief descriptions of some of the deterministic fire spread models that are currently in use within the forest fire community. Larry Bradshaw (Fire Science Lab, US Forest Service, Montana) gave a complementary talk, describing similarities and differences between U.S. and Canadian systems. Mike Wotton’s second talk concerned the prediction of forest fires in Ontario, using logistic regression models. Haigonoush Preisler (USDA Forest Service) concluded the first day with an overview of the statistical issues connected with wildfire prediction. She also made some comments on the possible incorporation of stochastic elements into wildfire spread models. The first day ended with a reception and a poster session.

The second day began with a more statistical flavour. Rolf Turner (UNB) described how to use an R package to analyze wildfire locations as point patterns. Rolf’s focus was on the New Brunswick area. He noted a number of difficulties associated with the data; data cleaning is always necessary, especially if one wished to guarantee that there are really no wildfire occurrences in the Bay of Fundy! Andre Dabrowski (Ottawa) carried on the theme of exploring wildfire location data; he considered a power law model for interpoint distances of Canadian wildfires, drawing a tentative conclusion that the correlation dimension might be less than the embedding dimension for these data. Rick Schoenberg (UCLA) discussed point process intensity estimation for space-time point processes. His techniques led to a possible way of supplementing the burning index which is used in the U.S.

The afternoon of the second day began with Boreal forest issues. Brian Stocks (CFS) gave an excellent overview of the subject, and Steve Cumming (Boreal Ecosystems Research) discussed a number of associated statistical issues, including the problem of parameter estimation for simulation models and probability mapping of wildfire incidence. Fangliang He (Alberta) and Ed Johnson (Calgary) described some of the ecological issues. Ed’s talk dealt with an interesting interplay between evolution and wildfires and other disturbances, briefly discussing a mathematical model for tree breakage in relation to avalanches. Reg Kulperger (Western) discussed a stochastic fire spread model based on cellular automata ideas, and Dave Stanford (Western) described a technique for applying a fluid queue as a model for the perimeter of a spreading fire.

The third day of the workshop centered on statistical techniques. John Braun (Western) gave a brief talk on the use of point process local likelihood techniques. David Vere-Jones (Wellington) gave an expository talk on modelling of space-time point processes, indicating how some of the ideas used in statistical seismology might or might not carry over to the wildfire setting. David Brillinger (Berkeley) discussed two marked point process data sets, one concerning an earthquake occurring in 18th century Portugal, and the other concerning more recent wildfires in Oregon.

The afternoon of the third day began with a European perspective. Fuensanta Saura Igual (Jaume I) described a spatial statistical analysis of Spanish forest fires. Domingos Xavier Viegas (Coimbra) discussed a number of issues, including the comparison of national fire danger indices. He also made some observations on the development of fire spread models, and he described some results coming from both field and laboratory experiments. This afternoon concluded with a further consideration of forest fire management issues. Marcia Gumertz (NCSU) and David Butry (USDA Forest Service) discussed a propensity-score matching approach which could be used to assess the effects of prescribed burns.

The fourth day began with a more theoretical view of point processes. Rafał Kulik (Ottawa) gave a tutorial introduction to the theory of point processes, and Dean Slonowsky (Manitoba) gave an overview of set-indexed martingales. Gail Ivanoff (Ottawa) gave a talk on spatial generalizations of the renewal process which was set at a level understandable to the many forestry researchers in the audience; time will tell whether we see the rapid dissemination of an idea stemming from deep probability theory to application in wildfire spread.
The afternoon of the fourth day started with Doug Woolford (Western) describing a data sharpening method for clustering lightning strikes in space and time. Sylvia Esterby (UBC-Okanagan) described an analysis of fire index data. Bo Song (Clemson) ended the day with a fascinating talk on fire data visualization techniques.

The final day was a half-day highlighted by an excellent concluding talk by Charmaine Dean and Farouk Nathoo (Simon Fraser) on the analysis of pine weevil infestations using space-time mixture models. The rest of the morning was devoted to a discussion of where to go from here; clearly there is interest in developing collaborative ties between the forestry community and statisticians. The group decided to pursue a full proposal to the National Program on Complex Data Structures (NPCDS) to further this aim.

**Speakers:**
Larry Bradshaw (Fire Sciences Lab, MT)
*Basics of the National Fire Danger Rating System*

John Braun (UWO)

David R. Brillinger (UC Berkeley)
*Risk analysis for two marked point process data sets*

David T. Butry (USDA Forest Service, Southern Research Station)
*Estimating the effect wildfire management has on fire behavior: a Propensity-Score Matching Approach*

Irena Creed (UWO)

Steve Cumming (Boreal Ecosystems Research Ltd.)
*A multivariate regionalisation of Canadian fire regimes*

Andre Dabrowski (Ottawa)
*Modeling distances between ignitions*

Charmaine Dean (Simon Fraser)
*Mixture models for Spatio-Temporal Multi-State processes*

Sylvia R. Esterby (UBC-Okanagan)
*Analysis of fire index data*

Marie-Josee Fortin (Toronto)
*Deforestation in Québec northern boreal forest due to fire regime*

Marcia L. Gumpertz (USDA Forest Service, Southern Research Station)
*Wildfires in Florida – preliminary analysis*

Fangliang He (Alberta)

Fuensanta Saura Igual (Jaume I, Spain)
*Analysis of forest fires in Comunidad Valenciana (Spain) using a spatial statistics methodology*

Gail Ivanoff (Ottawa)
*What is a multiparameter renewal process?*

Edward A. Johnson (Calgary)
*A process approach to predicting tree mortality in surface fires*

David Vere-Jones (Victoria U., Wellington & Statistical Research Associates Ltd.)
*Some models and procedures for Space-Time Point Processes*

Rafal Kulik (Ottawa)
*Tutorial on point processes*

Reg Kulperger (UWO)

David Martell (Toronto)
*Forest fire management - a systems modelling perspective*

Robert McAlpine (Ontario Ministry of Natural Resources)
*Forest fire management in Ontario - a primer and manager’s perspective*

Haiganoush Preisler (Southwest Research Station, USDA Forest)
*Some statistical issues in predicting wildland fire risk*

Rolf Turner (UNB)
*Planar Point Pattern Analysis of New Brunswick forest fire data*

Rick Schoenberg (UCLA)
*On the estimation of separable point processes and possible improvements to the Burning Index*

Dean Slonowsky (Manitoba)
*Set-indexed martingales: tools for multidimensional stochastic modelling and analysis*
Bo Song (Clemso)
Visualization of fires

James Stafford (Toronto)
NPCDS planning

David Stanford (UWO)
Fire perimeter analyzed as a fluid queue

Brian Stocks (CFS)
Fire in the Boreal Forest

Domingos Xavier Viegas (U. Coimbra)
A mathematical model for eruptive fire behaviour and related problems

Douglas Woolford (UWO)
Exploring lightning and fire ignition data using data sharpening techniques

Mike Wotton (Canadian Forest Service -Natural Resource Canada)
Using and interpreting output from the Canadian Forest Fire Danger Rating System
Methods for the prediction of forest fire occurrence in Ontario
The purpose of the meeting was to study and develop the applications of techniques of algebraic topology in various areas of theoretical computer science, including concurrency theory, computational geometry and problems related to combinatorics. There has been much progress in these areas since the time of the first meeting in Stanford. It is now clear that the higher dimensional automata which model parallel processing behaviour and their associated “fundamental categories” can be encoded in a purely combinatorial homotopy theory of cubical sets. Other new and interesting approaches to studying concurrent behaviour involve, respectively, a Quillen model structure on the category of 2-categories, and the homotopy theory of simplicial presheaves on a category of spaces admitting local partial orders.

Several talks were presented on the detection of shapes from point cloud data. The most effective and well understood method of carrying out such an analysis involves persistent homology, which amounts to keeping track of Betti numbers of simplicial complexes built from the data set as more data points are taken into account. The basic idea, which has proven to be quite robust experimentally, is that good Betti numbers (i.e. those which represent real features) should appear and persist once the resolution of the data is sufficiently fine.

There was an interesting discussion of a program initiated by Lovasz, concerning his cell complex $\text{Hom}(G,H)$, which is defined for graphs $G$ and $H$. The idea is that this complex contains obstructions to the existence of maps from $G$ to $H$. The question of the existence of such maps in the case when $H$ is a complete graph amounts to the graph colouring problem. Kozlov has recently proved a conjecture of Lovasz which asserts that if $G$ is a cycle of odd length and the cell complex $\text{Hom}(G,H)$ is $k$-connected, then the chromatic number of $H$ is greater than or equal to $k + 4$. The method of proof involves spectral sequence calculations and manipulations of Stiefel-Whitney classes. The homotopy theory of graphs which should underly this discussion remains to be explored.

Support for the meeting was received from NSF and the Fields Institute.

**Speakers:**
- Saugata Basu (Georgia Tech.)
  *Efficient algorithms for computing the Betti numbers of semi-algebraic Sets*
- Peter Bubenik (EPF, Lausanne)
  *Towards a model category for local po-spaces*
- Gunnar Carlsson (Stanford)
  *Topology of point cloud data*
- Anne Collins (Stanford)
  *A barcode shape descriptor for curve point cloud data*
- Peter Csorba (ETH, Zürich)
  *Homotopy types of box complexes*
- Vin de Silva (Stanford)
  *Harmonic methods in computational topology*
- Herbert Edelsbrunner (Duke)
  *Elevation on a 2-manifold*
- Robin Forman (Rice)
  *A topological approach to the game of “20 Questions”*
- Robert Ghrist (Illinois)
  *Reconfiguration and the geometry of cube complexes*
- Eric Goubault (CEA Saclay)
  *Algorithms for computing fundamental categories, and applications to the static analysis of concurrent programs*
- Kathryn Hess (EPF, Lausanne)
  *Quillen model categories applied to concurrency theory*
- Rick Jardine (UWO)
  *Higher order automata, cubical sets, and some conjectures of Grothendieck*
Quantum Information and Quantum Control
July 19–23 2004
Held at the Fields Institute

Organizers: Paul Brumer, Daniel Lidar, Hoi-Kwong Lo and Aephraim Steinberg (Toronto)

The First International Conference on Quantum Information and Quantum Control brought together 150 students, postdocs, and senior researchers from around the world, for an intense five days of lectures, discussions, fine food (for those who were able to navigate to Baldwin Street) and socializing. Keynote lectures were given by Charles Bennett (IBM), Gilles Brassard (U. de Montréal), Stuart Rice (Chicago), Emanuel Knill (NIST, Boulder), and Marlan Scully (Texas A&M, Princeton) who delivered the first CQIQC Keynote Lecture. CQIQC is the newly founded Center for Quantum Information and Quantum Control at the University of Toronto, whose founding members were the conference organizers.

The conference brought together, for the first time, a distinguished cadre of researchers from the two communities of Quantum Information and Quantum Control, in an effort to establish a dialogue between the two. While many felt that there is still a language barrier, seeds were planted for future collaborations. The overall positive impressions that many of the conference participants expressed left the organizers enthusiastic about making this event a tradition to be repeated sometime in the near future.

The meeting was supported by the Fields Institute, MIT-ACS, the Centre for Quantum Information and Quantum Control, CIAR, and the Connaught fund.

Invited Speakers:
Robert Alicki (U. Gdansk)
Is quantum error correction feasible?

Thomas Baumert (Universitaet Kassel)
Quantum control in intense phase shaped laser fields

Charles Bennett (IBM)
Back communication and forward capacities of quantum channels

Gilles Brassard (Montréal)
A quarter of century of quantum cryptography

Paul Brumer (Toronto)
General Scientific Activities

Mark Eriksson (Wisconsin)
*Silicon/Silicon-Germanium for quantum computation*

Daniel Gottesman, Perimeter Institute
*High fidelity to low weight*

Manny Knill (NIST)
*Postselected quantum computation*

Ronnie Kosloff (Hebrew U. of Jerusalem)
*Quantum molecular computing: Optimal control theory for unitary transformations*

Gershon Kurizki (Weizmann Inst. Science)
*A unified approach to dynamical control of decoherence*

Christian Kurtsiefer (Munich)
*Tools for experimental quantum cryptography*

Daniel Lidar (Toronto)
*Hybrid quantum error prevention, reduction, and correction method*

Raymond Laflamme (Waterloo)
*Experimental quantum error correction*

Hoi-Kwong Lo (Toronto)
*Extending the distance of unconditionally secure quantum key distribution*

Philip H. Bucksbaum (Michigan)
*Control analysis based on learning feedback experiments*

Richard Cleve (Calgary)
*Consequences and limits of nonlocal strategies*

Claude Crepeau (McGill)
*Cryptography in a quantum world*

David DiVincenzo (IBM)
*Control and decoherence in Josephson junction qubits*

Mark Dykman (Michigan State)
*Localizing excitations in a quantum computer with perpetually coupled qubits*
Norbert Lütkenhaus (Erlangen)
*Quantum correlations in quantum cryptography*

Hideo Mabuchi (Caltech)

David Meyer (UCSD)
*Topological quantum codes*

Ari Mizel (Penn State)
*Teleportation in ground state quantum computation*

Herschel Rabitz (Princeton)
*The landscape for controlling quantum phenomena*

Stuart A. Rice (Chicago)
*Variations on adiabatic passage in optical control of molecular processes*

Vwani Roychowdhury (UCLA)

Marlan Scully (Texas A & M)

Peter Shor (MIT)

Aephraim M. Steinberg (Toronto)
*Shedding a bit of information on light: measurement and manipulation of quantum states*

**McMaster Optimization Conference: Theory and Applications (MOPTA 04)**
July 28–30, 2004
Held at McMaster University
- see Commercial Industrial Mathematics section for a description of the event

**The 4th University of Manitoba Statistics Research Workshop**
August 4–6, 2004
Held at the University of Manitoba
Organizers: Alexandre Leblanc, Lisa Lix, Saumen Mandal and Xikui Wang (Manitoba)

This was the first year that the University of Manitoba Statistics Research Workshop was jointly organized by representatives from both the Faculties of Science and Medicine. The goals of the workshop were to promote research collaboration between statisticians and health and social science researchers, and to highlight current developments in both theoretical and applied statistical research. More than 60 participants attended the 2-1/2 day event, which brought together faculty, students, and staff from a variety of departments, universities, and government research departments, in both Canada and USA. The meeting was sponsored by the Fields Institute and the University of Manitoba.

The workshop included presentations on both the theory and applications of statistics, probability, and stochastic processes. Emphasis was given to applications in: (1) health and social science research, and (2) economics, business and finance. These topics reflect areas of current research and expertise among members of the Department of Community Health Sciences and the Department of Statistics, respectively.

Applications in health and social sciences were the focus of the first day of the workshop. Topics that were addressed included recent developments in random effects models, analysis of longitudinal data, spatial regression analyses, statistical design and analysis of clinical trials, and statistical genetics. Theoretical statistics and applications of statistics in economics, business, and finance were highlighted on the second and third days of the workshop. Topics that were addressed included mathematical finance, bandit models, and GARCH models. Roundtable discussions were organized in the first two days, facilitated by experts in various research areas.

Formal evaluation forms were distributed and collected. Feedbacks on both the organization of the workshop and on the coverage of the topics were overwhelmingly positive. Participants appreciated the opportunity for interaction and exchange of research ideas, and the chance to engage in in-depth discussions on specific topics via a series of roundtable sessions. The organizers are planning another workshop in 2006.

**Speakers:**

T.M. Beasley (Alabama at Birmingham)
*Using genetic admixture to control for population stratification and residual confounding*

J.F. Brewster (Manitoba)
*Uncertainty and sensitivity analysis of a model for SARS transmission*

D. Chateau and O. Ekuma (Manitoba)
*Application of hierarchical models to administrative health data*
C. Green (Manitoba Health)
Spatial statistics for epidemiological research

D.K. Ghosh (Saurashtra U.)
Diallel crosses and incomplete block designs

A. Gumel (Manitoba)
To vaccinate or not to vaccinate: the case for imperfect vaccines

C.-L. Huynh (Manitoba)
A mixed model approach for fitting semiparametric regression models with longitudinal data

L.M. Lix (Manitoba)
Step-down tests for multivariate independent group designs

R. Ma (Canadian Research Institute for Social Policy & UNB)
Longitudinal, multi-level and spatial analyses of non-normal health outcomes

A. Melnikov (Alberta)
On valuation of life insurance contracts with equity-linked maturity guarantees

P. Pahwa (Saskatchewan)
Modeling the longitudinal changes in prevalence of respiratory symptoms among Canadian grain elevator workers

B.K. Sinha (Maryland)
On some aspects of Berkson’s bioassay problem

A. Thavaneswaran (Manitoba)
Inference for random coefficient GARCH models

L. Wang (Manitoba)
Estimation of nonlinear regression models with Berkson measurement errors

X. Wang (Manitoba)
The use of bandit processes in mathematical finance and economics

IMS New Researchers Conference
August 4–7, 2004
Held at York University

Organizers: Peter Song, Steven Wang, Xin Gao and Cindy Fu (York)

This year, the 7th North American IMS New Researchers Conference (NRC), invited 54 young researchers from US, Canada, Australia, France, Germany, Italy, and Iran for regular 15-minute talks and poster presentations. Of the 54 invited young researchers, there were 9 Canadian participants including 6 tenure-track assistant professors, 2 senior statisticians in health research organizations, and 1 postdoc. This was the largest Canadian participation in the NRC ever! Fields was one of the eight organizations supporting the event.

On August 4, Terry Speed (UC-Berkeley) gave the IMS President Address on How to Do Statistical Research. The Banquet Speech on August 5 was delivered by Jeff Wu (Georgia Tech) on Statistics and Statisticians: An Amateur’s Tour Guide. On August 6, Xihong Lin (Michigan) gave the Special Luncheon Speech on Exploring Roads to a Successful
Career: Some Remarks. On August 7, Dick DeVeaux (Williams College) addressed teaching statistics in an invited speech on *Math is Music; Statistics is Literature – or Why are there no 6 year old novelists?* In addition, two invited panel sessions featured candid remarks and advice from journal editors (*Annals of Statistics, Canadian Journal of Statistics, Technometrics* and *Biometrics*) for publishing, and grant directors/managers (NSF, NSERC, NIH, ONR) for grant applications.

One highlight of the 2004 NRC is the first time nomination of the Richard L. Tweedie New Researcher Award. The award recipient will receive a prize of up to $2000 and be invited to give a special lecture at the NRC. The IMS Committee on Special Lectures will decide the award winner.

In summary, the 2004 NRC was a great success, offering a comfortable setting for new researchers to share their research and make connections with their peers in informal settings such as short research presentations and various social programs.

**Special Addresses:**

Richard D. DeVeaux (Williams College)
*Math is music; statistics is literature – or why are there no 6 year old novelists?*

Xihong Lin (Michigan)
*Exploring roads to a successful career: some remarks*

Terry Speed (UC Berkeley)
*How to do statistical research*

Jeff C.F. Wu (Georgia Inst. of Tech)
*Statistics and statisticians: an amateur’s tour guide*

**Workshop on Missing Data Problems**

August 5–6, 2004

Held at the Fields Institute

Organizers: Richard J. Cook and Don L. McLeish (Waterloo)

Modern data often includes some form of censorship or missing data. Data imputation is a critical component of the analysis of such data and crude methods for data imputation can lead to substantial bias in the results and the conclusions. Missing data problems are common in health research (e.g. retrospective and prospective studies), sample surveys (e.g. non-response), and less obvious parts of any study in which the data available is influenced by what is easy or feasible to collect. Longitudinal studies which collect data on a set of subjects repeatedly over time are subject to attrition, subjects drop out because they move and suffer side effects from drugs, or for other often unknown reasons. Similarly in sampling, survey non-respondents are often ignored, although factors related to the objectives of the study such as income may influence the completeness of a subject’s response.

The primary goal of this workshop was to provide impetus to the development of mathematical and statistical tools for the analysis of data under various patterns of censorship and mechanisms governing missingness and data imputation. The workshop brought together researchers from around the world with common interests in missing data problems and a broad range of approaches for dealing with them. Approaches ranged from those based on multiple imputation, inverse probability weighted and more general classes of estimating functions, and EM or generalized EM algorithms. Issues receiving lively discussion included the importance of robustness, efficiency, identifiability, and the role of sensitivity analyses. The range of contexts in which missing data problems were considered included studies involving retrospective observation, prospective longitudinal studies, event history studies, survey sampling, finance, and social sciences. The meeting was supported by Fields, NPCDS, the University of Waterloo, and GlaxoSmithKline.
Speakers:
Shelley B. Bull and Juan Pablo Lewinger (Toronto)
Missing data in family-based genetic association studies

Nilanjan Chatterjee (N.I.H.)
Missing data problems in statistical genetics

Jinbo Chen (N.I.H.)
Semiparametric efficiency and optimal estimation for missing data problems, with application to auxiliary outcomes

Richard Cook (Waterloo) and Grace Y. Yi (Princess Margaret Hospital)
Weighted generalized estimating equations for incomplete clustered longitudinal data

Joe DiCesare (Waterloo)
Estimating diffusions with missing data

Grigoris Karakoulas (Toronto)
Mixture-of-experts classification under different missing label mechanisms

Jerry F. Lawless (Waterloo)
Some problems concerning missing data in survival and event history analysis

Alan Lee (Auckland)
Asymptotic efficiency bounds in semi-parametric regression models

Roderick Little (Michigan)
Robust likelihood-based analysis of multivariate data with missing values

Don L. McLeish and Cynthia A. Struthers (Waterloo)
Regression with missing covariates: importance sampling and imputation

Bin Nan (Michigan)
A new look at some efficiency results for semiparametric models with missing data

Anastesia Nwankwo (Enugu State)
Missing multivariate data in banking computations

James L. Reilly (Auckland)
Multiple imputation and complex survey data

James Robins (Harvard)
Application of a unified theory of parametric, semi and nonparametric statistics based on higher dimensional influence functions to coarsened at random missing data models

Andrea Rotnitzky (Harvard)
Doubly-robust estimation of the area under the operating characteristic curve in the presence of non-ignorable verification bias

Donald B. Rubin (Harvard)
Multiple imputation for item nonresponse: some current theory and application to anthrax vaccine experiments at CDC

Daniel Scharfstein (Johns Hopkins)
Sensitivity analysis for informatively interval-censored discrete time-to-event data

Tulay Koru-Sengul (Pittsburgh)
The time-varying autoregressive model with covariates for analyzing longitudinal data with missing values

Alastair Scott (Auckland)
Fitting family-specific models to retrospective family data

Jamie Stafford (Toronto)
ICE: Iterated Conditional Expectations

Mary E. Thompson (Waterloo)
Interval censoring of event times in the National Population Health Survey

Chris Wild (Auckland)
Some issues of efficiency and robustness

Grace Y. Yi (Princess Margaret Hospital)
Median regression models for longitudinal data with missing observations

Yang Zhao (Waterloo)
Maximum likelihood methods for regression problems with missing data
New Directions in Probability Theory
August 6–7, 2004
Held at the Fields Institute

Organizers: Maury Bramson (Minnesota), Jeremy Quastel and Jeffrey Rosenthal (Toronto); and Tom Salisbury (Fields)

The meeting was held at the Fields Institute in cooperation with the Institute for Mathematical Statistics. Recent advances in a number of areas of probability were presented. Random matrices and self-avoiding walks are two very hot areas of research and were both well represented by sessions and by special lectures by Kurt Johansson and Craig Tracy (random matrices) and Greg Lawler (self-avoiding walk). Horng-Tzer Yau also lectured on his recent important work on Brownian motion in quantum dynamics. The talks by Johansson and Yau were designated Medallion Lectures by the IMS. Other sessions were on random media, superprocesses, and Markov chains and algorithms. The five session organizers were Craig Tracy, Greg Lawler, Michael Cranston, Tom Salisbury and Robin Pemantle.

There were approximately 60 participants at the meeting. The general atmosphere was friendly and informal. A considerable amount of material was covered, but there was still sufficient time for discussion.

Special Lectures:
Kurt Johansson (Royal Inst. of Technology)
Measures from non-intersecting paths

Greg Lawler (Cornell)
Self-avoiding walk in two dimensions: detailed conjectures and few results

Craig Tracy (UC Davis)
Differential equations for Dyson processes

Horng-Tzer Yau (Stanford & Courant)
Brownian motion in quantum dynamics

Sixteenth Canadian Conference on Computational Geometry
August 9-11, 2004
Held at Concordia University

Organizers: Prosenjit Bose (Carleton) and Thomas Fevens (Concordia)

This conference attracted 113 attendees (58 from Canada, 36 from the United States, and 19 from outside of North America), and there were fifty papers presented, a selection of which will be published in special issues of the Interna-
The conference was especially intended to attract students, through a low or waived registration fee. Indeed, for the first time for CCCG, the number of students in attendance was greater than the number of faculty, to the delight of the organizers. The relaxed atmosphere of the conference allowed for easy interaction between attendees and discussion of current problems (culminating in the annual open problem session).

The Paul Erdős Memorial Lecture was given by Timothy Chan (Waterloo). This lecture is meant to be a presentation by a distinguished mathematician in the spirit of Paul Erdős, and typically concerns discrete geometry. The other two invited speakers were Piotr Indyk (MIT), and Marc van Kreveld (Utrecht).

A highlight of the conference was the banquet during which the 60th birthday of Godfried Toussaint was celebrated through anecdotal speeches and the unveiling of a webpage Festschrift with papers dedicated to him. As a bonus, those at the banquet were treated to the sounds of The Algorhythms, a band comprised of Computer Science professors from Montréal.

The conference was sponsored by the Fields Institute and Concordia University.

Invited Speakers:
Timothy Chan (Waterloo)
On k-sets and k-levels

Piotr Indyk (MIT)
Streaming algorithms for geometric problems

Marc van Kreveld (Utrecht)
On rectangular cartograms

Workshop on Kazhdan’s Property (T)
August 25–27, 2004
Held at the University of Ottawa

Organizers: Thierry Giordano (Ottawa), David Handelman (Ottawa), Matthias Neufang (Carleton) and Vladimir Pestov (Ottawa)

The property (T), introduced by Kazhdan in 1967, is an important tool in representation theory. One of several equivalent definitions in the locally compact case is this: a locally compact group \( G \) has property (T) if every continuous action of \( G \) by isometries on a Hilbert space has a fixed point. Kazhdan has shown that real and \( p \)-adic simple groups of rank \( \geq 2 \), as well as their lattices, have property (T), for example, \( SL_n(\mathbb{R}) \), \( SL_n(\mathbb{Z}) \), \( n \geq 3 \).

Since then, the importance of property (T) has increased and numerous applications of this property have been found: from explicit construction of expander graphs through the uniqueness of invariant means to the structure of operator algebras. In recent years, new characterizations and applications of the property (T) have been discovered, linked to ergodic theory, cohomology and graphs.

The aim of the workshop is to let participants learn about Kazhdan’s property (T), as well as the most recent related developments and applications, directly from the world-class specialists in the area. (Claire Anantharaman-Delaroche has presented the property (T) at the Bourbaki seminar, Bachir Bekka, Pierre de la Harpe and Alain Valette have written a monograph on the property and have organized a workshop in Oberwolfach on the geometrization of
the property \((T)\) in 2001.)

The workshop was attended by 33 registered participants, including 18 graduate students and postdocs, and was supported by the Fields Institute and the University of Ottawa.

Bachir Bekka introduced Property \((T)\) in his first lecture and gave applications of it in his second lecture. In the third, he presented some new developments of the theory.

Alain Valette’s three lectures centered on the relations between Property \((T)\) and affine actions. In particular, in his first lecture he showed that Property \((T)\) is equivalent to the fixed point property for affine actions (Delorme-Guichardet theorem). In his second lecture, he gave Shalom’s characterization of property \((T)\) and in the third he linked finite presentability and property \((T)\).

Claire Anantharaman presented the links between von Neumann algebras and Property \((T)\). In her first lecture, she presented the basic definitions of type \(\text{II}_1\)-factors and gave examples constructed from discrete groups and discrete measured equivalence relations. In her second lecture, she introduced Property \((T)\) for type \(\text{II}_1\) factors and showed in particular that the fundamental group of such a factor is countable. In her third talk, Claire introduced Relative property \((T)\), Haagerup approximation property \((H)\) and the notion of \((HT)\) Cartan subalgebra. Using these notions, she then presented the recent developments of the theory of type \(\text{II}_1\) von Neumann factors.

At the first short communications session on August 25, Talia Fernos gave a talk: New examples of group pairs with Kazhdan’s Relative Property \((T)\). The result she presented is very interesting due to the scarcity of examples of group pairs with Kazhdan’s Relative Property \((T)\).

During the second short communications session on August 26, Stefaan Vaes presented a new proof of Nicoara, Popa, and Sasykk of Osawa’s result on the non-existence of a universal \(\text{II}_1\) factor: a \((\text{separable})\) \(\text{II}_1\) factor that contains any \((\text{separable})\) \(\text{II}_1\) factor as a subfactor.

In the last session of the workshop, the main speakers presented a list of very interesting open problems.

Overall, the workshop was a remarkably coherent event. The main speakers did a marvelous job not only in the quality of their lectures but also in the coordination of the materials they presented. Its impact on the directions of research pursued by younger attendees should be considerable.

**Speakers:**
- Bachir Bekka (Metz)
  - Introduction to Property \((T)\)
  - Applications of Property \((T)\)
  - Some new developments
- Claire Anantharaman-Delaroche (Orléans)
  - Type \(\text{II}_1\) factors in relation with group and ergodic theory
  - Property \((T)\) for type \(\text{II}_1\) factors
  - \((HT)\) type \(\text{II}_1\) factors
- Talia Fernos (UIC)
  - New examples of group pairs with Kazhdan’s Relative Property \((T)\)
- Stefaan Vaes (CNRS, Paris)
  - There is no universal \(\text{II}_1\) factor
- Alain Valette (Neuchâtel)
  - Property \((T)\) and affine actions I, II, and III

**Mini-symposium on Influenza: Models and Data**
September 8, 2004
Held at the Fields Institute
Organizer: David Earn (McMaster)
Picture: Influenza_Earn.jpeg
Caption: David Earn

On the afternoon of September 8, 2004, the Fields Institute hosted a mini-symposium on Influenza: Models and Data. An audience of about 40 participants heard presentations from five applied mathematicians and mathematical biologists who have been working together in an effort to make progress on understanding the epidemiology of influenza.
The speakers were Chris Bauch (Guelph), Jonathan Dushoff (Princeton), David Earn (McMaster), Junling Ma (McMaster) and Joshua Plotkin (Harvard). A very broad spectrum of scientists attended the meeting – mathematicians, zoologists, microbiologists, anthropologists, infectious disease epidemiologists and physicians.

Influenza represents an extremely important worldwide public health problem, with tens of thousands of deaths attributed every year to influenza in North America alone. The disease also presents an unusually challenging problem for mathematicians and statisticians who are trying to use mathematical and statistical models to help develop improved control strategies. The major difficulty in model development is that influenza evolves rapidly to evade our immune response – this is why the flu vaccine must be updated frequently. A person's susceptibility to a new influenza strain depends on his/her history of flu infections and vaccinations. Capturing this essential biological complexity in a tractable mathematical model has yet to be achieved.

The speakers reviewed the types of influenza data that are available, and discussed progress that has been made both in data analysis and in building mathematical and computational models that help to elucidate the underlying biological mechanisms that give rise to the observed pattern of influenza incidence and mortality. The mini-symposium was followed at McMaster University by a week of focused research-in-teams, also funded in part by the Fields Institute.

A second Fields Institute mini-symposium on influenza is planned for the 2005–2006 academic year.

**Speakers:**
- Chris Bauch (Guelph)  
  Detecting antigenic shifts in mortality data
- Jonathan Dushoff (Princeton)  
  The mortality burden of influenza
- David Earn (McMaster)  
  Overview of influenza data and recent modelling
- Junling Ma (McMaster)  
  Individual-based modelling of influenza
- Joshua Plotkin (Harvard)  
  Estimating selection pressures on influenza proteins

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**Noncommutative Geometry, the Local Index Formula and Hopf Algebras**

September 24 & 25, 2004
Held at the Fields Institute

Organizers: Nigel Higson (Penn State), Masoud Khalkhali (UWO) and Boris Tsygan (Northwestern)

From its inception in the classical papers of Alain Connes in early 1980s, the subject of Noncommutative Geometry has had close connections with the index theory of elliptic operators. The local index formula of Connes and Moscovici is a very powerful general theorem that goes far beyond the classical realm of the Atiyah-Singer index theorem for elliptic differential operators on smooth manifolds. To understand the Connes-Moscovici result, one must first absorb several key ideas of noncommutative geometry: that noncommutative spaces are represented by noncommutative algebras (of various types); topological invariants for spaces can be extended, via cyclic cohomology and K-theory, to invariants for noncommutative spaces; and that an elliptic differential operator finds its noncommutative analogue in Connes' notion of “spectral triples”.

Broadly speaking, a spectral triple $(A,H,D)$ consists of a Hilbert space $H$, an algebra $A$ acting by bounded operators on $H$, and a self-adjoint operator $D$ on $H$. This data must satisfy certain regularity properties similar to basic elliptic estimates for elliptic PDEs acting on sections of vector bundles on compact manifolds. The local index formula replaces the old non-local Chern-Connes cocycle by a new Chern character $Ch(A,H,D)$ in the cyclic complex of the algebra $A$. It is a local formula in the sense that the cochain $Ch(A,H,D)$ depends, in the classical case, only on the germ of the heat kernel of $D$ along the diagonal and in particular is independent of smooth perturbations. This makes the formula extremely attractive for practical calculations.
This conference brought together mathematicians from Canada, the United States and Europe who are working in various areas of noncommutative geometry and have a keen interest in applications of the local index formula. Survey talks by Higson (on the local index formula), Khalkhali (on renormalization in quantum field theory and the motivic Galois group) and Tsygan (on BV algebras in noncommutative geometry, topology and quantum field theory) gave a panoramic view of the subject and its possible future directions. An exciting and very recent development is the emerging relation between the local index formula and mathematical ideas of renormalization in quantum field theory (the work of Connes-Marcolli and Connes-Kreimer). Several lectures (by Phillips, Sitarz, and Hu) were devoted to applications of the local index formula. A total of 11 one hour talks were presented during this two day event.

Conferences like this are very helpful for graduate students, postdoctoral fellows and young mathematicians who want to enter into noncommutative geometry as an active field of research. The conference also gave an excellent opportunity to some of the best researchers in the field to exchange their most recent ideas.

Speakers:
Alexander Gorokhovsky (Colorado)
*Bivariant Chern character and Connes' index theorem*

Nigel Higson (Penn State)
*Introduction to the Connes-Moscovici form*

X. Hu (Toronto)
*Local index theorem for transversally elliptic operators*

Jerry Kaminker (IUPUI)
*Duality in noncommutative geometry*

Masoud Khalkhali (UWO)
*Renormalization and motivic Galois theory (after Connes and Marcolli)*

Eckhart Meinrenken (Toronto)
*Chern-Weil homomorphism for non-commutative differential algebras*

John Phillips (Victoria)
*From special flow to the odd local index formula*

Raphael Ponge (Ohio State)
*Noncommutative geometry, Heisenberg calculus and CR geometry*

Bahram Rangipour (Victoria)
*Hopf cyclic cohomology and Connes Moscovici characteristic map*

Andrzej Sitarz (Wroclaw)
*Local index formula: going beyond spectral triples*

Boris Tsygan (Northwestern)
*BV operators in noncommutative geometry*

**21st Canadian Econometrics Study Group Conference (CESG) – Financial Econometrics**

September 24–26, 2004
Held at York University

Scientific Committee: Sule Alan (York), Christian Gourieroux (Toronto), Joann Jasiak (York), Lynda Khalaf (Montréal), Angelo Melino (Toronto), Paul Rilstone (York), Andrei Semenov (York), and Thanasis Stengos (Guelph)

This conference focused on methodological developments and innovative empirical work in financial econometrics. It brought together Canadian econometricians, and interested statisticians and researchers from the United States. The format of the conference included 7 sessions, in which fourteen papers were presented and discussed, and a poster session for another nine papers.

Very stimulating talks were given by the invited speakers, Yacine Ait-Sahalia (Princeton), Adrian Pagan (Australian National), and Don Andrews (Yale).

The conference was very successful in documenting the current state of scientific advancement in Canadian econometrics.

*Econometrics banquet*
research in financial econometrics. The meeting also offered a forum for discussion and exchange of ideas.

The event was attended by many graduate students and young researchers who accounted for 45% of 87 registered participants. The contribution of the Fields Institute to the travel and accommodation expenses of this group of participants was vital, and was highly appreciated by the organizers and participants.

The organizers gratefully acknowledge financial support provided by: SSHRC, Journal of Applied Econometrics, chair Hydro-Quebec, CIRANO, The Fields Institute, and Institute for Social Research at York University.

**Invited Speakers:**
Don Andrews (Yale)
*Optimal invariant similar tests for instrumental variables regression*

Adrian Pagan (Australian National)
*Some econometric analysis of constructed binary time series*

Yacine Ait-Sahalia (Princeton)
*How often to sample a continuous-time process in the presence of market microstructure noise*

The conference opened with a talk by Robert Kottwitz, describing Arthur’s extensive contributions, including his work on the trace formula.

The trace formula is a powerful tool and one of the main techniques in attacking the Functoriality Conjecture and related problems in the Langlands program, started by Langlands’ visionary ideas in the late 1960’s. The trace formula has led to a number of conjectures relating different aspects of automorphic forms, number theory, analysis and geometry. James Arthur almost single handedly developed this very complicated machinery since the beginning of his career in the early 1970’s, and his contribution to the modern theory of automorphic forms may be considered as one of the most important. Recent years have seen exciting and real progress on different aspects of the Langlands program, including new results such as those of Lafforgue and Harris-Taylor in which the use of the trace formula has played important roles. As well there has been progress towards establishing the so called “Fundamental Lemma”, the major stumbling block in the use of trace formula, which when resolved, even in certain special but important cases, should lead to some spectacular results in the theory of automorphic forms by means of Arthur’s fundamental work on the trace formula.
Many speakers reported on recent progress made on the Langlands Program. Several speakers emphasized the trace formula approach, discussing topics such as stabilization of the twisted trace formula and norm maps, explicit trace identities, and analytic applications of trace formulas.

Robert Langlands’ talk on trace formulas and number theory drew a large audience, including many Toronto-area researchers and graduate students. Functoriality was a theme of some talks, namely functoriality for unitary groups, functoriality related to Arthur’s conjectures describing representations of real and $p$-adic groups that occur in spaces of automorphic forms, and relations between functoriality and the Ramanujan and Selberg conjectures. The subject of endoscopy came up in talks on endoscopic decompositions of local $L$-packets associated to certain depth zero supercuspidal representations, and also on character identities related to twisted endoscopy.

Bao Chau Ngo and Gérard Laumon discussed their joint work on the proof of the fundamental lemma for unitary groups over local fields of positive characteristic. Talks on Shimura varieties focused on recent progress on local models of such varieties, and questions concerning Shimura varieties and parahoric Hecke algebras.

Other topics discussed included simplification of reduction theory and Arthur’s truncation operator using buildings; questions of stability related to properties of characters of depth zero supercuspidal representations of reductive $p$-adic groups, and the problem of determining which Langlands parameters correspond to unitary representations.

After the end of the first day’s talks, the conference participants attended a reception at Hart House, sponsored by the University of Toronto Mathematics Department. The conference reception was held at the Faculty Club on the evening of the third day of the conference, immediately before the banquet, which was also held there. Everyone at the banquet enjoyed Steve Gelbart’s display of slides of photos featuring Jim and his wife Penny, dating back to the 1970’s. Several people took the opportunity to make some comments, perhaps recalling the circumstances of their first meeting with Jim, or telling a story involving Jim.

Funding was provided by the Clay Mathematics Institute, the Fields Institute, the MSRI-network conference fund, the U.S. National Science Foundation, and the Mathematics Department, the Faculty of Arts and Science, and the Connaught Committee at the University of Toronto.

**Speakers:**
Joseph Bernstein (Tel Aviv)
Subconvexity estimates and representation theory

William Casselman (UBC)
Truncation and buildings

Laurent Clozel (Paris South)
Arthur’s conjectures, restriction principle, and mysterious functorialities

Stephen DeBacker (Michigan)
Murnaghan-Kirillov theory for depth zero supercuspidal representations

Thomas Haines (Maryland)
Shimura varieties with parahoric level structure

David Kazhdan (The Hebrew University)
On endoscopic decomposition of certain weight zero representations

Henry Kim (Toronto)
Functoriality for unitary groups

Robert Kottwitz (Chicago)
Arthur’s work on the trace formula

Jean-Pierre Labesse (Paris 7)
Norm map for twisted endoscopy

Robert Langlands (IAS)
The trace formula and the theory of numbers

Erez Lapid (The Hebrew University)
Explicit trace identities

Gerard Laumon (Paris, Orsay)
The fundamental lemma for unitary groups (I)

Werner Muller (Bonn)
The trace formula and spectral theory of automorphic forms

Bao Chau Ngo (Paris 13)
The fundamental lemma for unitary groups (II)

Michael Rapoport (Bonn)
Local models of Shimura varieties
Peter Sarnak (Princeton)  
*Some analytic applications of the trace and related formulae*

Freydoon Shahidi (Purdue)  
*Infinite dimensional groups and automorphic L-functions*

David Vogan (M.I.T.)  
*Arthur packets and unitary representations*

Jean-Loup Waldspurger (Paris 7)  
*Identités de caractères entre représentations de SO(2n+1) et de GL(2n) tordé*

**Weekend Workshops on Arithmetic and Geometry of Algebraic Varieties with Special Emphasis on Calabi-Yau Varieties and Mirror Symmetry Workshops**  
October 23–24, 2004  
March 5–6, 2005  
Held at the Fields Institute  
Organizers: James Lewis (Alberta) and Noriko Yui (Queen’s)

The series of weekend workshops is now in its third year. This year, the workshops were coordinated with the Fields 2004-05 thematic program on “Geometry of String Theory”.

The speakers at the two workshops were James D. Lewis (Alberta), Shabham Kadir (Fields), Kenji Ueno (Kyoto), Kai Behrend (UBC), Andreas Rosenschon (Buffalo), Romyar Sharifi (McMaster), Manfred Herbst (Fields), Barbara Fantechi (ICTP), Victor Batyrev (Tübingen), Paul Horja (Fields), Roya Beheshti (Queen’s), Edward Lee (Harvard), Yuri Zarhin (Penn State), Ling Long (Iowa State), Ruxandra Moraru (Fields), and Klaus Hulek (Hannover).

The subjects covered ranged widely from arithmetic to geometry to physics with the common theme of Calabi–Yau varieties and mirror symmetry. For instance, talks included the topics of algebraic cycles, K-theory, conformal field theory, stable map spaces, quantum cohomology, orbifolds, A-infinity algebras in open string theory, class groups, toric mirror symmetry, modularity of Calabi–Yau varieties, Picard–Fuchs equations, monodromy, moduli spaces, and lines on hypersurfaces.

These weekend workshops are increasingly widely known. Besides regular local Canadian participants, there are now a number of participants from the United States.

The workshops were a huge success. Postdoctoral fellows and graduate students were especially encouraged to take part in the activities, as there is now a small fund to support their participation. The participants as well as several colleagues who could not be present at this year’s workshops have already asked for schedules for the workshops in the coming year—the first in the academic year 2005-06 will take place in October.

**Symposium on Mathematical and Statistical Methods in the Life Sciences**  
November 12, 2004  
Held at the University of Guelph  
Organizers: Hermann Josef Eberl and Anna T. Lawniczak (Guelph)

This very successful symposium attracted more than 60 participants, among them students and researchers from universities, government institutions and industry. The overall objective of the symposium was to provide a meeting and networking forum for researchers who develop and apply mathematical, statistical, and computational techniques for the life sciences, covering the spectrum from the mathematical sciences to the areas of application. Thus the lectures ranged from dynamical system theory to applied statistical methods, and from modern numerical analysis to data mining, connected by the shared interest of the participants in application areas in biology, medicine and bioprocess engineering.

The symposium consisted of invited lectures including *The Gordon Ashton Lecture* in Biometry given by Dr. Abdel H. El-Shaawari (National Water Research Institute, Burlington, Ont.), editor-in-chief of Environmetrics and founder of...
and former president of the International Environmetrics Society. The other invited lectures were given by Richard Cook (Waterloo), Ross Cressman (Wilfrid Laurier), Gerarda Darlington (Guelph), David Earn (McMaster), Igor Jurisica (Ontario Cancer Institute), Lindi Wahl (UWO) and Jianhong Wu (York). All the lectures were of very high quality and generated many discussions.

To promote and to facilitate networking among researchers, an extended poster session was held during the symposium. All participants – in particular students – were encouraged to present their research during this poster session. The posters addressed important interdisciplinary questions related to food safety, urban development and nest site locations, prediction of pregnancy, and biofilms. The winner of the Best Graduate Poster Competition was Judith Toms of the Department of Statistics and Actuarial Sciences at the University of Waterloo, for her poster “Modeling the Factors Influencing Choice of Nest Site Location in Wood Thrush”, jointly done with Lyle Friesen (Canadian Wildlife Service), Virgil Martin (City of Waterloo) and Jock MacKay (University of Waterloo). The selection committee consisted of Dr. Daniel Kobler of TM Bioscience, Toronto, and Roderick Melnik, Canada Research Chair in Mathematical Modeling at Wilfrid Laurier University. The Committee based its decision on the two major criteria of novelty of the problem and the advancement of knowledge in the context of the life sciences, and close interactions between mathematical/statistical sciences and the life sciences, including realistic experimental data.

The event was co-sponsored by the Fields Institute, and the Department of Mathematics and Statistics, the Office of Research and the Faculty of Environmental Science of the University of Guelph, and SHARCNET (The Shared Hierarchical Academic Research Computing Network).

**Invited Speakers:**

Richard Cook (Waterloo)

*Assessing association with clustered and truncated disease onset data*

Ross Cressman (Wilfrid Laurier)

*Co-evolution, adaptive dynamics and the replicator equation for a continuous trait space*

Gerarda Darlington (Guelph)

*Analysis of pretest-posttest data in cluster randomization trials*

David Earn (McMaster)

*The capacity of modern cities to resist infectious disease invasions*

A.H. El-Shaarawi (National Water Research Inst. & McMaster)

*Modelling and analyzing spatial-temporal environmental data*

Igor Jurisica (Ontario Cancer Inst.)

*Avoiding fusion of illusion and confusion integrated computational biology*

Lindi Wahl (UWO)

*Information theory reveals functional domains in proteins*

Jianhong Wu (York)

*Modelling spatio-temporal patterns in biological invasion and diseases spread*

**Resolutions, Inverse Systems, and Co-invariants**

January 13–15, 2005
Held at the University of Ottawa

Organizers: Riccardo Biagioli (UQAM), Sara Faridi (Ottawa), and Mercedes Rosas (York)

The purpose of this meeting was to bring together researchers from two different mathematical communities, namely commutative algebraists and algebraic combinatorialists. It was a continuation of the successful meeting that took place a year before at Queen’s University. That meeting highlighted several connections between similar techniques used by algebraic combinatorialists and commutative algebraists to study different problems. The Queen’s meeting led to collaborations among several of the participants on...
new research topics, applying techniques from algebraic combinatorics to examine conjectures in commutative algebra and vice-versa.

These new results were reported at this year’s workshop in Ottawa, and new topics were introduced. The main speakers generally spent the morning or a large part of the afternoon introducing a topic and talking about the main results of the field and the direction of current research. On the side of algebraic combinatorics, these included talks by François Bergeron (UQAM) on particular representations of symmetric groups, by James Haglund (Penn) about Macdonald polynomials, and by Nantel Bergeron (York) about open problems in algebraic combinatorics that grew out of topics discussed during the workshop.

From the commutative algebra side, Tony Geramita (Queen’s) explained where inverse systems appear in algebraic geometry and what kinds of problems they solve, and Tony Iarrobino (Northeastern) talked about more general questions regarding inverse systems and level algebras.

Each day ended with shorter talks by young researchers who presented specific research related to topics of the workshop.

The workshop was attended by 25 participants including 10 graduate students and postdocs. The younger participants commented afterwards how much they had enjoyed the workshop, and how they had benefited from the talks. The friendly and familiar atmosphere of the meeting contributed greatly to this feeling. The participants look forward to reconvening in a year.

Invited Speakers:
François Bergeron (UQAM)
Nantel Bergeron (York)
Tony Geramita (Queen’s)
James Haglund (Pennsylvania)
Anthony A. Iarrobino (Northeastern)

Young Mathematicians’ Conference on Partial Differential Equations and Dynamical Systems
January 29, 2005
Held at McMaster University

Organizers: Walter Craig (McMaster), Adrian Nachman (Toronto), Mary Pugh (Toronto), Dmitry Pelinovsky (McMaster), and Catherine Sulem (Toronto)

The second annual edition of this conference attracted about 40 participants from all over Canada.

The objective of this meeting was to encourage scientific exchange, and to create an opportunity for young mathematicians in an early stage of their career to get to know each other and each other’s work. The program consisted of two senior ‘plenary’ speakers, Pengfei Guan of McGill and Catherine Sulem of the University of Toronto, and 8 speakers chosen from the group of young invited participants. In addition to the speakers, numerous young mathematicians from around the country whose mathematical interests are in PDE and dynamical systems were invited to attend, with support for their participation from the conference (often shared with support from their doctoral or postdoctoral advisor). The informal rule has been that, except for the two ‘plenary’ speakers, all other talks are to be given by people within a few years (either way) of their PhD. Young people have been invited from all over Canada for the event, as well as a few who did their PhD in Canada and are presently post-doctoral fellows in the US. We feel that this is a good way to help to develop and to maintain a feeling of community in the discipline.

The topics presented during the lectures included geometric PDE, studies of nonlinear wave equations, inverse problems, mathematical aspects of kinetic theory, elliptic variational problems, mathematical modelling and statistical mechanics.

Funding was provided by the organizers NSERC Leadership Support Initiative Grant, the Fields Institute, the Department of Mathematics and Statistics at McMaster University, and the CRC Program.

Speakers:
P. Blue (Toronto)
Decay estimates and phase space analysis on some black hole manifolds

A. Comanici (Houston)
Transition from rotating waves to modulated rotating waves on a sphere

Pengfei Guan (McGill)
Convexity problems in nonlinear geometric equations

M. Merkli (McGill)
Non equilibrium stationary states and transport phenomena
S. Mitchell (UBC)
*An asymptotic framework for finite hydraulic fractures driven by multiple physical processes*

A. Montero (McMaster)
*On the regularity problem for the nonlinear Boltzmann equation in one space dimension*

V. Panferov (McMaster)
*On the weak solutions of the degenerate Monge-Ampere equation*

Mohammad Reza Pakzad (PIMS)
*On the weak solutions of the degenerate Monge Ampere equation*

Catherine Sulem (Toronto)
*Nonlinear Schrödinger equations and related systems*

A. Tamasan (Toronto)
*Inverse boundary value problems for the transport equation and applications*

**Text Mining Tools for Bioinformaticians and Biologists**

February 4, 2005
Held at the Fields Institute

This workshop was organized by the Ontario Centre for Genomic Computing, at the Hospital for Sick Children, and hosted by the Fields Institute.

Many of the relationships between biological entities are captured in scientific text articles where they are difficult to access and compute on. Biologists have an increasing need to review the results of their experiments in the light of this current knowledge. Experimental data sets are quite often very large as are the literature data sets that may hold information relevant to them. The process of placing experimental results into context requires the help of text-mining tools if the task is to be accomplished efficiently and accurately. The goal of this workshop was to bring together bioinformaticists and text-mining experts from Ontario and abroad to discuss the challenges and solutions related to these issues.

**Speakers:**
Christian Blaschke (ALMA Bioinformatics, Madrid)
*BioCreAtIvE: critical assessment of information extraction for biology*

Ian Donaldson (Samuel Lunenfeld Research Inst.)
*SeqHound and PreBind: tools for text-mining and consolidating results for multiple text-mining efforts*

Carolina Perez-Iratxeta and Miguel A. Andrade (Ottawa Health Research Inst.)
*Two text mining applications to select and explore MEDLINE references*

Joel Martin (National Research Council Inst. for Information Tech.)
*Rapid text mining across millions of abstracts*

Alexander Morgan (MITRE Corporation, Bedford MA)
*Linking text mentions to biological identifiers*

Hagit Shatkay (Queens University)
*Hairpins in bookstacks: information retrieval for biomedical informatics*

**Workshop on the Geometry of Very Large Data Sets**

February 23–25, 2005
Held at the University of Ottawa

Organizers: André Dabrowski, Paul-Eugène Parent, and Vladimir Pestov (Ottawa)

A workshop goal was to bring together researchers and students from areas of statistics, topology and computer science to explore and identify areas of potential research on the geometric structure of very large dimensional data sets. The essential elements of topology and stochastics were covered the first day by Paul-Eugène Parent, Barry Jessup and André Dabrowski, all of Ottawa. Peter Bubenik (Lausanne) presented slides of Gunnar Carlsson (Stanford), who was unable to attend, on *Persistent homology*. Two talks by Alexander Gorban (Leicester) on *How to discover a geometry and topology in a finite dataset by means of elastic nets* engendered numerous side discussions on the computational and conceptual tools involved. Peter Kim (Guelph) spoke on *Nonparametrics in high dimensions* with a particular emphasis on applications to cometary orbits and the statistical inverse problem on a Riemannian manifold. Additional presentations by Peter Bubenik (Lausanne), Maia Lesosky (Guelph) and Ulrich Fahrenberg (Aalborg) completed the scientific program.

Despite a short time frame, twenty-five participants in all enjoyed the workshop. This included senior faculty from...
Canada, postdoctoral fellows from Canada, Switzerland and Sweden, PhD and MSc students from Quebec, Nova Scotia and Ontario, and some undergraduate students from Ottawa and Nova Scotia. Participants were drawn from mathematics, statistics, management, and government. The workshop provided ample time for interaction, and each session was accompanied by numerous – sometimes heated – discussions on approaches and methods for particular problems. In particular, the entire group participated in contributing ideas towards a potential research program in this area. The organizers will be pursuing this line of research and will collect the comments of workshop participants and present progress a webpage. Researchers interested in joining this group are asked to contact the organizers.

Speakers:
Peter Bubenik (Lausanne) for Gunnar Carlsson (Stanford)
Persistant homology and directional statistics

André Dabrowski (Ottawa)
Aspects of statistics

Ulrich Fahrenberg (Aalborg)
Parallel composition of automata

Alexander Gorban (Leicester)
How to discover a geometry and topology in a finite dataset by means of elastic nets

Peter Kim (Guelph)
Nonparametrics in high dimensions

Maia Lesosky (Guelph)
Introduction to quantum computing

Paul-Eugène Parent and Barry Jessup (Ottawa)
Elements of topology

Workshop on Computational Biology in the Post Genomics Era – a collaborative workshop between universities, NRC and industry
March 19–20, 2005
Held at CRM in Montreal
- see the Joint Institutes Initiatives section for a description of this event

Carleton Functional Analysis Day 2005
April 12, 2005
Held at Carleton University
Organizers: C.K. Fong, Wojciech Jaworski and Matthias Neufang (Carleton)
This successful meeting, sponsored by the Fields Institute brought together world-class specialists in various areas of modern analysis where quantum methods play a crucial role. It consisted of four hour-long lectures that surveyed and described recent developments in non-commutative geometry, operator spaces and quantum field theory.

The event attracted many young Canadian researchers representing diverse areas of mathematics, including graduate students and postdoctoral fellows. The talks produced lively discussions and research collaboration among the participants.

Speakers:
David Blecher (Houston)
On the necessity of operator space methods

Masoud Khalkhali (UWO)
Locally compact quantum groups, non-commutative geometry, and cyclic cohomology

Zhong-Jin Ruan (Urbana-Champaign)
Operator spaces and their applications to harmonic analysis

Israel Michael Sigal (Toronto)
Spectral and dynamical problems arising in quantum field theory

Ontario Combinatorics Workshop
April 15–16, 2005
Held at the Fields Institute
Organizers: Chris Godsil and Bruce Richter (Waterloo)
This workshop brought together graduate students studying Combinatorics from (southern) Ontario so that they could get an idea of the scope and depth of their subject. In addition, it provided students with an opportunity to meet faculty from other institutions at which they might wish to pursue their studies or careers. It was also a useful opportunity for the faculty to maintain contact with each other.

The conference included twelve 25-minute student pre-
sentations and three invited talks from Robin Thomas (Georgia Institute of Technology), Claude Tardif (Royal Military College) and Jim Geelen (Waterloo).

Since 2003, the Peter Rodney Memorial Book Prize has been awarded to the best student presentation. This year’s winner was Lap Chi (Toronto) for his talk “Packing Steiner Trees and Forests”.

There were approximately 40 participants at the workshop.

Speakers:
Karel Casteels (Waterloo)  
Universal cycles

Lap Chi (Toronto)  
Packing Steiner trees and forests

Harold Connamacher (Toronto)  
Algorithmic behavior of DPLL on random XOR-SAT and a NP complete generalization of XOR-SAT

Babak Farzad (Toronto)  
Planar graphs and the discharging method

Jim Geelen (Waterloo)  
Universal cycles

Hamad Hatami (Toronto)  
Fourier analysis and large independent sets in powers of complete graphs

Danny Heap (Toronto)  
Improved sampling of Steiner triple systems

Graeme Kemkes (Waterloo)  
Long cycles in supercritical random graphs

Andrew King (McGill)  
An upper bound on the chromatic number of line graphs

Richard Krueger (Toronto)  
The graph search hierarchy: a characterizing view of vertex orderings

Karen Meagher (Ottawa)  
Eigenvalues of the uniform qualitative independence graphs

Shengjun Pan (Waterloo)  
Rectilinear crossing number

Aidan Roy (Waterloo)  
Complex lines with restricted angles

Claude Tardif (Royal Military College)  
Hedetniemi’s conjecture

Robin Thomas (Georgia Inst. of Tech.)  
Matching

MITACS/Fields Aeronautics Workshop
April 28-29, 2005
Held at the Fields Institute  
- see the Commercial/Industrial Mathematics section for a description of this event

The 2005 Great Lakes Geometry Conference
April 30–May 1, 2005
Held at Perimeter Institute

Organizers: Hans U. Boden (McMaster), Finnur Lárusson (UWO), B. Doug Park (UWO) and Mainak Poddar (Waterloo)

Scientific Committee: Ronald Fintushel (Michigan State), Robert Myers (Perimeter), and Yongbin Ruan (Wisconsin)

The Great Lakes Geometry Conference (GLGC) began in 1999 at the University of Wisconsin under the leadership of Yongbin Ruan. Since then, the conference has met at several major universities in the Great Lakes region, including Northwestern, Notre Dame, Michigan, and Michigan State. This year, the conference came to Canada for the first time and was hosted at Perimeter Institute for Theoretical Physics in Waterloo, Ontario.
The seventh annual GLGC, which was co-sponsored by Fields and Perimeter Institutes, and the University of Waterloo, included nearly 60 participants, mostly mathematicians but also a few physicists. Ronald Fintushel delivered a welcoming speech, and what followed were nine excellent talks that detailed progress on a number of important problems in geometry and topology.

Research in geometry is fueled in great part by physics, and this was evident in the talks. For example, Gukov’s talk used an analogy with string theory to motivate an ongoing search for an overarching triply-graded homology of knots that will unify different knot homologies in much the same way that M-theory unified the different string theories in physics. Another example of the pervasive influence of physics in geometry was Stipsicz’s talk, which outlined the construction of exotic smooth structures on the five-time blow-up of complex projective plane and the application of Seiberg-Witten gauge theory in proving exoticness.

Other topics included conformal compactification and general relativity, contact homology and cusped flow trees, Gromov-Witten and Donaldson-Thomas invariants, Hamiltonian dynamics and Floer homology, loop groups and models for equivariant K-theory and cohomology, Ricci curvature for metric measure spaces, and Toeplitz operators and quantization.

On Saturday evening, conference participants were treated to a banquet dinner in the Black Hole Bistro followed by a delightful classical music concert performed by the Perimeter Ensemble and hosted by the inimitable Tom Allen (CBC Radio). On Sunday afternoon, conference participants were given a guided tour of the Perimeter Institute. Thanks to the diligence of Perimeter’s IT staffs, a DVD of the talks can be ordered from the organizers.

 Speakers:

- Michael Anderson (New York at Stony Brook)
  *Conformal compactification in Riemannian geometry and general relativity*

- Kai Behrend (UBC)
  *Towards an understanding of Donaldson-Thomas invariants in terms of Euler characteristics*

- John Etnyre (Pennsylvania)
  *Cusped flow trees and contact homology*

- Tatyana Foth (UWO)
  *Toeplitz operators, automorphic forms, and quantization*

- Sergei Gukov (Clay Math)
  *The superpolynomial for knot homologies*

- Francois Lalonde (Montreal)
  *Hamiltonian dynamics and a universal Floer homology*

- John Lott (Michigan)
  *Ricci curvature for metric-measure spaces*

- Eckhard Meinrenken (Toronto)
  *Small models and twisted differentials*

- Andras Stipsicz (Alfred Renyi Inst. of Math)
  *Exotic smooth structures on rational surfaces*

**Workshop on Numerical and Analytic Methods in Fluid Dynamics**

May 5–7, 2005
Held at Carleton University

Organizers: David Amundsen and Lucy Campbell (Carleton)

The study of fluid dynamics has driven the development of numerous fundamental analytic and numerical methods of applied mathematics. As the sophistication of physical models increases and the scope of applications expands, the impetus for further developments is as great as ever. This three day workshop, funded by Fields and MITACS, brought together researchers from both of these essential sides of applied mathematics. It provided the opportunity to share in the latest developments, and foster new collaborations and avenues of research. In total there were over 28 participants including 18 students.
Each of the invited speakers presented a series of three lectures. Yves Bourgault (Ottawa) provided an extensive review and discussion of computing wave problems with finite element methods, beginning with the fundamental issues of stability, conservation, positivity etc. and leading into multi-phase flows and air flows charged with dispersed particles. Dale Durran (Washington) spoke on the numerical issues which arise in atmospheric modeling and various techniques to address them. After discussing the fundamental issues related to diffusion and dissipation (both physical and numerical), he discussed global strategies for minimization of error and construction of non-reflecting boundary conditions. Sherwin Maslowe’s (McGill) lectures concerned the method of matched asymptotic expansions for boundary layer problems and the derivation of the boundary layer equations in the context of fluid flows. He also spoke about solving eigenvalue problems arising in hydrodynamic stability theory, for example rotating pipe flow. Ray Spiteri (Saskatchewan) gave a series of lectures on Implicit-Explicit (IMEX) methods for solving ordinary differential equations such as those which arise from discretization of convection-diffusion-reaction problems. He introduced a wide array of methods along with a discussion of their advantages and weaknesses. On each day an hour was set aside for contributed talks by students, postdocs and other researchers.

Despite the busy schedule of lectures, participants were also able to get out and enjoy the beautiful spring weather in Ottawa. On the first day participants were treated to a reception barbecue on the Carleton campus overlooking the rapids of the Rideau River, certainly a suitable spot for experimental observation of fluid dynamics! In addition, as the workshop coincided with the first weekend of the Annual Tulip Festival in Ottawa, the second day ended with a leisurely walk from the Carleton campus to the tulip beds on Dow’s Lake and a nearby restaurant. By all accounts the workshop was a tremendous success.

**Invited Speakers:**

Yves Bourgault (Ottawa)
*Computing waves with finite element methods*

Dale Durran (Washington)
*Where is GFD’s room in the house of partial differential equations?*
*Dissipation and dispersion in numerical solutions to linear wave equations*
*Two significant numerical challenges in atmospheric modeling*

Sherwin Maslowe (McGill)
*Boundary layers and the method of matched asymptotic expansions*
*Numerical methods for solving eigenvalue problems arising in hydrodynamic stability theory*

Ray Spiteri (Saskatchewan)
*IMEX methods*

**IMACS International Symposium on Iterative Methods in Scientific Computing**

May 5–8, 2005
Held at the University of Toronto
Organizers: Christina Christara (Toronto), Peter Forsyth (Waterloo) Tamás Terlaky (McMaster) and Justin W.L. Wan (Waterloo)
About ninety participants from all over the world gathered in Toronto for this symposium. It featured eight invited talks, seven minisymposia with 3–4 talks each; about 30 contributed talks, as well as 15 student contributions in the student paper competition. Topics ranged from core iterative methods and eigenvalues to preconditioning, multigrid and parallel computation, as well as optimization, nonlinear equations and differential equations. Applications such as data and web mining, image processing, computational finance and computational fluid dynamics received special attention.

The symposium received funding from the Fields Institute, the Faculty of Mathematics at the University of Waterloo and MITACS, so that 13 applications for funding by students and postdoctoral fellows were at least partially funded, and five awards were given to student paper competition winners.

The Bahen Centre for Information Technology (BCIT) at the University of Toronto served as hosting venue. The high-ceiling hallways of BCIT were the ideal place for informal discussions and breaks, while the projectors in the rooms booked for the conference were working full-time during scientific sessions. Many participants indicated their appreciation of the high quality of the talks and the interaction provided by the conference. A special issue of the Applied Numerical Mathematics journal, arising from the symposium, will be sponsored by IMACS. On the social front, participants enjoyed the hospitality of the downtown Chinatown and of the Greek village on the Danforth, as well as the ethnic diversity and colour of Baldwin Street.

**Invited Speakers:**
- Tony Chan (UCLA)  
  *Duality-based iterative methods for total variation minimization*

- Tom Coleman (Cornell)  
  *Minimizing VaR, CVaR and hedging issues for a portfolio of derivatives*

- Andrew Conn (IBM)  
  *Derivative free optimization – some new results*

- Paul Fischer (Argonne National Laboratory)  
  *Spectral element multigrid for the incompressible Navier Stokes equations*

- Ilse Ipsen (North Carolina)  
  *Analysis and computation of Google’s page rank*

- Tim Kelley (North Carolina)  
  *Continuation algorithms for parameter dependent compact fixed point problems*

- Kees Oosterlee (DIAM)  
  *A novel multigrid based preconditioner for heterogeneous Helmholtz problems*

- Andy Wathen (Oxford)  
  *Fast solvers for incompressible flow*

**Workshop on Mathematical Modeling and Analysis of Computer Networks**

May 6, 2005  
Held at the University of Waterloo

Organizers: Shie Mannor (McGill) and Peter Marbach (Toronto)

This one-day workshop was part of the IFIP conference Networking 2005 held at the University of Waterloo. The workshop brought together researchers with a background in mathematics and/or computer networks in order to explore how mathematics can be used to model and analyze these networks.

Mathematical models have played an important role in the understanding of computer networks – in particular in the understanding of their fundamental performance limits and of the trade-offs involved. Because the network infrastructure keeps changing and new applications emerge, the mathematical models used need to evolve as well. The goal of the workshop was to explore recent advances in the mathematical modeling and analysis of computer networks.

The talks represented recent work on topics such as network coding, mobility models for wireless networks, auction mechanism for spectrum sharing in cellular networks, and the spreading of internet worms. Mathematical models used to study these issues ranged from stochastic models (random walks and Brownian motion, diffusion processes, large deviation) to optimization (such as geometric programming and semi-definite programming) and game theory.
Speakers:
Randy Berry (Northwestern)
Spectrum sharing games

George Kesidis (Penn State)
Coupled Kermack-McKendrick models for randomly scanning and bandwidth-saturating internet worms

Richard La (Maryland)
Providing guaranteed packet loss rate in wireless networks in the presence of random interference

Jang-Won Lee (Princeton)
Implications to network utility through physical and medium access layer innovations

Roland Malhame (Ecole Polytechnique Montreal)
Optimal scheduling of data transmission in wireless networks

Ravi Mazumdar (Waterloo)
Random mobility models in ad hoc networks: capacity and delay issues

Michael Neely (Southern California)
Stochastic control of ad-hoc networks: delay, energy, fairness

Asuman Ozdaglar (MIT)
Competition and Efficiency in Communication Networks

Saswati Sarkar (Pennsylvania)
Stochastic control problems in MAC layer wireless multicast

Sanjay Shakkottai (Texas at Austin)
The price of anarchy in min-cost multicast with network coding

R. Srikant (Illinois at Urbana Champaign)
Scheduling in multihop wireless networks

K. S. Srisankar (Motorola)
QoS provisioning in wireless ad-hoc networks

Edmund Yeh (Yale)
Power control, rate allocation, and routing in stochastic wireless networks

Workshop on Empirical Likelihood Methods
May 9–11, 2005
Held at the University of Ottawa

Organizers: Mayer Alvo (Ottawa) and Jon Rao (Carleton)

Inference based on likelihood methods has proven very effective in the past. The methods can be used for constructing tests with good asymptotic properties, confidence intervals with accurate coverage probability as well as to pool data from different sources. Unfortunately in parametric statistics one must suppose that the underlying family of distributions is known, save for some parameters which are estimated from the data. The use of parametric methods when the underlying distributions are unknown can lead to incorrect tests and inaccurate confidence intervals. Empirical Likelihood has been applied successfully in determining confidence intervals whose shape and orientation is dictated by the data. These intervals also respect the range of the parameter space. The method has proven effective in audit sampling where lower confidence bounds are used to compute the amount of money owed to government for example. The empirical confidence intervals outperformed the parametric likelihood intervals by providing large lower bounds respecting the nominal error rate.

Art Owens (Stanford) presented a tutorial on empirical likelihood methods. This was followed by presentations by Jon Rao, Jiahua Chen, Changbao Wu, P.K.Sen, Mayer Alvo, Qunshu Ren and Yongson Quin. There was a good exchange of ideas throughout the workshop, which will undoubtedly translate into a vigorous research in this growing field.
Speakers:
Mayer Alvo (Ottawa)
*Empirical likelihood and ranking problems*

Jiahua Chen (Waterloo)
*Model selection in generalized linear models*

Yongson Quin (Carleton)
*Confidence intervals for parameters of the response variable in a linear model with missing data*

Jon Rao (Carleton)
*Empirical likelihood intervals for missing data and measurement error problems*

Qunshu Ren (Carleton)
*Empirical likelihood confidence intervals under fractional imputation*

P.K. Sen (North Carolina at Chapel Hill)
*Curse of dimensionality in genomics: beyond the likelihood paradigm*

Changbao Wu (Waterloo)
*The empirical likelihood approach to calibration with survey data*

**Southern Ontario Statistics Graduate Student Seminar Day**
May 12-13 2005
Held at York University
Organizers: Nikolai Slobodianik, Tao Sun and Konstantin Zukker (York)

The purpose of SOSGSSD is to provide a forum for graduate students to discuss their latest work and research, exchange ideas and establish connections for future collaborations. The event was a great success involving 16 graduate student speakers, and four keynote speakers (Richard Cook, Hemant Ishwaran, Judy-Anne Chapman, and Ivan Hon), and a total of 39 participants representing 5 universities.

The presentations were composed of diverse subjects in statistical theory and application with particular emphasis on Biostatistics and Health Research. A vast range of topics was successfully covered by student presenters, some of them include: analysis of survival data, Markov chains, mixed models, Bayesian hierarchical and mixture models, random forests, cluster and discriminant analysis. Many students not only presented their achievements in statistical science but applied their findings to real life data and obtained important results in the fields of proteomics, genetics, stem cell research, mental health research, epidemiology, pollution reduction and even analysis of psychological aspects of winning in Olympic Games. Keynote speakers made a natural contribution to the main flow of the seminar days by addressing in a review manner key aspects of statistical analysis of biological data such as variable selection and longitudinal data analysis.

SOSGSSD 2005 was sponsored by York University, the Fields Institute, SORA and SAS Inc.

**Keynote Speakers:**
Judy-Anne Chapman (Queen’s)
*Accreditation of professional statisticians by the Statistical Society of Canada for a designation of P. Stat. or A. Stat.*

Richard J. Cook (Waterloo)
*Options for model specification and inference with longitudinal data*

Ivan Hon (Scotiabank)
*Mentoring - benefits for both A.Stat. and P.Stat*

Hemant Ishwaran (Case U.)
*Prediction and variable selection with applications to biostatistics*

**Workshop on Non-associative Algebras**
May 12–14, 2005
Held at the Fields Institute
Organizers: Yun Gao (York), Oleg Smirnov (College of Charleston) and Yoji Yoshii (North Dakota State)

The workshop was dedicated to Bruce Allison from the University of Alberta on the occasion of his 60th birthday.

Over 30 participants from North America, Europe, China, and Japan, ranging from the leading experts in the field to graduate students, gathered to present the latest results of...
their work, discuss new advances in the area, and honor Professor Allison’s contributions to the field.

In the course of three days, there were twenty-four 30–min-
ute talks in the general area of non-associative algebras and
their applications. Many talks were related to Professor
Allison’s mathematical legacy, including the structure
theory and applications of structurable algebras; extended
affine Lie algebras, their structure theory and representa-
tions; connections between non-associative algebras and
graded Lie algebras.

The event was sponsored by the Fields Institute.

Speakers:

Jose A. Anquela (Universidad de Oviedo)
Martindale-like covers of PI quadratic Jordan algebras

Saeid Azam (U. Isfahan)
Derivations, automorphisms and tensor product of algebras

Maribel Tocon Barroso (Ottawa)
The Kostrikin radical of EALAs of reduced type

Georgia Benkart (Wisconsin-Madison)
More than everything you want to know about centroids of Lie
algebras

Stephen Berman (Saskatchewan)
Conjugacy results for the Lie algebra $sl_2$ over an algebra which
is a U.F.D.

Yuly Billig (Carleton)
Jet modules

Kevin McCrimmon (Virginia)
Jordan derivations of TKK Lie algebras

Alberto Elduque (Universidad de Zaragoza)
Lie algebras with $S_4$ action and structurable algebras

John Faulkner (Virginia)
Structurable tori

Skip Garibaldi (Emory U.)
Algebras for algebraic groups of type $E_6$

Noriaki Kamiya (U. Aizu)
Examples of triple systems and Lie superalgebras associated
with their systems

Issai Kantor (Lund U.)
The Peirce decomposition for generalized Jordan triple systems
of finite order

Sergei Krutelevich (Ottawa)
Jordan algebras, exceptional groups, and higher composition
laws

Michael Lau (Ottawa)
Orbifold vertex algebras and EALA representations

Antonio Fernandez Lopez (Universidad de Malaga)
The socle of a nondegenerate Lie algebra

Consuelo Martinez Lopez (Universidad de Oviedo)
Bimodules over simple finite dimensional Jordan superalge-
bras

Fernando Montaner (Universidad de Zaragoza)
Jordan algebras of quotients

Jun Morita (Tsukuba)
Gauss decompositions for groups, Lie algebras and tilings
Erhard Neher (Ottawa)
*Skew-dihedral homology and skew derivations*

Susumu Okubo (Rochester)
*Triality and structurable algebras*

Arturo Pianzola (Alberta)
*Extended affine Lie algebras: a cohomological perspective*

Michel Racine (Ottawa)
*Maximal orders in split Lie algebras over a local field*

Oleg Smirnov (College of Charleston)
*Lie algebras and Lie triple systems*

Kaiming Zhao (Wilfrid Laurier)
*Theta-stable parabolic subalgebras*

**Ottawa–Carleton Discrete Mathematics Day 2005**
May 13–14, 2005
Held at the University of Ottawa

Organizers: Sylvia Boyd, Lucia Moura, and Mateja Šajna (Ottawa); Daniel Panario, Brett Stevens, and Steven Wang (Carleton)

Since its inception in its present form in the year 2002, the Ottawa–Carleton Discrete Mathematics Day has been held annually in the spring, alternating its location between Carleton University and the University of Ottawa. On the 13th and 14th of May 2005, the meeting was for the first time hosted by the University of Ottawa’s Department of Mathematics and Statistics. Over forty participants – many of them graduate students - gathered in the afternoon of the 13th of May for the special Ottawa – Carleton Joint Colloquium talk traditionally tied to the Discrete Mathematics Day. This year’s colloquium talk, entitled *Type-II Matrices*, was given by Chris Godsil (Waterloo). Its topic was a particularly interesting choice, connecting several vibrant areas of mathematics with algebra and combinatorics.

Four hour-long invited lectures by leading researchers in the areas of combinatorics, graph theory, algorithms, and finite fields were presented. The audience greatly appreciated the inspiring topics and skillful, engaging presentations. Ample time was left between the talks for socializing, networking, and collaboration.

The event was organized by, and generously sponsored by the Fields Institute and Centre de recherche mathématiques.

**Speakers:**
Kathie Cameron (Wilfred Laurier)
*Independent packings: algorithms and Min-Max Theorems*

Alex Rosa (McMaster)
*Ringel’s Conjecture and graceful labellings: forty years late*

Gary Mullen (Penn State)
*Distribution of irreducible polynomials over finite fields*

Frank Ruskey (Victoria)
*Polyominoes, Gray codes, and Venn diagrams*

**Modelling the Rapid Evolution of Infectious Disease: Epidemiology and Treatment Strategies**
May 14–17, 2005
Held at the University of Western Ontario

Organizers: Lindi Wahl (UWO), Glenn Webb (Vanderbilt) and Xingfu Zou (UWO)

Although the epidemiology of, and treatment strategies against infectious disease are fairly mature areas in mathematical biology, the concurrent evolution of the pathogen has only recently been addressed in these models. Since microbial evolution occurs on a timescale of weeks or even days, it is critical that models recognize this “moving target”.

The overall goal of this workshop was to discuss the incorporation of pathogenic evolution into standard models of epidemiology and drug therapy. With the support of the Fields Institute, MITACS and the NSF, 50–60 researchers attended this three day event. Students, PDFs and faculty members travelled from as far away as Spain, France, Arizona, Utah, New Mexico and British Columbia to attend. The format of the workshop allowed for 60 minute...
talks, each of which was followed by 30 minutes of open discussion. The discussions were lively and usually had to be cut-off at the 30 minute mark (only to continue in smaller groups over coffee). The speakers also encouraged questions and discussion during the talks, and participants did not hesitate to oblige. During and after the event, many participants expressed their appreciation of this format (and the lengthy discussions that ensued) to the organizers.

Another highlight of the workshop was the poster session. Discussion of the posters continued long past the scheduled 90 minutes for this session. Colleen Ball (UBC, supervised by Daniel Coombs) was declared the winner of the student poster competition.

In summary, the organizers were surprised and delighted by the attendance, lively participation and overall reaction to this workshop.

Speakers:
Troy Day (Queen’s)
The evolution of endemic and pandemic influenza

David Earn (McMaster)
Emerging infectious diseases: ecology, evolution and control

Zhilan Feng (Purdue)
Dynamics of two-strain influenza with isolation and partial immunity

Fabio Milner (Purdue)
What is missing in TB modeling?

Patrick Nelson (Michigan)
Back to the basics to improve our ability to model infectious diseases

Robert Smith (UCLA)
The epidemiological impact of low efficacy HIV prevention methods

Pauline van den Driessche (Victoria)
Patch models for disease spread

Hulin Wu (Rochester)
Can we model/simulate AIDS clinical trials and predict its outcomes?

Jianhong Wu (York)
Lessons learned from SARS and the 1918 influenza pandemic about the age of infection: its critical role and modeling

Workshop on Forest Fires and Point Processes
May 24–28, 2005
Held at the Fields Institute
-see the NPCDS section for a description of this event

Workshop on Number Theory and Random Matrix Theory
June 1–3, 2005
Held at the University of Waterloo
Organizers: Yu-Ru Liu, David McKinnon and Michael Rubinstein (Waterloo)
This workshop brought together number theorists and physicists from around the world and was intended as a satellite workshop to the summer CMS meeting at the University of Waterloo, June 4–6. Many participants in the workshop stayed on for a CMS session on L-functions and algebraic curves.

The workshop was meant to explore connections between number theory and random matrix theory. The first connection between number theory and random matrices was made in the seventies. Hugh Montgomery had just worked out the pair correlation statistic for the zeros of the Riemann zeta function, and, on a visit to the Institute for Advanced Study, was describing his results to Freeman Dyson. Dyson, who had studied similar statistics for the eigenvalues of random matrices in the context of modeling the energy levels of nuclei, pointed out that eigenvalues of large unitary matrices share the same behaviour that Montgomery had uncovered for the zeros of the Riemann zeta function. This supported the Hilbert-Polya conjecture, namely that the Riemann hypothesis should be true because the zeros of zeta somehow correspond to the eigenvalues of some unitary operator.

In recent years, there has been a flurry of activity in this area. Montgomery’s results have been shown to extend to other L-functions of number theory. This has led to insight into questions concerning the value distribution of L-functions and ranks of elliptic curves. On the other hand, questions raised by number theorists have stimulated work on analogous problems in random matrix theory and has helped to push further the rich subject of random matrices.

The workshop included amongst its participants some of the number theorists and physicists who have been at the forefront of this approach, as well as a good number of post docs and graduate students. It was supported by the Fields and Perimeter Institutes, PIMS, and the University of Waterloo.

Speakers:
E. Bogomolny (Paris-Sud)
Spectral statistics of a pseudo-integrable map

O. Bohigas (Paris-Sud)
Spacing distribution of zeros of Riemann’s zeta function

D. Farmer (AIM)
Example Maass L-functions

A. Gamburd (Stanford)
Averages of characteristic polynomials from classical groups

C. Hughes (Michigan)
The maximum size of the zeta function

H. Kisilevsky (Concordia)
Central values of cubic elliptic L-functions

P. Kurlberg (KTH)
Poisson statistics via the Chinese remainder theorem

J. Lagarias (Michigan)
Zero spacing distributions for differenced L-functions

F. Mezzadri (Bristol)
Random matrix theory and entanglement in quantum spin chains

S. Miller (Brown)
Identifying symmetry groups of zeros of families of L-functions

R. Murty (Queen’s)
Dirichlet series and hyperelliptic curves, part 1

N. Ng (Michigan)
Large gaps between the zeros of the zeta function

Y. Petridis (City U. & Max-Planck-Inst.)
Modular symbols and discrete logarithms

C. Roettger (Iowa State)
Counting matrices in the general linear group over algebraic integers

N. Snaith (Bristol)
Derivatives of random matrix characteristic polynomials and applications to elliptic curves

M. Young (AIM)
Moments of the critical values of families of elliptic curves

G. Yu (South Carolina)
Average Frobenius distribution of elliptic curves
Workshop on Mathematical Programming in Data Mining and Machine Learning
June 1–4, 2005
Held at McMaster University

Organizing Committee: Nello Cristianini (UC Davis), Laurent El Ghaoui (UC Berkeley), Jiming Peng (McMaster), Katya Scheinberg (IBM Research), Romy Shioda (Waterloo) and Tamás Terlaky (McMaster)

This event is the first international meeting on a new multi-disciplinary research area: mathematical programming modeling and problem solving in data mining and machine learning. The workshop brought together a diverse group of experts from data mining, machine learning and mathematical programming, working on both theoretical and applied aspects, to discuss recent research advances, ignite new collaborations and expose new possibilities. The framework of this medium-scale event provides these interdisciplinary communities a rare opportunity to expose each other to the possibilities available in each field, and identify solution methodologies for problems arising from their respective areas.

Mathematical programming provides a common language for many data mining and machine learning problems. One successful example of mathematical programming in learning is Support Vector Machines (SVMs) based on the use of space mapping via a kernel matrix. SVM, which can essentially be cast as a convex quadratic optimization problem, has been developed as the state of the art method for classification. Cluster analysis in pattern recognition and machine learning usually refers to global (discrete) optimization techniques.

The workshop’s featured 9 plenary talks which covered a wide range of topics from graph modeling and discovering, techniques for dimension reduction and capacity control, optimization modeling and problem solving in machine learning and bioinformatics, to applications of data mining in industry and other disciplines such as biology and chemistry.

In total there were 33 contributed talks in the workshop that addressed the same wide range of topics as the plenary talks. All the talks were well received and the organizers were happy to hear from many participants that the workshop was very informative and helpful. Motivated by the success of this event, one of the invited speakers, Yong Shi proposed to organize a similar workshop in Beijing, 2006.

During the workshop, the Advanced Optimization Lab in the Department of Computing and Software at McMaster University presented several posters that demonstrate the broad applications of optimization techniques in different disciplines. Thanks to the generous support from McMaster University, the Fields Institute, MITACS and IBM, the workshop was able to provide financial support for all the students who gave a presentation in the workshop.

Invited Speakers:
Kristin P. Bennett (Rensselaer Polytechnic Inst.)
Optimization challenges in capacity control

Peter Hammer (Rutgers)
Discrete optimization problems in the logical analysis of data

Pierre Hansen (HEC Montreal)
A mathematical programming approach to discovery in graph theory
John MacGregor (McMaster)
Latent variable methods for process analysis, monitoring and design

Alex Rubinov (U. Ballarat)
Unsupervised and supervised classification via nonsmooth optimization

Yong Shi (Nebraska)
Data mining techniques via multiple criteria optimization approaches

Martin Wainwright (Berkeley)
Mathematical programming and statistical models based on graphs

Stephen Wright (Wisconsin-Madison)
A review of some optimization techniques in machine learning and statistics

Stanley Young (National Inst. Statistical Sciences)
Identifying and solving important/complex problems

The 11th International Conference on DNA Computing (DNA11)
June 6–9, 2005
Held at the University of Western Ontario
Organizers: Lila Kari and Mark Daley (UWO)

Biomolecular computing has emerged as an interdisciplinary field that draws together computer science, mathematics, molecular biology, chemistry and physics. Our knowledge of DNA nanotechnology and biomolecular computing increases dramatically with every passing year. The international meeting on DNA Computing (formerly DNA Based Computers) has been the main international forum where scientists with different backgrounds, yet sharing a common interest in computing, meet and present their latest results. The 11th International Meeting on DNA Computing, now under the auspices of the International Society for Nanoscale Science, Computation and Engineering (ISNSCE), focuses on the current experimental and theoretical results with the greatest impact.

DNA11 was organized by Lila Kari (DNA11 Organizing Committee Chair and newly elected Chair of the DNA Computing International Steering Committee) and Mark Daley (DNA11 Organizing Committee Vice-Chair). With a total of 150 participants, DNA11 was the best attended DNA Computing conference to date.

The first day of the meeting was devoted to tutorials on computer science, molecular biology and DNA nanotechnology.

Four 55-minutes invited talks were delivered by senior scientists. Eshel Ben-Jacob (Tel Aviv University) spoke on bacterial intelligence and DNA computing. James Gimzewski (University of California, Los Angeles) described recent works exploring nanomechanical characterizations of cell bacteria and proteins. Pehr Harbury (Stanford...
University) presented recent results on the use of DNA molecules to govern generalized output processes. Eric Klavins (University of Washington) spoke on robotic self-organization. There were twenty three 25-minute oral presentations of research contributions, where the last minutes of each talk were devoted to an active time for questions and comments. Also, a poster session was held where forty five posters were presented.

With Len Adleman (the founder of the field of DNA Computing) in attendance, and with an impressive array of talks combining theoretical aspects with the latest achievements in nanotechnology, DNA11 has been a successful and inspiring meeting.

The Fields Institute was the lead sponsor for the conference. In addition, the conference was supported by MITACS, BIOMAR Inc. and the University of Western Ontario.

**Plenary Speakers:**
- Eshel Ben-Jacob (Tel Aviv)  
  *Bacterial intelligence and DNA computing*
- James Gimzewski (UCLA)  
  *Nanomechanical probes of biosystems*
- Pehr Harbury (Stanford)  
  *Translating DNA words into actions*
- Eric Klavins (Washington)  
  *Robotic self-organization*
- Dipankar Sen (Simon Fraser)  
  *DNA as the raw material for general-purpose electrical biosensors*

### Summer School in Operator Algebras

**33rd Canadian Operator Symposium (CoSy)**

June 7-17, 2005 and June 19-24, 2005

Held at the University of Ottawa

Organizing committee: Thierry Giordano (Ottawa), David Handelman (Ottawa), Jamie Mingo (Queen’s), Matthias Neufang (Carleton) and Vladimir Pestov (Ottawa)

Advisory Committee: George Elliott (Toronto), Ken Davidson (Waterloo), Nigel Higson (Penn State), Ian Putnam (Victoria) and Roland Speicher (Queen’s)

The University of Ottawa hosted a pair of linked events in June, starting with a two-week summer school in Operator Algebras, and concluding with the 33rd Canadian Operator Symposium (CoSy). The symposium was dedicated to George Elliott, on the occasion of his 60th birthday. George is one of Canada’s leading mathematicians, and a driving force behind operator algebras in Canada. Both events were sponsored by the Fields Institute.

Additional funding was supplied by a NSERC Leadership Support Initiative grant, held by J. Mingo, M. Neufang, A. Nica, and R. Speicher and by a grant from the US National Science Foundation to support US participants at the summer school and CoSy.

The summer school was a great success. Over 75 mathematicians have participated in at least one week of the summer school, nearly 60 of which number have attended both weeks. The participants came from Canada, the US and many European countries. The success of the summer school is largely due to the exceptional quality of the lecturers, who each delivered a series of 5 ninety minute lectures.

**First week lectures were:**
- Roger Smith (Texas A&M)  
  *An introduction to the theory of operator spaces*
- Roland Speicher (Queen’s)  
  *Free probability theory*
- Stefaan Vaes (Paris VI)  
  *Type III factors in non-commutative probability theory*

**Second week lectures were:**
- Nigel Higson (Penn State)  
  *An introduction to noncommutative geometry*
- Ian Putnam (Victoria)  
  *C*-algebras and dynamical systems*
- Mikael Rørdam (U. Southern Denmark)  
  *Amenable C*-algebras and their classification*

Moreover, additional specialized talks were presented, in particular by Marius Junge (Illinois at Urbana-Champaign) on *Probabilistic techniques in operator spaces*.

The summer school prepared students to get the most out of the advanced talks given at the symposium. CoSy itself represented a chance to assemble a large and active group of operator researchers. During the banquet held in the honour of George Elliott, many colleagues, friends and former students of George emphasized not only the importance of his mathematical contributions and achievements, but...
also the important and frequent help he offers to young researchers in operator algebras. In 1994-95, George was the main organizer of a very successful year long program in Operator Algebras at the Fields Institute. He rented a large house always filled by short and longer term visitors. This house was quickly known as Chateau Elliott. P. Fillmore, who was the master of ceremony of the banquet, delighted the audience with many anecdotes on the daily life in the chateau. The nearly one hundred participants of CoSy heard 11 plenary talks and 36 shorter presentations.

CoSy Plenary Speakers
Ola Bratteli
AF-algebras revisited

Søren Eilers
Known and unknown ranges

Uffe Haggerup
Random matrices in C*-algebra theory - a survey

Nigel Higson
Index theory for SL(3)

Akitaka Kishomoto
Rohlin flows on Kirchberg algebras

Ryszard Nest
What are the categories good for

N. Christopher Phillips
Classifiability of crossed products by minimal homeomorphisms

Ian Putnam
A non-commutative Lefschetz formula for chaotic systems

Mikael Rordam
C*-algebras that absorb the Jiang-Su algebra

Masamichi Takesaki
Discrete core of a factor of type III, 0<\lambda<1

Dan-Virgil Voiculescu
Topological Free Entropy

12th Conference of the International Linear Algebra Society
June 26–29, 2005
Held at the University of Regina

Organizers: Shaun Fallat, Doug Farenick, Chun-Hua Guo and Steve Kirkland (Regina)

The 12th Conference of the International Linear Algebra Society (ILAS) was hosted by the University of Regina. This was the first time that this meeting was held in Canada, and Regina was an ideal location for the meeting as the University of Regina has a number of people with research interests concentrated on linear algebra and related areas. The next two meetings are scheduled for Amsterdam and Shanghai.

ILAS was founded in 1989 for the purpose of promoting international activities in linear algebra. Such activities include the coordination of linear algebra meetings, workshops and discussions on educational issues in linear algebra, awarding of prizes for outstanding research in linear algebra, operation of both electronic and print information services, and publication of the Electronic Journal of Linear Algebra. The ILAS Conference Series is one the Society’s most important activities.

The scientific program for the conference was set by an international organizing committee that was chaired by Steve Kirkland (Regina) and included Pauline van den Driessche (Victoria) and Henry Wolkowicz (Waterloo). By all accounts, the program was a very strong one and the plenary lectures touched upon the subjects of matrix theory, geometry, algebraic methods, combinatorics and graph theory, numerical methods, operator theory, the teaching of linear algebra, and applications ranging from genomic signal processing to optimisation. At the Conference banquet Chandler Davis (Toronto) spoke on the development of linear algebra as a field of independent interest, as seen from the perspective of his own career and experience.

The conference featured 20 invited speakers who presented eight one hour and twelve half hour lectures. Four special lectures were among the invited talks: (i) the Hans Schneider Prize Lecture (sponsored by ILAS in recognition of outstanding achievement in linear algebra research) by Richard Varga (Kent State); (ii) the LAA Lecture (sponsored by the journal Linear Algebra and its Applications) by Orly Alter (Texas); (iii) the LAMA Lecture (sponsored by the journal Linear and Multilinear Algebra) by Chi-Kwong Li (William & Mary); and (iv) the ILAS Education Lecture (sponsored by ILAS in recognition of important contributions to the teaching of linear algebra) by Anna Sierpinska (Concordia). In addition, there were seventy contributed papers and four minisymposia, consisting of twenty-eight presentations on a range of fundamental issues of current interest in linear algebra. The Elsevier journal Linear Algebra and its Applications will publish a special issue devoted to papers presented at the conference. The Editors of this
volume are Rajendra Bhatia (India), Robert Guralnick (USA), Steve Kirkland (Canada), and Henry Wolkowicz (Canada).

A major event at the conference was the presentation of the Hans Schneider Prize, which recognizes outstanding contributions to research in linear algebra. Two of the previous winners are from Canada: David Handelman (Ottawa) and Peter Lancaster (Calgary). At this year's conference, the Hans Schneider Prize was awarded to Richard Varga of Kent State University for his career-long contributions to matrix analysis. Varga's prize lecture was devoted to Gershgorin's Circle Theorem, the subject of his very recent Springer monograph.

The ILAS Conference attracted 150 participants from all parts of the world. There was a high rate of participation from graduate students and postdoctoral fellows. Registration fees were waived for students and postdoctoral fellows in keeping with ILAS's goal of providing students and emerging researchers with the opportunity to interact with some of linear algebra's leading figures. A local undergraduate student in physics was also among the registered participants. With partial support from ILAS and the Canadian Mathematical Society, a Graduate Student Social was held at a downtown restaurant and it attracted 27 graduate students. In addition, there was an ILAS-sponsored lunch on the first day of the meeting which introduced each student and postdoctoral fellow participant and invited all conference participants to welcome these young people in the informal discussions and social activities that normally occur during a mathematics meeting.

The international flavour of the Society was reflected by conference participants, with many people from Asia, Europe, and North America, as well as a few participants from Africa and South America. A relatively high proportion of the participants and plenary speakers were women. The ILAS Conference thus provides a venue that brings people together and it contributes significantly to the exchange and dissemination of ideas.

In addition to the high quality scientific program, several participants commented upon the local charm and the friendliness of the city's people. A visit to the Canadian prairies was a first-time experience for a great many of the conference participants.

In addition to the support of the Fields Institute, financial assistance was provided by the University of Regina, PIMS, the CMS Student Committee, Elsevier, Taylor & Francis, Atlas Conferences, and ILAS. The local organizers were assisted in a variety of technical aspects by the Fields Institute and by University of Regina staff and students.

Speakers:
Orly Alter (Texas at Austin)
**Genomic signal processing: From matrix (and tensor) algebra to genetic networks**

Avi Berman (Technion)
**Positive matrices and TCP**

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ILAS Conference participants
Jim Demmel (UC Berkeley)
*On deciding whether accurate linear algebra algorithms exist*

Dragomir Djokovic (Waterloo)
*On the tridiagonalization of complex (real) matrices of small size by unitary (orthogonal) similarity*

Anne Greenbaum (Washington)
*Theory and applications of the polynomial numerical hull*

Olga Holtz (UC Berkeley)
*Bits and pieces of the nonnegative inverse eigenvalue problem*

Ilse Ipsen (North Carolina State)
*The Jordan form of complex tridiagonal matrices*

Charles Johnson (College of William and Mary)
*Ranks and patterns*

Adrian Lewis (Cornell)
*Eigenvalues and optimization*

Chi-Kwong Li (College of William and Mary)
*Induced operators on symmetry class of tensors*

Ren-Cang Li (Kentucky)
*Rectangular Vandermonde matrices with applications to Krylov Subspace methods*

Raphael Loewy (Technion)
*The exponent of a K-primitive matrix*

Joao Queiro (Coimbra)
*Composite norms and perfect conditioning*

Peter Rowlinson (Stirling)
*Star complements in infinite graphs*

Anna Sierpinska (Concordia)
*Innovations in the teaching of linear algebra: Why you’ll never hear the end of it*

Bryan Shader (Wyoming)
*Permanents of Hessenberg (0,1)-matrices*
Seminars

Algebraic Combinatorics Seminar
October 2004–June 2005
Held at the Fields Institute

Organizers: Christophe Hohlweg (Fields) and Mike Zabrocki (York)

The Algebraic Combinatorics Seminar is a weekly meeting of a group of grad students, post-docs and professors from York University and the Fields Institute. It met for about an hour and a half on Fridays during the Fall 2004 – Spring 2005 term. The seminar was attended by roughly 8–12 people.

Its purpose was to cover topics in algebraic combinatorics which were of interest to the organizers and those who attended. In the Fall term the seminar concentrated on the topic of symmetric and quasi-symmetric functions in non-commutative variables. This was a topic of active research of several members of the group and was related to the topic of ‘quasi-symmetric functions’ from the previous year. The group chose to try to find a connection between the Grothendieck group of a tower of algebras and the Hopf algebra of non-commutative symmetric functions. We are happy to report that this series of seminars lead to discovery of this connection and a paper is in production that came directly from the research conducted for that seminar. During the Spring term the seminar concentrated on the topic of languages and analytic classes of generating functions. Drawing on the expertise of Marni Mishna, the group has been learning about languages and the purpose of the seminars have been to try and find a class of languages which correspond to the analytic class of D-finite functions in a non-commutative setting. Several new ideas have developed from this series of seminars and it is hopeful that the group will be able to answer the question.

Speakers:
Nantel Bergeron (York)
Solomon-Tits algebra I, II
Computations with Solomon-Tits and noncommutative symmetric functions

Riccardo Biagioli (UQAM)
Colored descent representations for complex reflection

Srečko Brlek (UQAM)
On the palindromic complexity of infinite words

Murray Elder (St. Andrews U.)
Pattern avoiding permutations are context sensitive

Christophe Hohlweg (Fields & York)
Solomon-Tits algebra III: Coxeter complex of permutations

Sam Hsiao (Michigan)
Canonical Hopf algebras between QSym and the peak algebra

Marni Mishna (Fields)
Analytic classes of functions: algebraic, D-finite, D-algebraic
Combinatorial classes with D-finite generating series
Computations of indexed languages
A linguistic model for D-finite generating functions

Cristian Lenart (SUNY Albany)
Generalizing the combinatorics of Young tableaux to arbitrary Lie type

Mike Zabrocki (York)
Noncommutative symmetric and quasisymmetric functions I, II
Fundamental basis of NCSym I, II
Open problems on NCSym
Formal languages: regular, context free, indexed
Enumerating words in indexed languages
Linguistic models for rational and algebraic generating functions
Computational Neuroscience in Upper Canada (CNUC)
July 2004, November 2004 and March 2005
Held at the Fields Institute

Organizers: Randy McIntosh (Rotman Research Inst. & Toronto), Frances Skinner (Toronto Western Research Inst. & Toronto) and Richard Zemel (Toronto)

Conversations over coffee gave rise to a small group in southern Ontario with an interest in methods and problems in computational neuroscience. The primary motivation is to exchange information between experimentalists and computational modellers in order to investigate how computational and mathematical approaches have been-or could be-used to address critical issues in neuroscience. The talks are either in tutorial style, geared to general scientists, or more problem-oriented, where an issue is presented and the floor is then opened for discussion on how to deal with the issue (e.g., we have all this data from brain imaging; how do we characterize the dynamics?).

July 7, 2004
Nonlinear dynamics and bifurcations
Sue Ann Campbell (Waterloo), Marty Golubitsky (Houston), and Frances Skinner (Toronto)

November 10, 2004
Dynamics of a neural system with a multiscale architecture
Michael Breakspear (U. Sydney & Brain Dynamics Centre)

March 10, 2005
Memory across domains
Speakers: Sue Becker (McMaster), Jeremy Caplan (Rotman Research Inst.), Eve De Rosa (Toronto), Chris Eliasmith (Waterloo) and Christiane Linster (Cornell)

Fields Colloquium/Seminar in Applied Mathematics
September 7–June 30, 2005
Held at the Fields Institute

Organizers: Jim Colliander (Toronto), Walter Craig (McMaster), Barbara Keyfitz (Fields); Adrian Nachman, Mary Pugh and Catherine Sulem (Toronto)

The Fields Colloquium in Applied Mathematics started in 2001, forming a focal point for mathematicians in the Toronto region interested in applied mathematics and analysis of partial differential equations. This year there were talks in two formats: the Colloquium for broad lectures by senior speakers, and the Seminar, aimed at a more specialized audience. The highlight of this year’s colloquia was the talk by Charlie Fefferman on the Whitney extension problem. The seminars functioned very well as a place where visitors to Fields talked about their current research. Next year will continue in the same vein.

Speakers:
Y. S. Choi (Connecticut)
Moving boundary problem for a one-dimensional crawling Nematode sperm cell model

Charles Fefferman (Princeton)
Whitney’s extension problem II

Katarina Jegdic (Houston & Fields)
Transonic regular reflection for the unsteady transonic small disturbance equation

Nedyu Popivanov (U. Karlsruhe)
50 Years nonclassical Protter Problems for the wave equation

Katarzyna Saxton (New Orleans)
Low temperature phase transitions in heat propagation

Ralph Saxton (New Orleans & Fields)
Boundary layer separation and breakdown

Allen Tesdall (Houston & Fields)
Self-similar and steady solutions for weak shock reflection
Geometry and Model Theory Seminar
September 2004–March 2005
Held at the Fields Institute
Organizers: Edward Bierstone (Toronto) and Patrick Speissegger (McMaster)

The purpose of the seminar was to bring together people from the geometry and singularities group at the University of Toronto (including Ed Bierstone, Askold Khovanskii, Grisha Mihalkin and Pierre Milman) and the model theory group at McMaster (Bradd Hart, Deirdre Haskell, Patrick Speissegger and Matt Valeriote).

As was discovered during the programs in Algebraic Model Theory and in Singularity Theory and Geometry at the Fields Institute in 1996–97, geometers and model theorists have many common interests. The goal of the seminar is to further explore interactions between these areas.

Speakers:
Patrick Ahern (Wisconsin, Madison)
On the method of Ecalle and Voronin

Tobias Kaiser (Universität Regensburg)
Definability results for the Poisson equation

Rahim Moosa (Waterloo)
Nonstandard meromorphic groups

Wieslaw Pawlucki (Universytet Jagiellonski)
A linear extension operator for Lipschitz functions on \( o \)-minimal sets

Thomas Scanlon (UC Berkeley)
Regular types in partial differential fields

Sergei Starchenko (Notre Dame)
Complex-analytic subsets in analytic-geometric categories

Thierry Zell (Georgia Tech.)
Topology of Hausdorff limits in \( o \)-minimal structures

Motivic Integration Seminar
September 2004–March 2005
Held at the Fields Institute and the University of Toronto
Organizer: Julia Gordon (Toronto)

Motivic integration originated in a 1995 talk by M. Kontsevich, and since then has developed in several directions. Historically, the first theory that appeared (in the works of J. Denef and F. Loeser dated 1996–1998) was the theory of integration on arc spaces (what is nowadays called “geometric motivic integration”). The theory of arithmetic motivic integration was developed by J. Denef and F. Loeser in 1999, and that’s when they first introduced the machinery from logic into the construction. Arithmetic motivic integration provides a different point of view on the classical integration over \( p \)-adic fields. It should be noted here that the values of motivic measure are not numbers but geometric objects (such as, roughly speaking, isomorphism classes of varieties, or, sometimes, Chow motives). In the case of arithmetic motivic integration the way to get back to a classical, number-valued, measure, is roughly by counting points on the varieties over finite fields.

The aim of the seminar was to understand how motivic integration works. The goal was to bring together model theorists from McMaster University and people from different fields at the University of Toronto.

Speakers
Raf Cluckers (ENS)
New framework for motivic integration

Alf Dolich (McMaster)
Mapping formulas to Chow motives, with examples

Julia Gordon (Toronto)
The transformation rule for geometric motivic measure: example of a blow-up
Geometric motivic integration from the new point of view

Jonathan Korman (Toronto)
About geometric and arithmetic motivic integration in the new framework

Elliot Lawes (Toronto)
Prehistory of motivic integration

Kyu-Hwan Lee (Toronto)
Measure on 2-dimensional local fields

Geoffrey Lynch (Toronto)
Introduction to Chow motives

Yoav Yaffe (McMaster)
\( p \)-adic cell decomposition theorem
Set Theory Seminar
July 2004–June 2005
Held at Fields Institute

Organizers: Ilijas Farah and Juris Steprans (York)

For close to thirty years the Toronto Set Theory Seminar met on Wednesday evenings during the academic year. Recently the seminar has shifted its meetings to Friday afternoons in the mathematically accommodating lecture halls and pleasant atmosphere of the Fields Institute.

A typically broad range of topics were represented during the past twelve months.

Uri Abraham (Carnegie Mellon and Ben Gurion), Jean Larson (Florida), Grigorio Mijares (Caracas) and Lionel Nguyen Van (Paris) talked about Ramsey theory.

Dikran Dikranjan (Udine), Gábor Lukács (Dalhousie), Slawomir Solecki (UIUC) and Juris Steprans (York) talked about various aspects of topological (in particular, Polish) groups.

Combinatorics of filters and ideals on the natural numbers was the topic of Taras Banakh (Nipissing, Lwow), Mike Oliver (North Texas) and Paul Szeptycki (York).

Menachem Magidor (Hebrew University) and Stuart Zoble (Toronto) talked about applications of strong axioms of infinity (so-called ‘large cardinals’).

Combinatorics of the real line was the topic of Michael Hrusak (UNAM), Otmar Spinas (Kiel) and Beatriz Zamora Aviles (York).

A mini-conference under the auspices of the seminar was held in March. One of its highlights was the talk by J.T. Moore (Boise) who presented his recent spectacular results on combinatorics of the first uncountable cardinal: confirmation to the long-standing conjecture of Shelah on the basis for uncountable linear orders and the construction of an L-space.

The very successful Fall 2002 semester at the Fields Institute was devoted to interactions between Set Theory and Analysis. Aspects of topics such as measure theory and Banach spaces still play a prominent role in the seminar, as for example in talks by Juris Steprans (York) and Piotr Koszmider (São Paulo). In a four-talk series, Stevo Todorcevic used Baire category methods (‘forcing axioms’) to prove that every Banach space of density aleph-1, has a quotient with a Schauder basis of length $\omega_1$. This is closely related to the ‘separable quotient problem’ asking if every infinite dimensional Banach space has an infinite dimensional separable quotient, since both are based on an old problem of Pelcsynski asking if every infinite-dimensional Banach space has an infinite-dimensional quotient with a Schauder basis.

In this spirit, the main focus of the previous year’s seminar was on one of the remaining unsolved problems recorded in the notebook entrusted to the owner of the Scottish café by Banach and his colleagues. Although problems recorded in the Scottish book have had considerable attention devoted to them, many of them remain unsolved. Problem 163 was posed by John von Neumann during his 1937 visit to Lwow. A measure algebra is a complete Boolean algebra that carries accountably additive probability measure $\mu$ such that $\mu(A) > 0$ for every nonzero $A$. Von Neumann asked whether measure algebras can be characterized by two of their properties: the countable chain condition and a weak distributivity law. Dorothy Maharam gave a negative answer to this question, conditioned on assuming the failure of Suslin’s Hypothesis. She also introduced the notion of submeasure algebra. Every measure algebra is a submeasure algebra, and every submeasure algebra satisfies the countable chain condition and the weak distributivity law. Maharam posed the problem of whether every submeasure algebra is a measure algebra. The importance of Maharam’s problem largely derives from its many equivalent reformulations, chief among these being the ‘control measure problem’ for vector-valued measures. Maharam’s problem has attracted considerable attention but since the seminal 1984 paper by N. Kalton and J. Roberts there had been virtually no progress until recently.

Last decade has seen a surge of interest in von Neumann’s and Maharam’s problems followed by substantial develop-
ments. All of the results obtained on these problems in recent years have been reported at the Toronto Set Theory Seminar, often by the authors themselves. In December 2003 Balcar, Jech and Pazak used earlier results of Todorcevic and Balcar–Pazak to show that, granted a substantial large cardinal assumption (a ‘supercompact cardinal’), the only way to answer von Neumann’s problem is to answer Maharam’s problem. They did this by constructing a model of Set Theory in which every complete Boolean algebra satisfying von Neumann’s conditions is a submeasure algebra. In his talk I. Farah (York) presented joint work with B. Velickovic (Paris) to the effect that if every algebra satisfying von Neumann’s conditions is a submeasure algebra, then there are inner models with measurable cardinals of high Mitchell order. This shows that von Neumann’s problem has a negative solution, unless some substantial axioms of infinity are assumed.

On the other hand, in his talk S. Todorcevic showed that if ‘countable chain condition’ is strengthened to ‘sigma-finite chain condition’ then von Neumann’s problem is reduced to Maharam’s problem. Notably, the sigma-finite chain condition was considered by Horn and Tarski in the 1940s in connection with the question on what algebras carry a finitely additive measure.

Speakers:
Beatriz Zamora-Aviles (York)
Countable dense homogeneity of definable spaces

Taras Banakh (Nipissing)
Coherence of semifilters, I, II

Maxim R. Burke (UPEI)
Liftings for category algebras

Dikran Dikranjan (York)
Characterizing subgroups of the circle and of the compact abelian groups

Ilijas Farah (York)
Prikry problem for Suslin forcings
Von Neumann’s problem and large cardinals
If you can prove it, then it must be true
Fubini properties of sigma-ideals

James Hirschorn (Vienna)
Nonhomogeneous analytic families of trees, Part I, II, III

Michael Hrusak (Instituto de Matematicas Unidad Morelia)

Piotr Koszmider (São Paulo)
Banach spaces of continuous functions with few decompositions
On a problem of Rolewicz about Banach spaces that admit support sets

Paul B. Larson (Miami)
Pmax and the nonstationary

Victoria Lubitch (York)
Left-separated spaces and linearly Lindelof spaces

Gábor Lukács (Dalhousie)
Structure and cardinal invariants of topological groups

Menachem Magidor (Hebrew)
Reflection of second order properties

Goyo Mijares (Universidad Central de Venezuela)
Parametrizing the abstract Ellentuck theorem – Part I, II, III

Lionel Nguyen Van (Paris 7)
Partitioning Ultrametric Urysohn spaces

Mike Oliver (North Texas)
Many quotient Boolean algebras

Slawek Solecki (Illinois, Urbana-Champaign)
Local amenability and measure small sets

Otmar Spinas (Christian Albrechts University, Kiel)
F sigma and G delta splitting families

Juris Steprans (York)
A regular CLP-compact space of countable tightness whose square is not CLP-compact
A pigeon hole type of principle for measure spaces

Paul Szeptycki (York)
Some applications and possible applications of PFA(S)[S]
Stevo Todorcevic (Toronto)  
*Representing trees as relatively compact subsets of the first Baire class*  
*Biotrheogonal systems and quotient spaces via Baire category methods, Part I, II, III, VI*  
*Between the von Neumann and the control measure problems*

Stuart Zoble (Toronto)  
*Proving projective determinacy*  
*Weak capturing and stationary reflection*

**Probability Seminar**  
September 2004–May 2005  
Held at the Fields Institute and York University  
Coordinators: Dimitrios Cheliotis (Toronto), Neal Madras (York) and Bálint Virág (Toronto)

This year’s seminar had 13 talks. Four of them were related to the theory of superprocesses. Leonid Mytnik presented a uniqueness result for solutions of a stochastic partial differential equation arising from a certain superprocess. Tom Salisbury showed how one can get information on the history of a super Brownian motion with Levy branching in a domain, knowing that it hits the boundary of the domain at some given points. Vladimir Vinogradov examined properties of a family of densities appearing in a class of branching diffusion particle systems. And Carl Mueller showed regularity for the solution of a stochastic partial differential equation motivated by a superprocess.

Balázs Szegedy presented some properties of convergent sequences of dense graphs and a connection with problems of extremal graph theory.

Jacques Verstraete showed how probabilistic techniques solve some purely combinatorial problems.

On applied issues were the talks of Pablo Olivares and Manuel Morales. Olivares showed how martingale methods can be used to estimate the parameters of some diffusion models, while Morales discussed the problem of computing the discounted penalty function for a class of risk models.

Dimitrios Cheliotis presented a property of the two sided Brownian motion and its implication on the behavior of a diffusion having this motion as an environment.

Sharad Goel gave estimates on the time it takes for a deck of cards to become close to random when it is subjected to a certain kind of random shuffles.

Julien Dubedat discussed the problem of growing in a domain and in a consistent way two SLE’s that don’t intersect.

Stuart Whittington presented results on a probabilistic object used to model the behavior of a copolymer in a solution of two immiscible solvents.

Frank den Hollander studied the way the lattice gas subject to Kawasaki dynamics goes through metastable states.

**Speakers:**

Dimitrios Cheliotis (Toronto)  
*Diffusion in a one-dimensional random environment*

Frank den Hollander (EURANDOM)  
*Metastability for the lattice gas, subject to Kawasaki dynamics*

Julien Dubedat (NYU)  
*Commutation of SLEs*

Sharad Goel (Cornell)  
*Estimating convergence rates for finite Markov chains*

Manuel Morales (York)  
*Generalized risk models, Levy processes and the discounted penalty function*

Carl Mueller (Rochester)  
*Regularity of a one-dimensional stochastic heat equation with extra noise from a stochastic flow*

Leonid Mytnik (Technion)  
*On pathwise uniqueness for stochastic heat equations with non-Lipschitz coefficients*

Pablo Olivares (Havana)  
*Martingale methods for some diffusion with jump stochastic processes*

Tom Salisbury (York & Fields)  
*Conditioned superprocesses with Levy branching*

Balázs Szegedy (Microsoft Research)  
*Reflection positivity and limits of dense graph sequences*

Jacques Verstraete (Waterloo)  
*Martingale inequalities and enumeration*
Vladimir Vinogradov (Ohio)
On “contagious” exponential dispersion models related to continuous-state branching

Stuart Whittington (Toronto)
Randomly coloured self-avoiding walks and copolymer localization

Quantum Information Seminars
July 2004–June 2005
Held at Fields Institute
Organizers: Daniel Lidar, Hoi-Kwong Lo and Aephraim Steinberg (Toronto)
The purpose of the seminars is to introduce graduate students, postdoctoral fellows, and faculty, as well as any other interested parties, to the emerging new discipline of Quantum Information Science, including quantum computation, cryptography, teleportation etc. The seminars bring together interested researchers from a variety of backgrounds—mathematics, computer science, physics, chemistry, and engineering.

In addition to support by the Fields Institute, funding was provided through the CQIQC, NSERC, PRO, and DARPA grants of the organizers.

Speakers:
Robert Alicki
Hamiltonian models of quantum error correction

Dirk Bouwmeester
Photons, quantum dots and microcavities

Kenneth Brown
Arbitrarily accurate composite pulses

Hilary Carteret
Preparing high purity initial states for NMR quantum computing

Ignacio Cirac
Projected entangled-pair states: properties and applications

Chip Elliott
The DARPA Quantum Network

Joseph Emerson
Efficient pseudo-random unitary operators for quantum information processing: constructions and applications

Robert Garisto
How PRL works

John Howell
The Einstein Podolsky Rosen paradox

Jonathan Oppenheim
Partial quantum information can be negative

Ben Reichardt
Improved “magic states” distillation for quantum universality

Mohan Sarovar
Continuous quantum error correction

Moshe Shapiro
Principles of coherent control and the automatic detection and correction of mutations by coherent light

Frank Wilhelm
Quantum coherence in superconducting circuits

Zhaoyan Wu
Non-commutative analysis and hyper-operators in quantum physics

Paolo Zanardi
Entanglement and quantum phase transition in low dimensional spin systems

Karol Zyczkowski
On duality between quantum maps and quantum states
Directors: Amit Oza (Princess Margaret Hospital), and Siv Sivaloganathan (Waterloo)

Mathematics has always thrived and benefited from its interaction with the emerging sciences. The Biomedical sciences are at the forefront of 21st century research and will be amongst the premier sciences of the foreseeable future. Furthermore, the Biomedical sciences are at a critical juncture of a significant transformation into quantitative and predictive disciplines. This evolution will depend critically on their productive interaction with the mathematical and computational sciences. It is clear that if mathematical scientists do not become engaged and involved at this stage, they will not be part of what are likely to be the most significant and exciting scientific discoveries of the future.

The Centre for Mathematical Medicine (CMM) was launched in response to a perceived need and unique opportunity to create a Centre for interdisciplinary research in the mathematical and medical sciences. CMM is a research initiative launched, under the aegis of the Fields Institute, aimed at bringing together research expertise in mathematics and medicine to address the numerous questions arising at the mathematical/biomedical sciences interface. With the recent emergence of mathematical medicine as a distinct discipline, it has become abundantly clear that an interdisciplinary approach is essential for the successful application of the mathematical/computational sciences to problems arising in the medical sciences.

Due to the diversity of medical specialty hospitals in Toronto, in addition to the concentration of applied mathematics departments and research groups across Ontario, a Centre encompassing all the relevant groups was perceived as the most suitable means of developing an integrated and cohesive strategy. CMM will provide a focus for communication between the different research groups and a means of facilitating and fostering research collaborations as well as playing an educational role. This will involve a combination of workshops, seminars, collaborative research projects and short and long term visitor programs - all planned to stimulate interdisciplinary research both within Ontario and across Canada.

The priorities of CMM, as envisioned by the Directors, are threefold: firstly to create an exciting and productive research environment that will help to foster collaborative, interdisciplinary research in the Mathematical/Biomedical sciences. Secondly, an important goal of the Centre will be to stimulate and engage a new generation of graduate students and young researchers (medical practitioners/scientists and mathematical scientists) to work on problems arising in medicine. Thirdly, teaching will be a major component of CMM activities at both undergraduate and graduate levels.

**Mathematical Medicine Seminar Series**

March–May 2005
Held at the Fields Institute

There is a long and productive history of the interplay between mathematics, physics and the medical sciences. One of the unifying themes of mathematical modeling and experimental research in the medical sciences is the elucidation of the underlying biological processes that result in a particular observed phenomenon.

It is now apparent that, even in the rare cases where the mechanisms are well understood, mathematics is still essential to explore the consequences of changing various
parameters – for example, in the case of cancer and angiogenesis (with its possible implications for cancer therapy), the number of options fast becoming available to practicing oncologists will be overwhelming unless we find mathematical approaches for simulating particular treatment protocols before applying them in practice.

The monthly seminar series, launched by the newly formed Centre for Mathematical Medicine (CMM) at the Fields Institute, is aimed at bringing together research expertise in mathematics and medicine to address the plethora of research questions arising at the mathematics/medicine interface. As such, the talks are intended to be accessible to both mathematical and medical research communities.

The inaugural talk was given by Dr. Kristen Swanson, Shaw Research Assistant Professor in Pathology at the University of Washington, Seattle, who spoke on Clinical Applications of Quantitative Modeling for Invasive Brain Tumours. Her presentation demonstrated how quantitative modeling can not only shed light on the spatio-temporal growth of gliomas but also can have specific clinical application in real patients. The conclusion was that, although current imaging techniques remain woefully inadequate in accurately resolving the true extent of gliomas, quantitative modeling provides a new approach for the dynamic assessment of real patients and helps direct the way to novel therapeutic approaches.

In May 2005, Carl Panetta (Tennessee) presented a talk titled Modeling Chemotherapy Induced Myelosuppression.

A workshop on Modelling in Oncology: problems and challenges, has been co-organized with the BIOM&S Working group at the University of Guelph. This meeting is slated to take place at the Fields Institute on 5 October, 2005. CMM is also co-organizing a workshop (Oncology: Current problems and future challenges) with MITACS and MSRI. This meeting is scheduled for October 16-19, 2005 at the Banff Research Station. A number of other initiatives with various research groups are in the planning stages, as are plans for a Journal Club and short courses. The official opening of CMM will take place on Friday, 2 September 4pm-6pm at the Fields Institute.
Joint Institute Initiatives

Support for certain activities of various societies in the mathematical sciences is provided jointly by the Fields Institute, the Centre de recherches mathématiques, the Pacific Institute for the Mathematical Sciences, and in some cases by MITACS.

Workshop on Computational Biology in the Post Genomics Era – a collaborative workshop between universities, NRC and industry
March 19–20, 2005
Held at CRM in Montreal

Steering Committee:
Isabelle Blain (Vice-President, NSERC)
William Cowley (Senior Program Officer, NRC)
Ivar Ekeland (Director, PIMS)
Barbara Lee Keyfitz (Director, Fields)
Francois Lalonde (Director, CRM)

Scientific Committee:
Sandrine Dudoit (UC Berkeley)
Avner Friedman (Ohio)
Michael Hallet (McGill)
Leah Keshet (UBC)
Mark Lewis (Alberta)
Normand Mousseau (Montreal)
John Nash (NRC – IBS)
Enrico Purisima (NRC – BRI)
Jamie Stafford (Toronto)
Ray Somorjai (NRC – IBD)

This meeting was initiated by the three mathematics institutes – Fields, CRM, and PIMS – and NRC with the idea of looking for common research topics. At a deeper level, this is part of an initiative to explore ways that collaborations between mathematical scientists, including computational scientists, and biologists, including biomedical researchers, can be developed. The workshop was hosted by CRM, and included four sessions on quantitative topics in biology (biomedical data analysis, computational structural biology, proteomics and protein modeling, and genomic analysis). There were three plenary discussion sessions that focused on the challenges of getting funding for interdisciplinary research, of the place of interdisciplinary activity in universities, and of communication difficulties between mathematicians and biologists. Follow-up activities are planned for the coming year.

This meeting was supported by Fields, CRM, PIMS, NRC, NSERC, and the Canadian Biotechnology Strategy.

First Joint Canada-France Meeting of the Mathematical Sciences
July 12–15, 2004
Held in Toulouse

Scientific Director: Francis Clarke (Lyon)

The first Canada-France congress involved the three Canadian societies; CMS, CAIMS, SSC and their French counterparts: SMF, SMAI and SFdS. Four hundred and thirty delegates registered with a significant number of students and postdocs. Several lectures were given in French. The Institutes funded student travel.

The plenary lectures were given by Laurent Lafforgue (IHES), Grégoire Allaire (École Polytechnique), Mathieu Bergounioux (Orléans), Jonathan Borwein (Dalhousie), David Brillinger (Berkeley), Walter Craig (McMaster), Henri Darmon (McGill), Emmanuel Giroux (ENS-Lyon), Gabor Lugosi (Barcelona), Mikhail Lyubich (Toronto), Christophe Reutenauer (UQAM), Alain-Sol Sznitman (ETH Zürich), Murad Taqqu (Boston) and Henry Wolkowicz (Waterloo). Michèle Artigue (Jussieu) gave the education lecture.


Moreover there was a poster session for students and postdocs. Eric Muller (Brock) organized a panel on the popularization of mathematics.

Discussions are under way for a second Canada-France meeting in the summer of 2008 in Montreal.
Winter 2004 Meeting of the Canadian Mathematical Society
December 11–13, 2004
Held at Hilton Bonaventure Hotel, Montreal

Meeting Director: Olga Kharlampovich (McGill)

The Meeting welcomed 450 participants. Following the usual format of the CMS Winter Meeting, the program included a wide variety of sessions, a contributed paper session, plenary and prize lectures, and a public lecture. Most activities and all scientific talks were held at the Hilton Bonaventure Hotel. The meeting began with Alexei G. Myasnikov (McGill) delivering a public lecture entitled Complexity of computations and cryptography. The event, held at the Best Western Hotel Europa, drew a large audience and was followed by a welcoming reception.

Plenary Speakers:
Michael Bennett (UBC)
Classical Diophantine equations via modern and not-so-modern methods

Persi Diaconis (Stanford)
A mathematician flips a coin

Rostislav Grigorchuk (Texas A&M)
Algebraic, algorithmic, and spectral properties of automata groups

François Lalonde (Montréal)
How pure mathematical aspects of String theory can solve deep problems of geometric group theory

Rainer Steinwandt (Karlsruhe)
Non-abelian groups in public key cryptography

CMS Coxeter-James Prize Lecture
Izabella Laba (UBC)
Harmonic analysis and combinatorics: Are we there yet?

CMS Doctoral Prize Lecture
Nicolaas Spronk (Waterloo)
Operator spaces and abstract harmonic analysis

CMS Adrien Pouliot Prize Lecture
Jean-Marie De Koninck (Laval)
Mathematics and the media

Special sessions and their organizers:
Algebraic combinatorics; François Bergeron, Riccardo Biagioli, Peter McNamara, and Christophe Reutenauer (UQAM)

Approximation theory; Richard Fournier and Paul Gauthier (Montreal)

Arithmetic geometry; Eyal Goren (McGill) and Adrian Iovita (Concordia)

Combinatorial and geometric group theory; Inna Bumagin (Carleton) and Dani Wise (McGill)

Commutative algebra; Sara Faridi (Ottawa), Sindi Sabourin (York), Will Traves (US Naval Academy) and Adam van Tuyl (Lakehead)

Discrete geometry; Karoly Bezdek (Calgary), Rob Calderbank (Princeton), Robert Connelly (Cornell) and Bob Erdahl (Queen’s)

Dynamical systems and applications; Michael A. Radin (RIT)

Groups, equations, non-commutative algebraic geometry; Olga Kharlampovich and Alexei G. Myasnikov (McGill)

Harmonic analysis; Galia Dafni (Concordia)

History of mathematics; Thomas Archibald (Acadia, Dibner Institute MA), Rich O’Lander (St. John’s), Ron Sklar, (St. John’s) and Alexei Volkov (UQAM)

Interactions between algebra and computer science; Olga Kharlampovich (McGill), Alexei G. Myasnikov (McGill) and Vladimir Shpilrain (CUNY)

Mathematical methods in statistics; Russell Steele, Alain Vandal and David Wolfson (McGill)

Mathematics for future teachers; Leo Jonker (Queen’s)

Number theory; Chantal David (Concordia) and Andrew Granville (Montreal)

Special structures in differential geometry; Gordon Craig (Bishop’s) and Spiro Karigiannis (McMaster)
Universal algebra and complexity; Jennifer Hyndman (UNBC), Benoit Larose (Concordia) and Denis Therien (McGill)

A contributed papers session was organized by William G. Brown (McGill).

The meeting was sponsored by the McGill University Provost, McGill University Dean of Science, McGill University Department of Mathematics and Statistics, Centre de recherches mathématiques, Fields Institute, MITACS and Pacific Institute for the Mathematical Sciences.

Summer 2005 meeting of the Canadian Mathematical Society
June 4–6, 2005
Held at the University of Waterloo

Meeting Director: Alexandru Nica (Waterloo)

The CMS meeting welcomed a record number of 540 participants – the first CMS meeting to have more than 500 attendees. This was a joint meeting with CSHPM (the Canadian Society for History and Philosophy of Mathematics). Following the usual format of the CMS Summer meeting, the program included a wide variety of special sessions, plenary and prize lectures, and a public lecture. Most activities and all scientific talks were held on the University of Waterloo campus.

**Plenary Lectures:**

Len Berggren (Simon Fraser)
*Currents and counter-currents in the history of mathematics in medieval Islam*

Keith Devlin (Stanford)
*How much mathematics can be for all?*

Dan Freed (Texas at Austin)
*Correspondences, K‐theory, and loop groups*

Robert McCann (Toronto)
*Fluid flow in the semigeostrophic oceans and atmosphere*

Andrei Okounkov (Princeton)
*Enumerative geometry of curves in threefolds*

Gilles Pisier (Paris 6 & Texas A&M)
*Similarity problems and amenability’*

Ken Ribet (UC at Berkeley)
*The modularity of some mod p Galois representations*

**Public Lecture:**

Moshe Milevsky (Schulich School of Business, York)
*The mathematics of silly investment strategies, or how to win the Globe and Mail’s stock picking contest*

**Prize Lectures:**

The Krieger-Nelson address:
Barabara Lee Keyfitz (Fields & Houston)
*Conservation laws: past and future*

The Jeffery-Williams addresses:
Edward Bierstone (Toronto)
*Resolution of singularities*

Pierre Milman (Toronto)
*Geometry and differentiable functions*

**Excellence in Teaching address:**

Philip Loewen (UBC)
*r = 1 - sin(q)* (For a hint on how to read this title we also add here the first sentence of the abstract, which is: ‘Love mathematics; love your students.’)
Special Sessions:

Automatic Sequences and Related Topics  
Organizers: Jean-Paul Allouche (Orsay, France) and Jeffrey Shallit (Waterloo)

Combinatorics and Geometry  
Organizer: Ian Goulden (Waterloo)

Complex Variables  
Organizers: Thomas Bloom (Toronto) and Paul Gauthier (Montreal)

Discrete and Computational Geometry  
Organizers: Leroy J. Dickey (Waterloo) and Asia Ivic Weiss (York)

Dynamical Systems  
Organizers: Sue Ann Campbell (Waterloo), Yuming Chen (Wilfrid Laurier) and Huaiqing Zhu (York)

Exploratory Classroom Problems in Calculus  
Organizer: Peter Taylor (Queen’s)

Functional Equations and Their Applications  
Organizers: Janos Aczel and Che-Tat Ng (Waterloo)

General Topology and Its Applications  
Organizers: E.D. Tymchatyn (Saskatoon), A. Karassev, M. Tuncali and V. Valov (Nipissing)

Geometric Topology  
Organizers: Hans Boden (McMaster), Doug Park and Mainak Poddar (Waterloo)

History and Philosophy of Mathematics (CSHPM Session)  
Organizer: Duncan Melville (St. Lawrence)

History of Mathematics from Medieval Islam to Renaissance Europe (CSHPM Session)  
Organizers: Rob Bradley (Adelphi) and Glen van Brummelen (Bennington College)

Invariant Theory and Differential Geometry  
Organizers: Ray MacLennan (Waterloo) and Roman Smirnov (Dalhousie)

L-Functions and Algebraic Curves  
Organizers: Yu-Ru Liu, David McKinnon and Michael Rubinstein (Waterloo)

Mathematical Aspects of Quantum Information  
Organizers: Daniel Gottesman (Perimeter Inst.), Achim Kempf (Waterloo), David Kribs (Guelph) and Mike Mosca (Waterloo)

Mathematics from Ancient to Modern Times  
Organizers: Richard O’Lander and Ronald Sklar (St. John’s)

Mathematics of Actuarial Finance  
Organizer: Tom Salisbury (York, Fields)

Mathematics of Computer Algebra and Analysis  
Organizers: Keith Geddes, Mark Giesbrecht, George Labahn and Arne Storjohann (Waterloo)

Nonlinear Partial Differential Equations  
Organizers: Robert McCann (Toronto), Walter Craig (McMaster) and Catherine Sulem (Toronto)

Operator Algebras, Operator Spaces and Harmonic Analysis  
Organizers: Ken Davidson and Brian Forrest (Waterloo)

Random Graphs and Their Applications  
Organizers: Anthony Bonato (Wilfrid Laurier), Penny Haxell and Nicholas Wormald (Waterloo)

Representation Theory  
Organizer: Wentang Kuo (Waterloo)

String Theory and Integrable Systems  
Organizers: Lisa Jeffrey (Toronto), Boris Khesin (Toronto) and Rob Myers (Perimeter Inst.)

Contributed Papers Session  
Organizer: Peter Hoffman (Waterloo)

Sponsors:  
University of Waterloo, Faculty of Mathematics  
Centre de recherches mathématiques (CRM)  
Fields Institute  
MITACS  
Pacific Institute for the Mathematical Sciences
The 26th annual meeting of CAIMS was held at the Fort Garry campus of the University of Manitoba in Winnipeg. The meeting featured six themes namely: Dynamical Systems and Mathematical Biology; Signal Processing; Bioinformatics; Mathematics in Industry; Computational Mathematics; Pattern Recognition. These themes were chosen not only to reflect some of the main current research interests of CAIMS members and the wider global applied and industrial mathematics community, but also to reflect and highlight the research expertise and interests of mathematical scientists within the University of Manitoba and the local research community and industry.

There were approximately 60 speakers and 130 participants at CAIMS 2005. Furthermore, 20 graduate students and post-doctoral fellows presented posters during the Poster Session held concurrently with the opening night stand-up reception. The banquet, on the second night of the conference, took place at the historic Fort Gibraltar. This Fort, which was once the centre of the fur trade at the Forks in the 18th and 19th centuries, provided a distinct “Manitoba flavour” at the conference. The menu was also uniquely Manitoban, with roast bison tenderloin served with hunter sauce as the main course.

Themes and Plenary Lectures:

- **Dynamical Systems and Mathematical Biology**
  - Organizers: William F. Langford (Guelph) and Pauline van den Driessche (Victoria)
  - Plenary Speaker: Michael Mackey (McGill)
  - Modelling the dynamics of gene regulatory networks

- **Signal Processing**
  - Organizer: Witold Kinsner (Manitoba)
  - Plenary Speaker: Simon Haykin (McMaster)
  - Large-scale dynamical systems

- **Bioinformatics**
  - Organizers: Steven Wang and Augustine Wong (York)
  - Plenary Speaker: Ruben Zamar (UBC)
  - A linear grouping algorithm

- **Mathematics in Industry**
  - Organizers: Abba Gumel (Manitoba) and John Stockie (SFU)
  - Plenary Speakers: Heinz Engl (Austrian Academy of Sciences)
  - Sam Howison (Oxford)
  - Challenges and opportunities for mathematicians in the finance industry

- **Computational Mathematics**
  - Organizer: Raymond Spiteri (Dalhousie)
  - Plenary Speaker: Sebastian Reich (Imperial College)
  - Numerical resolution of mixing in the atmosphere

- **Pattern Recognition**
  - Organizers: Chris Bowman and Richard Baumgartner (Inst. for Biodiagnostics, NRC)
  - Plenary Speaker: Tin Kam Ho (Bell Laboratories)
  - Geometrical complexity of classification problems

In addition to the above well-chosen themes and collection of very distinguished list of plenary speakers, the Winnipeg
meeting introduced an Industry/Academia Dialogue on Day 2 of the conference. The Dialogue served as a forum for members of the two communities to share ideas and challenges pertaining to various aspects of industrial mathematics (particularly in terms of teaching and research collaborations). The Dialogue, very ably moderated by William Langford (Guelph), featured four distinguished panellists, representing various institutes around the world interested in industrial mathematics, namely Heinz Engl (Director, RICAM, Austrian Academy of Sciences, Austria), Sam Howison (Director, Oxford Centre for Industrial and Applied Mathematics, Oxford University, UK), Barbara Keyfitz (Director, Fields, Canada) and John Stockie (Associate Scientific Director, MITACS, Canada). The Dialogue, which was well-attended by members of the two communities, is in line with one of the key mandates of the IIMS, which is to enhance greater interaction and collaboration between mathematical scientists at the University of Manitoba and members of the industry.

Research Prize:
Michel Fortin (Laval)
Contact problems in solid mechanics

Doctoral Dissertation Awards (two co-winners):
Ovidiu Voitcu (Alberta)
Neural network approach for nonlinear dynamics prediction and feature extraction

Lindsay Anderson (UWO)
A hybrid model for electricity spot prices

Arthur Beaumont Distinguished Service Award:
Sue Ann Campbell (Waterloo)

Best Poster Award:
Adenike Bamgbade (Inst. for Biodiagnostics, NRC)

Statistical Society of Canada 2005 Annual Meeting
June 12-15, 2005
Held at the University of Saskatchewan
Organizers: Augustine Wong (York) and Mik Bickis (Saskatchewan)

The thirty-third annual meeting of the Statistical Society of Canada was hosted by the University of Saskatchewan. The meeting featured a wide range of sessions, including workshops of the three SSC sections: Biostatistics, Survey Methods, and Business and Industrial Statistics.

The meeting was sponsored by the Centre de recherches mathématiques, the Fields Institute, PIMS, MITACS, the University of Saskatchewan, AON Consulting, MyTravel Sinfonia, and W.H. Freeman.

The scientific program included 100 invited papers, 81 contributed papers, and 400 participants. Keynote addresses included the following:

Presidential Invited Address:
Barbara Lee Keyfitz (Fields & Houston)
Deterministic and statistical models for turbulence: What could Burgers have said to Kolmogorov?

Gold Medal Address:
Keith Worsley (McGill)
Correlation random fields, brain connectivity, and cosmology

Canadian Journal of Statistics Award Address:
Naomi Altman (Pennsylvania State)

Pierre Robillard Award Address:
Zeny Feng (Waterloo)

CRM-SSC Award Address:
Jiahua Chen (Waterloo)

SSC Section Invited Addresses:
Gerald Van Belle (Washington)
Biostatistics as narrative

Jerry Lawless (Waterloo)
Statistics and technology

Randy Sitter (Simon Fraser)
Bootstrapping in complex surveys

Atlantic Association for Research in the Mathematical Sciences (AARMS)
AARMS was founded in March 1997, and exists to encourage and advance research in the mathematical sciences in the Atlantic region of Canada.

The numerous scientific activities (workshops and conferences, summer schools for graduate students, PDF support, public lectures) were made possible by the generous financial support from the Centre de recherches mathématiques (CRM), the Fields Institute, and the Pacific Institute for the Mathematical Sciences (PIMS), with matching funding
from Memorial University of Newfoundland, Dalhousie University, the University of New Brunswick (Fredericton), and Acadia University.

Activities supported through AARMS funding during the year ending June 30, 2005 include:

**International Conference on Nonlinear Dynamics and Evolution Equations**
Held at Memorial University
July 6–10, 2004

Organizers: Andy Foster (Memorial), Brian Sleeman (Leeds), Yuan Yuan (Memorial), Xiaoqiang Zhao (Memorial) and Xingfu Zou (Memorial)

This workshop was attended by some 60 participants (including 10 graduate students and PDFs) from 15 countries (Australia, Belgium, Canada, P.R. China, Finland, Hungary, India, Italy, Japan, The Netherlands, Poland, Slovenia, Spain, Turkey, USA). The exciting program of 16 plenary lectures and some 40 contributed talks was complemented by a well-attended Public Lecture (hosted by Dr. Chris Loomis, Vice-President (Research) of Memorial University) given by Dr. Pauline van den Driessche (University of Victoria) on *Contributions of Mathematical Modeling to Controlling Infectious Diseases*. The award “AARMS Distinguished Lecturer” (recognizing excellence in Mathematics and its exposition) was presented to Professor Boju Jiang of Beijing University.

**2004 AARMS Summer School**
Held at Memorial University
July 12–August 16, 2004

Director: Edgar Goodaire (Memorial)

The third in the series of highly successful summer schools was attended by 30 graduate and senior undergraduate students from Atlantic Canada (9), Quebec (4), Ontario (2), British Columbia (3), Austria (1), Croatia (1), Italy (1), Poland (3), Romania (2), Spain (1), Turkey (2), USA (1), each of whom was registered in two of the following four courses offered during the four week school:

- Number Theoretic Cryptology (Renate Scheidler, Calgary)
- Statistical Genomics (Priscilla Greenwood, Arizona State)
- Mathematical Biology (Brian Sleeman, Leeds)
- Number Theory (Michael Bennett, UBC)

In addition to the support mentioned above, AARMS also acknowledges the contributions by MITACS and Aliant.

**APICS 2004: AARMS Symposium on Functional Analysis and Operator Algebra**
Held at the University of New Brunswick
October 17, 2004

Organizers: Dan Kucerovsky and Andrew Toms (UNB)

This symposium continued the tradition of holding special AARMS sessions during the annual APICS conferences in Mathematics, Statistics, and Computer Science. It again attracted a good number of researchers and graduate students from across Atlantic Canada, and its program included 10 lectures.

**East Coast Combinatorics Conference 2005**
Held at University of New Brunswick
January 22, 2005

Organizers: David Bremner and Hugh Tomas (UNB)

The aim of the conference was twofold: to bring together combinatorialists (including graduate students) from the Atlantic provinces, to initiate or advance their collaborations, and to expose them to lectures by leading researchers from the region and beyond. The conference was attended by about 25 people; they heard four invited talks by speakers from Dalhousie, McGill, MIT, and UC Davis. This conference was also supported by UNB (Department of Mathematics and Faculty of Computer Science) and by MITACS.

**Quantum Gravity Workshop**
Held at the University of New Brunswick
April 28–30, 2005

Organizers: Arundhati Dasgupta, Jack Gegenberg and Viqar Husain (UNB)
The workshop was attended by approximately 25 participants who heard six plenary talks (90 minutes each, including 30 minutes for discussion). It was followed by the annual one-day Atlantic Relativity Mini-Conference on April 30.

**Sixth Annual Bluenose Numerical Analysis Day**
Held at Cape Breton University
June 10, 2005

Organizers: George (Shaohua) Chen (CBU), Pat Keast (Dalhousie), Paul Muir (Saint Mary’s), Ronald Haynes, Richard Karsten and Holger Teismann (Acadia)

This annual meeting brought again together researchers from Atlantic Canada (including graduate students) interested in the theory and “use” of numerical analysis, applied mathematics and computer science. The ten invited and contributed talks were arranged around the one by the keynote speaker, Dr. Steve Ruuth (Simon Fraser University).

In addition to the above events, AARMS is pleased partially to support the newly created “Center for Research in Operator Algebras” at the University of New Brunswick (Fredericton). The center was approved by UNB in the spring of 2005; its current director is Dan Kucerovsky, and its international advisory board includes leading researchers from Canada, the US, Denmark, and France.

Following the second AARMS postdoctoral fellowship competition of January 2005, AARMS will extend partial support of $15K per year, starting in September 2005, to each of three PDFs, two of whom will be based at Dalhousie University and one at the University of New Brunswick (Fredericton).

After three years at Memorial University of Newfoundland, the AARMS Summer School has now moved to Dalhousie University in Halifax. The new directors are Tony Thompson and Renzo Piccinini, and the 2005 edition of the school (July 17 to August 14) will offer courses on Convexity and Fixed Point Algorithms in Hilbert Space (Heinz Bauschke, Guelph), Integral Geometry of Convex Bodies and Polyhedra (Daniel Klein, U. Massachusetts, Lowell), The Mathematics of Finance (Wolfgang Runggaldier, Padova), and Mathematical Statistics (Bruce Smith, Dalhousie).

AARMS would like to thank Dr. Edgar Goodaire not only for being instrumental in creating the AARMS Summer School series but also for his superb stewardship during its first three years.
COMMERCIAL/INDUSTRIAL MATHEMATICS

The Institute’s 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. Program activities include seminars and workshops in mathematical areas of direct interest to industry, networking activities, and assisting mathematicians in connecting with industry or in initiating their own commercial ventures. Activities take place across a broad spectrum of areas, of which financial mathematics forms one important part. The program is coordinated by the Fields Institute’s Industrial Advisory Panel.

WORKSHOPS AND SEMINARS

McMaster Optimization Conference: Theory and Applications (MOPTA 04)
July 28–30, 2004
Held at McMaster University

Organizers: Christopher Anand, George Karakostas, Jiming Peng and Tamás Terlaky (McMaster)

This three-day conference was aimed at bringing together a diverse group of people from discrete and continuous optimization, working on both theoretical and applied aspects. It sought to bring together researchers from both the theoretical and applied communities who would not normally have the chance to interact in the framework of a medium-scale event.

The conference featured a combination of theoretical and applied one-hour talks by distinguished invited researchers. Jong-Shi Pang (RPI) opened the conference with his talk on dynamic variational inequality and presented newly established results concerning Zeno states. Later that day, Larry Biegler (Carnegie Mellon) described the applications of large-scale nonlinear programming to chemical processes. On the second day, Christine Shoemaker (Cornell) presented various environmental engineering applications of response surface optimization and Jon Lee (IBM, T.J.Watson, NY) introduced the maximum-entropy sampling problem and surveyed the latest techniques and heuristics to tackle this NP-hard problem. On the third day, Gary Vanderplaats (Vanderplaats R&D Inc., Colorado Springs) gave an overview of industrial optimization and discussed current commercial software for design optimization. Aharon Ben Tal (Technion), and Dimitris Bertsimas (MIT) spoke on their recent work on robust optimization. Aharon Ben Tal presented the newly developed affinely adjustable robust optimization methodology, and Dimitris Bertsimas introduced a novel tractable theory of robust stochastic optimization.

The conference, with about 100 participants and 30 contributed talks, was hosted by the Advanced Optimization Lab in the Department of Computing and Software at McMaster, and was co-sponsored by the Fields Institute, MITACS and the McMaster Faculty of Engineering. For more details on the conference, see www.cas.mcmaster.ca/~mopta/

Beginning in 2005, the MOPTA series will be held at universities other than McMaster, returning to its home base.

MOPTA participants
tri-annually. MOPTA 05 will be held July 25–27, 2005 at the University of Windsor.

**Invited Speakers:**

Aharon Ben Tal (Technion)  
*Adjustable robust optimization: analysis and application*

Dimitris Bertsimas (MIT)  
*Robust optimization: a tractable theory of stochastic optimization*

Larry Biegler (Carnegie-Mellon)  
*Large-scale nonlinear programming in chemical process engineering*

Jon Lee (IBM T.J. Watson Research Centre)  
*Maximum-entropy sampling*

Jong-Shi Pang (RPI)  
*Linear complementarity systems*

Christine Shoemaker (Cornell)  
*Response surface optimization for computationally expensive non convex functions including environmental applications*

Garret Vanderplaats (Vanderplaats R&D Inc.)  
*Industrial optimization: status and prospects*

**Data Mining Methodology and Applications Workshop**  
Held at the Fields Institute  
- see the NPCDS section for a description of this event

**MITACS/Fields Aeronautics Workshop**  
April 28-29, 2005  
Held at the Fields Institute

Organizers: Somon Chowdhury (Bell Helicopter), Carlos Trindade (Bombardier), Ricardo Camarero (École Polytechnique), Wagdi Habashi (McGill), Ben Lee (NRC), Hany Moustapha (Pratt & Witney Canada), Yau Shu Wong (Alberta), David Zingg (Toronto), Jim Brookes (MITACS), Jeff Lucas (MITACS)

The purpose of the workshop was to bring together individuals from industry, government, and academia who are interested in aeronautics research. The workshop focused on algorithms pertaining to the analysis and optimization of aerodynamics, structures, and materials with application to aircraft and engines. There were fourteen thirty-minute presentations spread over the two days, ten by members of academia and four by representatives of industry. This was followed by round table discussions on future research priorities in the following two areas:

1. Structures and multi-disciplinary optimization  
2. Aerodynamics, CFD, and aerodynamic optimization

The presentations were used to find areas of overlap between academic interests and capabilities, and industrial needs, in addition to revealing potential areas of collaboration among academics. These potential areas for collaboration between one or more industrial partners with multiple academic partners were then further explored during the round table discussions. This format was very effective. Although most of the academics were already well known to the industrial partners, there are too few opportunities to brainstorm about research directions with most of the key Canadian players in one room. Some large-scale schemes were hatched, including the “Canadian CFD Code”, which was subsequently rejected as coming several years too late.

Time will tell whether the workshop will lead to increased collaboration in the Canadian aeronautics sector. In any case, the workshop revealed many common interests and made clear that this small community can benefit from closer interaction and coordination.

**Speakers:**

Martin Aube (Newmerical Technologies Intl.)  
*Overview of R&D activities at NTI*

Maciej Floryan (UWO)  
*Certain aspects of flow control*

Carl Ollivier-Gooch (UBC)  
*Towards automating highly-accurate flow solutions*

Clinton Groth (Toronto)  
*A Parallel Adaptive Mesh Refinement (AMR) computational framework for physically complex flows*

Jorn Hansen (Toronto)  
*Composite materials and structural optimization*

Eric Laurendeau (Bombardier)  
*Bombardier Aerospace 2005 project proposals for advanced computing methods*
Joaquim Martins (Toronto)
*High-fidelity multidisciplinary design optimization of aircraft configurations*

Martin Peeters (Pratt & Whitney Canada)
*Design system development at Pratt & Whitney Canada*

Stuart Price (McGill)
*The effects of structural nonlinearities on the aeroelastic response of an airfoil*

Raymond Spiteri (Saskatchewan)
*Efficient time-stepping*

Jean-Yves Trépanier (École Polytechnique)
*Some topics in CFD, optimization and MDO*

Dan Williams (ANSYS)
*FSI and advanced turbulence model development at ANSYS CFX*

Yau Shu Wong (Alberta)
*Prediction in nonlinear aeroelasticity*

David Zingg (Toronto)
*Aerodynamic optimization: recent progress and future prospects*

The IFID Centre 4th Annual Conference
*Fixed and Variable Annuities: A Do-It-Yourself Pension Plan?*
*May 31, 2005*
*Held at the Fields Institute*

The Individual Finance and Insurance Decisions Centre hosted its 4th Annual Conference in May. This year the focus of the conference was the topic of fixed and variable annuities, which are increasingly drawing the attention of academics, practitioners and retirees as traditional defined benefit pensions are en route to becoming a rarity and human life expectancy continues to increase. Opening remarks were made by Moshe Milevsky, Associate Professor of Finance at the Schulich School of Business and the Executive Director of The IFID Centre, who was the organizer of the one day event.

Jeffrey Brown (Illinois at Urbana-Champaign), who has served as the Senior Economist at the White House Council of Economic Advisers, as well as a member of George W. Bush’s Social Security Advisory Board, delivered the Keynote Address. He discussed the benefits of annuitization, the characteristics of the life annuity market, the psychological challenges and misconceptions that discourage the purchase of these products, as well as anticipated future developments in the area.

Phelim Boyle (Waterloo) followed with his presentation of the characteristics and behaviour of complex guarantees that are offered on tax-sheltered accumulation variable annuities. Next, William Reichenstein (Baylor) stressed the importance of working with after-tax dollars for asset allocation decisions and discussed optimal asset location strategies for individual investors. Insightful comments were added by Tom Salisbury (Fields Institute) and Chester Spatt (Carnegie Mellon), the discussants of the papers presented by the two aforementioned speakers.

The afternoon session consisted of a panel of three speakers and provided attendees with insights into recent developments in the life annuity market. Lowell Aronoff (Cannex Financial Exchanges) discussed the history, evolution and implications of the life annuity exchanges for the Canadian and US markets. Next, Garth Bernard (MetLife) presented the keys to successful innovation and development of products that serve the personal financial planning industry, and Paul Kaplan (Morningstar, Inc.) presented the results of Monte Carlo simulations that investigate whether certain financial retirement strategies are probabilistically feasible, when particular combinations of variables are altered. The ensuing period of attendees’ questions, directed at the panel members, highlighted additional issues and challenges pertaining to annuities that future retirees and the insurance industry face.

The IFID Centre wishes to thank all speakers and attendees who participated in this conference, as well as the generous sponsors of the event, including MITACS, Ibbotson Associates and Cannex Financial Exchanges.

**Speakers:**
Jeffrey Brown (Illinois at Urbana-Champaign)
*The new retirement challenge*

Phelim Boyle (Waterloo)
*Variable annuity guarantees*

William Reichenstein (Baylor)
*Non-qualified guarantees in after-tax optimizations*
Lowell Aronoff (Cannex Financial Exchanges)
An exchange for the Canadian and US payout annuity markets

Garth Bernard (MetLife)
Successful product innovation: taking concepts to market

Paul Kaplan (Morningstar, Inc.)
Asset allocation with annuities for retirement income management

PRMIA Risk Management Seminars
November 2004 – June 2005
Held at the Fields Institute and the Rotman School of Management

Organizers: Dan Rosen (Algorithmics) and Luis Seco (Toronto)

The Fields Institute hosts two regular seminars with strong participation from the business community. The Quantitative Finance seminar has been in place for over ten years. It has a primarily academic focus, and draws its audience from groups ranging from mathematics and business faculty to financial professionals. New in 2003-2004 was the PRMIA Risk Management seminar, which focuses more closely on the needs of practitioners. It built on that success with the 2004-2005 seminar, which regularly left the Fields lecture hall with standing room only. The seminar is organized by Dan Rosen (Algorithmics) and Luis Seco (Risklab, Sigma Analysis, and the University of Toronto), who are both officers of the Toronto chapter of PRMIA – the Professional Risk Managers’ International Association. PRMIA is a nonprofit professional association that organizes risk management events and certification programs around the world.

In November, the risk management seminar heard a panel discuss the 2002 Sarbanes-Oxley act (SOX 404), and its implications for risk management. SOX 404 is a reaction to the Enron and WorldCom scandals, and imposes legal obligations on CEOs and CFOs of US corporations to implement, test, and certify internal financial controls. Risk management enters into all three stages of this process, and the audience heard about the experience of various corporations with this. Building the necessary infrastructure is proving to be more complicated and costly than predicted, even though Canada will likely not adopt similar rules until 2006.

In February the seminar moved to the atrium of the Rotman School, where several hundred participants heard a presentation sponsored by SunGard Trading and Risk. John Hull (Rotman) discussed the structure of Collateralized Debt Obligations, in which a portfolio of debt obligations are combined and sold in tranches as a number of individual securities. He described the modeling and pricing of these CDO’s, and indicated how Gaussian copulas have emerged as the standard for modeling the dependence of default events in portfolios or baskets credit derivatives. Following Hull’s talk, a panel of discussants spoke about the evolution of the market for these products, and commented on a variety of associated risk factors.

Suzanne Labarge, who recently retired as Vice-Chair and Chief Risk Officer at RBC financial group, gave the audience at Fields her perspective on the evolution of risk management, at a seminar in March. She described the market’s increasing intolerance of poor risk management. This has led to better defined structures through which firms manage risk, among them the creation and recognition of such positions as Chief Risk Officer. Vanilla lending is no longer central – instead structured or illiquid products and international agreements such as Basel II have made risk management a key aspect of the operation of any modern bank.

The seminar concluded in June, with a pair of talks on alternative investments, such as hedge funds. Ron Mock (Ontario Teachers’ Pension Plan) described the perspective of a practitioner, picking and choosing among a variety of alternative investments. The goal is to buy alpha – or a return uncorrelated with the rest of the market. He indicated some of the many pitfalls this entails, including the
difficulty of finding alpha without at the same time loading up on other risks heavily correlated with the market. He was followed by Bill Fung (London Business School) who provided a complementary academic viewpoint, discussing the history of the field, some of the quantitative tools practitioners can use to evaluate hedge fund performance, as well as challenges facing the industry.

Speakers:
Panel: Rani Turna (Senior Manager, Risk and Regulatory Advisory Services, PricewaterhouseCoopers), Paul Kunkel (Head of Audit, Ontario Power Generation), Sheila Jones (Senior Manager, Financial Controls, RBC). Chris Scammell (Senior Manager, Financial Governance, BMO)

Practical issues in addressing Sarbanes-Oxley (SOX 404) requirements

John Hull (Rotman School of Management, University of Toronto).

Discussants Nico Meijer (SVP Trading Risk, TD Bank Financial Group), Keith Isaac (Senior Capital Markets Analyst, Office of the Superintendent of Financial Institutions), David Rowe (Group EVP-Risk Management, SunGard)

The current and future state of credit risk

Suzanne Labarge (former Vice-Chair and CRO, RBC Financial Group)

The changing face of risk management

Ron Mock (VP-Alternative Investments, Ontario Teachers’ Pension Plan)

Pure alpha: the practitioners’ viewpoint

Bill Fung (London Business School)

Lessons from a decade of hedge fund performance: Is the party over, or the beginning of a new paradigm?

Quantitative Finance Seminars
September 2004 – May 2005
Held at the Fields Institute

Organizers: Phelim Boyle (Waterloo), Michel Crouhy (CDC IXIS), Ron Dembo (RiskArchitect), John Hull (Toronto), Tom Hurd (McMaster), Alexander Levin (TD), Moshe Milevsky (York), and Tom Salisbury (Fields)

The monthly quantitative finance seminar celebrated its 10th anniversary in January 2005. Over that ten year period it has successfully established itself as the principal occasion at which academics and practitioners in the Toronto area gather regularly to discuss financial mathematics. Participants come from mathematics or economics departments, business schools, financial service or software firms, banks, and regulatory agencies, to name just a few.

The September speakers were Luis Seco and Mark Kamstra (Schulich School of Business). Seco spoke about credit risk, and the valuation of collateralized debt obligations. In particular, he obtained pricing formulae for an nth-to-default swap, using first passage time densities that can be efficiently computed. Kamstra spoke about reconciling the widely varying estimates of the equity risk premium. By precisely modeling dividend yields, and conducting extensive simulations based on historical interest rates, he derives very tight bounds on the value of the premium.

In October, the seminar heard from Stanley R. Pliska (Illinois at Chicago), founding editor of Mathematical Finance. He discussed the interplay between mortgage pre-payment/refinancing and mortgage rates, in the presence of refinancing fees. Given mortgage rates, he computed an optimal refinancing strategy. Knowing that strategy allows mortgage rates to be adjusted to eliminate arbitrage, and iteration of this process produces equilibrium values for both rates and refinancing.

The group that braved late-November weather listened to talks by Vicky Henderson (Princeton) and David Hobson (Bath). Henderson spoke about the “Real Option” methodology for deciding when to make an irreversible capital investment. Traditionally this has been done in the setting of complete markets, where the resulting cash flows can be replicated using more liquid assets. She instead considered the incomplete case, where only a portion can be dynamically replicated, and obtained closed-form solutions to the problem of maximizing the expected (exponential) utility of these cash flows. In particular, she could quantify the extent to which capital investments occur earlier due to incompleteness. Hobson spoke about market bubbles, and how these can be modeled by stock prices that are only local martingales (not true martingales) when discounted and viewed under the risk-neutral measure. He showed how standard features of option pricing (e.g. put-call parity) fail to hold in such markets, but can be restored by imposing collateral constraints on the portfolios admissible for option replication.

Tom Hurd, director of PhiMac at McMaster University spoke in February about the pricing of collateralized debt obligations, such as credit default swaps. In work with A.
Kuznetsov, he models each firm using a Markov chain, with the dependence between firms arising from a stochastic time change. This gives a parsimonious but flexible model in which computations can be carried out rapidly and efficiently.

Robert Almgren, who administers the Computational Finance program at the University of Toronto, gave the seminar in March. In many cases, only imprecise information is available about the expected performance of firms. Almgren showed how to build optimal portfolios based only on qualitative information about the ranking of firms relative to each other. He presented data, showing striking improvements in performance of such algorithms over naive portfolio selection strategies.

Finishing the year was Didier Sornette, Professor of Geophysics at UCLA, and bestselling author of the book Why Stock Markets Crash. He spoke about extreme financial risks, the topic of his forthcoming book with Y. Malevergne. While the distribution of individual returns for stocks or commodities is well understood, the dependencies between several such stocks or commodities are not. In particular, traditional modeling using Gaussian copulas often breaks down when price movements are extreme. Sornette discussed when such models are appropriate, and some alternatives that can replace traditional models when the latter break down. He drew interesting parallels between financial problems, and recent successes in the modeling and prediction of earthquakes and extreme meteorological events.

The seminar is sponsored by the Fields Institute and by MITACS. It meets the last Wednesday evening of each month, combining one or two talks with informal discussion and a small reception.

Speakers:
Robert Almgren (Toronto)
Optimal portfolios from ordering information

David Hobson (Bath)
Local martingales and option prices

Tom Hurd (McMaster)
Fast CDO pricing in an affine Markov chain model of credit risk

Mark Kamstra (Schulich School of Business, York)
Investing confidence in the Ex Ante Equity Premium: a new methodology and a narrower range of estimates

Stanley R. Pliska (Illinois at Chicago)
Optimal mortgage refinancing with endogenous mortgage rates: an intensity based, equilibrium approach

Luis A. Seco (Risklab & Toronto)
Pricing default correlation products within a structural framework

Didier Sornette (UCLA)
Extreme financial risks

Industrial Optimization Seminars
November 2004 – May 2005
Held at the Fields Institute

Organizers: Natalia Alexandrov (NASA), Andrew R. Conn (IBM Watson), Ron Dembo (footprint), John E. Dennis (Rice), Stefan Karisch (Carmen Systems), Barbara Lee Keyfitz (Fields), Tamás Terlaky, (McMaster, Chair) and Margaret H. Wright (NYU)

The Fields Industrial Optimization Seminar series has completed its first year. The series offers two one-hour long seminars at 5pm on the first Tuesday of each month by leading experts on a topic in optimization; the first speaker is a theoretical/algorithmic expert from a university or a research lab, while the second speaker will come from engineering, the private or government sectors, and will present the needs and uses of theoretical/algorithmic achievements in engineering practice or industry. This approach brings to the fore the power and importance of mathematical optimization methods that enable engineers and practitioners to solve industrial problems efficiently.

The organizers’ aim is to facilitate communication, collaboration and synergy between the mathematical, engineering and industrial optimization communities, and to trigger the use and development of novel optimization methods.
Participation is welcome from everyone in the academic or industrial community with an interest in optimization theory or practice – researcher, expert, enthusiast, user, or student.

The inaugural meeting of the seminar took place November 2. Henry Wolkowicz (Waterloo) lectured on robust algorithms for large sparse semidefinite programming. Semidefinite programming is a generalization of linear programming in which the variable is a positive semidefinite matrix. The talk explored recent advances in efficient solutions for these types of problems. The second speaker Anthony Vannelli demonstrated the need and power of modern optimization methodology in VLSI design. His presentation was entitled *New modeling techniques for the global routing problem*.

The program of the inaugural year demonstrated the broad spectrum of optimization methodology on one hand, and the richness of the engineering and industrial applications on the other. The optimization methods discussed by the speakers included semidefinite programming (Wolkowicz), automatic differentiation (Corliss), surrogate modeling and methods (Dennis), interior point methods (Waechter), sequential linear programming (Lasdon) and derivative free optimization (Conn). Industrial and engineering application areas covered a broad spectrum, including VLSI design (Vannelli and Viswesvariah), multidisciplinary aircraft design optimization (Martins), optimal trajectory design (Betts), dynamical systems in chemical process optimization (Biegler), refinery planning (Heltne). The last seminar of the year by Chandu Viswesvariah (IBM) entitled *Mathematics and engineering: a clash of cultures?* triggered lively discussion on the impact of mathematical optimization methods in industry and engineering design.

**Speakers:**
John Betts (The Boeing Company)
*Is a good NLP all you need to solve optimal control problems?*

Andrew Conn (IBM T.J. Watson Research Center)
*Optimization at Watson: derivative free optimization and not an introduction and new results*

George F. Corliss (Marquette)
*Automatic differentiation*

John Dennis (Rice)
*Optimization using surrogates for engineering design*

David R. Heltne (SCM, Lakeside Technology Associates)
*Refinery planning using SLP algorithms*

Joaquim Martins (Toronto)
*Aero-Structural wing design using coupled sensitivity analysis*

Anthony Vannelli (Waterloo)
*New modelling techniques for the global routing problem*

Chandu Viswesvariah (IBM T.J. Watson Research Center)
*Mathematics and engineering: a clash of cultures?*

Andreas Waechter (IBM T.J. Watson Research Center) and Larry Biegler (Carnegie Mellon)
*Interior point algorithms for large-scale nonlinear programming: theory and algorithmic development*

Henry Wolkowicz (Waterloo)
*Rust algorithms for large sparse semidefinite programming (SDP)*

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**START-UP FIRMS FOSTERED BY THE FIELDS INSTITUTE**

**Sigma Financial Analysis and Management**
Sigma is a financial analysis and management firm housed within and assisted by the Fields Institute. It was founded by David Rudd, and Luis Seco of the University of Toronto. For the first eighteen months, Sigma analyzed the performance of hedge funds, trading advisors, and other investment managers who try to provide superior invest-
ment returns. The object of the research was to construct portfolios of investments which can insulate investors from risk to the economy and provide superior, sustainable returns.

"Investors and institutions such as pension funds are looking for alternatives to exposure to the economy and will want positive returns with investment profiles not dependent on economic growth. Sigma’s detailed research permits us to deliver that product,” comments David Rudd. Sigma has two basic business themes: 1) providing investment consulting services to large financial institutions in Canada, the U.S., and South America; 2) acting as sub advisor to firms who wish to invest in global structured product and alternative investments. Sigma has seven full-time staff including four senior math researchers and is now registered as an investment counsellor.

**The Individual Finance and Insurance Decisions (IFID) Centre @ the Fields Institute**

The Individual Finance and Insurance Decisions Centre (IFID) is a non-profit corporation that is currently housed at the Fields Institute and is closely associated with the Schulich School of Business at York University in Toronto. The broad objectives of The IFID Centre are to conduct and disseminate applied research in the field of financial risk management for individuals. This mandate covers the areas of finance, 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 Centre has two primary and ongoing activities. The first is to link and support a wide network of academic researchers interested in the topic of personal finance and insurance. The second is to engage in quantitatively-based contract work for industry and government. The IFID Centre is supported by a variety of sponsors that provide funding for targeted research projects, graduate and postdoctoral fellowships, and an annual conference devoted to personal risk management. The IFID Centre’s organizational structure consists of an Executive Director, a governing board of directors, in-house support staff, and research associates from industry and academia. The current executive director of The IFID Centre is Moshe A. Milevsky, Associate Professor of Finance at the Schulich School of Business at York University.
**Mathematics Education**

**Fields Mathematics Education Forum**  
September 2004–June 2005  
Held at the Fields Institute

**Steering Committee**  
Co-chair: George Gadanidis (UWO) and Tom Salisbury (Fields)  
Members: Stewart Craven (Toronto District School Board), Shirley Dalrymple (York Region District School Board), Gary Flewelling, Bradd Hart (McMaster), Kenning Marchant, Dragana Martinovic (Sheridan College), and Margaret Sinclair (York)

The Fields Mathematics Education forum meets during the school year, one Saturday a month, from 10am–2pm. It brings together individuals from faculties of education, university and college mathematics departments, teachers and mathematics coordinators from area school boards, textbook publishers, consultants or government representatives and members of the public interested in mathematics education. Attendance ranges from 20 to 30, and participants come regularly from as far afield as Ottawa, Kingston, Peterborough, London, and St. Catherines.

The Forum serves as a lively venue for sharing ideas and initiatives, discussing current mathematics education issues, and forging partnerships for mathematics education research and service. Some driving questions include: How do we improve mathematics education? How do we better prepare mathematics teachers? How do we forge productive links among various stakeholders?

The Fields Mathematics Education Forum is open to the public and anyone may attend without invitation.

In June, the forum sponsored a meeting of university representatives discussing revisions to the Ontario mathematics curriculum.

The Fields Mathematics Education Forum also supported the planning of the CMS Canadian Math Education Forum 2005, which was hosted by Fields, and included opportunities for sharing Mathematics Education Success Stories from across Canada.

**WORKSHOPS AND CONFERENCES**

**CATM/ACEM meeting**  
November 6–7, 2004  
Held at the Fields Institute

At the Canadian Mathematical Society’s national forum on school mathematics, held in Montreal in May 2003, it was proposed that closer connections between provincial associations for mathematics teachers would benefit all such groups. This idea struck a chord in many quarters, and was subsequently discussed at a meeting of the Canadian Mathematics Education Study Group (CMESG).

In November 2003, the Fields Institute invited representatives of provincial teacher associations to the Fields Institute to discuss this possibility, at a meeting organized by Florence Glanfield (Saskatchewan) and Stewart Craven (Toronto District School Board). The response was very enthusiastic.

A second meeting of representatives was held at the Fields Institute November 6–7, 2004, with the same organizers, to follow up on the work done over the previous year, and to flesh out organization details. This meeting was supported by an endowment grant from the Canadian Mathematical Society. The results of these discussions were shared at the 2005 Canadian Mathematics Education Forum, held in May 2005 at the Fields Institute. At that occasion, the name of the fledgling organization was announced: The Canadian Association for the Teaching of Mathematics (CATM)/Association canadienne pour l’enseignement des mathématiques (ACEM). It is expected that this group will soon launch its public meetings, and will add a new and welcome dimension to the mathematics education landscape in Canada.
Math Camp Program 2004
The Esso/CMS Math Camp Program started in 1999 with three camps, and the program has now grown to include at least one camp in every province. The support received from the Fields Institute, NSERC PromoScience, the other research institutes, and the host universities enabled the Canadian Mathematics Society to ensure these camps were accessible to students from across Canada who demonstrated an excellence and interest in mathematics.

In 2004, there were thirteen regional math camps in ten provinces, as well as a national camp. Over three hundred and fifty students participated in these math camps. The 2004 regional camps took place at Sir Wilfrid Grenfell College, the University of New Brunswick (Fredericton), Dalhousie University, University of Prince Edward Island, Université du Québec à Rimouski, the University of Ottawa (two camps – one in English and one in French), Brock University, the University of Western Ontario, the University of Regina, the University of Manitoba, the University of Alberta, and Simon Fraser University. The University of Western Ontario was also the host of the National Math Camp which took place from June 5 to 12.

The Math Camp Program has been an undoubted success for all of the associated partners. The comments from both the student participants and the organizers were extremely positive. These camps are not only valuable in motivating students to do mathematics and science, but they also stimulate all of those involved by enriching their teaching accordingly. It is one of the Society’s priorities to continue to support these camps and help create new ones.

2005 CMS Canadian Mathematics Education Forum
May 6–8, 2005
Held at the University of Toronto
Co-chairs: Florence Glanfield (Saskatchewan), Frédéric Gourdeau (Laval) and Bradd Hart (McMaster)

The 2005 Canadian Mathematics Education Forum was held May 6–8, 2005 on the campus of the University of Toronto, with some events taking place at the Fields Institute. It was organized under the aegis of the Canadian Mathematical Society, with the support of the Fields Institute. Planned over a two year period by the three co-chairs, with input from a program committee of 36, it attracted over 200 participants drawn in roughly equal numbers from K-12 teachers, from mathematics education researchers, and from mathematicians. A deliberate effort was made to ensure balanced participation by region, and simultaneous translation was provided for all plenary sessions. In 2003, the CMS’s previous forum was held in Montreal, stimulating a national discussion about mathematics education and setting the stage for the 2005 event. The CMS has announced its intent to sponsor similar forums every 2 or 3 years.

The purpose of the 2005 forum was to engage in a national and on-going dialogue about important issues and concerns in the development and future of mathematics education in Canada, at all levels of schooling. The overall theme of the forum was “Why Teach Mathematics?”, a
phrase meant to be interpreted in multiple ways. Three sub-themes were identified: mathematics and society, mathematics in the classroom, and the mathematics education community in Canada. Together these provided the perspectives from which forum participants provided responses to the overall themes.

The plenary portion of the program consisted of three panel discussions, and a public lecture by Stephen Lewis titled *Deciphering our World* (see the “Public Lecture” section of the annual report for details). Three parallel sessions on the first day provided brief and at times inspirational presentations titled *Sharing Successes*. But the main work of the forum was conducted by the 10 working groups, each meeting three times over the course of the forum. Together, the groups’ participants worked to create projects, initiatives, and documents that outlined ways in which Canadians may address issues and concerns arising out of mathematics education. The final plenary session of the forum included reports from all groups. Work continues after the forum, to share these ideas and documents widely with policy makers, school boards, universities, colleges, parents, students, and the general public in a variety of ways.

**Working Groups:**

- Mathematics education in the aboriginal community
- Early numeracy: Developing mathematical literacy in the early years
- Why is mathematics relevant in our society?
- Supporting student success – Helping students reach their potential
- Creating a curriculum that affords learners opportunity to develop powerful mathematics
- Learning in the presence of technology
- Mathematics through the eyes of a child

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- BC Association of Mathematics Teachers
- Saskatchewan Mathematics Teacher Society
- Association Mathématique du Québec
- Groupe des responsables en mathématiques au secondaire

**Designing Mathematical Thinking Tools**

A Fields Symposium

June 10–12, 2005

Held at the University of Western Ontario

Organizers: George Gadanidis (UWO), William Higginson (Queen’s), Robin Kay (UOIT), Kamran Sedig (UWO) and Christine Suurtamm (Ottawa)
This Fields-sponsored symposium was, to use Richard Noss’s phrase, a rare event. Unlike typical conferences where papers are presented and discussed, the only symposium presentations were the keynote addresses by Richard Noss from the University of London, Rafael Núñez from the University of California, and Anna Sfard from the Michigan State University and the University of Haifa (via videoconference from Haifa). The remaining time was devoted to small group discussions on the symposium’s theme, with Noss and Núñez participating fully.

The symposium explored mathematical thinking tools. The group was especially interested in investigating the role of metaphor (or ‘seeing-as’) in the development of mathematical understanding. And they were interested in the role of technology, in this context. The initial questions included the following:

- What are mathematical thinking tools?
- How are mathematical thinking tools designed? Are they actually designed? Who designs them? What is the role of technology?
- What are the roles of metaphor and the nature of metaphorical thinking in mathematics?
- What is understanding? What is mathematical understanding? How do we define such terms as understanding, misunderstanding, conception and misconception?
- What are some mathematical, pedagogical and research implications of this work on mathematical metaphor and thinking tools?

**Keynote Speakers:**
Richard Noss (London)
*Building and critiquing representational systems for mathematical thinking*

Rafael Núñez (UC, San Diego)
*Metaphor’s (often) ignored side: a view from contemporary cognitive science*

Anna Sfard (Michigan State & U. Haifa)
*Metaphor of object in mathematics and in mathematics education courses: a prop and a trap*

**JUMP 2005**
Junior Undiscovered Math Prodigies (JUMP) is a volunteer-based tutoring organization founded in 1998 by mathematician John Mighton. The program started in John’s apartment with 7 tutors and 15 students and now has been implemented in 100 schools across Canada as well as in Britain, Australia and the United States.

JUMP was founded with the objective of providing free tutoring in mathematics for under-privileged children. Over the past two years, however, in response to an explosive growth of interest in the program among educators and parents, they began to make their methods and materials available to a wider public. The organization produced workbooks for students and training materials for teachers (for grades 3 to 6) which were tested in over a hundred classrooms this year and which will be available in a second draft at the end of August. The team is presently developing curriculum based materials for grades 1 to 2 and 7 to 8, as well as units on problem solving and a series of activities that will show how mathematics appears in biology, chemistry, magic tricks, secret codes, strategy games, art and computer science, as well as units on logic, topology and graph theory.

One of the goals of JUMP is to change the perception of mathematics among the general public. Many adults look
back on the time they spent learning math at school as a kind of purgatory. Because they once struggled themselves, the majority think of math as the most difficult subject, one that very few children will naturally do well at or enjoy. Based on work done by John and the JUMP staff with hundreds of extremely challenged children, JUMP believes this view is incorrect and does inestimable damage to children: mathematics, when taught properly, can be the easiest subject for children to learn, particularly for children with behavioural problems, attention deficits and learning difficulties. By failing to teach mathematics effectively, we neglect a tool that could be used to transform society for the better in a very short time, by allowing us to harness the vast creative and intellectual potential of children who are traditionally left behind.

In the twenty years John has spent teaching mathematics to children, he has never met an educator who would say that students who lack confidence in their intellectual or academic abilities are likely to do well in school. But no program of mathematics used in our public schools has ever, in JUMP’s view, taken proper account of the role of confidence in learning. If students are more apt to do well in a subject when they believe they are capable of doing well, it seems obvious that any math program that aims to harness the potential of every student must start by building the confidence of every student.

The method of teaching used in the early part of the JUMP program might well be called “guided discovery”. The steps instructors follow are initially extremely small, so weaker students needn’t be left behind, but the method of instruction is not rote. From the outset, students are expected to discover or extend patterns or rules on their own, to see what changes and what stays the same in sequences of mathematical expressions and to apply chains of inference or computation in new situations. Students become very excited at making these discoveries and meeting these challenges. As students become more confident and attentive they begin to work more independently and to discover more by themselves. The new drafts of JUMP grade-specific workbooks contain a variety of exercises that teach problem-solving, communication and independent thinking, with a balance of concrete and symbolic work and independent and guided work that has proven to be very effective.

Some highlights of the year:

The Australian Mathematical Sciences Institute and the International Centre of Excellence for Education in Mathematics invited John to give talks at schools and universities in Australia in May and plan to adapt JUMP materials and start research pilots in Australia in the fall. A successful test pilot was run in London England in May by the Lambeth Board of Education: the Director of Maths Strategy, who observed several JUMP lessons and a training session, has called JUMP one of the most exciting programs she has seen in years.

JUMP has begun to establish a network of very enthusiastic lead teachers across Canada: one of their teachers won a provincial teaching award in BC and has spoken about the program on TV. Her school, and a number of other schools in BC (including several first nations schools and a private school that ranked highest on the provincial math tests in BC) are adopting JUMP after successful pilots.

In Winnipeg, John trained over a hundred resource teachers in April. A number of teachers have already reported very good results with the program and at least five schools will start much larger implementations in the fall. The Ontario Ministry invited JUMP to run a program this summer at a camp for disadvantaged youth and is supporting the introduction of JUMP in the province.

All of the teachers who took part in a JUMP pilot in Toronto said on surveys that the fractions unit had shown them that they had underestimated their weaker students in ten categories, including enthusiasm, willingness to ask for harder work, ability to remember number facts and ability to keep up with faster students.

Two teachers using JUMP at an inner city school in Toronto raised the school’s grade 3 EQAO results from 61% of students achieving at grade level or beyond to 93%.

Based on the success of JUMP in Toronto, the Toronto District School Board has invited submissions of a proposal for a formal research pilot this fall. Three schools have signed up to test the program. Another 20 schools in Toronto are already using the program in-class or after school.

JUMP held talks and training session for hundreds of teachers, administrators, parents and volunteer tutors at the Fields Institute and at schools, universities and community centres across Canada. Till December 2004, the JUMP administration office was located with the Fields Institute. In January it moved to more spacious quarters at 401 Richmond St. W, in Toronto. Fields continues to supply space for training seminars.
The honour of being named a Fields Institute Fellow was established as a part of the Fields tenth anniversary celebration in 2002. It is a lifetime appointment for individuals who have made outstanding contributions to the Fields Institute and to the Canadian mathematical community. To the original group of 33 fellows, an additional seven were named in 2003, six in 2004, and five in 2005. Listed below are the names of all Fields Fellows.

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The Fields Institute publishes a newsletter three times a year, titled Fields Notes. Issues appeared in September 2004, January 2005, and May 2005. Over 2000 copies of each issue are distributed free of charge in mailings to a wide range of universities throughout Canada and the United States. A redesigned format was initiated with the January 2004 issue, created by Scott Thornley + Co.
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The Scientific Advisory Panel (SAP) provides 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 mathematicians from Canada and abroad. The panel makes recommendations to the Board of Directors on the selection of thematic programs and other major activity.

JENNIFER CHAYES is Manager of the Theory Group at Microsoft Research. The group includes mathematicians, physicists and theoretical computer scientists working on problems at the interface of these three fields. In addition to managing the Theory Group at Microsoft, Chayes has been Professor of Mathematics at UCLA and is Affiliate Professor of Mathematics and Physics at the University of Washington. She has been Vice-President of the American Mathematical Society. Chayes has also served on numerous other boards and advisory committees. Chayes received her BA in biology and physics from Wesleyan University, where she graduated first in her class. She received her PhD in mathematical physics from Princeton University. She was a postdoctoral fellow in the Physics and Mathematics departments at Harvard University, and at the Laboratory of Atomic and Solid State Physics and the Army Mathematics Center at Cornell University. Chayes was awarded a National Science Foundation Postdoctoral Fellowship in Mathematics and a Sloan Foundation Fellowship. She has also won several teaching awards including the Distinguished Teaching Award in Mathematics at UCLA. She has twice been a member of the Institute for Advanced Study in Princeton. Chayes is the author of over sixty-five papers in mathematics and physics. She is one of the world’s experts on phase transitions, particularly on the probabilistic and stochastic geometric approach to statistical physics. Since joining Microsoft in 1997, Chayes has begun to apply methods from mathematics and physics to problems in theoretical computer science, networking, and information technology.

WALTER CRAIG received his MS and PhD from the Courant Institute of Mathematical Sciences, New York University. His research focuses on the theory of nonlinear partial differential equations and Hamiltonian dynamical systems, and their applications. 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, the ICMS Edinburgh, the ETH, the INI, and IHES. He is currently on the Council of the AMS, and is a member of the editorial boards of the SIAM Journal on Mathematical Analysis, the AMS Graduate Studies, the Proceedings of the Royal Society, the Canadian Journal of Mathematics, and the Mathematical Physics Electronic Journal. He helped organize the Institute’s 2003 thematic program in Partial Differential Equations.

HENRI DARMON received his BSc in Mathematics and Computer Science from McGill University in 1987 and his PhD in Mathematics from Harvard University in 1991. He is currently Professor in the Department of Mathematics at McGill University. Prior to his present appointment he taught at Princeton University. He has received a Sloan Doctoral Dissertation Fellowship, an Alfred P. Sloan Research Award, the G. De B. Robinson Award, the Coxeter-James Prize of the Canadian Mathematical Society, the CRM’s André Aisenstadt Prize, NSERC’s E.W.R. Steacie Memorial Fellowship, and the Ribenboim Prize of the Canadian Number Theory Association. He was elected a fellow of the Royal Society of Canada in 2003. Darmon is currently editor-in-chief (with Niky Kamran) of the Canadian Journal of Mathematics and has served on the editorial boards of the International Journal of Number Theory, Commentari Mathematici Helvetici, the Journal of Number Theory, and the Annales des Sciences Mathématiques du Québec. He is a member of NSERC’s Grant Selection Committee and of the CMS prize committee. His main research interests are in p-adic analysis and the theory of automorphic forms with special emphasis on elliptic curves and explicit class field theory.

KENNETH R. DAVIDSON received his undergraduate degree at the University of Waterloo in 1972 and his PhD 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 is an editor of the Journal of Operator Theory. He has served the CMS in various capacities including Vice-President (Ontario) in 1995-97. He sat on the NSERC mathematics GSC in 1990-
93, serving 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. He served as Director of the Fields Institute during 2001-2004.

**LISA JEFFREY** obtained her BA degree in 1986 from Princeton University, her MA from Cambridge University in 1988, and her doctorate in mathematics from the University of Oxford in 1992. She is currently Professor in the Department of Mathematics at the 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, the University of Toronto’s McLean Award, the Aisenstadt Prize of the Centre de recherches mathématiques and an NSERC Steacie Fellowship (2004-6) as well as the 2001 Krieger-Nelson Prize of the Canadian Mathematical Society. Her research group obtained an NSERC LSI (Leadership Support Initiative) grant (2003-6). She is a past member of the Council of NSERC, and is on the editorial board of the Transactions of the American Mathematical Society and a member of the BIRS Scientific Advisory Panel and the AARMS Scientific Advisory Panel. She is one of the organizers of the 2004-2005 thematic program at the Fields Institute, on the Geometry of String Theory, and is a new member of the Canadian Mathematical Society. She is a Fellow of the American Mathematical Society.

**BARBARA LEE KEYFITZ** received her undergraduate education at the University of Toronto and her MS and PhD from NYU’s Courant Institute. She is currently serving as Director of the Fields Institute and she continues as John and Rebecca Moores Professor of Mathematics at the University of Houston. Her research area is Nonlinear Partial Differential Equations. She is a Fellow of the American Association for the Advancement of Science and serves on the editorial boards of *Mathematical Methods in the Applied Sciences*, and *CMS Treatises in Mathematics*. She serves on the Board of Directors of MITACS and of AARMS. 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 held visiting positions at the University of Nice, at Duke University, at Berkeley, at the Institute for Mathematics and its Applications in Minneapolis, at the Fields Institute, and at Brown University. She is President of the Association for Women in Mathematics, Chair of Section A of the American Association for the Advancement of Science; and treasurer of ICIAM.

**ANGUS MACINTYRE** is a Professor of Mathematics at Edinburgh University and the past scientific director of the International Centre for the Mathematical Sciences. He received his PhD from Stanford in 1969. His work over the past thirty years on the applications of model theory to other parts of mathematics has contributed significantly to the field of model-theoretic algebra. He gave a plenary address at the International Congress of Mathematicians in 1978 and has been a Fellow of the Royal Society since 1993. He has held professorships at Oxford and Yale, and visiting positions at numerous universities and research institutes. He is an editor of a wide variety of journals and a past editor of the *Annals of Mathematics*. He is the author of over fifty research articles and has been thesis advisor to more than thirty students.

**ROBERT MIURA** received his BS and MS in Mechanical Engineering from the University of California at Berkeley and his MA and PhD in Aerospace and Mechanical Sciences from Princeton University. He held postdoctoral positions at the Princeton Plasma Physics Laboratory and the Courant Institute. He has taught at New York University, Vanderbilt University, and the University of British Columbia, and currently is Professor of Mathematical Sciences and of Biomedical Engineering at the New Jersey Institute of Technology, where he is Acting Chair of the Department of Mathematical Sciences. His main research interests are in applied mathematics with applications to mathematical biology, especially excitable cells and physiology. He has been a John Simon Guggenheim Fellow and is a Fellow of the Royal Society of Canada. He has served on many editorial boards, and presently is on the editorial boards of the *Canadian Applied Mathematics Quarterly* and *Integrative Neuroscience*, and is co-editor-in-chief of *Analysis and Applications*. He has been a member of various committees and boards.

**MICHAEL L. OVERTON** received his BSc from UBC in 1974, along with the Governor General’s Gold Medal for 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. He is the chair of the Board of Trustees of SIAM (Society for Industrial and Applied Mathematics) and has also served on the SIAM Council. He is a member of the Council of FoCM (Foundations of Computational Mathematics).
the Board of Directors of the Canadian Mathematical Society. He serves on the editorial boards of *SIAM Journal on Optimization* (for which he was editor-in-chief, 1995–99), *SIAM Journal on Matrix Analysis and Applications*, the *IMA Journal on Numerical Analysis*, *SIAM Review*, and *ESAIM Journal on Control, Optimisation and Calculus of Variations*. His research interests are at the interface of optimization and linear algebra, especially nonsmooth optimization problems involving eigenvalues, with applications to many different subjects including robust control, structural analysis, combinatorial optimization, and convex analysis. He is author of *Numerical Computing with IEEE Floating Point Arithmetic* (SIAM, 2001).

**BRUCE REED** received his PhD from McGill in 1986. He subsequently worked as a scientist or professor at Bell Communications Research, the University of Waterloo, Carnegie-Mellon University, and the CNRS in France. He was appointed to the Canada Research Chair in Graph Theory at McGill University in November 2001. He was invited to speak at the International Congress of Mathematicians in 2002. His main research interests are in algorithmic graph theory and probabilistic combinatorics.

**THOMAS SALISBURY** received his BSc from McGill University, and his PhD in probability theory from the University of British Columbia. After spending two years at Purdue University, he moved to York University, in whose Department of Mathematics and Statistics he is a Professor and former Chair. His research area is probability theory, specifically Brownian motion and Markov processes, including their applications to actuarial finance. He has served on the editorial boards of several journals in both probability and statistics. He was one of the organizers of the Fields Institute Probability year in 1998–99, and is secretary and treasurer of the Individual Finance and Insurance Decision Centre (IFID). For the Canadian Mathematical Society he served as co-editor-in-chief of the *Canadian Mathematical Bulletin*, and is currently President-elect of the Society. He is a fellow of the Fields Institute and of the Institute of Mathematical Statistics. He is currently Deputy Director of the Fields Institute.

**GORDON D. SLADE** received the BASc and MSc 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 thirteen 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 was a co-organizer of the 1998–1999 Fields Institute thematic program in Probability and Its Applications.

**ROBERT TIBSHIRANI** is Professor in the Departments of Health Research and Policy, and Statistics at the Stanford University. He received his Bachelor of Mathematics in 1978 from the University of Waterloo, his MSc in Statistics from the University of Toronto in 1979, and his PhD in 1984 from Stanford University. From 1985 to 1998 he was a professor in the Departments of Public Health Sciences and Statistics at the University of Toronto. He is a fellow of the Royal Society of Canada, the American Statistical Association, and the Institute of Mathematical Statistics, a recipient of the Presidents’ Award of the Committee of Presidents of Statistical Societies, a Steacie Fellow and a Guggenheim Fellow. He is well known for his work in computational statistics, data mining, biostatistics, and genomics. He has co-written three popular texts: *Generalized Additive Models* (with Hastie, 1990); *An Introduction to the Bootstrap* (with Efron, 1993); and *The Elements of Statistical Learning* (with Hastie and Friedman, 2000).

**EFIM ZELMANOV** is Rita L. Atkinson Chair in Mathematics at University of California, San Diego. He attended Novosibirsk State University, obtaining his PhD in 1980 having had his research supervised by Shirshov and Bokut. His PhD thesis completely changed the whole of the subject of Jordan algebras by extending results from the classical theory of finite dimensional Jordan algebras to infinite dimensional Jordan algebras. Zelmanov described this work on Jordan algebras in his invited lecture to the International Congress of Mathematicians at Warsaw in 1983. In 1980 Zelmanov was appointed as a Junior Researcher at the Institute of Mathematics of the Academy of Sciences of the USSR at Novosibirsk. By 1986 had had been promoted to Leading Researcher. In 1987 Zelmanov solved one of the big open questions in the theory of Lie algebras. He proved that the Engel identity $ad(y)n= 0$ in a Lie algebra of zero characteristic implies nilpotence. This was a classical result for finite dimensional Lie algebras but Zelmanov proved that the result also held also for infinite dimensional Lie algebras. In 1990 Zelmanov was appointed a professor at the University of Wisconsin-Madison in the USA. He held this appointment until 1994 when he was appointed to the University of Chicago. In 1995 he moved to Yale University and in 2002 to the University of California at San Diego. In 1991, Zelmanov went on to settle one of the most fundamental results in the theory of groups: the restricted
Burnside problem, which had occupied group theorists throughout the 20th century. In 1994 Zelmanov was awarded a Fields Medal for this work at the International Congress of Mathematicians in Zurich in 1994. He is a Fellow of the American Academy of Arts and Sciences and a Member of the National Academy of Sciences.
Industrial Advisory Board

The Industrial Advisory Board (IAB) is chaired by the Deputy Director of the Institute, and includes a rotating membership of distinguished mathematicians or users of mathematics. The committee reviews major proposals for Commercial & Industrial mathematical activity, and advises the institute on directions to pursue for the Commercial & Industrial mathematics program.

RON DEMBO  *offootprint*
DAVID FIELD  *General Motors*
BRADD HART  *McMaster University*
HUAXIONG HUANG  *York University*
BARBARA KEYFITZ  *Fields Institute*
DANIEL KOBLER  *TmBioscience*
MILORAD KRNETA  *Generation 5*
MOSHE MILEVSKY  *York University - Schulich School of Business* and *The IFID centre*
KUMAR MURTY  *University of Toronto* and *Cyrca*
THOMAS SALISBURY  *Fields Institute*
LUIS SECO  *Sigma Analysis and Management* and *University of Toronto*
TAMÁS TERLAKY  *McMaster University*
Carleton University
The School of Mathematics and Statistics at Carleton University has a long history of research and graduate study. Besides the 32 research faculty, there are nine Distinguished Research Professors (including four FRSCs) who, although retired, are still very active in research. Areas of research include algebra, functional analysis, applied mathematics, combinatorics, geometry, logic, number theory, probability and statistics (both theoretical and applied). The Laboratory for Research in Statistics and Probability, which is supported by an NSERC Major Facilities Access Grant, is situated in the School. The research activity of the School is enhanced by the presence of post-doctoral fellows and numerous international visitors. Among the honours recently received by members of the School are a PREA and an NSERC Leadership Support Initiative Award. The graduate program (M.Sc. and Ph.D.) is joint with the Department of Mathematics and Statistics of the University of Ottawa with over 80 students on the Carleton campus. In addition, the School sponsors (jointly with the School of Computer Science and the Department of Systems and Computer Engineering at Carleton) a popular Information and Systems Science program, with 20 students in this unit. The School also offers an M.Sc. in biostatistics through the Ottawa-Carleton Collaborative Program in Biostatistics.

The School of Computer Science has a large research effort in theoretical computer science. Active areas of research include: network computing; geometric computing; digital security and cryptography; algorithmic graph theory; provability, logics, and verification; stochastic modeling and probabilistic algorithms. The School is the home of the Carleton-Cloakware Security Research Lab, headed by a CRC in Network Security (Van Oorschot), and is part of the High Performance Computing Virtual Laboratory (HPCVL), a four-university consortium with a budget of $37 million. Carleton’s HPCVL lab is headed by an NSERC-Sun Industrial Research Chair in Applied Parallel Computing (Sack). The School offers both an MSc and PhD degree in Computer Science, as well as an MSc in Information and Systems Science (jointly with the departments of Mathematics and Systems Engineering).

McMaster University
McMaster University is a research-intensive, mid-sized university located in Hamilton at the west end of Lake Ontario. The Mathematics and Statistics Department has thirty-eight 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 twenty positions each year and a graduate program with over seventy 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 fifteen joint McMaster-Fields postdoctoral fellowships. PhiMac, a group of faculty, graduate students, and postdoctoral fellows dedicated to the theory and practice of financial mathematics, has been a regular participant in the quantitative finance seminar and has received support from MITACS. The Faculty of Engineering, and in particular, the Advanced Optimization Lab in the Department of Computing and Software has also been a strong participant in Fields initiatives.

The Department of Mathematics and Statistics is located in the newly renovated 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, linkage, and impact of mathematics at McMaster University and the larger community.

University of Ottawa
The Department of Mathematics and Statistics at the University of Ottawa is an active research department. It has about thirty-two faculty members with research grants, working in a wide range of areas, including algebra, analysis, applied mathematics, logic and foundations of computing, number theory, statistics, probability, and topology. The department is home to a Canada Research Chair in mathematical genomics, to a Fellow of the Royal Society of Canada (FRSC), and to two holders of Ontario Premier’s Researcher Excellence Awards (PREA). The department has a vibrant graduate program joint with Carleton University, with currently about forty graduate
students at the University of Ottawa. In addition to offering MSc and PhD degrees in traditional areas, the department also offers an MSc program in Biostatistics, joint with the Department of Epidemiology, as well as an MSc in High Technology. Besides being a member of the Fields Institute, the department is also a member of the Centre de recherches mathématiques (CRM). The department is also proud of its postdoctoral program, which now provides about twelve postdoctoral positions. The University of Ottawa is a bilingual institution in the heart of Canada’s capital. The department benefits from its proximity to the government, with a number of appointments of adjunct professors who are active mathematicians affiliated with Canadian research agencies.

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 one hundred and forty 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 Fullkerson Prize in Discrete Mathematics (A. Lehman), the IJCAI Award for Research Excellence (R. Reiter) and the Order of Canada (C.C. Gotlieb). 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 recent thematic program on Numerical and Computational Challenges in Science and Engineering (2001–2002).

The Department of Mathematics at the University of Toronto is one of the leading mathematics research departments in Canada. Mathematics has been taught there since 1827, and the department’s first PhD 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 participation in its workshops and thematic programs, in events for 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.

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 more than forty-six hundred full-time undergraduate and four hundred and twenty-five graduate students, and one hundred and eighty-five 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 units: Applied Mathematics, Combinatorics & Optimization, Computer Science, Pure Mathematics, and Statistics & 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 and quantum computation have become major strengths in the Faculty. The Faculty of Mathematics generated over $12 million in research funding last year. With the University’s liberal position on intellectual property, research conducted in the Faculty has resulted in several spin-off companies founded by professors, students, and graduates. Known for its mathematics and computer contests, the success of its graduates,
and its high standards, the Faculty of Mathematics consistently attracts the best students from around the world.

Waterloo has placed among the top ten schools eleven times in the past thirteen years in the Association for Computing Machinery (ACM) International Programming Competition. It has been the world champion twice (1994, 1999) and North American champion six times during that period. As well, the University has placed in the top ten in the Putnam Competition fifteen times in the past sixteen years, placing first in 1999 and fourth in the most recent competition. Waterloo routinely ranks among the top three or four schools in terms of the number of students who place in the top two hundred in that competition. For thirteen years in a row, a group of more than three thousand 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 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, algebraic combinatorics, invariant theory, number theory, combinatorial algebra, noncommutative geometry, harmonic analysis, complex analysis and complex geometry, mathematical physics, and quantization.

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, including two Canada Research Chairs. 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), mathematical modelling and numerical analysis, algebra, geometry, financial mathematics, 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. Three faculty members recently received CFI funding for research in mathematics and statistics. 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).

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. An MSc program in Industrial and Applied Mathematics was begun in 2002. 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 also has active mathematical sciences researchers in many other departments, including Computer Science and Engineering, Analytic Studies and Information Technology, Schulich School of Business, Administrative Studies, and Biology.
Financial Report

The statement of operations and changes in net assets shows a deficit for the twelve months ending March 31, 2005. Both income and expenses grew from the corresponding amounts in the previous fiscal year, principally because of the large size of this year’s thematic program, which was co-sponsored by Perimeter Institute. The size of the deficit was substantially reduced from that of the previous year, but nevertheless resulted in a significant decrease in the unrestricted surplus (see Note 4). The increase in donation revenue is promising, in view of the short time since the Institute began to engage in fundraising.

The method of reporting capital expenditures has changed. As a result, capital assets not yet amortized are now included in the statement of net assets (see Notes 3 and 4). Figures from the fiscal year ending March 31, 2004 have been restated to reflect this change, and differ from those in the previous year’s annual report in that respect only (see Note 2).

Financial Statements

The Fields Institute for Research in Mathematical Sciences
March 31, 2005
AUDITORS' 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, 2005 and the statement of operations and changes in net assets 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, 2005 and the results of its operations and its cash flows for the year then ended in accordance with Canadian generally accepted accounting principles. As required by the Corporations Act (Ontario), we report that, in our opinion, these principles have been applied on a basis consistent with that of the preceding year.

Toronto, Canada,
May 16, 2005.

Ernst & Young LLP
Chartered Accountants
The Fields Institute for Research in Mathematical Sciences

**BALANCE SHEET**

As at March 31

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td><strong>ASSETS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Current</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Due from University of Toronto [note 5]</td>
<td>217,130</td>
<td>78,280</td>
</tr>
<tr>
<td>Accounts receivable</td>
<td>172,215</td>
<td>181,741</td>
</tr>
<tr>
<td>Goods and Services Tax receivable</td>
<td>57,335</td>
<td>28,027</td>
</tr>
<tr>
<td>Prepaid expenses</td>
<td>10,074</td>
<td>3,142</td>
</tr>
<tr>
<td><strong>Total current assets</strong></td>
<td>456,754</td>
<td>291,190</td>
</tr>
<tr>
<td>Capital assets, net [note 3]</td>
<td>49,094</td>
<td>46,275</td>
</tr>
<tr>
<td><strong>Total assets</strong></td>
<td>505,848</td>
<td>337,465</td>
</tr>
</tbody>
</table>

| **LIABILITIES AND NET ASSETS** |       |       |
| **Current liabilities**       |       |       |
| Accounts payable and accrued liabilities | 248,445 | 106,859 |
| Deferred contributions         | 132,100 | 81,650 |
| **Total liabilities**          | 380,545 | 188,509 |

| **Net assets \[note 4\]**     |       |       |
| Invested in capital assets    | 49,094  | 46,275 |
| Unrestricted surplus          | 76,209  | 102,681 |
| **Total net assets**          | 125,303 | 148,956 |
| **Total liabilities and net assets** | 505,848 | 337,465 |

See accompanying notes
The Fields Institute for Research in Mathematical Sciences

STATEMENT OF OPERATIONS AND
CHANGES IN NET ASSETS

Year ended March 31

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td><strong>INCOME</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Sciences and Engineering Research Council of Canada</td>
<td>966,000</td>
<td>966,000</td>
</tr>
<tr>
<td>Natural Sciences and Engineering Research Council of Canada - National Program on Complex Data Structures</td>
<td>44,446</td>
<td>21,397</td>
</tr>
<tr>
<td>Ontario Ministry of Training, Colleges and Universities</td>
<td>1,000,000</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Other scientific program grants</td>
<td>476,727</td>
<td>401,707</td>
</tr>
<tr>
<td>Sponsoring revenue</td>
<td>474,936</td>
<td>420,440</td>
</tr>
<tr>
<td>Commercial/industrial mathematics grants</td>
<td>161,110</td>
<td>149,012</td>
</tr>
<tr>
<td>Registration fees</td>
<td>74,026</td>
<td>94,308</td>
</tr>
<tr>
<td>Recovery of indirect costs</td>
<td>100,010</td>
<td>107,550</td>
</tr>
<tr>
<td>Mathematics of Information Technology and Complex Systems</td>
<td>74,676</td>
<td>103,932</td>
</tr>
<tr>
<td>Publications</td>
<td>48,159</td>
<td>39,041</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>29,525</td>
<td>49,352</td>
</tr>
<tr>
<td>Donations</td>
<td>18,362</td>
<td>2,358</td>
</tr>
<tr>
<td>Interest</td>
<td>1,262</td>
<td>2,287</td>
</tr>
<tr>
<td><strong>Total Income</strong></td>
<td>3,469,239</td>
<td>3,357,384</td>
</tr>
</tbody>
</table>

| **EXPENSES**               |       |       |
| Scientific program         |       |       |
| Visitors | 928,880 | 725,330 |
| Post Doctorate Fellows' salaries | 515,106 | 539,869 |
| General scientific | 297,636 | 344,921 |
| Guests - teaching and lecture fees | 35,570 | 73,600 |
|                           | 1,777,192 | 1,683,720 |
| Salaries and benefits      |       |       |
| Scientific and support staff | 358,706 | 333,000 |
| Directorate staff | 302,003 | 348,648 |
| Administrative support staff | 333,820 | 994,529 |
|                           | 994,529 | 1,025,493 |
| Professional services | 17,334 | 60,589 |
| Rent and services [note 5] | 525,048 | 524,675 |
| Repairs and maintenance | 45,187 | 38,590 |
| Amortization of capital assets | 37,143 | 24,179 |
| Communications | 24,950 | 25,237 |
| General and office supplies | 38,962 | 34,230 |
| Administrative | 9,509 | 15,661 |
| Printed material and publishing | 23,038 | 26,155 |
|                           | 3,492,892 | 3,458,529 |
| **Net operating deficit for the year** | (23,653) | (101,145) |
| **Net assets, end of year** | 125,303 | 148,956 |

See accompanying notes
The Fields Institute for Research in Mathematical Sciences

NOTES TO FINANCIAL STATEMENTS

March 31, 2005

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.

The Institute is a charitable organization under the Income Tax Act (Canada).

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.

Capital assets

Purchased capital assets are recorded at cost less accumulated amortization. Contributed capital assets are recorded at market value at the date of contribution. Amortization is provided on a straight-line basis using the following annual rates:

<table>
<thead>
<tr>
<th>Asset Type</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furniture</td>
<td>20%</td>
</tr>
<tr>
<td>Equipment</td>
<td>33 1/3%</td>
</tr>
<tr>
<td>Computer equipment</td>
<td>33 1/3%</td>
</tr>
</tbody>
</table>

During the year, the Institute retroactively changed its policy for accounting for capital assets from expensing to capitalizing the cost of capital asset additions and amortizing these costs over the useful lives of the assets. As a result, capital assets and net assets invested in capital assets have increased by $49,094 and $46,275 as at March 31, 2005 and 2004, respectively. Net operating deficit decreased by $2,819 and $28,221 for the year ended March 31, 2005 and 2004, respectively.
The Fields Institute for Research in Mathematical Sciences

NOTES TO FINANCIAL STATEMENTS

March 31, 2005

Contributed materials and services

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

Use of estimates

The preparation of financial statements in conformity with Canadian generally accepted accounting principles requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and the disclosure of contingent assets and liabilities at the date of the financial statements and the reported amounts of income and expenses during the reporting period. Actual results could differ from those estimates.

3. CAPITAL ASSETS

Capital assets consist of the following:

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cost $</td>
<td>Accumulated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>amortization $</td>
</tr>
<tr>
<td>Furniture</td>
<td>18,369</td>
<td>11,404</td>
</tr>
<tr>
<td>Equipment</td>
<td>18,205</td>
<td>6,996</td>
</tr>
<tr>
<td>Computer</td>
<td>82,203</td>
<td>51,283</td>
</tr>
<tr>
<td></td>
<td>118,777</td>
<td>69,683</td>
</tr>
</tbody>
</table>

[Restated - note 2]
The Fields Institute for Research in Mathematical Sciences

NOTES TO FINANCIAL STATEMENTS

March 31, 2005

4. NET ASSETS

The continuity of the components of net assets is as follows:

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unrestricted surplus</td>
<td>Invested in capital assets</td>
</tr>
<tr>
<td>Balance, beginning of year, as previously stated</td>
<td>102,681</td>
<td>—</td>
</tr>
<tr>
<td>Effect of change in accounting policy for capital assets</td>
<td>—</td>
<td>46,275</td>
</tr>
<tr>
<td>Restated balance, beginning of year</td>
<td>102,681</td>
<td>46,275</td>
</tr>
<tr>
<td>Net deficit for the year</td>
<td>(23,653)</td>
<td>—</td>
</tr>
<tr>
<td>Net change in net assets invested in capital assets</td>
<td>(2,819)</td>
<td>2,819</td>
</tr>
<tr>
<td>Balance, end of year</td>
<td>76,209</td>
<td>49,094</td>
</tr>
</tbody>
</table>

5. 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, Ontario and charges the Institute an annual "Block Fee" of $500,000 for the cost of this space and services.

6. 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.
NOTES TO FINANCIAL STATEMENTS

March 31, 2005

7. FINANCIAL INSTRUMENTS

The carrying values of due from University of Toronto, accounts receivable and accounts payable on the balance sheet approximate their fair values due to the short-term nature of these instruments.

Credit risk on financial instruments is the risk of financial loss occurring as a result of default of a counterparty on its obligation to the Institute. Credit risk is managed by dealing only with counterparties the Institute believes to be creditworthy.
Acknowlegements

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